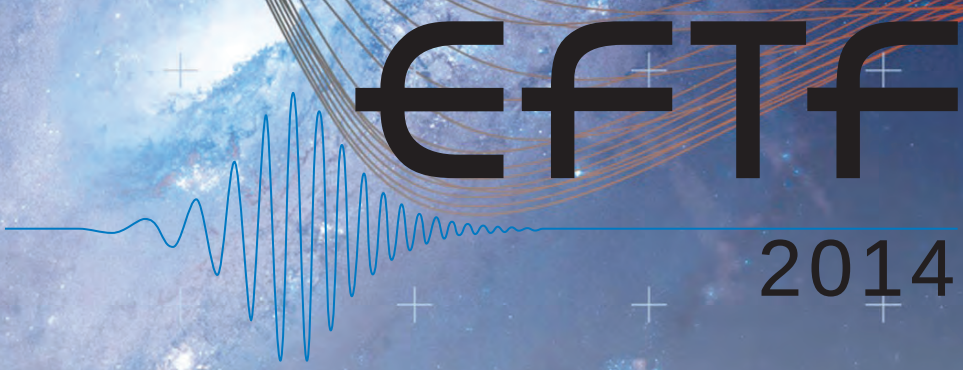
Programme



EFTF 2014

28th European Frequency and Time Forum

Neuchâtel, Switzerland - June 23-26, 2014

WELCOME to EFTF 2014 in Neuchâtel

We are delighted to welcome you to the 2014 edition of the European Frequency and Time Forum (EFTF), being held in Neuchâtel, Switzerland from June 23-26, 2014. This edition marks the 28th in a series of successful meetings that started in 1987. After more than ten years, the Forum returns to one of its two founding cities, in a region with old and strong tradition in precision manufacturing and timekeeping. The different tutorials, technical sessions, keynote presentations, invited speakers, exhibits and a newly-introduced post deadline session will cover the many aspects of the very active field of Time & Frequency.

As usual, three Committees, that we have the honour to chair, have joined their efforts to organise the event: the Local Organising Committee (LOC), the Scientific Committee (SC) and the Executive Committee.

The **Local Organising Committee** of EFTF-2014 includes representatives from the University of Neuchâtel, Spectratime Orolia, Fondation Suisse pour la Recherche en Microtechnique (FSRM) and the Centre Suisse d'Electronique et de Microtechnique (CSEM). We acknowledge also the strong support from the numerous institutional and industrial sponsors that is essential for an event that will gather over 300 persons around scientific, social and friendly meetings during the whole week.

The **Scientific Committee** of EFTF-2014 is glad to propose a rich scientific program resulting from the record number of 318 submitted abstracts. The schedule includes three parallel sessions of lectures (approximately 90 talks in 24 sessions), a poster session every day and a short presentation from each exhibitor on Thursday morning. This year, the Wednesday morning plenary talks will be given by Prof. Serge Haroche (ENS, Paris, and Nobel Prize in Physics in 2012) and Dr. John Kitching (NIST, Boulder, chip-scale atomic devices). The student poster finalists will be displayed during the whole duration of the conference. We are indebted to all the members of the SC and in particular the six group chairs: Emmanuel Defay, Jean-Pierre Aubry, Krzysztof Szymaniec, Leo Reindl, Pierre Waller and Sébastien Bize.

The **Executive Committee** of EFTF is very pleased that scientists, students and professionals meet once more and take this unique opportunity to learn, to exchange and to present their latest scientific and technological achievements to the community. We are particularly grateful to our members who organised the tutorials (Jeremy Everard), the EFTF awards (Noël Dimarcq), the exhibits (Wolfgang Schäfer) and to the sponsors having allowed also this year a strong student travel support program. We are also pleased that EFTF represents an occasion for several other committees, working groups and project consortia, from CCTF, EURAMET, ESA, and other organisations, to convene in splinter and satellite meetings.

We would like to wish you a motivating and inspiring forum.

Kind regards,

Steve Lecomte
Chairman
of the EFTF-2014 LOC

Gaetano Mileti
Chairman
of the EFTF-2014 SC

Ekkehard Peik
Chairman
of the EFTF EC

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GENERAL CONFERENCE SCHEDULE

Sunday June 22

17.00 – 19.00 Registration – UniNe, Jeunes-Rives

Monday June 23

08.00 – 18.00 Registration – UniNe, Jeunes-Rives
08.15 – 18.00 **Tutorials – UniNe, Aula Breguet 1**
18.15 – 19.30 *Ice-Breaker– UniNe, Jeunes-Rives*

Tuesday June 24

08.00 – 18.00 Registration – UniNe, Jeunes-Rives
09.00 – 17.40 Exhibition & Mobile Lab – UniNe, Jeunes-Rives
08.30 – 08.55 **Opening session A0L-A** - UniNe, Jeunes-Rives, Main Aula
09.00 – 10.40 **Lecture sessions A1**
Fiber I, A1L-A, Main Aula
Microsystems Resonators, A1L-B, Room 2 (R.N.02)
Sensors & Resonators, A1L-C, Room 3 (R.E.48)
10.40 – 11.00 *Coffee break*
11.00 – 12.40 **Lecture sessions A2**
Frequency Combs I, A2L-A, Main Aula
Physics in Resonators, A2L-B, Room 2 (R.N.02)
Low Noise Microwave & Optical, A2L-C, Room 3 (R.E.48)
12.40 – 14.00 *Lunch break, patinoire*
14.00 – 15.40 **Poster sessions A3**
Materials & Characterization, A3P-D, R.0.12 (Mobile Lab)
Time Scales, A3P-E, R.0.14
Sensors & Transducers, A3P-F, R.0.14
Microwave Frequency Standards I, A3P-G, R.S.38
Optical Combs and Standards I, A3P-H, R.S.38
Student Poster Competition, A3P-J, Cafeteria Entrance
15.40 – 16.00 *Coffee break*
16.00 – 17.40 **Lecture sessions A4**
Laser Stabilization, A4L-A, Main Aula
Time Transfer I, A4L-B, Room 2 (R.N.02)
Acoustic Materials, A4L-C, Room 3 (R.E.48)
17.40 – 18.15 *Refreshments*
18.15 – 19.15 **Post-deadline session** – UniNe, Jeunes-Rives, Main Aula

Wednesday June 25

08.00 – 18.00 Registration – UniNe, Jeunes-Rives
10.40 – 17.40 Exhibition & Mobile Lab – UniNe, Jeunes-Rives
08.30 – 10.40 **Plenary session B0L-A** - UniNe, Jeunes-Rives, Main Aula
Serge Haroche, John Kitching
10.40 – 11.00 *Coffee break*

11.00 – 12.40	**Lecture sessions B1**
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	Fiber II, B1L-B, Room 2 (R.N.02)
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12.40 – 14.00	*Lunch break, patinoire*
14.00 – 15.40	**Poster sessions B2**
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	Fiber & Optical, B2P-E, R.0.14
	Oscillators, Synthesizers, Noise & Circuit Techniques, B2P-F, R.0.14
	Microwave Frequency Standards II, B2P-G, R.S.38
	Optical Clocks II, B2P-H, R.S.38
	Student Poster Competition, B2P-J, Cafeteria Entrance
15.40 – 16.00	*Coffee break*
16.00 – 17.40	**Lecture sessions B3**
	Space Clocks, B3L-A, Main Aula
	Optical Clocks I, B3L-B, Room 2 (R.N.02)
	MEMS Oscillators, B3L-C, Room 3 (R.E.48)
18.30 – 23.00	**Banquet – Conference dinner – Awards**, patinoire

Thursday June 26

08.00 – 18.00	Registration – UniNe, Jeunes-Rives
09.00 – 16.00	Exhibition & Mobile Lab – UniNe, Jeunes-Rives
08.00 – 08.55	**Exhibitors presentation**, C0L-A, Main Aula
09.00 – 10.40	**Lecture sessions C1**
	New Concepts in Atomic Clocks & Sensors, C1L-A, Main Aula
	Ion Clocks, C1L-B, Room 2 (R.N.02)
	Time Transfer II, C1L-C, Room 3 (R.E.48)
10.40 – 11.00	*Coffee break*
11.00 – 12.40	**Lecture sessions C2**
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	Cold Atoms and Clocks, C2L-B, Room 2 (R.N.02)
	Galileo and Time Dissemination, C2L-C, Room 3 (R.E.48)
12.30 – 14.00	*Lunch break*
14.00 – 15.40	**Poster sessions C3**
	GNSS & Space, C3P-E, R.0.14
	Microwave Frequency Standards III, C3P-G, R.S.38
	Laser Stabilization & Atom Manipulation, C3P-H, R.S.38
	Student Poster Competition, C3P-J, Cafeteria Entrance
15.40 – 16.00	*Coffee break*
16.00 – 17.40	**Lecture sessions C4**
	Fundamental Tests, C4L-A, Main Aula
	Compact Atomic Clocks, C4L-B, Room 2 (R.N.02)
	Time Scales & Time Stamping, C4L-C, Room 3 (R.E.48)

Friday June 27

08:30 – 18:00	Visit of museum & lab tours
08:30 – 18:00	Satellite workshops, Faculty of Sciences of UniNe, Unimail

SPONSORS

The organising committee gratefully acknowledges the support of the following supporters of EFTF 2014.

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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI
Swiss Space Office

SATW
Schweizerische Akademie der Technischen Wissenschaften
Académie suisse des sciences techniques
Accademia svizzera delle scienze tecniche
Swiss Academy of Engineering Sciences

METAS
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PLENARY SESSION

The EFTF 2014 Scientific Committee is pleased to announce the following plenary session for EFTF 2014.

Location:	Main Aula, University of Neuchâtel
Date:	Wednesday, June 25, 2014
Time:	08:30 - 10:40
Chair:	Gaetano Mileti, Laboratoire Temps – Fréquence, UniNe

Professor Serge Haroche

ENS and Collège de France, Paris, France

Nobel Prize for Physics 2012 (link)

An atomic clock tames light

A Ramsey interferometer of the kind used in standard atomic clocks can be turned into a versatile tool to count photons non destructively and to manipulate non classical states of light. Applications to quantum metrology and quantum information science will be considered.

More about Haroche

Dr. John Kitching

NIST, Boulder, CO, USA

Chip-scale atomic devices: from atomic clocks to brain imaging and beyond

In recent years, the combination of precision atomic spectroscopy, micromachining technology and advanced diode lasers have enabled a new generation of atomic clocks and precision atomic sensors characterized by small size and low power dissipation. We discuss work at NIST over the last decade to develop such instruments and to use them in applications ranging from nuclear magnetic resonance to magnetic measurements of the human brain.

More about Kitching

EFTF AWARDS

Three Awards, sponsored by the Federal Institute of Metrology METAS and the Local Organising Committee, will be presented at EFTF 2014 to recipients selected by the Executive Committee of the EFTF.

European Frequency and Time Award 2014

The European Frequency and Time Award recognizes outstanding contributions in all fields covered by the EFTF.

Winners of the European Frequency and Time Award 2014 are

Alexey V. Taichenachev and Valeriy I. Yudin,
Institute of Laser Physics, Siberian Branch, Russian Academy of Sciences, and Novosibirsk State University, Novosibirsk, Russia

"For novel methods in the preparation and interrogation of atoms that have led to new kinds of spectroscopy and improved atomic clocks"

Young Scientist Award 2014

The EFTF Young Scientist Award is conferred in recognition of a personal contribution that has demonstrated a high degree of initiative and creativity and led to already established or easily foreseeable outstanding advances in the field of time and frequency metrology. The award honors a person under the age of 40 at the date of the opening session of the EFTF conference.

Winner of the EFTF Young Scientist Award 2014 is

Yann Le Coq, SYRTE, Paris, France

"For outstanding contributions to the development of fiber-based optical frequency combs for optical frequency metrology"

Marcel Ecabert Award 2014

The Marcel Ecabert Award of the EFTF is a lifetime award and honours the excellent achievements of the recipient or an institution in the field of time and frequency. It is named after the late Marcel Ecabert, founding member of the EFTF and member of its Executive Committee.

Winner of the Marcel Ecabert Award 2014 is

Jean-Pierre Aubry, Neuchâtel, Switzerland

"For his outstanding involvement in industrial developments in time and frequency metrology and in recognition of his major contribution dedicated to the strengthening of interactions between industry and academic research"

Sponsors of the student travel support programme

The EFTF 2014 Organising Committee gratefully acknowledges the support of the following companies and institutions:

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sfmc.gandi-site.net

Orolia Switzerland
Spectratime
Neuchâtel, Switzerland
www.spectratime.com

T4Science
Neuchâtel, Switzerland
www.t4science.com

EFTF-2014 STUDENT POSTER FINALISTS

The following papers were selected as finalists by the EFTF-2014 Scientific Committee for the EFTF 2014 Student Poster Competition.

This year, the Student poster awards were sponsored by the Swiss Space Office

Session code:	A3P-J
Location:	Cafeteria Entrance, University of Neuchâtel
Date & Time:	Tuesday, June 24, 14:00 - 15:40
	The poster will remain during the whole conference
Chair:	Gaetano Mileti, University of Neuchatel

7164 **Quartz-Based Vibrating MEMS on Structured Silicon Using Wafer Bonding Technology**
Sebastien Grousset, CEA-Leti; Rachid Taïbi, Office National d'Etudes et Recherches Aérospatiales; Lamine Benaissa, CEA-Leti; Emmanuel Augendre, CEA-Leti; Thomas Signamarcheix, CEA-Leti; Olivier Le Traon, Office National d'Etudes et Recherches Aérospatiales; Sylvain Ballandras, frec|n|sys SAS

7176 **Assessment of the Acoustic Shear Velocity in SiO_2 and Mo for Acoustic Reflectors**
Mario DeMiguel-Ramos, Universidad Politécnica de Madrid; T. Mirea, Universidad Politécnica de Madrid; J. Olivares, Universidad Politécnica de Madrid; M. Clement, Universidad Politécnica de Madrid; J. Sangrador, Universidad Politécnica de Madrid; E. Iborra, Universidad Politécnica de Madrid

7276 **Effects of a Plasma Etching Process on a Longitudinally Coupled Resonator Filter**
Loïc Braun, AR Electronique SAS; E. Courjon, frec|n|sys SAS; O. Franquet, AR Electronique SAS; W. Daniau, FEMTO-ST Institute; T. Baron, FEMTO-ST Institute; S. Ballandras, frec|n|sys SAS

7284 **Active Electronic Cancellation of Nonlinearity in a High-Q Longitudinal-Mode Silicon Resonator by Current Biasing**
Haoshen Zhu, City University of Hong Kong; Cheng Tu, City University of Hong Kong; Libor Rufer, TIMA Laboratory; Joshua Lee, City University of Hong Kong

7230 **Photodiode Nonlinear Modeling and its Impact on Optical Links Phase Noise**
Zeina Abdallah, LAAS-CNRS / Centre National d'Etudes Spatiales; A. Rumeau, LAAS-CNRS; J. Maxin, LAAS-CNRS / Thales Research and Technology; A. Fernandez, LAAS-CNRS; G. Pillet, Thales Research and Technology; L. Morvan, Thales Research and Technology; O. Llopis, LAAS-CNRS; G. Cibiel, Centre National d'Etudes Spatiales

7301 **Compact Low Phase Noise 3.8GHz Oscillator**
Pratik D. Deshpande, University of York; Jeremy Everard, University of York

7069 **High-Purity Microwave Signal from a Dual-Frequency Semiconductor Laser for CPT Atomic Clocks**

Paul Dumont, Laboratoire Charles Fabry, Institut d'Optique; J.-M. Danet, Observatoire de Paris; F.A. Camargo, Laboratoire Charles Fabry, Institut d'Optique; D. Holleville, Observatoire de Paris; S. Guerandel, Observatoire de Paris; G. Baili, Thales Research and Technology; L. Morvan, Thales Research and Technology; G. Pillet, Thales Research and Technology; D. Dolfi, Thales Research and Technology; I. Gozhyk, Laboratoire Charles Fabry, Institut d'Optique / Laboratoire de Photoniques et de Nanostructures; G. Beaudoin, Laboratoire de Photoniques et de Nanostructures; I. Sagnes, Laboratoire de Photoniques et de Nanostructures; P. Georges, Laboratoire Charles Fabry, Institut d'Optique; G. Lucas-Leclin, Laboratoire Charles Fabry, Institut d'Optique

7196 **Experimental and Numerical Study of the Microwave Field Distribution in a Compact Magnetron-Type Microwave Cavity**

Anton Ivanov, École Polytechnique Fédérale de Lausanne; Thejesh Bandi, Université de Neuchâtel; Guan- Xiang Du, Universität Basel; Andrew Horsley, Universität Basel; Christoph Affolderbach, Université de Neuchâtel; Anja K. Skrivervik, École Polytechnique Fédérale de Lausanne; Philipp Treutlein, Universität Basel; Gaetano Mileti, Université de Neuchâtel

7212 **Mitigation of Frequency Shifts in a Cold-Atom Coherent Population Trapping Clock**

Eric Blanshan, National Institute of Standards and Technology; F.-X. Esnault, National Institute of Standards and Technology; J. Kitching, National Institute of Standards and Technology; E.A. Donley, National Institute of Standards and Technology

7242 **Imaging Rb-Wall Interactions and Microwave Fields in Vapor Cells**

Andrew Horsley, Universität Basel; Guan-Xiang Du, Universität Basel; Matthieu Pellaton, Université de Neuchâtel; Christoph Affolderbach, Université de Neuchâtel; Gaetano Mileti, Université de Neuchâtel; Philipp Treutlein, Universität Basel

7034 **Miniature Optical Fiber Cavity for a Trapped Atom Clock**

Ramon Szmuk, Observatoire de Paris; Konstantin Ott, Observatoire de Paris / École Normale Supérieure; Ralf Kohlhaas, Observatoire de Paris; Jakob Reichel, École Normale Supérieure; Peter Rosenbusch, Observatoire de Paris

7293 **Electromagnetic Induction Readout Silicon-on-Insulator MEMS Resonant Magnetometer**

Weiguan Zhang, City University of Hong Kong; Joshua E.-Y. Lee, City University of Hong Kong

7307 **Studying Particulate Adsorption by Drying Droplets on a Microfabricated Electro-Acoustic Resonator**

Abhinav Prasad, University of Cambridge; Arthur T. Zielinski, University of Cambridge; Markus Kalberer, University of Cambridge; Roderic L. Jones, University of Cambridge; Ashwin A. Seshia, University of Cambridge

7150 **Time Transfer Over Delay-Stabilized Fibre Links Using an Optical Pulse Train**

Maurice Lessing, National Physical Laboratory / University of St. Andrews; Giuseppe Marra, National Physical Laboratory

7201 **A Detection Algorithm of Atomic Clock Frequency Jumps with the Prediction Wiener Filter**
Xinming Huang, National University of Defense Technology

7203 **In-Line Extraction of an Ultra-Stable Frequency Signal Over an Optical Fiber Link**
Anthony Bercy, Université Paris 13 / Observatoire de Paris; S. Guellati-Khelifa, Université Pierre et Marie Curie; F. Stefani, Université Paris 13 / Observatoire de Paris; G. Santarelli, Université de Bordeaux 1; C. Chardonnet, Université Paris 13; P.-E. Pottie, Observatoire de Paris; O. Lopez, Université Paris 13; A. Amy-Klein, Université Paris 13

7288 **A Method of Satellite Autonomous on-Board Clock Monitoring Using High-Stability Crystal Oscillator**
Gangqiang Guan, National University of Defense Technology

7052 **On the Prospects of Building Optical Atomic Clocks Using Er I or Er III**
Alexander Kozlov, University of New South Wales; Vladimir Dzuba, University of New South Wales; Victor Flambaum, University of New South Wales

7112 **Laser Stabilization System for Space Applications Based on Hydroxide-Catalysis Bonding**
Yingxin Luo, Huazhong University of Science and Technology; Hongyin Li, Huazhong University of Science and Technology; Huizong Duan, Huazhong University of Science and Technology; Hsien-Chi Yeh, Huazhong University of Science and Technology

7165 **An Ultra-Low Frequency Noise Laser Based on a 48 cm Long ULE Cavity for a Sr Lattice Clock**
Sebastian Häfner, Physikalisch-Technische Bundesanstalt; S. Vogt, Physikalisch-Technische Bundesanstalt; A. Al- Masoudi, Physikalisch-Technische Bundesanstalt; St. Falke, Physikalisch-Technische Bundesanstalt; C. Grebing, Physikalisch-Technische Bundesanstalt; M. Merimaa, Centre for Metrology and Accreditation; Th. Legero, Physikalisch-Technische Bundesanstalt; Ch. Lisdat, Physikalisch-Technische Bundesanstalt; Uwe Sterr, Physikalisch-Technische Bundesanstalt

7179 **Thin Disk Lasers Enable High-Power Frequency Combs**
Florian Emaury, ETH Zurich; Alexander Klenner, ETH Zurich; Andreas Diebold, ETH Zurich; Cinia Schriber, ETH Zurich; Clara J. Saraceno, ETH Zurich / Université de Neuchâtel; Stéphane Schilt, Université de Neuchâtel; Ursula Keller, ETH Zurich; Thomas Südmeyer, Université de Neuchâtel

PRACTICAL INFORMATION

The following organizational details have been summarized, in order to help make your stay and experience at EFTF 2014 both efficient and enjoyable.

Conference Address

Aula des Jeunes Rives, University of Neuchâtel
Espace Louis-Agassiz 1, 2000 Neuchâtel (Switzerland)
Main conference telephone (FSRM): +41 (0)32 720 09 00
Registration desk email: registration@eftf2014.ch
Web: www.eftf2014.ch/venue

Language

The official language of EFTF 2014 is **English**, including all oral and poster presentations as well as all printed supports.

Venue

EFTF 2014 will be held at the **University of Neuchâtel**, in the beautiful lakeside city of Neuchâtel, Switzerland. The main conference venue is the Aula des Jeunes Rives. All related events are located within a few minutes' walk of the main venue.

Tutorials on Monday June 23 will be held at the "Auditoire, Breguet 1", just a 3-minute walk from the main Aula.

All lunches, and the **gala dinner** on Wednesday evening, will be held in the "Patinoire du Littoral", also located just next door to the main Aula (to the east, a 3-minute walk).

Appropriate signage is in place to guide you to these places.

Dialling Codes

The country code for Switzerland is +41. For domestic calls, the area code must be added, including the preceding "0". i.e. for local calls in Neuchâtel, dial 032-xxx-xxxx.

Emergency Numbers

Police: 117 **Fire**: 118 **Ambulance**: 144

Meeting Room Locations at the University of Neuchâtel

Tutorials ..... Auditoire, Breguet 1
Plenary Sessions ..... Aula des Jeunes Rives
Poster Sessions..... R.O. 12, R.O.14, R.E.48
Oral Presentations ..... Aula des Jeunes Rives, R.N. 02 (Room 2) & R.E.48 (Room 3)
Lunches and Gala Dinner..... Patinoire du Littoral
Registration (Sunday - Thursday) ..... Aula des Jeunes Rives, main lobby
Please refer to the venue map.

Registration & Information Desk

Sunday, June 22..... 17:00 – 19:00
Monday-Thursday, June 23-26 ..... 08:00 – 18:00

Badges

All participants must wear the conference name badge for admission to all conference events (sessions, exhibition, social program).

Internet Service

Complimentary WiFi will be available at EFTF 2014. There are two options to connect.

1. Please select the network "*public-unine"*. In the window that appears give your email address in the field "*Login pour Invités"*.
2. Alternatively, if you already have access to EDUROAM, please select the network "*eduroam"* and, if needed, give your username and password.

Conference Programme

A portable version of the conference program, including all abstracts in pdf format, is distributed to participants on a USB drive. The information is indexed chronologically by Table of Contents, As well, an author index and a full text search are available. You will need the free version of Adobe Acrobat Reader to access this program. You are reminded as well that you have the possibility to create and print a personalised schedule of the technical program. For more information, please visit this page
http://www.eftf2014.ch/mySchedule

Camera and Filming Policy

Please refrain from taking any photos or video during any of the conference sessions and poster presentations.

Cell Phones and Alarms

As a courtesy to all participants, please ensure that all cell phones and other alarms (watches, pagers) are turned off during all presentations.

Tipping & Taxes

Prices in restaurants in Switzerland always include the tip. However, in the case of very good service, it is common to leave 5-10% more. A goods and service tax (8.0%) is included in store prices and restaurant menus.

Smoking

Smoking policies in Switzerland differ from Canton to Canton. In Neuchâtel, smoking is forbidden within all public buildings and restaurants (this includes all facilities used for EFTF 2014).

EFTF 2014 Presenter Information

Oral Presenters

- **The duration of a presentation slot is 20 minutes** (40 minutes for invited speakers). You will have about 15 minutes for the presentation itself and about 5 minutes for questions from the audience (35 minutes for presentation and 5 minutes Q&A for invited speakers). Since most speakers spend an average of one minute per slide, it would probably be best if the number of slides in your presentation is around 15 (respectively 30).
- **LCD projectors and laptop computers** (MS PowerPoint & Adobe Acrobat Reader) will be available in every session room for regular presentations. Neither overhead projectors, 35mm slides projectors nor VHS videotape player will be available.
- If you have special requests please let us know well in advance. An AV technician will be available should any assistance be needed.
- **All presentations must be pre-loaded in the talks upload area** (close to the registration desk) **at the beginning of each day**. Please bring a memory stick containing your presentation. To avoid software compatibility problems (MS PowerPoint), speakers are advised to save their PowerPoint presentation in "pack-n-go" format AND bring a backup PDF version of their presentation. "Pack-n-go" format is used when burning a presentation to a CD for use on another computer that may or may not have your current version of PowerPoint installed. It installs a viewer capability. The file should be saved as "Package for CD" under the "File" tab in PowerPoint 2003, under the "File > Publish" tab in PowerPoint 2007, under “File > Save & Send > Package Presentation for CD” in PowerPoint 2010, and under “File > Export > Package Presentation for CD” in PowerPoint 2013.

Preparation of Visuals

Limit the number of words per visual to no more than 20. Leave space, at least the height of a capital letter, between lines of text. All fonts, including that on graphs, should be 18 point or larger. (22 point is generally best). Graphs and charts should have bold lines and symbols that contrast sharply with the background.

Poster Presentations

Poster boards will be available for presenters to put up their poster presentations. The size of the area for each poster is 100 cm. (wide) 250 cm. (tall). Your poster will be attached with push pins which will be provided. The recommended format is A0 portrait: 84.1 cm x 118.9 cm (33.1 inch x 46.8 inch). The location of your poster will be noted on each board in accordance with the corresponding number listed in the Program Book given out at registration. There will be a dedicated area for the student poster competition finalists. You will be required to be present at your poster presentation during the hours listed in the Program Book for the Poster Session.

Conference Proceedings

The proceedings and copyright forms shall be submitted before the start of the conference. More information on www.eftf2014.ch/authors and www.epapers.org/eftf2014/ESR/authorinfo1.php

ORGANISING COMMITTEES

Local Organisation Committee

- Steve Lecomte, CSEM, General Chair
- Philippe Fischer, FSRM, General co-Chair
- Gaetano Mileti, University of Neuchâtel
- Christoph Affolderbach, University of Neuchâtel
- Edward Byrne, FSRM
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- Anne-Lise Poffet, Spectratime
- Stephane Schilt, University of Neuchâtel
- Claudine Julia-Schmutz, CSEM
- Beatriz Tur, CSEM
- Daniel Varidel, University of Neuchâtel
- Igor Chlebny, University of Neuchâtel

EFTF Executive Committee (Elected Members)

- Bernard Dulmet, Femto-ST, France
- Noël Dimarcq, Observatoire de Paris, SYRTE, France, Awards Chair
- Jeremy Everard, University of York, United Kingdom, Tutorial Chair
- Helen Margolis, NPL, National Physical Laboratory, United Kingdom
- Ekkehard Peik, Physikalisch-Technische Bundesanstalt, Germany, Chair
- Pascal Rochat, Spectratime, Switzerland
- Wolfgang Schäfer, TimeTech, Germany, Exhibition Chair
- Patrizia Tavella, INRIM Istituto Nazionale di Ricerca Metrologica, Italy, Vice Chair
- Francois Vernotte, Observatoire de Besançon, France
- Pierre Waller, European Space Agency, The Netherlands

Ex Officio Members of the Executive Committee

- Sébastien Thibaud, SFMC, France
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- Michael Driscoll, Northrop Grumman Electronic Systems, IEEE-IFCS – Standing Committee Chair
- Steve Lecomte, CSEM, Switzerland – EFTF 2014 Local Organising Committee Chair

Scientific Committee of EFTF-2014

Gaetano Mileti (Scientific chair), LTF-UniNE, Switzerland

Group 1 – Materials, Resonators, & Resonator Circuits

- **Emmanuel Defay (vice-chair), LETI, France**
- Ventsislav Yantchev, Uppsala University, Sweden
- Bernard Dulmet, Femto, France
- Dana Weinstein, MIT, USA
- Marc Faucher, IEMN, France
- Ashwin A. Seshia, University of Cambridge, UK
- Gianluca Piazza, Carnegie Melon University, USA
- Olivier Le Traon, Onera, France
- Clark Nguyen, Univ. of California, Berkeley, USA

Group 2 – Oscillators, Synthesizers, Noise, & Circuit Techniques

- **Jean Pierre Aubry (vice-chair), Aubry Conseil, Switzerland**
- Steve Tanner, IMT-EPFL, Switzerland
- Olivier Lopis, LASS, France
- Claudio Calosso, INRIM, Italy
- Fabrice Sthal, FEMTO, France
- Jeremy Everard, Univ. York, UK
- Mike Underhill, Underhill Research, UK
- Enrico Rubiola, FEMTO, France
- David Howe, NIST, USA

Group 3 – Microwave Frequency Standards

- **Krzysztof Szymaniec (vice-chair), NPL, UK**
- Patrick Berthoud, Oscilloquartz, Switzerland
- Arnaud Landragin, SYRTE, France
- Qinghua Wang, Spectratime, Switzerland
- Kurt Gibble, Penn State University, USA
- Svenja Knappe, NIST, USA
- Motohiro Kumagai, NICT, Japan
- Peter Rosenbusch, SYRTE, France
- Stefan Weyers, PTB, Germany
- John Kitching, NIST, USA
- Salvatore Micalizio, INRIM, Italy

Group 4 – Sensors & Transducers

- **Leonhard Reindl (vice-chair), Uni Freiburg, Germany**
- Ralf Lucklum, University of Magdeburg, Germany,
- Alfred Binder, CTR AG, Austria
- Clemens Ruppel, Epcos AG, Germany
- Paul Muralt, EPFL, Switzerland
- Sylvain Ballandras, Frecnsys, France
- Diethelm Johannsmann, TU Clausthal Germany,
- Fritze Holger, TU Clausthal, Germany
- Jean-Michel Fried, FEMTO, France
- Ventsislav Yantchev, Uppsala University, Sweden
- Victor Plessky, GVR Trade SA, Switzerland

Group 5 – Timekeeping, T&F Transfer, Telecom and GNSS applications

- **Pierre Waller (vice-chair), ESA, The Netherlands**
- Laurent-Guy Bernier, METAS, Switzerland
- Davide Calonico, INRiM, Italy
- Pascale Defraigne, ORB, Belgium
- Jerome Delporte, CNES, France
- Miho Fujieda, ICT, Japan
- Gesine Grosche, PTB, Germany
- Per Olof Hedekvist, SP, Sweden
- Judah Levine, NIST, USA
- Huang-Tien Lin, NTFSL – TL, Taiwan
- Xiao Chun Lu, NTSC, China
- Vitaly Pal'chikov, VNIIFTR, Russia
- Andreas Bauch, PTB, Germany
- Ed Powers, USNO, USA
- Wolfgang Schäfer, Timetech, Germany
- Amitava Sen Gupta, NPLI, India
- Patrizia Tavella, INRiM, Italy
- Pierre Uhrich, SYRTE, France
- Peter Whibberley, NPLI, UK
- Michael Wouters, NMI, Australia
- Aimin Zhang, NIM, China
- Victor Zhang, NIST, USA

Group 6 – Optical Frequency Standards and Applications

- **Sébastien Bize (vice-chair), SYRTE, France**
- Luigi Cacciapuoti, ESA, The Netherlands
- Davide Calonico, INRIM, Italy
- Roman Ciurylo, Nicolaus Copernicus Univ., Poland
- Pierre Dube, NRC, Canada
- Patrick Gill, NPL, United Kingdom
- Tetsuya Ido, NICT, Japan
- Steve Lecomte, CSEM, Switzerland
- Yann Le Coq, SYRTE, France
- Christian Lisdat, PTB, Germany
- Andrew Ludlow, NIST, USA
- Andre Luiten, University of Adelaide, Australia
- Long-Sheng Ma, East China Normal Univ., China
- Helen Margolis, NPL, United Kingdom
- Mikko Merimaa, MIKES, Finland
- Jacques Morel, METAS, Switzerland
- Ekkehard Peik, PTB, Germany
- Thomas Südmeyer, LTF-UniNE, Switzerland
- Alexey Taichenachev, Inst. of Laser Physics, Russia

ABOUT THE LOCAL ORGANISERS

CSEM is a private Swiss research and technology organization which delivers advanced technologies and unique R&D services to industry. Targeting emerging, strategic, high-impact technologies, CSEM brings new products to market and creates new ventures. A 440-strong workforce with industrial backgrounds, mostly top-level engineers and holders of PhDs, dedicates its passion to this mission.

FSRM – Crossroads of Microtechnology
The FSRM (Swiss Foundation for Research in Microtechnology) promotes micro technology and its applications with offers in continuous education, project management and organization. The complete course schedule is available at www.fsrm.ch/agenda.

Laboratoire Temps – Fréquence, Université de Neuchâtel
Active in the domains of space and miniature atomic clocks, primary standards, stabilised lasers, optical metrology and ultrafast lasers, Laboratoire Temps – Fréquence (LTF) is part of the University of Neuchâtel (UniNe), the host organisation of the 2014 edition of EFTF. Constituted of five Faculties, UniNe has more than 4300 students and offers Bachelors, Master and PhD degrees in line with society's expectations in a variety of innovative and highly-specialized fields.

Spectratime (Orolia Switzerland SA) is a world leader in the generation, synchronization of precise time and frequency signals. Spectratime designs, manufactures and markets atomic clocks and network timing and synchronization solutions used in wireline and wireless telecom networks, as well as in space and defense systems.

SOCIAL PROGRAM

Monday, June 23 from 18:15

Icebreaker reception – Jeunes-Rives, University of Neuchâtel (Main conference venue)

Whether you are just arriving or finishing a day of tutorials, join us for a welcome drink to relax and catch up with colleagues.

Supper afterwards on your own.

Wednesday, June 25 from 18:00

Conference Banquet – Patinoire du Littoral Neuchâtel

After 2 full days of intense collaboration and conference rooms, it's time to unwind and relax over a nice meal. Student and EFTF awards will be presented during the banquet as well.

The ”Patinoire” is located just 3-4 minute walk from the main EFTF venue at the University of Neuchâtel (link).

Friday, June 27, 9:15 – 12:30

International Watch Museum visit – La Chaux-de-Fonds (www.chaux-de-fonds.ch/musees/mih, in French only)

> **Departure from Neuchâtel** at 9:15
> **Visit duration**: 1h30
> **Back to Neuchâtel** at 12:15-12:30.

Cost: CHF 30.- (includes transportation by bus, museum entrance and guided visit in English).

Max. participants: 100

For registrations, please have a look at the WEB-page or ask to the reception desk

Lab tours

Visits of CSEM, Spectratime and LTF-UniNe will be organized. Please refer to the conference WEB page and the conference information desk.

DETAILED PROGRAMME (DAY BY DAY)

Sunday June 22

17:00 - 19:00 **Registration** **Main Aula**
University of Neuchâtel Jeunes Rives

Monday June 23

08:00 – 18:00 **Registration** **Main Aula**
University of Neuchâtel Jeunes Rives

08:30 – 18:00 **Tutorials** **UniNe, Rue Breguet 1, Auditoire, 2nd floor**
University of Neuchâtel Jeunes Rives

8:15	**Université de Neuchâtel, Rue Breguet 1, Auditoire, 2nd floor**
	The Leeson Effect - PM and AM noise and frequency stability in oscillators, including OEOs and lasers Enrico Rubiola, CNRS FEMTO-ST Institute, Dept. Time & Frequency, France
09:45	***Coffee break***
10:00	**Vapor Cell Frequency Standards** Salvatore Micalizio, INRIM, Italy
11:30	***Lunch at the Patinoire***
13:00	**Global Navigation Satellite Systems (GNSS)** Pascale Defraigne, Royal Observatory of Belgium, Belgium
14:30	***Tea break***
14:45	**Lasers for Optical Frequency Standards** Stephen Webster, M Squared Lasers, United Kingdom
16:15	***Tea break***
16:30 – 18:00	**Frequency & Time Transfer using Optical Fibres** Gesine Grosche, PTB, Germany
18:15	***University of Neuchâtel Jeunes Rives***
	Ice-breaker reception
20:00	***End of the day – Supper afterwards on your own***

Note:

For reasons of limited space, only the name and affiliation of the first author of each communication is given in this program booklet. For the full list of authors and affiliations, please refer to the USB drive and online program.

Tutorials

Location:	University of Neuchâtel, Rue Breguet 1
Room:	Auditoire, 2nd floor
Date:	Monday, June 23, 2014
Time:	8:30 – 18:00
Organiser:	Jeremy Everard

8:15 – 09:45 The Leeson Effect: PM and AM noise and frequency stability in oscillators, including OEOs and lasers

By **Enrico Rubiola**, CNRS FEMTO-ST Institute, Besancon, France
e-mail: rubiola@femto-st.fr, web http://rubiola.org

Abstract

Simply stated, an oscillator consists of a loop in which a resonator sets the oscillation frequency and an amplifier compensates for the resonator loss. The oscillation amplitude is set by clipping or other gain-saturation mechanisms, usually in the amplifier. When phase noise is introduced in the loop, the oscillator converts it to frequency noise through a process of time-domain integration. The consequence is that the oscillator phase fluctuation diverges in the long run.

The first part explains the phase-to-frequency conversion mechanism as a general phenomenon inherent in the feedback, following an heuristic approach based on physical insight. There follow the relationships between the noise of the internal components (sustaining amplifier, resonator, etc.) and the phase noise at the oscillator output, or equivalently the frequency stability.

The second part is the analysis of the phase noise spectra found in the data-sheet of commercial oscillators: dielectric-resonator oscillator (DRO), whispering gallery oscillator (WGO), 5-100 MHz quartz crystal oscillators, opto-electronic oscillator (OEO). The analysis gives information on the most relevant design parameters, like the quality factor Q and the driving power of the resonator, and the flicker noise of the sustaining amplifier.

The last part shows the derivation of the oscillator phase noise formulae from the elementary properties of the resonator. Interestingly, the amplitude non-linearity, necessary for the oscillation amplitude to be stable, splits the resonator relaxation time into two time constants. The approach shown in this last part is general. It applies to all oscillators, including quartz, RLC, microwave cavity, delay-line, laser, etc.

Biography

Enrico Rubiola is full professor at the Université de Franche Comté and deputy director of the Department of Time and Frequency of the CNRS FEMTO-ST Institute, Besançon, France. Formerly, he was a full professor at the Université Henri Poincaré, Nancy, France, a guest scientist at the NASA JPL, a professor at the Università di Parma, Italy, and an assistant professor at the Politecnico di Torino, Italy.

He graduated in electronic engineering at the Politecnico di Torino in 1983, received a Ph.D. in Metrology from the Italian Minister of University and Research, Roma (1989), and a Sc.D. degree from the Université de Franche Comté in 1999.

Prof. Rubiola has worked on various topics of electronics and metrology, navigation systems, time/frequency comparisons, and frequency standards. His main fields of interest are precision electronics from dc to microwaves and phase noise metrology, which include analogue and digital frequency synthesis, high spectral purity oscillators, photonic systems, sophisticated instrumentation, and noise. He has developed innovative instruments for AM/PM noise measurement with ultimate sensitivity, and a variety of signal-processing methods. Currently, he is the PI of Oscillator IMP, a platform under development, dedicated to the measurement of AM/PM noise and short-term frequency stability.

A wealth of articles, reports and conference presentations are available on Enrico Rubiola's home page http://rubiola.org.

10:00 – 11:30 Vapour Cell Frequency Standards

By **Salvatore Micalizio**, INRIM, Italy

Abstract

Since their first realization in the 1960s, vapour-cell frequency standards have been considered extremely attractive devices in all those applications where good frequency stability performance joined with small size, reliability, reduced power consumption and costs are required. These applications include telecommunication, defence, energy, space and radio-navigation. The passive rubidium frequency standard with state selection performed by the incoherent light of a lamp is still nowadays widely adopted in many measurement systems, as well as in advanced technological sectors, such as GPS and GALILEO.

The development of single mode semiconductor laser diodes in the 1980s opened new perspectives in the field of gas cell frequency standards, thanks to the replacement of the discharge lamp with a coherent optical source. In terms of frequency stability, the expected performance improvement was theoretically estimated of 2-3 orders of magnitude, predicting a white frequency noise limit in the 10-14 τ-1/2 region, τ being the integration time. However, laser noise transferred to the clock signal via the light-shift effect prevented from reaching this result. In the last twenty years, innovative schemes have been considered with the aim of approaching the expected theoretical limit and new concept laser-pumped frequency standards have been developed. These clocks are the object of this tutorial.

After resuming the main features of the traditional lamp-pumped Rb clock, the tutorial will focus into several interesting approaches that have been envisaged not only to get close to the fundamental stability limit, but also to reduce at the same time the requirements on the laser noise. These techniques include coherent population trapping, light-shift compensated schemes and pulsed optical pumping. The tutorial will describe these proposals, their main advantages and limitations and the most significant results obtained by various research groups.

Biography

Salvatore Micalizio is a researcher in the Optics Division of INRIM. After receiving the degree in theoretical particle physics from University of Torino, he joined the Time and Frequency Division of IEN where he was involved in the realization of a Rb maser without inversion of population. In 2001 he received the PhD in Metrology from Politecnico of Torino and since 2004 he is on the permanent staff of INRIM. His research activity is mainly devoted to the development of vapour cell frequency standards. He made studies on coherent population trapping, electromagnetically induced transparency, pulsed optical pumping and their possible application to frequency metrology. He was in the key personnel of several research programs funded by the ESA. He was responsible for INRIM of a contract funded by the Italian Space Agency devoted to the realization of a POP maser prototype for space applications. He is coordinating the project Mclocks IND 55 funded by the European Metrological Research Program concerning the development of vapour cell clocks for industrial applications. He is also involved in studies on primary atomic frequency standards developed at INRIM.

13:00 – 14:30 Global Navigation Satellite Systems (GNSS)

By **Pascale Defraigne**, Royal Observatory of Belgium, Belgium

Abstract

Humans have always needed time for precise navigation. To date, GNSS also relies on time: everything is based on the measurements of the signal travel time between the satellite and the receiver.

GNSS therefore needs a reference timescale maintained by the operators and broadcast by the satellites. On the other hand, the satellite navigation systems offer a wonderful tool for time and frequency metrology, as these flying atomic clocks on board the satellites can be used as a reference for the comparison of ground time and frequency standards.

The tutorial will raise both aspects of the link between GNSS and TIME. After showing concretely the need for accurate time scales for the GNSS, the “GNSS time transfer” technique will be detailed. Code and carrier phase measurements will be presented and the procedure to get a precise and accurate clock comparison will be explained, both from the instrumental point of view and in terms of data analysis. GNSS Common View (or All in View) as well as Precise Point Positioning will be detailed in the presentation. The different error sources on the measurements will be studied and hence an ideal station setup will be presented.

Biography

P. Defraigne obtained her PhD in Geophysics in 1995 at the Université Catholique de Louvain. Since 1997 she manages the time and frequency activities at the Royal Observatory of Belgium, where the Belgian reference UTC (ORB) is maintained.

Her research activities mainly concern the use of satellite navigation systems for time and frequency transfer. P. Defraigne presently chairs the CCTF working group on GNSS time transfer, and contributes to the validation of Galileo timing signals.

14:45 – 16:15 Lasers for Optical Frequency Standards

By **Stephen Webster**, M Squared Lasers, 1 Kelvin Campus, West of Scotland Science Park, Maryhill Road, Glasgow, G20 0SP, UK
email: stephen.webster@m2lasers.com

Abstract

Over the past 50 years, atomic clocks have been based on microwave frequencies and primary standards have demonstrated uncertainties at the level of a few parts in 1016. Optical clocks are a new generation of atomic clock, in which the frequency of light is the signal used for timing. They are based on “forbidden” atomic transitions for which light is absorbed over a very narrow range of frequencies. Depending on the particular atomic species and transition used, the ratio of the frequency to the frequency width (Q-factor) ranges from 1014-1023, thus, these transitions constitute very precise frequency references. They are also insensitive to external electromagnetic fields and can be highly reproducible, and it is anticipated that optical clocks will reach uncertainties of a part in 1018. Further, given that the frequency of light is ~100,000 times higher than that of microwaves, the same level of precision as a microwave atomic clock may be reached in a much shorter time. As optical clocks come of age and prove the stability and reproducibility predicted of them, the prospect will open up for a redefinition of the second in terms of an optical frequency.

The atomic absorber in an optical clock takes one of two forms: it is either a single ion confined in an electro-dynamic trap (Paul trap), or an ensemble of neutral atoms held in an electric dipole force trap (optical lattice). The atomic absorbers are laser cooled so that they are nearly at rest and, to first order, do not experience a Doppler shift on interaction with the light used to probe the atomic transition. To make use of the high-Q of the atomic transition, the probe light must also have a very narrow frequency width and this is achieved by stabilizing a laser to a secondary reference, a high-finesse Fabry-Pérot etalon. A mode-locked femtosecond-pulsed laser (femtosecond comb) converts the very rapid oscillations of the light from some 100’s of THz down to a radio frequency so that output of the optical clock can be counted by commercial electronics and compared to the SI second and the outputs of other optical clocks.

This tutorial will give an overview of the essential elements of an optical clock: the atomic reference, the ultra-stable laser and the femtosecond comb. It will describe how each of these elements is realized in practice and the experimental challenges involved in operating

such an apparatus. In particular, a review will be made of the laser sources required for operation of an optical frequency standard, the techniques employed in their stabilisation and the characterization of their noise.

Biography

Stephen joined M Squared lasers as their Scientific Products Specialist in September 2012. The company specialises in the research, development and manufacture of solid-state lasers and photonic instruments for a wide range of industrial and scientific applications; his role is to engage with scientific customers and develop new products to meet scientific needs.

Previous to his work at M Squared, Stephen was a senior research scientist at the National Physical Laboratory in the UK for over a decade, where he worked on optical frequency standards, ultra-stable lasers and vibration-insensitive cavities. Highlights of his work there were publications on a force-insensitive optical cavity, the lowest reported acceleration sensitivity for an optical cavity, subhertz laser linewidth, observation of the thermal-noise limit for a cavity and frequency measurements of the electric quadrupole and octupole transitions in 171Yb+ ion with a fractional uncertainty of 10-15. In 2008, he received the Young Scientist of the Year Award at the European Frequency & Time Forum.

Stephen was awarded a D.Phil from the University of Oxford in 2000 for work on Bose-Einstein Condensation of atomic gases.

Outside of work, Stephen is a keen musician and enjoys hiking and cycling. He is married with two children, aged 4 and 1.

16:30 – 18:00 Frequency & Time Transfer using Optical Fibres

By **Gesine Grosche**, PTB, Germany

Abstract

“Ever more accurate clocks and frequency references are being developed in dedicated laboratories around the world, reaching astonishingly low instability and high accuracy, currently near 1 part in 10 to the 18.

Making the ultra-stable output of these powerful instruments available beyond the walls of the metrology laboratory, to enable physics experiments, remains a challenge. In the wake of the optical telecommunication revolution, transfer techniques that make use of optical fibre have greatly developed: within one decade, improvements of more than three orders of magnitude in precision have been achieved.

Frequency transfer accuracy at the level of 1 part in 10 to the 19, and, for 1 km-scale links, synchronisation at the level of femtoseconds has been reported. Fibre based transfer of frequency and time has been achieved over distances exceeding 500 km, enabling international comparisons and joint experiments.

In this tutorial I will illustrate the advantages and challenges of using optical fibre as a transmission medium for precision metrology. This will cover basic concepts, techniques and limitations, focusing on optical telecommunication fibre (1.5 µm), which is both cheap and optimised for low loss, making it suitable for long-distance transfer. The tutorial will give an overview and comparison of different frequency and time transfer techniques, including methods based on radio-frequency modulation, on using the optical carrier phase, and on the transmission of fs-pulses generated by mode-locked lasers. "

Biography

Gesine Grosche is head of the research group for optical frequency dissemination at the German Metrology Institute, PTB, in Braunschweig, Germany. She received her B.A. degree in Physics from Cambridge University, UK (Trinity College, 1993) and her PhD in Semiconductor Physics from University of London (Imperial College, 1997). After initially joining PTB to invent optical methods for measuring fluid flow velocities from an airplane, she moved on to coordinate a European project providing reference wavelengths for optical telecommunications, and, from 2003, to establish and develop frequency comb metrology based on mode-locked fiber lasers at PTB. From 2001, she has pursued the vision of ultra-stable frequency dissemination using telecommunication fibre, pioneering and refining techniques for remote metrology, which includes remote frequency measurements and frequency synthesis. Her group currently concentrates on long-distance phase-stable fibre links to connect metrology institutes across Europe.

Tuesday June 24

08:00 – 18:00 Registration Main Aula
University of Neuchâtel Jeunes Rives

8:30	**Opening Session in Main Aula**			
	Peter Kropf, Dean of the Faculty of Sciences of the University of Neuchâtel **Steve Lecomte**, CSEM SA, Chairman of the Local Organising Committee **Ekkehard Peik**, Physikalisch-Technische Bundesanstalt, Germany, Chairman of the EFTF Executive Committee			
9:00	**Lecture sessions**			
	Main Aula	**Room R.N.02**	**Room R.E. 48**	
	A1L-A – Fiber I Chair: Per Olof Hedekvist	A1L-B – Microsystems Resonators Chair: Emmanuel Defay	A1L-C – Sensors & Resonators Chair: Leonhard Reindl	
10:40	***Coffee break***			
11:00	**Lecture sessions**			
	Main Aula	**Room R.N.02**	**Room R.E. 48**	
	A2L-A – Frequency Combs I Chair: Helen Margolis	A2L-B – Physics in Resonators Chair: Ashwin Seshia	A2L-C – Low Noise Microwave & Optical Chair: Jeremy Everard	
12:40	***Lunch at the Patinoire***			
14:00	**Poster sessions**			
	Mobile Lab – R.O.12	**Room R.O.14**	**Room R.S.38**	**Cafeteria Entrance**
	A3P-D – Materials & Characterization Chair: Sunil Bhave	A3P-E – Time Scales Chair: Pierre Uhrich A3P-F – Sensors & Transducers Chair: Victor Plessky	A3P-G – Microwave Frequency Standards I Chair: Salvatore Micalizio A3P-H – Optical Frequency Combs & Standards Chair: Rodolphe Le Targat	A3P-J – Student Poster Finalists Chair: Gaetano Mileti
15:40	***Coffee break***			
16:00	**Lecture sessions**			
	Main Aula	**R.N.02**	**R.E.48**	
	A4L-A – Laser Stabilization Chair: Jacques Morel	A4L-B – Time Transfer I Chair: Wolfgang Schaeffer	A4L-C – Acoustic Materials Chair: Paul Muralt	
17:40	***Refreshments***			
18:15	**Main Aula hall**			
	Session A5L-A Oral Post-Deadline, Chair: Stéphane Schilt			
19:15	***End of the day – Supper afterwards on your own***			

Session A1L-A – Fiber I — Main Aula

09:00 ***INVITED*** **– NEAT-FT: the European Fiber Link Collaboration**
Harald Schnatz, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

The development of clocks based on optical transitions during the past three decades culminates in the availability of optical clocks with unprecedented stability and uncertainty. The European joint research project Network for European Accurate Time and Frequency Transfer (NEAT-FT) investigates the dissemination of high-precision timing and ultrastable frequency signals by using existing fiber infrastructure. This talk highlights recent achievements and discusses some applications and prospects.

09:40 **Optical Frequency Transfer with a 1284 km Coherent Fiber Link**
Davide Calonico, Istituto Nazionale di Ricerca Metrologica (Italy), *et al.*

We describe a coherent optical fiber link in Italy for the dissemination of a high accuracy frequency reference, devoted to metrology, radio-astronomy and precision atomic physics. We started with a 642 km link that connects the Italian metrological institute (INRIM) with the University of Florence-European Nonlinear Spectroscopy Laboratory (LENS). Then we doubled the length to 1284 km, sending the signal back from LENS to INRIM, to have both ends of the link in the same laboratory. We have characterizied the frequency trasfer with a resolution of 3E-19. This optical link is the backbone of the project LIFT (Italian Link for Time and Frequency), that aims to connect Italian scientific poles in Milan, Bologna and Florence, and to connect Italy to other European institutes.

10:00 **High Resolution Characterisation of a 450-km-Baseline GPS Carrier Phase Link via Optical Fibre**
Stefan Droste, Max-Planck-Institut für Quantenoptik (Germany), *et al.*

We use a 920 km optical fibre link as reference link (with a negligible uncertainty contribution) for high-resolution characterisation of a GPS carrier phase (CP) Precise Point Positioning (PPP) link, covering a baseline of 450 km. Two active H-masers at the link endpoints MPQ Garching and PTB Braunschweig are simultaneously compared via the fibre link and the GPS link, and both links give the same mean frequency offset between the two masers. For the difference between GPS link data and fibre link data, the H-maser fluctuations cancel, revealing just the GPS link properties with a resolution below 1E-15.

10:20 **Novel Techniques for Optical Fiber Links Beyond Current Practice**
Claudio Eligio Calosso, Istituto Nazionale di Ricerca Metrologica (Italy), *et al.*

We propose two techniques to overcome the main limitations of current Doppler fiber noise compensation. The first one can be applied to existing links and surpasses the fundamental limit by 6 dB. This concept is demonstrated through the well-known bounce diagram: it enables to visualize the fiber noise as a function of space and time, and gives some clues on how to minimize it. Second, we introduce an optical Two-Way Phase Transfer in which two signals travel the fiber in opposite directions. This scheme enables the bridging of longer distances, as the light travels the fiber only once.

09:00 ***INVITED*** **– High Frequency Silicon Nanowire Resonators for Mass Sensing**
Laurent Duraffourg, CEA-Leti (France)

Interfacing NEMS and more specifically nanowires with the macro world remains a challenge. During the talk, an overview of the transduction schemes used for detecting tiny displacements of suspended nanowires will be presented. The presentation will introduce VLSI-NEMS manufacturing with and without its co-integrated CMOS readout electronics. As an example, highly efficient in-plane motion detection based on suspended p++-doped piezoresistive nanowires will be presented. The smallest devices have been co-integrated with their readout electronics to extract the useful signal from the background with a fairly good Allan deviation lower than 1ppm. Finally, the talk will conclude on several emblematic applications related to mass sensing. Recent results on multi-gas detections and mass spectrometry with NEMS including silicon nanowires will be reported.

09:40 **Quartz-Based Vibrating MEMS on Structured Silicon Using Wafer Bonding Technology**
Sebastien Grousset, CEA-Leti (France), *et al.*

In this study, we partially use strategies developed for Si-based MEMS device fabrication and in the meantime, we adjust some parameters to the specifications of single-crystal quartz material. We will present the results of our wafer-level approach that allows the collective fabrication of gyroscope sensors based on quartz vibrating MEMS. More specifically, we focus on suspended quartz tuning fork microstructures of a desired thickness over controlled depth cavities which integration is based on the bonding and thinning of 4-inch z-cut quartz wafer on pre-structured silicon wafer.

10:00 **Effects of a Plasma Etching Process on a Longitudinally Coupled Resonator Filter**
Loïc Braun, AR Electronique SAS (France), *et al.*

In our work we have developed a trimming process using a reactive-ion etching machine. We have applied this process to longitudinally-coupled resonators filters operating at gigahertz-frequencies, and studied the effects on the whole response of the device.

10:20 **Active Electronic Cancellation of Nonlinearity in a High-Q Longitudinal-Mode Silicon Resonator by Current Biasing**
Haoshen Zhu, City University of Hong Kong (Hong Kong), *et al.*

In this work, for the first time, we report a means to actively cancel nonlinearity for a high quality factor bulk-mode single-crystal-silicon micromechanical resonator through its bias current. The results show that the power handling is enhanced by over 4.5 times. It is found that increasing the bias current changes the third-order elastic modulus of silicon, thus providing us the desirable effect of electronically 'tuning out' material-induced nonlinearity.

09:00 ***INVITED*** **– Ultra-Wide-Band SAW RFID/Sensors**
Victor Plessky, GVR Trade SA (Switzerland), *et al.*

This invited paper describes development of a SAW tag and sensor system operating in the Ultra-Wide-Band (UWB) frequency range. We have developed prototype devices operating in 200MHz - 400 MHz and 2000 MHz - 2500 MHz UWB frequency ranges. The first remote measurements show compressed RF pulses of about 2 ns duration, which include unique RF filling of a few sinusoids with amplitude modulation. Precise measurement of the pulse position is possible by correlation methods, avoiding the phase ambiguity problem. The feasibility of the UWB (B=750MHz) SAW-tags operating in 6 GHz range was demonstrated experimentally. The devices have small chip size of 0.8 x 2.1 mm^2, small antenna size, and demonstrate loss level only about 10 dB higher than typical values of 2.45 GHz analogues. The use of Hyperbolically Frequency Modulated (HFM) signals instead of traditional Linear Fre-quency Modulation (LFM) simplifies the compression algorithms, making them invariant to temperature.

09:40 **SH-SAW Biosensors for One Step Test**
Hiromi Yatsuda, Japan Radio Co. Ltd. (Japan), *et al.*

This paper describes an immunoassay-based shear horizontal surface acoustic wave (SH-SAW) biosensor for the measurement of a variety of biomarkers (protein, hormone, virus, bacteria) in various sample types (nasal swabs, whole blood, urine, saliva). A 250 MHz and 380MHz SH-SAW delay-line sensor are designed and fabricated on quartz substrate. In order to protect the interdigital transducers of the SH-SAW device from liquids, the sensor device has a unique air-cavity structure over the transducers. Three attractive design techniques for SH-SAW biosensors are described; reflection-type technique, reference-type technique and a technique using membranes on the sensor surface.

10:00 **Electromagnetic Induction Readout Silicon-on-Insulator MEMS Resonant Magnetometer**
Weiguan Zhang, City University of Hong Kong (Hong Kong), *et al.*

We report an electromagnetic induction readout MEMS resonant magnetometer. It benefits from a CMOS-compatible process and promises lower power consumption compared to devices based on Lorentz force action since no bias current is needed. This readout mechanism has been reported for a bulk-mode square-plate resonator . Our device holds multiple benefits over the bulk-mode design including simpler fabrication process (3 vs 6 masks), lower drive voltage requirements (5V vs 50V), smaller foot print (700μm×600μm vs 2mm×2mm), and higher sensitivity due to the larger displacements afforded by designing with compliant flexural beams.

10:20 **Studying Particulate Adsorption by Drying Droplets on a Microfabricated Electro-Acoustic Resonator**

Abhinav Prasad, University of Cambridge (United Kingdom), *et al.*

Two identical silicon resonators were used to study particle adsorption via water droplet evaporation. High-purity water droplets with dispersed polystyrene particles were dispensed onto a sensor resonator while high-purity water droplets were dispensed onto a reference resonator. Both resonators saw ring stains, known as the "coffee-ring effect", and negative frequency shifts after each droplet. While the reference resonator experienced a linear frequency shift, the sensor resonator experienced much larger shifts that were higher than expected. Droplet drying and subsequent particle redistribution will be further examined in terms of their effect on frequency response.

Session A2L-A – Frequency Combs I — Main Aula

11:00 ***INVITED*** **– Attoclock**

Ursula Keller, ETH Zurich (Switzerland)

Ultrafast solid-state lasers enabled the world's most accurate clocks - the optical clock and the attoclock. In collaboration with Dr. Telle (PTB, Braunschweig), we pioneered self-referencing frequency comb stabilization from modelocked lasers, introduced and made first feasibility demonstrations for several novel techniques to measure and stabilize the carrier envelope offset phase (i.e. CEO phase or CEP) fluctuations - for example we proposed the f-to-2f heterodyne technique which is being used today.

11:40 **Phase Measurements of Optical Frequency Comb Modes in Microresonators**

Pascal Del'Haye, National Institute of Standards and Technology (USA), *et al.*

We present a novel scheme for precise phase measurements of individual modes in microresonator-based optical frequency combs. We find microcomb states with characteristic phase-steps of multiples of π and $\pi/2$ in the comb spectrum.

12:00 **Frequency Comb Self-Referencing Using an Intra-Cavity SESAM as Fast Opto-Optical Modulator**

Stephane Schilt, Université de Neuchâtel (Switzerland), *et al.*

We present a novel method for frequency comb self-referencing that combines high bandwidth with low loss, nonlinearity and dispersion. It uses a semiconductor saturable absorber mirror (SESAM), optically pumped by a continuous wave diode, as a fast intra-cavity opto-optical modulator to control the comb carrier-envelop offset (CEO) frequency. We demonstrate proof-of-principle operation in a diode-pumped solid-state laser previously self-referenced by standard feedback to the pump current, achieving 10-fold higher CEO modulation bandwidth, 4-fold better frequency stability and 10-fold lower residual integrated phase noise. The method has high potential for CEO stabilization of novel high power or high repetition rate oscillators.

12:20 **Thin Disk Lasers Enable High-Power Frequency Combs**
Florian Emaury, ETH Zurich (Switzerland), *et al.*

We present the first phase-stabilization of the carrier-envelope-offset (CEO) frequency of a SESAM modelocked thin disk laser (TDL). The residual in-loop integrated phase noise is 120 mrad (1 Hz-1 MHz), with negligible contributions of amplitude-to-phase noise conversion in the generated CEO beat. In spite of the strongly spatially multimode pumping scheme of TDLs, our result shows that a reliable lock of the CEO frequency can be achieved using straightforward pump modulation. This opens the door to fully-stabilized low-noise frequency combs with hundreds of watts of average power from table-top SESAM modelocked thin disk oscillators.

Session A2L-B – Physics in Resonators R.N.02

11:00 ***INVITED*** **– Surface Phononic Gratings as Building Blocks of Transducers and Reflectors with Complete Bandgap Characteristics**
Ventsislav Yantchev, Uppsala University (Sweden)

A concept is demonstrated for the development of phononic surface acoustic wave (SAW) interdigital transducers (IDT) able to excite acoustic waves propagating within the complete frequency bandgap of the transducer structure. The proposed phononic structures are compatible with the SAW planar technology and can be used as building blocks of SAW resonant devices. Three distinct types of phononic IDTs are theoretically described and experimentally verified. Resonant SAW test structures exhibiting complete bandgap characteristics are demonstrated on 128° YX LiNbO3.

11:40 **Properties Related to Q-Factors and Noise of Quartz Resonator-Based Systems at 4K**
Serge Galliou, FEMTO-ST Institute (France), *et al.*

Very high values of quality-factors, greater than 1 billion, have been measured recently on quartz crystal resonators at cryogenic temperatures. Added to the fact that Q-factors and frequency flicker noise are related, interesting applications emerge. The operating regime of propagating waves at cryogenic temperature, i.e. the Landau-Rumer regime, is reminded as well as some limitations due to extra losses. Noise measurements from bibliography are compared to current results achieved with our experimental set-up.

12:00 **Assessment of the Acoustic Shear Velocity in SiO_2 and Mo for Acoustic Reflectors**
Mario Demiguel-Ramos, Universidad Politécnica de Madrid (Spain), *et al.*

We propose a straightforward method to assess the acoustic shear velocity of the high and low acoustic impedance materials that form the acoustic reflector of SMRs, in this particular case Mo and porous SiO_2. The method is based on inducing a $\lambda/2$ shear resonance in the material under study, whose frequency depends on its thickness, density and sound velocity. The response is then fitted using Mason's Model. The deduced shear sound velocities are 3333 m/s for Mo and 3130 m/s for SiO_2.

12:20 **Selective Excitation of a Single Mode in a Multimode BAW Resonator**
Victor Plessky, GVR Trade SA (Switzerland), *et al.*

In this paper we propose a structure including the HBAR with no electrodes on its surface, but with a system of grooves or ridges with period 2p, and with IDT electrode structure suspended (with pitch equal to p) over the surface of HBAR. The electric fields created by the IDT excite SAW in bottom piezoelectric material in a narrow frequency band, when the frequency of excitation corresponds to VSAW,piezo/2p. The excited SAW is scattered into the bulk of the piezoelectric in direction perpendicular to the surface by the periodic (λ=2p) grooves. If the frequency corresponds to the frequency of one of the bulk modes of the high-overtone BAW resonator only this mode is efficiently generated.

Session A2L-C – Low Noise Microwave & Optical R.E.48

11:00 ***INVITED*** **– Ultra-Low Phase Noise Frequency Synthesis for Optical Atomic Frequency Standards**
David Howe, National Institute of Standards and Technology (United States), *et al.*

We present frequency synthesizer needs that are consistent with new high-accuracy optical atomic standards. Optical atomic standards achieve extremely low frequency uncertainty in only hundreds of minutes due to their unprecedented levels of phase stability and accuracy. Formidable challenges face metrologists in synthesizing frequencies for direct measurements of these new breeds of ultra-low phase noise (ULPN) signals. Applications are presented that need ULPN fast-accuracy oscillators in the radio frequency (RF) range of 5 MHz to a few GHz. We address how and why accurate ULPN oscillators mitigate problems in: (a) the synchronization segment, (b) the effect of lag time, and (c) phase-noise and frequency-uncertainty effects. We present recent research and measurements at NIST of a chain of ULPN regenerative dividers whose input is a cavity-stabilized OFD and whose end output at 5 MHz has a phase noise of L(1 Hz) = -150 dBc/Hz. Importantly, this chain provides cascading intermediate, exceptionally low-noise frequencies suitable for synthesizing many ULPN signals at convenient RF and microwave frequencies.

11:40 **Photodiode Nonlinear Modeling and its Impact on Optical Links Phase Noise**
Zeina Abdallah, LAAS-CNRS (France), *et al.*

An equivalent model of a microwave optical link is proposed. In this model, the photodiode description includes a photo-generation time delay dependence on the optical power. This phenomenon is indeed responsible for the conversion of the laser amplitude noise into microwave phase noise, which is now correctly described.

12:00 **Latest Improvements in the Performances of a Cryogenic Sapphire Oscillator**
Serge Grop, FEMTO-ST Institute (France), *et al.*

The preliminary measurement of two identical Cryogenic Sapphire Oscillators (CSO) was realized in the frame of the ULISS project and presented during the last EFTF in Prague [1]. Since, the two instruments have been improved leading today to an unprecedented frequency stability better than $1x10^{-15}$ between 1 s and 10,000 s integration times (one unit flicker floor: $3x10^{-16}$) with a

measured frequency drift of 1.7x10^{-15}/day. The frequency synthesis providing from the CSO signal the useful frequencies (10GHz, 1GHz, 100MHz) has been improved and completely characterised.

12:20 Ultra-High Stability Cryocooled Sapphire Microwave Oscillators
Ashby Hilton, University of Western Australia (Australia), *et al.*

Two nominally identical microwave cryocooled sapphire oscillators (CSOs) have been implemented at the University of Adelaide. The self-noise of the control systems have been measured, under operating conditions, using a novel parallel measurement arrangement, which provides strong noise rejection of the noise measurement and probing systems. Using these measurements, a detailed noise model was built, which can explain the current CSO performance in terms of measurable parameters. The short-term performance is dominated by noise in the frequency control system. This model allows us to better optimize the operational parameters and minimize the noise floors associated with the control systems' self-noise.

Session A4L-A – Laser Stabilization — Main Aula

16:00 Quantum Cascade Laser Stabilization at Hz-Level by Use of a Frequency Comb and an Optical Link
Berengere Argence, Université Paris 13 (France), *et al.*

We have built a frequency chain which enables to transfer coherently the stability and accuracy of an ultrastable laser emitting at 1.54 µm to the mid-infrared spectral region. It includes an optical frequency comb and an ultrastable 1.54 µm frequency signal, referenced to primary standards and transferred from LNE-SYRTE to LPL through an optical link. With this set-up, we stabilized a Quantum Cascade Laser emitting at 10 µm at an unprecedented Hz-level. We are now progressing towards high resolution spectroscopy of molecules with this stabilized laser. Such a development is very challenging for fundamental test of physics with molecules.

16:20 Hybrid Fibre-Atomic Optical Frequency Standard
Chris Perrella, University of Adelaide (Australia), *et al.*

The advent of high-quality hollow-core photonic-crystal fiber (HC-PCF) offers the potential to build robust and compact optical frequency standards with a total volume of below 1 litre. We report on such a standard based on Rubidium vapour loaded into HC-PCF that is interrogated using two-photon Doppler free excitation. We expect that the performance of the standard should be in the low-10^{-13} range in an optimized arrangement.

16:40 Investigations and Reduction of Frequency Noise in Mid-Infrared Quantum Cascade Lasers
Stéphane Schilt, Université de Neuchâtel (Switzerland), *et al.*

We studied the origin of frequency noise in mid-infrared quantum cascade lasers (QCLs) and present a novel noise reduction method without using any optical measurement. We performed a detailed noise study in a set of 22 different QCLs and show that frequency noise results from electrical noise generated within the structure. Our results reveal much lower noise in ridge waveguide lasers than in buried heterostructures. Large lasers also have less noise than narrow devices. Frequency noise reduction using the electrical fluctuations across the laser as an error signal is also demonstrated, with 10-fold reduction of the noise power spectral density.

17:00 **Investigation of a High-Finesse Silicon Optical Resonator at Cryogenic Temperatures**

E. Wiens, Heinrich-Heine Universität Düsseldorf (Germany), *et al.*

We investigated properties of a high-finesse (> 200 000) silicon resonator at temperatures down to 1.5 K. Long-term frequency instability of the resonator on the level of 1 x10^{-14} at several 10^{3} s was determined by comparison with a frequency comb and a H maser. No discernible long-term drift has been observed. The coefficient of thermal expansion has been measured in the temperature range 1.5 - 20 K. At 1.6 K, it is 3x10^{-12}/K. Laser power insensitivity and temperature instability are compatible with a potential frequency instability in the low 10^{-17} range.

17:20 **Laser Frequency Reference for 1064 nm Based on Molecular Iodine - Towards Space Qualification**

Klaus Döringshoff, Humboldt-Universität zu Berlin (Germany), *et al.*

With the goal of a space qualified optical frequency reference, we have realized an engineering model (EM) of an iodine spectroscopy setup for laser frequency stabilization to hyperfine transition in molecular iodine. We report on details of our laser system, environmental tests of the EM and the characterization of the frequency stability achieved with the EM compared to a cavity stabilized laser system.

Session A4L-B – Time Transfer I — R.N.02

16:00 **A Sub-Ns Comparison Between GPS Common View and T2L2**

Etienne Samain, Géoazur / Université de Nice Sophia-Antipolis (France), *et al.*

T2L2 (Time Transfer by Laser Link) permits the synchronization of remote ultra stable clocks over intercontinental distances. T2L2 permits to realize some links between distant clocks with time stability of a few picoseconds and accuracy better than 100 ps. Results obtained during the last two months comparisons between GPS in common view and T2L2 with 3 European laboratories shows some differences below 300 ps with a standard deviation better than 500 ps.

16:20 **Calibration of System Delays in the European Laser Timing to 10 Ps Accuracy**

Ivan Prochazka, Czech Technical University in Prague (Czech Rep.), *et al.*

Recently the European Laser Timing (ELT) experiment is under preparation. It is an optical link prepared in the frame of the European Space Agency mission "Atomic Clock Ensemble in Space". The objective of this laser time transfer is the synchronization of the ground based clocks and the clock on board the International Space Station with precision of the order of units of picoseconds and the accuracy of 50 ps. We are reporting on a progress in calibration of the system delays involved. The first field calibration results acquired at the SLR Station Wettzell, Germany, will be presented.

16:40 Practical Evaluation of Relativistic Effects in Two-Way Satellite Time and Frequency Transfer
Setnam Shemar, National Physical Laboratory (United Kingdom), *et al.*

We investigate the practical application of existing theory to take account of relativistic effects in Two-Way Satellite Time and Frequency Transfer (TWSTFT). This is achieved using satellite position data available from internet sources. The work is part of the EMRP-funded ITOC project and provides an input to a broadband TWSTFT experiment. The aim is to compare optical atomic clocks within Europe to an experimental uncertainty of $1x10^{-16}$. Relativistic corrections are required to be evaluated to an uncertainty of $5x10^{-17}$.

17:00 Time Transfer Capabilities in a DTM Transmission System
Magnus Danielson, Net Insight (Sweden)

This article describes the enhancement of a commercial network system to include network wide time-transfer capability to meet customer needs for GPS independent timing of broadcast transmitters. The Dynamic synchronous Transfer Mode (DTM) transmission system is a network technology based on a 8 kHz Time Division Multiplex (TDM) structure, providing the basis for predictable and reliable transport and switching. With the adaptation of various native signals, it has found use in broadcast networks for both contribution and distribution networks.

17:20 Towards Accurate Optical Fibre Time Transfer in UTC
Zhiheng Jiang, Bureau International des Poids et Mesures (France), *et al.*

At present accurate time transfer is fully based on space techniques. Time transfer via optical fibre will certainly serve to the generation of UTC in the coming future. In particular, Two-way Optical Fibre Time Transfer (TWOTT). TWOTT could bring substantial improvement to the UTC generation. The TWOTT can reach tens of ps stability in a few minutes and therefore could provide an effective new tool for the assessment of GNSS and TWSTFT time links calibration. The present structure of international time links relies on time comparisons with a single pivot laboratory, which is not adapted for this new technology. Many fibre links will become operational between UTC contributing laboratories in the near future; this could provoke fundamental change in UTC construction, such as the time link strategy and with a multi-pivot configuration of the UTC time transfer network.

Session A4L-C – Acoustic Materials R.E.48

16:00 *INVITED* – Acoustic Cloaks for Airborne Sound
José Sánchez-Dehesa, Universitat Politècnica de València (Spain)

I will review the recent advances on acoustic cloaking for airborne sound in two and three dimensions. Two different approaches have been proposed so far: one uses acoustic metamaterials for designing the cloaking shell; the other obtains the scattering cancellation by using a discrete set of scatterers surrounding the central object. The last approach has the drawback of being one-directional and has narrow band operation, but actual cloaks have been already fabricated and their performance in two and three dimensions was demonstrated.

16:40 **Alpha-Quartz Type MIIIXVO4 (M= Al, Ga and X= P, As) Piezoelectric Single Crystals - a Review**
Olivier Cambon, Université Montpellier 2 (France)

This oral presentation will summarize the scientific evolution of the knowledge in the alpha-quartz type materials. Crystal growth processes and crystals will be presented. The results will show how fundamental research can improve our understanding of the structures of these materials and their links to piezoelectric applications.

17:20 **A Comparative Study of LGS Coefficient Set Accuracy Assessed by Experiments**
Bruno François, FEMTO-ST Institute (France), *et al.*

Surface acoustic wave (SAW) resonators built on Langasite have revealed capable to withstand high temperature in excess of 900°C and wireless interrogation of packaged sensors has been demonstrated at 700°C. The SAWHOT project has yield numerous experimental results of SAW resonators on LGS crystal cuts, yielding a data base consistent for an evaluation of the SAW characteristics prediction provided by published set of LGS constants. In this paper, this material is used to assess the capability to predict measured TCF for several crystal cuts supporting Rayleigh and surface transverse waves (STW).

Session A5L-A Oral Post-Deadline — Main Aula

18:15 **Accurate Thermometry with Atoms**
André Luiten , University of Adelaide and University of Western Australia, Perth (Australia), et al.

We have developed an atomic spectrometer that delivers ultra-high precision measurements of the shape of an absorption line. This has been motivated out of call by the metrological community to base the SI units on robust physical principles – our measurements can yield a new value for Boltzmann's constant. We will present quantum-limited transmission measurements of a Cs absorption line that have an accuracy of 2 ppm in a 1 second measurement. This extreme precision allows us to directly detect subtle lineshape perturbations that have not been previously observed. Using a new theoretical model of the spectrum we obtain a measurement of Boltzmann's constant with 6ppm precision and a 71ppm uncertainty.

18:30 **Ultra-stable Mid-IR Quantum Cascade Laser for high-resolution spectroscopy and metrology**
Sinda Mejri , CNRS and Université Paris 13 (France), et al.

We report the coherent phase-locking of a quantum cascade laser (QCL) at 10 µm to the secondary frequency standard of this spectral region, a CO_2 laser stabilized on a saturated absorption line of OsO4. The stability and accuracy of the standard are transferred to the QCL resulting in a line width of the order of 10 Hz, and leading to our knowledge to the narrowest QCL to date. The locked QCL is then used to perform absorption spectroscopy spanning 6 GHz of NH_3 and methyltrioxorhenium, two species of interest for applications in precision measurements

18:45 Optical Beam Size Effects in Spin Polarized Pumping
Xi Zeng, CSEM SA, et al.

We present what we believe to be the first study on the effects of optical beam size on the spin polarized pumping of atoms with narrowband optical pump sources. We experimentally measured and theoretically modeled the beam size dependence of ground state hyperfine level net relaxation time, net spin relaxation time, and spin polarization for 87Rb D_1 transition, and we obtained good agreement between theory and measurement for the two relaxation times. We present parameters such as the achievable spin polarization as a function beam diameter for typical operating conditions of single and dual frequency optical pumping.

19:00 Relativistic corrections for time and frequency transfer in optical fibers
Jan Geršl, Czech Metrology Institute (Czech Republic), et al.

In the first part of the paper we derive a relativistic differential equation governing the signal propagation in optical fiber. Solving this equation we obtain formulas for signal propagation times depending on the refractive index, fiber positioning on Earth surface and Earth's gravitational field. All terms larger than 1 ps are included. Next we derive formulas for proper frequency evolution during the signal propagation in the fiber. We derive how the frequency of signal changes depending on the fiber motion, expansion and time evolution of the refractive index. All terms with relative contribution to frequency of 10^{-18} or larger are included.

Details of Tuesday poster sessions (14:00 – 15:40)

Session A3P-D – Materials & Characterization — Mobile Lab – R.O.12

7013 Phase-Sensitive and Fast-Scanning Laser Probe System for Radio Frequency Surface/Bulk Acoustic Wave Devices
Ken-Ya Hashimoto, Chiba University (Japan), et al.

This talk reviews the current status of a laser probe for RF surface and bulk acoustic wave devices developed by the authors' group. The system operes upto 6 GHz, and the lateral resolution is better than 0.4 um. A focus adjustment system was installed for making the image in focus throughout the scanning area. The system has been used for the characterization of various RF SAW/BAW devices by many academic and industrial partners. Through the collaboration, the system has been evolved year by year, its effectiveness has been demonstrated, and is well recognized all over the world.

7049 Analysis of Contributions of Nonlinear Material Constants to Temperature-Induced Velocity Shifts of Quartz and Langasite Surface Acoustic Wave Resonators
Haifeng Zhang, University of North Texas (United States), et al.

Temperature-induced surface acoustic wave (SAW) velocity shifts are analyzed for quartz and langasite SAW resonators. The analytical methodology has been verified by comparing experimental results and analytical results for quartz resonators. Sensitivity of the analytical results to different groups of nonlinear material constants (third-order elastic constants (TOE), third-order piezoelectric constants (TOP), third-order dielectric constants (TOD) and electrostrictive con-stants (EL)) for SAW quartz resonators is discussed; it was found that in general, the third-order elastic constants contribute most significantly to the wave velocity shift. The contribution from the third-order dielectric constants and electrostrictive constants are negligible. For some specific cases, the

elimination of the third-order piezoelectric constants may cause significant errors. The sensitivity of each third-order elastic constants to the temperature-velocity effect is analyzed by applying 10% error to the third-order elastic constants separately. The analysis for SAW quartz resonators has been extended to langasite SAW resonators as well.

7076 Investigation of Rotated X-Cut Ca3TaGa3Si2O14 Single Crystals Operating in FS Mode in the Temperature Range Up to 900°C

Andrey Medvedev, Fomos-Materials (Russia), et al.

Ca3TaGa3Si2O14 single crystals operating in face shear mode in the temperature range up to 900°C were investigated. It was shown that the largest coupling factor of Ca3TaGa3Si2O14 single crystals operating in FS mode is close to 21.1% for (XYt)9°- cut. The frequency versus temperature characteristics of rotated X-cuts have points of extremum in the temperature range 330 ~ 580 °C

7077 Advanced Ordered Piezoelectric Ca3NbGa3Si2O14 Crystal: Piezoelectric and Acoustic Properties

Dmitry Roshchupkin, Institute of Microelectronics Technology and High-Purity Materials Russian Academy of Sciences (Russia), et al.

Ca3NbGa3Si2O14 (CNGS) crystal is a new promising piezoelectric crystal for acoustoelectronics based on surface acoustic waves (SAW) devices. CNGS is an ordered crystal of langasite family with point group symmetry 32. CNGS has a low density and higher values of the SAW velocities. Independent piezoelectric strain coefficients d11 and d14 and SAW velocities were measured using high-resolution X-ray Bragg and Laue diffractions.

7099 X-Ray Analysis of Surface and Pseudo-Surface Acoustic Waves Propagation in Disordered La3Ga5SiO14 and Ordered Ca3TaGa3Si2O14 Crystals

Olga Plotitcyna, Institute of Microelectronics Technology and High-Purity Materials Russian Academy of Sciences (Russia), et al.

The process of X-ray diffraction on acoustically modulated disordered La3Ga5SiO14 (LGS) and ordered Ca3TaGa3Si2O14 (CTGS) crystals was used to study the excitation and propagation of surface (SAW) and pseudo-surface acoustic waves (PSAW).The process of SAW and PSAW excitation and propagation is strongly different in ordered and disordered crystals.

7132 A Comprehensive Model of the Electrical Response of SAW Devices Submitted to Thermal Perturbation

Thierry Laroche, frec'n'sys SAS (Finland), et al.

Temperature sensitivity of surface acoustic wave (SAW) devices has been studied by numerous research groups for improving the thermal control of resonators, filters and sensors for analog signal processing. In the present work, the possibility to derive the thermal evolution of all the wave parameters used to design and optimize SAW devices is exploited to develop a simulation tool based on the mixed-matrix formalism capable to provide a comprehensive representation of the temperature dependence of the electrical response of SAW devices.

7155 New LGT Crystal for Ultra-Stable Resonators
Jean-Jacques Boy, FEMTO-ST Institute / ENSMM (France), et al.

As LGT seems the best candidate to substitute to the quartz crystal, we analyze here the influence of defects (macroscopic or microscopic) on the acoustic quality of the resonator. We study also our own LGT boules and the influence of certain growth parameters on the color obtained before and after annealing. At least, we discuss some perspectives of the use of LGT crystal for frequency and time applications.

7204 Femtosecond Heterodyne Pump Probe Platform
Guillaume Dodane, FEMTO-ST Institute (France), et al.

We develop a femtosecond heterodyne pump probe platform. The main goal of this platform is to provide a need in the field of thermal characterization at short space and time scales. With the pump probe method, the thermal conductivity and thermal resistivity can be extracted from the different layers of material in the sample studied. The surface acoustic wave propagation can also be imaged.

7275 Study of Surface Acoustic Wave Propagation Using Raman Spectroscopy
Artemij Irhzak, Institute of Microelectronics Technology and High-Purity Materials Russian Academy of Sciences (Russia), et al.

In this work Raman spectroscopy method was used for surface acoustic wave propagation characterization on Y-cut of the lanthanum gallium silicate (La3Ga5SiO14) single crystal. The difference between the points situated inside the acoustic path and outside it was found. This phenomenon can be explained by the presence of additional deformation of the crystal lattice which arises due to the SAW propagation.

7214 Fundamental Validation of the FEM Based Calculations Concerning Simulation of SAW and LSAW Devices
Boris Sveshnikov, Lebedev Physical Institute of the Russian Academy of Sciences (Russia), et al.

A novel integral method is proposed to validate simulation of filters and resonators based on surface (SAW) and leaky surface (LSAW) acoustic waves. This method requires the perfect satisfaction of the energy balance over the whole spectrum of analysis. It allows us to evaluate quantitatively a precision of calculations made by means of the software packages utilizing the three-dimensional finite element method (3D-FEM). Therefore, it simplifies a search for the optimal mesh discretization of a continuous domain into a set of discrete sub-domains, demanded by ordinary FEM technique.

7014 Improvement of Remote Clock Comparisons by GLONASS Signals

Alexander Bandura, Russian Institute of Radionavigation and Time (Russia), et al.

Approaches that can increase the accuracy of remote clock comparisons by GLONASS signals include using the results of receiver calibration, combined using of code and phase measurements, improved measurement processing techniques, using a posteriori data for measurement processing, etc. The results obtained with using new dual-frequency Time Transfer Unit show that the proposed approaches can improve the accuracy of remote clock comparisons to (2-3)ns by GLONASS signals and (1-2)ns by GPS signals.

7044 Calibration of the TWSTFT Link Between OCA and OP Using a GPS Link Calibration

Myrtille Laas-Bourez, Géoazur / Université de Nice Sophia-Antipolis (France), et al.

OCA is one of the rare laboratories to operate three completely independent time transfer techniques: GPS and TWSTFT techniques and T2L2. A dedicated T2L2 calibration station has been developed to provide results totally independent from other techniques. In 2013, the link between OCA and OP was calibrated during a GPS receiver relative calibration campaign. We decided to calibrate the TWSTFT link between OCA and OP by using these results. This calibration can be used for triangle closures via OP between OCA and any other TWSTFT stations.

7102 Modeling of Low-Stability GPS Receiver Clocks and its Impact on Pseudo-Range Kinematic Coordinates

Kan Wang, ETH Zurich / Institute of Geodesy and Photogrammetry (Switzerland), et al.

In this paper we discuss the deterministic and stochastic modelling of the lwo-stability receiver clocks and its impact on the pseudo-range kinematic coordinates based on simulated and real data. The relationship between the code measurement noise, the clock quality, the sampling rate and the improvement of the stability of the height coordinates is studied in detail.

7220 Optimal Design of GNSS Satellite Link Emulator Architecture and Adaptive Channel Calibration Algorithm

Pengpeng Li, National University of Defense Technology (China)

This paper improve GNSS satellite link emulator architecture. It presents an new architecture,direct RF sampling,and the performance of satellite link emulator significantly improved. Relative to the traditional architecture, the new ideal innovation that direct RF sampling, self-calibration for both analog local-oscillator(LO) frequency-drift and RF channel non-ideal characteristics. The simulation and experimental results show that, it has obvious advantages. This article analyzed the traditional architecture would introduce errors into the amount of Doppler shift, targeted proposed a method to improve the design, that contains direct RF sampling and channel self-calibrating architecture. Based on the new system architecture it proposed a set of adaptive channel self-calibration algorithm. Derived by the model, simulation and experimental verification, the new architecture of satellite link emulator and the adaptive channel self-calibration algorithm, which solves the problems of the traditional architecture effectively, while effectively enhance the adjustment accuracy for delay and frequency resolution of satellite link emulator.

7054 Development and Applications of a Traceable Time-Transfer System
Michael Wouters, National Measurement Institute Australia (Australia), et al.

NMIA has been developing GPSCV systems since the 1990's for supporting traceability to the Australian National Standard. These systems are used in a number of applications, including providing traceability for a user's frequency reference, but also providing time-of-day to users and auditing time-of-day on user NTP infrastructure.

7183 Application of Miniaturized Atomic Clocks in Kinematic GNSS Single Point Positioning
Thomas Krawinkel, Gottfried Wilhelm Leibniz Universität Hannover (Germany), et al.

Kinematic GNSS Single Point Positioning (SPP) requires epoch-wise estimation of a receiver synchronization error w.r.t. GPS system time. Modeling this error source improves the accuracy of the up-coordinate and makes the adjustment more robust. We will discuss the performance of three different atomic frequency standards that were characterized in terms of their frequency stabilities. To analyse the clock performance when connected to GNSS receivers, a static experiment was carried out. Preliminary results show improvements of the up-coordinate residuals RMS of up to 23 % when applying receiver clock modeling.

7056 A Modification of Z12T Metronome Time Transfer System
Shinn Yan Lin, National Time and Frequency Standard Laboratory / Telecommunication Laboratories (Taiwan), et al.

The aim of this paper is to modify the Ashtech Z12-T Metronome time and frequency transfer system for making its internal reference point traced to external 1 PPS input. In this paper, we modify one Z12T Metronome by adding a time interval counter (SR-620) to measure the time difference between the external 1 PPS and the following first zero crossing of the external 20 MHz. The time differences are added into the pseudorange measurement of its RINEX file. In consequence, the reference time of the modified pseudorange and REFGPS are re-defined to be the system's external 1 PPS reference, and it's independent of the external 20 MHz. A PPP result using original and modified RINEX are compared and showed the antenna position keeps unity among both files. CCD results demonstrate that the total delay of the modified system always keep the same or 50 ns ambiguity no matter we use different cable lengths of the external 20 MHz input. It allows us to use an arbitrary 20 MHz frequency devices without re-calibrating.

7083 Time Link Calibration Using Two Mobile TWSTFT Stations for T2K Experiment
Miho Fujieda, National Institute of Information and Communications Technology (Japan), et al.

The National Institute of Information and Communications Technology (NICT) performed a time link calibration for T2K experiment using two mobile two-way satellite time and frequency transfer (TWSTFT) stations. We estimated the internal delay difference between two GPS receivers with a total uncertainty of 1 ns and confirmed that the time transfer results achieved by TWSTFT and GPS agreed well. The calibration procedure and uncertainty budget will be presented in this paper.

7175 Stability of the BIPM GNSS Travelling Calibrator

Zhiheng Jiang, Bureau International des Poids et Mesures (Finland), et al.

To unify the UTC time link calibration uncertainties ≤ 2 ns, a key issue is instability of the travelling calibrator which is composed of two or three independent GNSS receiver systems. Since April 2013, it has being setup at BIPM, OP, PTB, AOS, PL, TL, NMIJ and NICT. The short- and long-terms instability of the receivers can be investigated by comparing each other. On the other side, we monitor the closures to study their stability. We present the results and discuss the calibration variations and how to implement the calibration correction in the GNSS time transfer computation.

7218 The Research on Carrier Phase Time Transfer of BeiDou Geo Navigation Satellite

Wei Guang, National Time Service Center/Chinese Academy of Sciences, et al.

In the Paper, The Carrier Phase Time Transfer on GEO Navigation satellite is implemented. The technology is referenced with GPS carrier phase time transfer principle and combined with 2 frequency observation from the GEO Navigation Satellite. The result is tested by the measurement data at last, and the performance of this time transfer technology is analyzed on the respect of precise, frequency accuracy and stability. The results show that the time transfer precise is better than 2ns by this method.

7157 Evaluation of Environmental Effects on GPS Signals by Submitting Rinex Files to Online PPP Software

Luiz Vicente Gomes Tarelho, Instituto Nacional de Metrologia, Qualidade e Tecnologia (Brazil), et al.

This paper describes the determination of ionospheric and tropospheric effects on satellite communications between Inmetro ground station and GPS constellation satellites with the use of a geodesic receiver to collect data and with post processing softwares for Precise Point Positioning (PPP) implementation. These effects are not evaluated completely in time and frequency transfer in Brazil, because we are located near Ionospheric Equatorial Anomaly and Northern models cannot be applied.

7249 Analysis of the Code / Phase Behavior in the GPS-iPPP Time Transfer

Philippe Guillemot, Centre National d'Etudes Spatiales (France)

GPS Carrier Phase appears to be the most suitable technique to assess the performances of time transfer by optical links. However, despite the development of special data processing schemes to reduce phase ambiguity, this technique is still not absolute and do not guarantee the accuracy of the time transfer. In a previous study, we explored different methods of adjusting the phase on the code of the GPS signal in an attempt to improve the accuracy of the time transfer. If the results did not allow validating the method, they showed an unexplained behavior of code / phase solutions. We propose to further explore the behavior of the Code and Phase solutions of the GPS time transfer using iPPP method.

7160 SATRE Modem Performance Characterization for 20 Mcps TWSTFT Optical Clock Comparisons

Franziska Riedel, Physikalisch-Technische Bundesanstalt (Germany), et al.

In order to reach a two-way satellite time and frequency transfer (TWSTFT) uncertainty level of below 1E-15 in one day, such as required for remote optical clock comparisons, we performed preparatory broadband laboratory experiments mimicking the satellite transmission. At high chiprates up to 20 MChip/s, we measured the dependence of SATRE TWSTFT modem jitter performance on the carrier to noise-density ratio and investigated the robustness against simultaneously transmitted, nominally uncorrelated SATRE code sequences.

7268 Two-Way Satellite Time and Frequency Transfer:Overview, Recent Developments and Apllication

Wenjun Wu, National Time Service Center / Chinese Academy of Sciences, et al.

Two-way satellite time and frequency transfer (TWSTFT) has been recognized one of the most accurate means for remote clock comparisons. It is the advantage that the symmetry of the signal paths of two earth stations makes the errors to be mostly canceled. In two-way links, it is found that there are diurnal variety errors whose magnitude is 1-3 ns in most TWSTFT results. Combined with the character of diurnal variety, the diurnal variety error is removed by function fitting method and the precision is improved to about 0.3 ns.

7289 Common Estimation of the Frequency Bias of DORIS Jason2's Oscillator, with T2L2 and Diode Onboard Instruments

Nicolas Martin, Centre National de la Recherche Scientifique (France), et al.

In orbit since June 2008, the Jason-2 satellite embarks among several instruments the T2L2 experiment based on Satellite Laser Ranging (SLR) and the navigation system DIODE based on Doppler effect measure by DORIS. Both are synchronized by an ultra stable quartz oscillator (USO) so each one can determine his frequency independently. In order to better understand the respective limits of both techniques, a laser station and a DORIS beacon have been connected to the same hydrogen maser at Grasse's SLR station. In this paper, we will present the latest developments of restitution of the USO frequency by the two systems.

7180 Nonstationarities in Space Clocks: Investigations on Experimental Data

Alice Cernigliaro, aizoOn (Italy), et al.

Nonstationarities in GNSS clocks must be detected and communicated to the system users within a few seconds. In this paper we analyze more than five years of public satellite clock data for GPS, GLONASS and Galileo.We evaluate and compare the stability of the system clocks under stationary behavior.Then we classify the most evident clock apparent anomalies and we analyze them with tools specifically designed for clock nonstationarities.

7109 Investigation of Space Passive Hydrogen Maser Atomic Beam Formation System Life-Time

Konstantin Pavlenko, Vremya-CH (Russia), et al.

For SPHM life-time the most critical part is atomic beam formation system. Two special set-ups were made to evaluate necessary amount of hydrogen in H2-source and ability of evacuation system to absorb required amount of hydrogen. The experiment has shown that both systems restrict SPHM life time with a period of more than 15 years.

7300 The Time Service Performance Evaluation of GNSS
Wei Li, National Time Service Center / Chinese Academy of Sciences (China), et al.

Time service is the most important function of GNSS,it is necessary to using the UTC as a unified time reference for the user in different regions and countries with GNSS compatibility and interoperability, so the performance of user getting UTC through GNSS is needed to evaluated. From the perspective of the user, a testing and evaluation method of GNSS time service performance is put forward in this paper. Using the UTC (NTSC) as the user's local time, through the GPS, GLONASS and Beidou multimode receiver signal, the time difference of UTC (NTSC) and UTC(k) broadcasted by GNSS is got, to amend the UTC (k) to UTC with the Circular T issued by BIPM, the complete time service is obtained. In order to evaluate the time service performance, the time difference of UTC(NTSC) and UTC is obtained with Circular T as a reference to be compared and analyzed with the time service results of GPS, GLONASS and Beidou, the results show that the GPS time service deviation is controled within 15ns, and the error is small, the performance is higher than Beidou and GLONASS.

7305 Timing Performance of GNSS on-Board Clocks
Jerome Delporte, Centre National d'Etudes Spatiales (France), et al.

The purpose of this paper is to review and compare the frequency stability of GNSS on-board clocks using the MGEX products and the polynomial method, and to assess the consistency of the results when both methods are available. Furthermore, the timing performance of GNSS onboard clocks in terms of extrapolation error using MGEX clock products will be assessed and compared to expected theoretical performance and to broadcast parameters when available.

Session A3P-F – Sensors & Transducers R.O.14

7033 Microwave Sensors of the Fast Process's in Thermal Power Engines (TPE)
Ekaterina Safonova, Kazan State Technical University named after A. N. Tupolev (Russia), et al.

Sensors are applicative for diagnostics of the most dynamic processes in combustion chambers and other TPE nodes during the takeoff and flight. The main test subjects are space- and aero-engines. Controlled parameters are fluctuations spectrum of electron density and flame temperature, as well as engine vibrations. Principle of operation is an intra-chamber space microwave probing.Sensor is presented as a miniaturized transceiver of the near-field radiolocation. Three- parameters sensors are quite similar both the principle of operation and the construction, but also by their disturbance's sensitivity. The main result of the work is the measuring transformation processes analysis. Sensitivities and amplitude-frequency characteristics of the sensors by main and neighbors parameters were found. Probing frequency choice was suggested as the main mean of disturbances responses decay. Constructively sensors are presented as antenna-oscillator modules based on coaxial lengths and circular waveguides with ring-slit antenna or open end.

7046 Microwave Autodyne Vibrosensor in Aeroengine Diagnostics
Fanis Mirsaitov, Kazan State Technical University, A. N. Tupolev (Russia), et al.

Sensor represents an antenna-oscillator module. It excites electromagnetic field in "diagnostic chamber" being a section of air flow duct, bounded by stator and rotor parts surfaces. 3D EM field structure and its fluctuation depending on regular, vibrating and damaged blade travel states

have been researched in quasi-static approximation. Probing frequency varied from 4 to 40 GHz, and range from 28 to 37 GHz was accepted as preferable. Field structure impact on antenna current flow, its vector admittance, and reflectivity have been found out. Furthermore, electromagnetic simulation by FEKO software tool was applied. Then autodyne frequency response form was found out.

7079 Digital-Locking Optically Pumped Cesium Magnetometer

Rongye Shi, Peking University (China), et al.

This paper presents a portable lamp-pumped and digital-locking cesium atomic magnetometer, including the probe of detecting Zeeman transition signal and the digital servo system of locking the Zeeman transition frequency based on C8051F020.The measurement of the magnetic field is experimentally realized with the sensitivity of about 40 pT/Hz$^{1/2}$.

7087 Passive Wireless SAW - MEMS Microphone

Victor Plessky, GVR Trade SA (Switzerland), et al.

Propose a SAW - MEMS microphone which operation principle based on electrical field distortion of SAW. Simulation results are presented. The microphone membrane displacement on 90 nanometers under 1 Pa sound pressure results about 20 kHz resonance frequency shift that is more than enough to speech transmission. Proposed SAW - MEMS microphone also can be used as a wireless passive accelerometer and pressure sensor.

7091 Resonator Defects Identification Technique with Using a Vector Network Analyzer

Alex Shimko, JSC Avangard (Russia), et al.

SAW resonators are widely used as sensitive elements of sensors where the resonance frequency fr is an informative parameter. Resonance frequency fr defines by the maximum amplitude of the probing signal response. In case of defects in resonator structure the parasitic modes are excites which impact on the measurement accuracy. In this paper a resonator defects identification technique with using a vector network analyzer is proposed.

7092 6GHz SAW-Tags and Sensors

Victor Plessky, GVR Trade SA (Switzerland), et al.

It has been shown recently that despite a strong increase of SAW propagation losses at 6 GHz frequency range, the final loss increase of the signal reflected by a SAW tag back to the "reader" can be only about 10dB. The 6 GHz range SAWtags and sensors has been produced either using E-beam lithography or nano-imprint lithography (NIL). The advantage of NIL is that hundreds of SAW devices can be imprinted at once. In E-beam lithography the devices are written serially, thus the problem of individual coding of SAW-tags does not exist. The response of a probed on wafer 6-GHz SAW-tag is very strong compared to the noise level. It is also very close to the simulation results. Recently we have received first wafers with 3GHz-6GHz SAW tags and sensors manufactured by NIL technology.

7095 SAW Temperature Sensors for Electric Power Transmission Lines
Vladimir Kalinin, JSC Avangard (Russia), et al.

We consider a system to control 12 temperature sensors. this system the collision problem is solved for 12 sensors in the time domain. All sensors have identical combination of differences of delays, which simplifies the deciphering algorithm. These specially designed sensors have reduced level on loss of only about 25 dB to 30 dB and can be "read" with the same reader as the SAW-tags.

7145 ZnO Nanorods on the 128LN Substrate for Surface Acoustic Wave Sensors
Oleksandr Bogdan, National Technical University of Ukraine (Ukraine), et al.

In this work the technology of ZnO nanorods growing for application in 2-port surface acoustic wave sensor was presented. The ZnO nanorods with the diameter of 30-60 nm and the length of about 0.6 μm as sensing element were synthesized on 128°YX-LiNbO3 substrate in zinc nitrate based solution by the low-temperature chemical processes. Nanorods could be additionally coated by the active layer for selectivity improvement. Greatly increased surface area of active layer not only improves sensitivity but also decrease the response time, that allows the application of such configuration in smart integrated sensor systems.

7158 High Throughput Fabrication of SHF SAW Components Based on Jet and Flash Imprint Lithography
Zachary James Davis, Danish Technological Institute (Denmark), et al.

The we report on a novel high throughput technique for manufacturing SAW components in the SHF (> 3 GHz) range. The fabrication process is based on Jet and Flash Imprint Lithography and has demonstrated fabrication of a 4GHz SAW id-tag sensor. The capabilities as well as the results of the manufacturing process will be presented.

7252 Simulation and Experimental Studies of Gallium Arsenide Bulk Acoustic Wave Transducer Under Lateral Field Excitation
Vivien Lacour, FEMTO-ST Institute (France), et al.

We have decided to develop high sensitive piezoelectric sensors in Gallium Arsenide (GaAs) for biological detection in liquid environment. The lateral field excitation is used to generate bulk acoustic waves through GaAs(001) membranes. This plane is used to obtain the highest coupling coefficient. Gallium Arsenide presents interesting alternative to quartz crystal concerning resonant biosensors thanks to its piezoelectric, acoustic properties, and its common micro-fabrication processes. This kind of device opens up new opportunities to fabricate sensor using low cost microfabrication processes.

7264 Highly Displacement Sensitive Higher Order Modes in a Cylindrical Reentrant-Ring Cavity Resonator
Y. Fan, University of Western Australia (Australia), et al.

Rigorous analysis of the properties of resonant modes in a reentrant cavity structure comprising of a post and a ring is undertaken and verified experimentally. In particular we show the existence of higher order reentrant cavity modes in such a structure. Results show this cavity has a better displacement sensitivity of between a factor of 2 and 1.5 compared to the common fundamental mode in a reentrant cylindrical cavity with just a single post and a gap spacing below 100 micro meters. Thus, this type of cavity has the potential to operate as a highly sensitive transducer for a variety of precision measurement applications.

7303 **State Selection in 87Rb Beam by Laser Optical Pumping**
Alexander Magunov, A.M. Prokhorov General Physics Institute of Russian Academy of Sciences (Russia), et al.

In this paper the optical pumping efficiency of the lower sublevel (5S_1/2 Fg =1 M=0) for the "clock" transition F_g = 1 M=0 " F_f =2 M =0 in rubidium standards is analyzed in detail.

7304 **Coherent Population Trapping Resonance on Zeeman Sublevels for Quantum Magnetometer**
I.M. Sokolov, Saint Petersburg State Polytechnical University (Russia), et al.

The aim of our work is finding the optimal operating conditions, active gas and laser parameters for maximum sensitivity of the magnetometer. We are going to calculate the physical limit of sensitivity of the magnetometer, based on the CPT resonance.

Session A3P-G – Microwave Frequency Standards I R.S.38

7004 **Exploring a New Scheme for Ramsey-CPT Atomic Clock**
Jing Yang, Wuhan Institute of Physics and Mathematics / Chinese Academy of Sciences (China), et al.

We propose a Ramsey-CPT atomic clock scheme by which Ramsey-CPT interference is realized by interaction between atoms and frequency switched laser. A compact Ramsey-CPT atomic clock can be realized with the scheme as the AOM used in prevalent Ramsey-CPT atomic clocks is not needed. We have experimentally compared with the prevalent ones, and our experimental results suggest that the frequency stability of the proposed one could be competitive with that of the prevalent Ramsey-CPT atomic clocks. Therefore, it is promising to realize an application competitive Ramsey-CPT atomic clock.

7026 **The Light and Orientation End Resonance Frequency Shifts in Alkaline Atoms Vapors**
Alexey Baranov, Saint Petersburg State Polytechnical University (Russia), et al.

This work is dedicated to end resonance atomic clock frequency shift investigation. It is shown that linear polarized laser usage provides an order of magnitude improvement in light and orientation shifts for both D1 and D2 lines since in this case vector component of the light shift is absent.

7063 **On the Single-State Selection for H-Maser and its Signal Application for Fountain Atomic Standard**
Mikhail Aleynikov, National Research Institute for Physical-Technical and Radiotechnical Measurements (Russia), et al.

It is well known one of the way to ensure a presence only operating atoms in the H-maser's storage bulb is a method associated with Majorana transition. To implement this method a magnetic field created by two coaxial identical coils, that are placed at the region between state selection magnets, is used. It is extremely important to know transverse (in regard to the beam axis) coordinates of the region where the field change its sign, and the magnitude of the field gradient in this region. In the paper the dependences of H-maser's selection state system quality factor on the value of the magnetic field gradient and on the transverse coordinate of its zero value are calculated and examined. On the other hand the hydrogen beam intensity is a principal

value for Power Spectral Density of the H-maser's output signal, and thus in the second part of the paper a principal circuit for using the output signal to form interrogation waveform (a synthesizer) for Rb atomic fountain is discussed, quantity of the Dick effect is calculated. In conclusion it is shown that achievable fountain's stability due to a technical noise of such RF synthesizer can reach $6x10^{-14}/\sqrt{\tau}$.

7064 Drift Compensation of Hydrogen Frequency Standard Output Signal

Vladimir I. Vasilyev, Institute of Electronic Measurements KVARZ (Russia), et al.

Frequency drift of the output signal of the hydrogen frequency standard was detected about 40 years ago, but so far this phenomenon has been poorly studied. In our previous work the physical model of frequency drift was proposed.The paper proposes the method of drift compensation according to frequency forecasting.

7073 New Method for Observing Ultra-Narrow and High-Contrast Electromagnetically-Induced-Absorption Resonances

Denis Brazhnikov, Institute of Laser Physics SB RAS (Russia), et al.

New method for observing ultra-narrow and high-contrast resonances of electromagnetically induced absorption (EIA) in the Hanle configuration is proposed. We analyze the absorption of probe light wave in presence of counterpropagating one with the same frequency as the function of a static magnetic field, applied along the waves' vectors. We attract attention to the "dark" types of atomic systems, where usually electromagnetically induced transparency (EIT) due to coherent population trapping (CPT) is observed. By proper choosing of polarization parameters and using of a buffer gas one can observe EIA signals with significantly enhanced properties.

7075 About Long Term Stability of the Self-Generating Magnetometer in Weak Magnetic Field

Alexey Baranov, Saint Petersburg State Polytechnical University (Russia), et al.

In this work the results of self-generating magnetometer long term stability for different operating conditions are presented.

7078 An Optically Detected Cesium Beam Frequency Standard with Magnetic State Selection

Chang Liu, Peking University (China), et al.

Cesium beam clocks with magnetic state selection are widely used, for their long term stability, while optically pumped cesium beam clocks have better short term stability, benefitting from the high pumping rate. This paper describes a new scheme adopting magnetic state selection together with optical detection. Our aim is to build a compact, maintenance-free clock with improved long term stability, when the short term stability is identical, or even better, with traditional magnetic-selection clocks, e.g. Symmetricom's 5071A.

7089 Aging Study on a Micro-Fabricated Cs Buffer-Gas Cell for Atomic Clock Applications

Salman Abdullah, Université de Neuchâtel (Switzerland), et al.

We report an aging study on miniature MEMS Cs-Ne cells, conducted by repeatedly measuring the cell's intrinsic clock frequency over a period of 5 months. The study was carried out by extrapolating the measured clock frequency to vanishing light intensity in order to ensure light-shift free data, and the impact of other experimental parameters was analyzed. We find a

negative fractional frequency drift of few 10^{-9} /month, suggesting a slow decrease of buffer-gas pressure in the cell.

7094 Demonstration of Optical Pumping Using a Micro-Fabricated Rb Dielectric Barrier Discharge (DBD) Lamp

Songbai Kang, Université de Neuchâtel (Switzerland), et al.

The demonstration of optical pumping using a micro-fabricated Rb dielectric barrier discharge (DBD) lamp in the Mz magnetometer configuration is presented. The double resonance (DR) between the Zeeman levels is obtained in a micro-fabricated Rb cell and comparison tests show that the pumping ability of the DBD lamp is comparable to or even better than that of a conventional glass-blown lamp.

7103 Progress in the Evaluation of a Cs Cell CPT Clock Using Push-Pull Optical Pumping

Moustafa Abdel Hafiz, FEMTO-ST Institute (France), et al.

We report progress in the evaluation of a Cs cell CPT clock using push-pull optical pumping.

7278 Microwave-Optical Double-Resonance Spectroscopy Experiment of 199Hg+ Ground State Hyperfine Splitting in Linear Ion Trap

Liu Hao, Wuhan Institute of Physics and Mathematics / Chinese Academy of Sciences (China), et al.

We report the measurement experiment of the 199Hg+ ground state hyperfine splitting in a linear ion trap. The ions are optically pumped by a discharge lamp and cooled by helium buffer gas. The ground state hyperfine splitting is measured to be 40507347996.8(0.1) Hz by Ramsey interrogation. A narrow line width as 30 mHz is also observed. All these progress build the foundation for the realization of the trapped 199Hg+ ion frequency standards.

Session A3P-H – Optical Frequency Combs & Standards R.S.38

7030 Amplitude-to-Phase Conversion in Fiber Laser Frequency Combs

Christian Grebing, Physikalisch-Technische Bundesanstalt (Germany), et al.

In frequency metrology mode-locked fiber lasers have proven to be a powerful tool to compare arbitrary oscillators with output frequencies ranging from the microwave to optical regime. However, phase fluctuations not compliant with the elastic tape model deteriorate the short-term stability during frequency ratio measurements. We investigate the effect of amplitude-to-phase conversion in multi-branch fiber combs as a source of harmful phase noise.

7074 Development of an Optical Carrier Hybrid Transfer System

Ken-Ichi Watabe, National Institute of Advanced Industrial Science and Technology (Japan), et al.

We are developing an optical carrier hybrid transfer system for transferring optical carrier signals of Yb and Sr optical lattice clocks at NMIJ. The optical carrier hybrid transfer system consists of phase stabilization systems to stabilize the phase fluctuations of an optical carrier, bidirectional optical amplifiers, and regenerators. Using a spooled fiber of 90 km, the measured fractional frequency stability of the transferred light with phase stabilization was a fractional frequency stability of 4×10^{-15} at an averaging time of 1 s and 6×10^{-18} at 1000 s, measured with a phase measurement system.

7098 Progress Towards a Fibre-Based Frequency Reference for Atmospheric CO2 Measurements
Philip Westergaard, DFM (Denmark), et al.

A laser source stabilised to an absorption line of CO2 sent into orbit around Earth can be used for differential optical absorption measurements of the CO2 content of the atmosphere. The accuracy of the measurement hinges strongly upon the frequency stability of the laser used. We present here an ongoing effort to produce a fibre-based frequency reference at 2051 nm with an accuracy of better than 5 MHz for measurements of CO2.

7107 Evaluation of an Ultra-Stable Laser System Based on a Linewidth Transfer Method for Optical Clocks
Kazumoto Hosaka, National Institute of Advanced Industrial Science and Technology (Japan), et al.

We have developed a narrow linewidth laser system by combining an optical frequency comb and an ultra stable laser to stabilise several lasers at different wavelengths simultaneously. The system is characterised by comparison with another ultra stable laser. The frequency stability of this system is limited by thermal noise of an optical cavity that is used for the ultra stable laser. We have also demonstrated atomic spectroscopy of ultra narrow linewidth transitions in ultra cold ytterbium and strontium.

7110 New Locking Schemes for a Carrier-Envelope Offset Frequency
Atsushi Onae, National Institute of Advanced Industrial Science and Technology (Japan), et al.

An optical frequency comb connects optical and microwave frequencies with two parameters, the repetition rate (frep) and the carrier-envelope offset frequency (fceo). To realize an optical frequency ruler, we need to control these two parameters. In this report, we propose new and simple methods to lock the fceo referring to the frep.

7117 Phase-Locking of a 3THz Quantum Cascade Laser to an Optically Generated Terahertz Reference
Motohiro Kumagai, National Institute of Information and Communications Technology (Japan), et al.

We have successfully demonstrated a phase-locking of the 3THz quantum cascade laser (QCL) to a stable THz reference based on an optical freuqnecy comb. The THz reference was optically generated by photomixing of two optical modes of the comb. The heterodyne beat signal between THz QCL and THz reference was obtained using a hot-electrom bolometer mixer.

7126 A Narrow-Linewidth Frequency-Tunable cw Laser from 700 nm to 1000 nm
Yanyi Jiang, East China Normal University (China), et al.

Optical frequency synthesizers can generate optical light with high precision and high spectral purity at any moment and at any wavelength over a wide range. In this presentation, a narrow-linewidth frequency-tunable cw laser will be introduced. Using an optical frequency comb, the coherence of a cavity-stabilized laser at 1064 nm is transferred to a frequency-tunable Ti:Sapphire laser with power of >1 W and wavelength tunable rage from 700 nm to near 1000 nm.

7172 Compact All-Fibre Wavelength Standards Based on Micro-Structured Fibres
Natascia Castagna, Federal Institute of Metrology METAS (Switzerland), et al.

We demonstrate the realization of all-fibre gas cells using hollow core fibres combined with standard singlemode fibres. The all-fibre gas cell that we developed consists in a piece of hollow core fibre, which is butt-coupled on both extremities with a singlemode fibre, whose endface has an anti-reflection coating. The butt-coupling is achieved using an especially developed gas-tight connector adapter, allowing a simultaneous access to the hollow core for the gas filling and for the light coupling. We built high and low pressure gas cells, whose application for the calibration of optical spectrum analyzers and for laser frequency stabilization are demonstrated.

7198 Characterization of a SESAM Mode-Locked Erbium Laser Frequency Comb with an Integrated Electro-Optic Modulator
Sebastian Schweyer, Technische Universität München (Germany), et al.

In this paper the characteristics of a SESAM mode-locked frequency comb with an intra-cavity electro-optic modulator are examined. To prove the comb's function as a high stable and accurate interface between optical and HF standards, e.g. for atomic clocks, three different locking schemes for frep are investigated using phase noise measurements as reference. These results underline a high gain in performance compared to commercial SESAM mode locked fiber laser frequency combs.

7229 High-Bandwidth Intensity and Phase Noise Stabilization of an Yb:fiber Femtosecond Frequency Comb
Tobias Lamour, Max-Planck-Institut für Quantenoptik (Germany), et al.

We present a high-bandwidth feedback scheme, suppressing intensity and phase noise of a polarization Kerr-Lens mode-locked Yb:doped fiber laser. Intensity noise suppression is achieved with a pump diode current servo-loop while the phase is conserved through a piezo-actuated mirror. We will present in-loop measurements of the phase noise, using an optical heterodyne beating against a CW laser, demonstrating >20dB phase noise suppression over a bandwidth of 200kHz. The pump diode current servo suppresses intensity noise with >20dB and unity-gain crossing of 600kHz. Transfer functions of the laser system and the piezo actuator will be presented in detail.

7232 A Microwave-Optical Local Oscillator for Future Applications in Space
I. Ernsting, Heinrich-Heine Universität Düsseldorf (Germany), et al.

Future atomic clocks in space need microwave radiation with ultralow phase noise. We present the development, performed in the frame of the STE-QUEST mission study, of a breadboard demonstrator composed of a laser stabilized to a robust reference cavity, a fiber frequency comb, and a microwave generation subunit. For the microwave generation at 9.5 GHz, we phase-lock the fiber comb to the ultrastable laser wave and detect a high harmonic. An alternative microwave generation system based on a Ti:Sapphire frequency comb has been developed and will be used to characterize the phase noise introduced in the microwave generation process.

7238 Optical Clock Based on a Fully Stabilized Microcomb
Katja Beha, National Institute of Standards and Technology (United States), et al.

We demonstrate for the first time an optical clock based on all-optical frequency control of a silica disk microresonator frequency comb to an atomic reference. The clock's output is the 33 GHz microcomb mode spacing, which is a phase-coherent, integer sub-division of the rubidium reference.

7245 Generalized Representation of Noise in Optical Frequency Combs by Spectral Correlation Analysis

Roman Schmeissner, LKB / Université Pierre et Marie Curie (France), et al.

Amplitude and phase noise of optical frequency combs have been studied extensively for individual optical frequencies or for the mean field. Repetition-rate and CEO-phase noise are examples of noise properties of the entire comb. Here we characterize amplitude and phase noise of a Ti:Sapph oscillator spectral resolved and even reveal the correlation structure. Covariance matrices are an appropriate representation for such data. Their eigenvectors, the noise modes, correspond to spectral structures of correlated noise. Repetition-rate and CEO-phase noise are associated to special noise modes. By the use of the covariance data, we characterize both down to the standard quantum limit.

7246 Compact Frequency Combs from Ytterbium-Doped Diode-Pumped Solid-State Lasers

Alexander Klenner, ETH Zurich (Switzerland), et al.

We successfully demonstrated the first carrier-envelope-offset (CEO) frequency stabilization of an unamplified Yb-based diode-pumped solid-state laser. The oscillator is pumped with a highly multimode laser diode in conventional single-pass geometry. The frequency comb achieves an in-loop residual integrated CEO phase noise of only 407 mrad (1 Hz - 5 MHz). Our study revealed essential requirements for multimode pumped frequency combs and will allow for fully stabilized high-power Yb-based frequency combs with GHz repetition rate in the near future.

7250 Digital System for Keeping Optical Frequency Comb in Long-Term Stable Operation

Martin Cizek, Institute of Scientific Instruments of the ASCR, v. v. i. (Czech Rep.), et al.

The presented work deals with a novel application of digital signal processing and software-defined radio algorithms for keeping an optical frequency comb in long-term stable operation. We are using a two-stage stabilization scheme. A frequency-locked loop (FLL) pre-stabilizes the offset frequency and steers it into the capture range of a phase-locked loop (PLL) that consequently takes control. Such combination of FLL and PLL together with additional control logics is also able to handle situations when the PLL unexpectedly goes out of lock and so it is capable of keeping the optical frequency comb in a long-time stable operation. The stability of the resulting system was investigated. Allan deviations from data measured during 8 days of operation were computed. The resulting long-term stability of the setup is better than 1.6×10^{-11}.

7260 Photodetection of Ultrashort Optical Pulses for Low Phase Noise Microwave Generation

Franklyn Quinlan, National Institute of Standards and Technology (USA), et al.

To fully exploit the low microwave phase noise potential of an ultra-stable optical reference and an optical frequency comb, noise limitations associated with photodetection must be mitigated. Results and limitations of techniques to reduce the impact of photodetection noise, including the use of highly linear, high power handling PDs, short pulse illumination to reduce the impact of shot noise of the phase stability, optical amplification and pulse interleaving to increase the attainable microwave power, will be presented.

7270 Rb-Based Stabilized Laser System as Frequency Reference for CO2 Monitoring

Renaud Matthey, Université de Neuchâtel (Switzerland), et al.

In order to precisely control the emission frequency of a lidar transmitter laser operating at 1572 nm to monitor the atmospheric CO2 concentration from space in the frame of a possible satellite mission, we are developing a laser system which transfers the frequency stability of Rubidium atoms at 780 nm to the 1572-nm wavelength region. The laser frequency stability at the doubled Rubidium wavelength, 1560 nm, has been evaluated to be better than 2 kHz between 1'000 and 200'000 seconds. The gap between 1560 nm and 1572 nm is filled by an optical frequency comb, currently under evaluation.

7272 Sub-100 Attosecond Timing Jitter from Low-Noise Passively Mode-Locked Solid-State Laser

Erwin Portuondo-Campa, Centre Suisse d'Electronique et Microtechnique SA (Switzerland), et al.

The relative timing jitter between the pulse trains of two identical passively modelocked DPSSLs has been measured using a balanced optical cross-correlator as timing discriminator. Single-laser timing jitter values as low as 83 attoseconds were calculated (integrated from 10 kHz to 50 MHz) assuming identical behaviors of the two lasers. A theoretical timing jitter spectrum was calculated and it was found that the measured jitter is significantly above the theoretical limit in the considered frequency span. The possible technical origin of this exceeding jitter and measures to reduce it will be discussed.

7291 Fluoride Output Coupler for Cavity HHG Toward VUV Direct State-Detection of Ion Clocks

Kentaro Wakui, National Institute of Information and Communications Technology (Japan), et al.

Using a fluoride-based output coupler, we increased the output of the cavity HHG. The HHG aims direct excitation of VUV transition for alkaline-earth-like ions. Currently it amounts to 4.5uW of average intensity at 159nm that matches the 1S0-1P1 transition of indium ions.

7292 Polarization Maintaining Pulse Interleaving for Low Noise Photonic Microwave Generation

Gilles Buchs, Centre Suisse d'Electronique et Microtechnique SA (Switzerland), et al.

We study the impact of pulse interleaving on the spectral purity of microwave signals generated by photodetection of a passively mode-locked diode-pumped solid-state laser emitting at ~1560 nm. The interleaver consisting of up to 5 cascaded polarization maintaining fiber Mach-Zehnder interferometers is terminated by a beam recombiner. Phase noise measurements are performed on different carriers at harmonics of the interleaver output frequencies and the effect of delay length and splitting ratio errors are simulated with a dedicated model. The advantages of using a polarization maintaining interleaver are also discussed.

7309 **Direct Measurement of Correlations of Amplitude and Phase Noise in Optical Frequency Combs**

Roman Schmeissner, Laboratoire Kastler Brossel / Université Pierre et Marie Curie (France), et al.

Phase noise limits the ultimate precisions of measurements with phase noise. In order to reduce even lowest levels of phase noise close to the standard quantum limit, the characterization of correlations between amplitude and phase noise for the investigated comb source is of principal interest. We show that such correlations are directly accessible from the transmission signal of a broadband resonant passive cavity.

Session A3P-J – Student Poster Finalists — Cafeteria Entrance

7164 **Quartz-Based Vibrating MEMS on Structured Silicon Using Wafer Bonding Technology**

Sebastien Grousset, CEA-Leti,et al.

In this study, we partially use strategies developed for Si-based MEMS device fabrication and in the meantime, we adjust some parameters to the specifications of single-crystal quartz material. We will present the results of our wafer-level approach that allows the collective fabrication of gyroscope sensors based on quartz vibrating MEMS. More specifically, we focus on suspended quartz tuning fork microstructures of a desired thickness over controlled depth cavities which integration is based on the bonding and thinning of 4-inch z-cut quartz wafer on pre-structured silicon wafer.

7176 **Assessment of the Acoustic Shear Velocity in SiO_2 and Mo for Acoustic Reflectors**

Mario DeMiguel-Ramos, Universidad Politécnica de Madrid, et al.

We propose a straightforward method to assess the acoustic shear velocity of the high and low acoustic impedance materials that form the acoustic reflector of SMRs, in this particular case Mo and porous SiO_2. The method is based on inducing a $\lambda/2$ shear resonance in the material under study, whose frequency depends on its thickness, density and sound velocity. The response is then fitted using Mason's Model. The deduced shear sound velocities are 3333 m/s for Mo and 3130 m/s for SiO_2.

7276 **Effects of a Plasma Etching Process on a Longitudinally Coupled Resonator Filter**

Loïc Braun, AR Electronique SAS et al.

In our work we have developed a trimming process using a reactive-ion etching machine. We have applied this process to longitudinally-coupled resonators filters operating at gigahertz-frequencies, and studied the effects on the whole response of the device.

7284 Active Electronic Cancellation of Nonlinearity in a High-Q Longitudinal-Mode Silicon Resonator by Current Biasing

Haoshen Zhu, City University of Hong Kong et al.

In this work, for the first time, we report a means to actively cancel nonlinearity for a high quality factor bulk-mode single-crystal-silicon micromechanical resonator through its bias current. The results show that the power handling is enhanced by over 4.5 times. It is found that increasing the bias current changes the third-order elastic modulus of silicon, thus providing us the desirable effect of electronically 'tuning out' material-induced nonlinearity.

7230 Photodiode Nonlinear Modeling and its Impact on Optical Links Phase Noise

Zeina Abdallah, LAAS-CNRS / Centre National d'Etudes Spatiales et al.

An equivalent model of a microwave optical link is proposed. In this model, the photodiode description includes a photo-generation time delay dependence on the optical power. This phenomenon is indeed responsible for the conversion of the laser amplitude noise into microwave phase noise, which is now correctly described.

7301 Compact Low Phase Noise 3.8GHz Oscillator

Pratik Deshpande, University of York (United Kingdom), et al.

This paper describes the theory and design of a compact low noise dielectric resonator oscillator operating at 3.8GHz. The oscillator demonstrates a phase noise performance of -150 dBc/Hz at 10kHz offset with a tuning range of 200kHz and a vibration sensitivity between 10^{-8} and 10^{-9} g^{-1}. The power supply requirements are 6V without a regulator or 8V regulated at 160mA. The box dimensions are 11 x 11 x 5 cm.

7069 High-Purity Microwave Signal from a Dual-Frequency Semiconductor Laser for CPT Atomic Clocks

Paul Dumont, Laboratoire Charles Fabry - Institut d'Optique (France), et al.

We describe an innovating laser source for the production of the two cross-polarized coherent laser fields which are necessary in CPT-based atomic clocks. It relies on the dual-frequency and dual-polarization operation of an optically-pumped semiconductor laser. The laser operation is controlled by intracavity birefringent components which force the emission on two cross-polarized longitudinal modes. This configuration results in a tunable microwave beatnote with a high spectral purity. The laser performance is already adequate for the interrogation of atoms in a CPT atomic clock with a relative frequency stability better than 1.10^{-12} $\tau^{-1/2}$.

7196 Experimental and Numerical Study of the Microwave Field Distribution in a Compact Magnetron-Type Microwave Cavity

Anton Ivanov, Ecole Polytechnique Fédérale de Lausanne (Switzerland), et al.

We study the microwave magnetic field distribution in a compact magnetron microwave resonator cavity, in view of the realization of high-performance Rb atomic clocks using continuous-wave and pulsed optical pumping interrogation. The homogeneity of the microwave magnetic field component is measured experimentally, using a spatially-resolved imaging of the Rabi oscillations in the Rb ground state. Numerical simulations of the cavity field distribution are in good agreement with the imaging results, and provide design guidelines for the realization of future improved cavities.

7212 Mitigation of Frequency Shifts in a Cold-Atom Coherent Population Trapping Clock

Eric Blanshan, National Institute of Standards and Technology et al.

The performance of a compact cold-atom clock based on lin || lin coherent population trapping with Ramsey spectroscopy and phase-locked DFB/DBR lasers is presented, along with a characterization of primary systematics in the system. Mitigation techniques for the Doppler shift and light shift are discussed along with future plans to improve the stability at long integration times.

7242 Imaging Rb-Wall Interactions and Microwave Fields in Vapor Cells

Andrew Horsley, Universität Basel (Switzerland), et al.

In our lab, we apply time-domain measurements and absorption imaging to vapor cells. These techniques are well-established with cold atoms, but relatively unexplored in use with vapor cells. We show how images of the optical pumping efficiency in a cell can be used as a new tool to investigate Rb-wall interactions, and we also present the latest in high-resolution microwave field imaging from the lab.

7034 Miniature Optical Fiber Cavity for a Trapped Atom Clock

Ramon Szmuk, Observatoire de Paris (France), et al.

Trapped atoms have grown in importance for the development of metrology instruments. Trapped atom clocks for in-the-field applications, benefit from the volume reduction whilst allowing long interrogation times and thus good stability. Trapped atom interferometers for acceleration and rotation sensing are under development. We present plans for a second-generation of our "Trapped Atom Clock on a Chip (TACC)" which interrogates the Rb microwave transition. We will include a microscopic optical fibre cavity for non-destructive detection with the aim to reduce dead time from atom loading.

7293 Electromagnetic Induction Readout Silicon-on-Insulator MEMS Resonant Magnetometer

Weiguan Zhang, City University of Hong Kong et al.

We report an electromagnetic induction readout MEMS resonant magnetometer. It benefits from a CMOS-compatible process and promises lower power consumption compared to devices based on Lorentz force action since no bias current is needed. This readout mechanism has been reported for a bulk-mode square-plate resonator . Our device holds multiple benefits over the bulk-mode design including simpler fabrication process (3 vs 6 masks), lower drive voltage requirements (5V vs 50V), smaller foot print (700μm×600μm vs 2mm×2mm), and higher sensitivity due to the larger displacements afforded by designing with compliant flexural beams.

7307 Studying Particulate Adsorption by Drying Droplets on a Microfabricated Electro-Acoustic Resonator

Abhinav Prasad, University of Cambridge et al.

Two identical silicon resonators were used to study particle adsorption via water droplet evaporation. High-purity water droplets with dispersed polystyrene particles were dispensed onto a sensor resonator while high-purity water droplets were dispensed onto a reference resonator. Both resonators saw ring stains, known as the "coffee-ring effect", and negative frequency shifts after each droplet. While the reference resonator experienced a linear frequency shift, the sensor resonator experienced much larger shifts that were higher than expected. Droplet drying and subsequent particle redistribution will be further examined in terms of their effect on frequency response.

7150 Time Transfer Over Delay-Stabilized Fibre Links Using an Optical Pulse Train

Maurice Lessing, National Physical Laboratory (United Kingdom), et al.

We investigate using a frequency comb (a pulse train in the time domain), with 100 MHz repetition rate, for simultaneous time and frequency transfer. In order for the technique to be compatible with internet-carrying fibre networks, we restrict the bandwidth to one ITU channel (100 GHz). A pulse with different amplitude acts as a time marker used to measure the absolute one-way and round-trip delays of the fibre, whilst the delay is kept constant by the fibre noise cancellation feedback loop. The full implementation of the delay-stabilized, calibrated time transfer over km-scale fibre spools will be presented at the conference.

7201 A Detection Algorithm of Atomic Clock Frequency Jumps with the Prediction Wiener Filter

Xinming Huang, National University of Defense Technology (China)

In this paper, we proposed an optimal prediction wiener filter applicable to atomic clock frequency jump detection. A detection method is provided base on the optimal filter. The case of frequency jump has been investigated in detail by simulation via measurements of a space-based rubidium frequency standard. Characteristics of the method have been discussed and examined. Simulation results show that this method can detect weak frequency anomalies quickly and effectively. Such a method is simple to implement and can provide an effective solution to GNSS satellite clock autonomous integrity monitoring.

7203 In-Line Extraction of an Ultra-Stable Frequency Signal Over an Optical Fiber Link

Anthony Bercy, Université Paris 13 / Observatoire de Paris et al.

Optical frequency links give the possibility to disseminate an ultrastable frequency reference to many research laboratories for a wide range of applications beyond metrology. We demonstrate the extraction of an ultrastable signal at different points along an urban optical link of 92 km. We obtain a fractional frequency instability of about $1x10^{-15}$ at 1 s averaging time for the extracted signal, which is equal or sensibly better than the instability of the main link, in agreement with a simple model of the noise compensation. This technique of multiple users dissemination is compatible with fiber links with data traffic.

7288 A Method of Satellite Autonomous on-Board Clock Monitoring Using High-Stability Crystal Oscillator

Gangqiang Guan, National University of Defense Technology (China)

This paper presents a method of satellite autonomous on-board clock monitoring in SAIM receiver, which takes advantage of the short term good characteristics of high-stability crystal oscillator. Using digital phase locked loop(DPLL) to keep the frequency of 10.23MHz generated by high-stability crystal oscillator synchronized with the on-board atomic frequency standard, while the loop is locked the clock phase error and frequency bias between the two frequencies are measured and processed, then the integrity flag of clock monitoring can be generated after comparing the measurements value to the preset threshold. Simulation results and experimental data show that using the method proposed in this paper the accuracy of clock phase and frequency monitoring can achieve 0.018ns and 0.26mHz respectively while the time to generate the clock integrity flag is no more than two seconds.

7052 On the Prospects of Building Optical Atomic Clocks Using Er I or Er III

Alexander Kozlov, University of New South Wales et al.

We show that neutral Er I and double ionized Er III are promising candidates for optical atomic clocks. Both systems are not sensitive to BBR shift due to extremely small differential scalar polarizability. Dominating systematic shift comes from coupling of the atomic quadrupole moments to the gradients of an electric field. However, this shift can be strongly suppressed by averaging over transitions with different projections of the total angular momentum. Other systematic shifts are either small or can be suppressed. A fractional accuracy of 10^{-18} is achievable for both types of clocks.

7112 Laser Stabilization System for Space Applications Based on Hydroxide-Catalysis Bonding

Yingxin Luo, Huazhong University of Science and Technology (China), et al.

The development of an ultra-stable Nd:YAG laser system for space missions based on the Pound-Drever-Hall (PDH) method is presented in this paper. We apply the hydroxide-catalysis bonding technique to establish a monolithic ultra-stable bench, consisting of the cavity and the mode-matching coupling optics; all-fiber optics are used for the PDH optical system and a digital controller based on FPGA is used for the laser stabilization.

7165 An Ultra-Low Frequency Noise Laser Based on a 48 cm Long ULE Cavity for a Sr Lattice Clock

Sebastian Häfner, Physikalisch-Technische Bundesanstalt et al.

To improve the interrogation laser of a strontium optical lattice clock we have designed a 48 cm long cavity made of ultra low expansion glass operating directly on the 698 nm clock transition. From a comparison to three other ultra-stable lasers and to the Sr lattice clock we observed a laser instability of 7×10^{-17} at 300 s averaging time. With this laser the stability of the lattice clock was improved to $7\times10^{-16}\ (\tau/s)^{-1/2}$.

7179 Thin Disk Lasers Enable High-Power Frequency Combs
Florian Emaury, ETH Zurich et al.

We present the first phase-stabilization of the carrier-envelope-offset (CEO) frequency of a SESAM modelocked thin disk laser (TDL). The residual in-loop integrated phase noise is 120 mrad (1 Hz-1 MHz), with negligible contributions of amplitude-to-phase noise conversion in the generated CEO beat. In spite of the strongly spatially multimode pumping scheme of TDLs, our result shows that a reliable lock of the CEO frequency can be achieved using straightforward pump modulation. This opens the door to fully-stabilized low-noise frequency combs with hundreds of watts of average power from table-top SESAM modelocked thin disk oscillators.

Wednesday June 25

08:00 – 18:00 Registration Main Aula
University of Neuchâtel Jeunes Rives

8:30	**Plenary Session in Main Aula**		
	Professor Serge Haroche, ENS and Collège de France (France) An atomic clock tames light **Dr. John Kitching**, NIST, Boulder, CO, USA Chip-scale atomic devices: from atomic clocks to brain imaging and beyond Chair: Gaetano Mileti		
10:40	***Coffee break***		
11:00	**Lecture sessions**		
	Main Aula	**Room R.N.02**	**Room R.E. 48**
	B1L-A – Lattice Clocks Chair: Davide Calonico	A2L-B – Physics in Resonators B1L-B – Fiber II Chair: Anne Amy-Klein	B1L-C – Materials & Resonators Chair: Ventsislav Yantchev
12:40	***Lunch at the Patinoire***		
14:00	**Poster sessions**		
	Mobile Lab – R.O.12	**Room R.O.14**	**Room R.S.38**
	B2P-D – Resonators Chair: by Marc Faucher	B2P-E – Fiber & Optical Chair: Gesine Grosche B2P-F – Oscillators, Synthesizers, Noise & Circuit Techniques Chair: Olivier Lopis	B2P-G – Microwave Frequency Standards II Chair: Stefan Weyers B2P-H – Optical Clocks II Chair: Thomas Legero
15:40	***Coffe break***		
16:00	**Lecture sessions**		
	Main Aula	**Room R.N.02**	**Room R.E.48**
	B3L-A – Space Clocks Chair: Johann Richard	B3L-B – Optical Clocks I Chair: Andrew Ludlow	B3L-C – MEMS Oscillators Chair: Steve Tanner
17:40	***Free time***		
18:30	***Conference Banquet & Awards Patinoire du Littoral Neuchâtel***		

Note:

For reasons of limited space, only the name and affiliation of the first author of each communication is given in this program booklet. For the full list of authors and affiliations, please refer to the USB drive and online program.

Session B1L-A – Lattice Clocks — Main Aula

11:00 **Optical Lattice Clock Measurements at the mHz Level**
Andrew Ludlow, National Institute of Standards and Technology (United States), *et al.*

We demonstrate operation of a lattice clock at $1.6x10^{-18}$ instability, near the quantum projection noise limit. We also demonstrate control of the blackbody Stark effect in a lattice clock at the $1x10^{-18}$ level.

11:20 **The PTB Sr Lattice Clock: Status and Frequency Measurement**
Stephan Falke, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

We have measured the frequency of our Sr lattice clock with the two PTB caesium fountain clocks. With an averaging time of $3.5x10^{5}$s against the fountain clocks the statistical uncertainty is reduced to about $2×10^{-16}$. Adding systematic uncertainty contributions, we were able to determine the frequency of our lattice clock with an uncertainty of 170 mHz or $4×10^{-16}$. The frequency is in very good agreement with a long series of other measurements of several groups.

11:40 **Developing Yb and Sr Optical Lattice Clocks in the Same Laboratory**
Daisuke Akamatsu, National Institute of Advanced Industrial Science and Technology (Japan), *et al.*

We have developed Yb and Sr optical lattice clocks and measured the absolute frequencies of the clocks. The frequency ratio between the two lattice clocks is also measured by an optical-optical direct frequency link using a narrow-linewidth fiber comb. We determined the frequency ratio with a fractional uncertainty smaller than that of the absolute frequency measurements using the combination of a H-maser and the International Atomic Time (TAI) link. Our measurement enables the first international comparison of the frequency ratios of optical clocks.

12:00 **Higher-Order Shifts of a Clock Frequency in Sr, Yb and Hg Atoms Trapped in an Optical Lattice**
Vitaly Ovsiannikov, Voronezh State University (Russia), *et al.*

The optical frequency standards with an uncertainty at a level of 10^{-17} - 10^{-18} requires unprecedented accuracy in estimating the role of higher-order uncertainties of optical clocks. The multipole, nonlinear and other higher-order contributions to uncertainty for the alkaline-earth-like-atoms Sr, Yb and Hg are evaluated systematically

12:20 **Spectroscopy of the 1S0 -> 3P0 Clock Transition in Magnesium**
Ernst M. Rasel, Gottfried Wilhelm Leibniz Universität Hannover (Germany), *et al.*

10^4 magnesium atoms have been trapped in an optical lattice at the predicted magic wavelength of 469 nm. Performing magnetic field-induced spectroscopy on the 1S0 -> 3P0 clock transition in bosonic magnesium24, we are able to resolve the carrier transition together with a red and a blue sideband. The asymmetry of the latter ones allows us to deduce an ensemble temperature of 1.3 µK. Studying the frequency shift of the carrier transition as a function of lattice power and wavelength, we are able to give a first estimate on the magic wavelength of magnesium between 467.66 nm and 468.95 nm.

11:00 **Time Transfer in a Wide Area White Rabbit Network**
Anders Wallin, Centre for Metrology and Accreditation (Finland), *et al.*

Time transfer over optical fiber has potential to outperform the best satellite based methods (TWSTFT and GPS-PPP) that are used for maintenance of UTC and other precision experiments. The White Rabbit Precision Time Protocol1 (WR-PTP) uses a combination of synchronous Ethernet and enhancements to PTP (IEEE 1588) to achieve sub-nanosecond synchronization in local area (<10 km) optical fiber networks. Here we test how WR-PTP scales to wide area (1000 km) optical fiber networks.

11:20 **In-Line Extraction of an Ultra-Stable Frequency Signal Over an Optical Fiber Link**
Anthony Bercy, Université Paris 13 (France), *et al.*

Optical frequency links give the possibility to disseminate an ultrastable frequency reference to many research laboratories for a wide range of applications beyond metrology. We demonstrate the extraction of an ultrastable signal at different points along an urban optical link of 92 km. We obtain a fractional frequency instability of about $1x10^{-15}$ at 1 s averaging time for the extracted signal, which is equal or sensibly better than the instability of the main link, in agreement with a simple model of the noise compensation. This technique of multiple users dissemination is compatible with fiber links with data traffic.

11:40 **Tapping Nodes in Actively Stabilized Fiber Optic Time Transfer**
Przemyslaw Krehlik, AGH University of Science and Technology (Poland), *et al.*

In our previous papers we described the idea of a multipoint distribution of frequency signal in a fiber optic system with an active delay stabilization. In this work we extend this idea for joint time and frequency distribution. The proposed solution allows to place the tapping nodes along the actively stabilized time and frequency distributing link. In the paper we describe the idea of stabilizing the tapping node outputs and the time calibration procedure. Finally experimental results are reported.

12:00 **Towards Brillouin-Amplified Fibre Links for Long-Distance Optical Frequency Transfer**
Sebastian Raupach, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

In long-distance fiber links for optical frequency transfer, attentuation has to be compensated by optical amplification. Typically this is done using broad-band Erbium doped amplifiers. These can only be used at low gain to avoid spontaneous lasing due to backscatter or back reflections. Here we describe a field-able Brillouin amplification system locked to the incoming signal. Brillouin amplifiers benefit from narrow-band amplification, allowing the exploitation of high gain in excess of 40 dB. We will present results from a field trial on a 660 km, Brillouin-amplified fiber loop.

12:20 **The Three Corner Hat Measurement of Three Hydrogen Masers in Remote Locations via Fiber Based Frequency Synchronization Network**
Chao Gao, Tsinghua university (China), *et al.*

Atomic clocks in the same place always affected by common environments,certain correlations always exist between these clocks. From 2011, we start the program of Beijing regional time and frequency network. Currently, through stable frequency synchronization method, we realized three hydrogen masers' comparison which are located at remote sites. Using the comparison results, we will calculate the weight of each clock, and generate the coordinated frequency via offsetting the phase of a synthesizer referenced by a master maser clock.

Session B1L-C – Materials & Resonators R.E.48

11:00 ***INVITED*** **– Lithium Niobate Thin-Film Resonators**
Sunil A. Bhave, Cornell University (United States)

In this talk I present the fabrication technology, design and characterization of thin-film lithium niobate contour-mode resonators. By carefully positioning the inter-digital transducer, we achieved CMRs with kt2×Q of 148 (IDT @ node) and very high kt2 resonators with spur-attenuated response. We have demonstrated resonators with frequencies ranging from 400MHz to 1.9GHz on a single chip.

11:40 **High Frequency-Low Loss SAW Resonators Built on Nano-Crystalline Diamond-Based Substrate**
Loïc Braun, AR Electronique SAS (France), *et al.*

In this work we investigate the way of diamond-based substrates as SAW waveguides. Results show the feasibility to make SAW devices at 4 GHz with very low losses.

12:00 **STW Resonator on (0°, 22°, 90°) Cut of Langasite with Al Electrodes**
Ayrat Galisultanov, JSC Avangard (Russia), *et al.*

In this paper we present the results of measurements of the three types of STW resonators on langasite (0°, 22°, 90°) with aluminum electrodes. The experimentally obtained values of Q <3000 is lower than the calculated ones. The results are discussed.

12:20 **Investigation of Geo2 Thin Film Properties for Improvement of Temperature Coefficient of Frequency of SAW Devices**
Matthias Knapp, TDK Corporation / Albert-Ludwigs-Universität Freiburg (Germany), *et al.*

We have investigated the elastic constants of GeO2 thin film. For this purpose, the phase velocity of a layered system is calculated using surface acoustic wave (SAW) differential delay lines on LiNbO3 substrate. From phase velocity measurement the elastic constants (c11 and c44) and the density rho of the GeO2 film has been determined. Additionally, we have investigated the stability of the GeO2 film.

Session B3L-A – Space Clocks — Main Aula

16:00 ***INVITED*** **– Tests on Ground of the Flight Model of the PHARAO Cold Atom Space Clock**
Philippe Laurent, Observatoire de Paris (France), *et al.*

The PHARAO (Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbite) development entered in the last phase: All the Flight Model (FM) sub-systems have passed the qualification process and the whole FM of the cold cesium clock is now assembled. We start the functional and performance tests.

16:40 **Accuracy Evaluation of the ACES/PHARAO Laser-Cooled Space Atomic Clock**
Phillip Peterman, Pennsylvania State University (United States), *et al.*

The three largest systematic errors in the preliminary PHARAO accuracy budget are the collisional frequency shift, the distributed cavity phase shift (DCP) and the microwave lensing frequency shift. We report on the evaluation of these systematic shifts.

17:00 **Preliminary Test of a Cold-Atom Based Clock Prototype on a Microgravity Platform: Rubiclock on the a-300 0g**
Luigi De Sarlo, Observatoire de Paris (France), *et al.*

We will show the preliminary results of the Rubiclock cold-atoms based atomic clock operating in microgravity during the latest flight campaign of the Airbus A300-0g (march 2014). We will begin our presentation by briefly describing the key technical aspects of the different subsystems of our clock and then report on the results of the microgravity flight campaign. We will then conclude presenting the perspectives of our collaboration with the French space agency for making a demonstration of clock operation on the same platform.

17:20 **Industrialisation Approach of the POP Clock for Application to GNSS**
Alberto Battisti, Selex ES (Italy), *et al.*

This paper intends to present the Selex ES industrialization approach required to pass from a laboratory successful prototype of POP very promising atomic clock technology for navigation systems to a POP engineering model designed to sustain space environment and life time requirements, but at the same time offering clock performances at the state of the art in terms of frequency stability, mass, power consumption and cost. The first step of the development plan will address the realisation of electronic and optical units based on commercial components with either space heritage or ability to be space qualified.

16:00 **Very Long Baseline Comparison of Sr Lattice Clocks Using Carrier-Phase Two-Way Satellite Frequency Transfer**

Hidekazu Hachisu, National Institute of Informat. and Com. Technology (Japan), *et al.*

We have demonstrated a direct frequency comparison of two 87Sr lattice clocks, one at NICT in Japan and the other at PTB in Germany, using a lately-developed satellite-based technique. The reproducibility of 87Sr lattice clocks has been confirmed in Europe with an uncertainty of 6×10^{-16} by absolute frequency measurements. The same level of agreement has been also reached inside Japan by an all-optical fiber link. The agreement between the two regions, on the other hand, is limited to an uncertainty of $>3\times10^{-15}$. The direct comparison demonstrated here has reduced this uncertainty close to the 10^{-16} level.

16:20 **Optical Clocks Based on Highly Charged Ions with Enhanced Sensitivity to Variations in the Fundamental Constants**

Julian Berengut, University of New South Wales (Australia), *et al.*

Clocks based on optical transitions in selected highly charged ions could have very high sensitivity to variations of the fine structure constant, potentially confirming the cosmological gradient reported by astronomers.

16:40 **On the Prospects of Building Optical Atomic Clocks Using Er I or Er III**

Alexander Kozlov, University of New South Wales (Australia), *et al.*

We show that neutral Er I and double ionized Er III are promising candidates for optical atomic clocks. Both systems are not sensitive to BBR shift due to extremely small differential scalar polarizability. Dominating systematic shift comes from coupling of the atomic quadrupole moments to the gradients of an electric field. However, this shift can be strongly suppressed by averaging over transitions with different projections of the total angular momentum. Other systematic shifts are either small or can be suppressed. A fractional accuracy of 10^{-18} is achievable for both types of clocks.

17:00 **An Ultra-Low Frequency Noise Laser Based on a 48 cm Long ULE Cavity for a Sr Lattice Clock**

Sebastian Häfner, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

To improve the interrogation laser of a strontium optical lattice clock we have designed a 48 cm long cavity made of ultra low expansion glass operating directly on the 698 nm clock transition. From a comparison to three other ultra-stable lasers and to the Sr lattice clock we observed a laser instability of 7×10^{-17} at 300 s averaging time. With this laser the stability of the lattice clock was improved to $7\times10^{-16}\ (\tau/s)^{-1/2}$.

17:20 **Compact Atomics Package and Integration of a Transportable Strontium Lattice Clock**

Yeshpal Singh, University of Birmingham (United Kingdom), *et al.*

In the framework of the research project SOC2:"Towards Neutral-atom Space Optical Clocks" with the main aim of developing demonstrators of transportable lattice clocks with $5x10^{-17}$ relative frequency accurac, we are reporting on the realization of a very compact, light and energy efficient atomics package for a Sr clock prototype. At the heart of the atomics package is a 3D MOT chamber (Fig.1) which can be loaded either with a permanent magnet Zeeman slower or

with a 2D MOT facility. We will also report on the integration of different components (e.g. lasers, FSS unit) of the SOC2 apparatus, which have been developed by other partners of the consortium and have been transported to us at the University of Birmingham from the University of Florence. The total budget of the system will be <10 l, <10-10 mbar, < 20 kg.

Session B3L-C – MEMS Oscillators R.E.48

16:00 ***INVITED*** **– High Frequency Piezoelectric MEMS Oscillators**
Gianluca Piazza, Carnegie Mellon University (United States)

We present the development of high frequency oscillators based on high-Q AlN piezoelectric MEMS resonators. This technology could displace quartz crystals and surface acoustic wave oscillators and enable new frequency generation paradigms based on the integration of multi-frequency resonators. We explain how self-heating impacts the non-linear dynamics of the AlN resonators and hence phase noise. We also directly measure the resonator residual flicker noise. We report on low power ovenization of these devices and show a prototype 586.9 MHz oscillator exhibiting PN < -93 dBc/Hz at 1kHz offset, temperature stability of 2 ppm over 100 ºC, and acceleration sensitivity < 30 ppb/G.

16:40 **Low Power MEMS Oscillators for Sensor Applications**
Cuong Do, University of Cambridge (United Kingdom), *et al.*

This abstract reports on the design of an oscillator circuit implemented in standard CMOS as a low power front-end circuit interface for micromachined resonant sensors. Micromachined resonators have been previously employed as transduction elements in accelerometers, gyroscopes, strain sensors and electrometers, and this low power front-end interface therefore has broad applicability to a variety of sensing contexts.

17:00 **Low-G Sensitivity of HBAR Oscillator**
Thomas Baron, FEMTO-ST Institute (France), *et al.*

One of the challenges of frequency sources dedicated to space and airborne systems is controlling the oscillator sensitivity to acceleration generated by chocks and vibrations. As operating frequency of acoustic wave devices tends to increase, new resonator principles have been investigated recently, in Particular High-overtone Bulk Acoustic Resonators (HBAR). This work presents first acceleration sensitivity measurements of oscillators stabilized by very high Q-f product HBARs (Qf in excess of 3.1013).

17:20 **A Compact, Versatile, Miniature Timing Microsystem Using Two Co-Integrated Wafer-Level Packaged Silicon Resonators**
David Ruffieux, Centre Suisse d'Electronique et Microtechnique SA (Switzerland), *et al.*

This paper presents a miniature timing microsystem based on a pair of 300μm thick, wafer-level packaged, co-integrated low and high frequency silicon resonators operating at 432kHz and 26.7MHz respectively. Over 700 singulated such parts were flip-chip bonded on a CMOS wafer using thermo-compression on Au stud bumps and the resulting system was calibrated at wafer level and characterized over temperature.

Details of Wednesday poster sessions (14:00 – 15:40)

Session B2P-D – Resonators — Mobile Lab – R.O.12

7016 Leaky SAW with Reduced TCF on LT42/Silicon Substrates
Haixia Wang, FEMTO-ST Institute (France), et al.

In the present work, A room temperature Au/Au bounding process has been applied for the fabrication of (YXl)/42° lithium tantalate plates, bounded onto (100) silicon wafers and thinned down to 25 µm. 2 GHz resonators have been built on such plates and tested electrically and thermally, first by tip probing.A dramatic reduction of the TCF is observed for all the tested devices, allowing to reduce the thermal drift of the resonators down to a few ppm.K-1 within the standard temperature range.

7059 Tunable Reflector of SAW Based on Induced Piezoeffect in Ferroelectrics
Vladimir P. Pashchenko, JSC Avangard (Russia), et al.

Theoretical investigation results of the periodic domain structures induced by electric field in barium strontium titanate ferroelectric thin film are presented. A novel type of tunable reflector of SAW based on electric field induced piezoelectric effect in ferroelectric thin film is proposed. Finite element simulation shows that by changing the bias voltage we can tune the reflectivity in a wide range.

7066 Complete Bandgap SAW Phononic Resonators
Ventsislav Yantchev, Uppsala University (Sweden)

In this work we demonstrate and analyze measurements on complete bandgap phononic SAW resonators fabricated on 128° YX LiNbO3 substrate. The influences of the phononic grating over the spurious responses and the busbar quality are experimentally tested. Future optimization steps are discussed. The proposed work initiates a discussion on the applicability of the surface phononic gratings in commercial SAW components.

7151 Quartz Resonator for MEMS Oscillator
Béatrice Bourgeteau, Office National d'Etudes et Recherches Aérospatiales (France), et al.

A dedicated three dimensional quartz crystal micro-resonator in a length-extension mode (LEM) has been developed for fundamental physics experiments. This concept is now being studied in a planar 2D configuration compatible with collective etching processes as well but can be more easily integrated.This work will present the global optimization of the 2D resonator, including the energy losses minimization, the identification of specific quartz cuts reducing the frequency temperature de-pendence while allowing an efficient piezoelectric coupling for low motional resistance.This new quartz resonator should find interesting applications in the field of high stability crystal MEMS oscillators.

7195 Ridge-Shaped Periodically Poled Transducer for Wide Band R-F Filter
Fabien Henrot, FEMTO-ST Institute (France), et al.

Most resonators and filters for telecommunication applications are based on Surface Acoustic Wave (SAW) technology using inter-digitated transducer (IDT). This mature technology is particularly addressing radio-frequency filter demand, but it is limited by various factors. Recently, the interest of periodically poled transducer (PPT) built on single crystal LiNbO3 Z-cut plates was investigated as an interesting alternative to classical IDTs1. This paper shows the manufacturing and test of an acoustic filter, exhibiting a band pass of about 5 MHz at 250MHz, based on a PPT ridge-shaped transducer.

7197 Application of Lagrangian Configuration to the Analysis of Electrostatically-Driven MEMS Resonators
Bernard Dulmet, FEMTO-ST Institute (France), et al.

This paper proposes an example of application of Lagrange configuration to the modelling of the electrostatically-driven vibrations of a silicon bar in flexure modes. Since the method was developped to model the influence of static bias on small amplitude vibrations, it is well-adapted to the modelling of MEMS resonators, which are submitted to a DC-bias voltage necessary to control the electromechanical coupling of the resonator.

7199 Seed Layer Controlled Deposition of ZnO Films with a Tilted C-Axis for Shear Mode Resonators
Girish Rughoobur, University of Cambridge (United Kingdom), et al.

In this work we investigate different structures and seed layers intended to enhance the growth of ZnO tilted grains. The structures include Mo/ZnO/Mo piezoelectric stacks directly deposited on the rough uppermost SiO_2 layer of the reflector, and ZnO films grown on 1000 Å-thick seed layers (ZnO or AlN) grown either on top or below the Mo bottom electrode on polished Bragg mirrors. A method to achieve ZnO shear mode resonators with reproducible characteristics is proposed. The devices have been tested in liquid, showing a Qshear and k2shear values above 200 and 3%, respectively.

7247 Influence of Electrical Extensions in AlN BAW Resonator Response for in-Liquid Biosensors
Mariano Barba, Universidad Politécnica de Madrid (Spain), et al.

We study the influence of electrical extensions of the electrodes in shear mode BAW resonators for applications in biosensors. The extensions keep separated the electrical contacts from the active zone where the liquid is confined. The parasitic effects on the resonator response is modelled and test devices are fabricated and characterized. The influence of the electrode geometry and the materials of the substrate are analysed concluding that the added capacitance of the electrical extension has to be minimized by making the electrical extensions narrow and by using full insulating acoustic reflectors of SiO_2 and Ta2O5 on high resistivity silicon wafers.

7306 High-Frequency Piezoelectric on Si MEMS Resonator and Numerical Method for Parameter Extraction
Andreja Erbes, University of Cambridge (United Kingdom), et al.

This paper presents a piezoelectric (AlN) on Si MEMS resonator operating in its width-extensional mode at 28.73 MHz. In order to extract the equivalent circuit model, we write the input admittance of the micro-resonator and introduce ai parameters. We use a modified X data matrix which is populated with N measured data points yi. The LSE solution is computed and the model parameters are extracted. We report a Q factor of 5970 and motional resistance Rx of 273 (ohms).

Session B2P-E – Fiber & Optical R.O.14

7053 Time-Transfer Over Optical Fibre Using Pseudo-Random Noise Ranging
Michael Wouters, National Measurement Institute Australia (Australia)

We have been developing all-digital modems for time-transfer over optical fibre. The modems use pseudo-random noise ranging to make the delay measurements.

7190 The Concept of Differential Wavelength Stabilization of the Semiconductor Lasers for Time and Frequency Transfer System
Lukasz Buczek, AGH University of Science and Technology (Poland)

The precision of any bidirectional time and frequency transfer system depends, among other factors, on fluctuations of difference of lasers wavelengths. This paper describes the concept of differential wavelength stabilization of distributed feedback (DFB) semiconductor lasers. Experimental evaluation of the concept shows relative stability of the wavelengths below 1 pm.

7202 Theoretical and Experimental Investigation of Phase Noise Processes on Optical Fiber Links for Frequency Comparison and Dissemination
Fabio Stefani, Observatoire de Paris (France), et al.

We will show an autocorrelation-based method for the theoretical calculation of the so-called delay-unsuppressed phase noise for various configurations of frequency dissemination / comparison optical fiber links: a classical compensated frequency dissemination link, an extraction link, a two way / Sagnac link, and a mixed two-way / compensated link. The second part of our contribution will be dedicated to the study of the interferometer-related noise, which typically affects the long-term stability of a fiber link

7086 Progress of Ultra-Stable Frequency Dissemination and Synchronization in Free Space
Jing Miao, Tsinghua University (China), et al.

We demonstrate a new ultra-stable frequency dissemination scheme on L band over 100 m atmosphere. By compensating phase noise actively and a series of frequency conversions, the phase fluctuation is well compensated. Two links disseminate different frequency signals phase locked to a common reference simultaneously, and recover the disseminated frequency respectively at remote site. The stability of dissemination with phase compensation in free space is better than 3E-13/s and 4E-17/day.

7085 Testbed for Measuring of the Effect of Fiber Acoustic-Band Phase Noise on the T&F Transfer Stability
Marcin Lipinski, AGH University of Science and Technology (Poland), et al.

In several recently published papers on fiber-optic Time and Frequency (T&F) transfer the phenomenon of some low frequency acoustic-band optical phase noise apparently mechanically induced in the fiber has been reported. In the paper we describe and characterize the testbed in which the acoustic phase noise is generated by the specialized vibration exciter. In the second part of paper the first experimental research on the effect of acoustic-band noise on T&F transfer stability are presented.

7111 Free-Space RF Transfer Between Buildings Using Single-Mode-Fiber-Coupled Optical Communication Terminal
Miho Fujieda, National Institute of Information and Communications Technology (Japan), et al.

We performed a free-space RF signal transfer experiment between two buildings using a pair of free-space optical terminals and 1-GHz transfer system to investigate the stability against wireless link environment.The result shows that short-range free-space optical transfer is a promising alternative to the fiber transfer. The experimental setup and result will be presented in this report.

7209 OPTIME - Time and Frequency Dissemination System Based on Fiber Optical Network - Local Repository Project
Waldemar Adamowicz, Orange Polska S.A. (Poland), et al.

The document describes a current stage of creating a high precision dissemination system for time and frequency reference signals - OPTIME and a comparison of UTC(PL) and UTC(AOS) which are provided by time/frequency laboratories: GUM in Warsaw and AOS in Borowiec by using an operational 420-km long link between them.

7236 Towards an International Optical Clock Comparison Between NPL and SYRTE Using an Optical Fibre Network
Giuseppe Marra, National Physical Laboratory (United Kingdom), et al.

We aim at performing an international optical clock comparison of the clocks developed at NPL (UK) and SYRTE (France) using a 760 km-long optical fibre link. Results on the fibre noise cancellation over portions of the London-Paris link are presented with discussions on the experiment outlook and next steps.

7123 Progress on a Cascaded Optical Link Between Paris and Strasbourg
Olivier Lopez, Université Paris 13 (France), et al.

We are currently developing a cascaded optical frequency link between Paris and Strasbourg using the French National Research and Education Network. The ultrastable signal is copropagating with data traffic using wavelength division multiplexing. We have developed some repeater stations to amplify and filter the ultrastable signal between each sections of the link and compensate the propagation noise. The remote operation of these stations is a key element for the deployment of a reliable and large scale metrological network. We will report on the first implementation of such a remote station on a 540-km cascaded link between Paris and Reims.

7237 Time and Frequency Transfer Using Amplified Optical Links
Vladimir Smotlacha, CESNET (Czech Rep.), et al.

Time or frequency transfer in longer (typically above 100 km) optical fiber requires optical amplification. As standard telecommunication amplifiers are design for unidirectional signal amplification, it is not possible to use them directly for bidirectional signal that is common in two-way time or frequency transfer. In this paper, we describe our laboratory and field test results and experience with practical setup of optical amplifiers in heterogeneous time and frequency optical transfer infrastructure.

7296 Digital Implementation of a Two-Way Coherent Phase Transfer Over Optical Fiber for Remote Clocks Comparisons
Claudio Eligio Calosso, Istituto Nazionale di Ricerca Metrologica (Italy), et al.

In typical Doppler-cancellation scheme the light travels twice in the fiber. This is the main limitation to the maximum achievable length. We present a Two-Way approach in which the light travels only once in the link, with significantly less attenuation, less required amplification and better Signal to Noise Ratio at the two link ends. We tested this scheme on a 47 km fiber loop, performing a frequency comparison at the $4x10^{-21}$ level. To implement the scheme we used digital electronics based on tracking DDSs that will be shown in detail at the conference.

7178 Multi-Purpose Constant-Delay Optical Link
Jurij Tratnik, InLambda BDT d.o.o. (Slovenia), et al.

A constant-delay optical transfer system in presented where multi-purpose user signals (e. g. pulses, RF, data) are transferred over independent bidirectional xWDM channels. Propagation-delay changes are detected with a RF-phase comparison method and corrected with a heated/cooled fiber spool and/or a piezo-controlled fiber stretcher. The measurements show a delay stability better than 1 ps peak-peak in a 24 hour period.

7251 Noise Performance Optimization of Time and Frequency Dissemination System in Presence of Fiber Mechanical Vibration
Jacek Kolodziej, AGH University of Science and Technology (Poland), et al.

A detailed analysis of fiber link phase stability showed an increase of its spectral noise power in the band from 10Hz to 30Hz. Environmental vibration causes mechanical deformations in the fiber which induce phase fluctuations that are converted into frequency noise. In the paper we present a simulation method of phase noise analyzing. Presented approach allows finding optimal system configuration that minimize induced frequency noise by mechanical fiber link vibration. The fiber link macro model takes into account the real acoustic noise characteristics, measured on 100 km distance-long fiber link installed along a highway.

7043 Measurement of Acoustic Noise in Field-Deployed Fiber Optic Cables
Lukasz Sliwczynski, AGH University of Science and Technology (Poland), et al.

The stability of a time/frequency transfer through an optical fiber is affected by the phase noise originating in the fiber. Apart from slowly varying, temperature induced variations some much faster component exists resulting from vibrations and mechanical stresses. In the paper we are presenting the measurement system and methods we developed to characterize this acoustic noise. We also present some experimental results for field-deployed optical cables, one running along the motorway and the other one running along the railroad tracks. We observed substantial differences in both spectral and temporal characteristics of observed noise in mentioned cases.

7081 **Driver for an External Mach-Zehnder Intensity Modulator with High Propagation Delay Stability**

Lukasz Sliwczynski, AGH University of Science and Technology (Poland), et al.

In the paper we are describing the electronics we developed to set the stable operating point of the Mach-Zehnder LiNbO3modulator having the requirement of very high stability of the propagation delay in mind. Initial tests of the driver showed low thermal coefficient of the propagation delay around 1 ps/K, that is very close to the coefficient of the measurement system used.

7042 **Extending the Delay Compensation Range of the Fiber Optic Time and Frequency Transfer System**

Przemyslaw Krehlik, AGH University of Science and Technology (Poland), et al.

Fiber optic based distribution of time and frequency signals suffers from seasonal delay fluctuations, observed in fibers due to temperature variations. In this work we described and analyzed three different solutions for this problem: cascading of currently used electronic delay lines, redesign of the delay lines for higher tuning range, and a new idea of hybrid, electronic and optical delay compensation scheme.

7018 **Verification of Tic Characteristics for Precise Optical Fiber Time Transfer Links**

Albin Czubla, Glowny Urzad Miar, Central Office of Measures (Poland), et al.

In this poster, we would like to show and discuss the results of our test of non-linearity effect in precise Time Interval Counter (TIC) used for precise optical fiber time transfer link. Measurement were performed for SR620 and for other TICs avaliable in our group. All measurement are performed with ps resolution.

Session B2P-F – Oscillators, Synthesizers, Noise & Circuit Techniques R.O.14

7012 **Wideband, Low Noise and Low Spurious Agile Direct Frequency Synthesis Based on Combination of SAW Oscillator and High Speed DAC**

Jean-Marc Lesage, DGA (France), et al.

Electronic warfare sub-systems always need wider frequency band agile synthesizer. This one must show low noise and low spurious levels. We demonstrate in this article that combination multiplied-frequency OCSO (Oven control SAW Oscillator) and high frequency DAC let reach state of the art agile frequency synthesis.

7037 **Active Complementary Coupled Resonator for Low Phase Noise X-Band Oscillator**

Chung-Tse Wu, University of California, Los Angeles (United States), et al.

This work presents a novel active complementary coupled resonator for X-band low phase noise oscillator which operates at 10GHz. The active resonator is based on a complementary coupled resonator (CCR) proposed recently using substrate integrated waveguide (SIW) technology. The complementary coupled resonator is essentially a complementary version of a conventional microstrip coupled line resonator. The circuit simulation shows that the active resonator can have a much higher unloaded Q of around 3000 at 10GHz when the transistor is drain-biased at 2V.

7068 Micro-Miniature, SMD, Ultra Low Phase Noise, HF OCXO
Roman Boroditsky, NEL Frequency Controls (United States), et al.

The goal of this work was to develop an OCXO with order of magnitude smaller size, light weight, lower supply voltage, lower power consumption, surface mountable, while maintaining outstanding ultra low phase noise and stability performance. The implementation of the original oven and oscillator circuit designs resulted in the development of a SMD OCXO with the dimensions of 21x14x6.8 mm^3, volume of 2.0 cc, operating off 5.0 V supply voltage, consuming 1 W of power at room temperature, and exhibiting the phase noise (100 MHz carrier), of -110 dBc/Hz at 10 Hz offset, -163 dBc/Hz at 1 KHz offset, and better than -180 dBc/Hz on the noise floor

7141 Exploration of 1/F Noise Origin Using Time Measurements
Santunu Ghosh, FEMTO-ST Institute (France), et al.

High speed measurements of the acoustic wave attenuation of very good and bad 5 MHz SC-cut quartz resonators are under way. Qualitative differences in the residuals of the fit of the envelop by the classical viscoelastic model are sought and the possibility to extract parameters of an internal friction model is explored.

7149 A Low Phase Noise NLTL-Based Synthesis Chain for a High Performance Cs CPT Atomic Clock
Bruno Francois, FEMTO-ST Institute (France), et al.

We report performances of a a low phase noise NLTL-based synthesis chain for a high performance Cs CPT atomic clock

7163 Recent Achievements in Performance of 100 MHz Crystals and OCXOs
Yakov Vorokhovsky, Morion Inc (Russia), et al.

In recent years requirements for phase noise of OCXOs at 100 MHz became significantly tighter. Often it is important to minimize both close-in phase noise (at 10, 100 and 1000 Hz from carrier) and noise floor (at 10, 100 and 1000 kHz from carrier). To meet modern requirements to phase noise it is necessary to optimize both construction and electronics of oscillator and significantly improve quartz crystal. New design of OCXO at 100 MHz shows -180 dBc/Hz at 100 kHz from the carrier and -140 dBc at 100 Hz from the carrier.

7174 Highly-Stable Metrological Thermostat for Active Characterization of Resonators with Automatic Turnover Point Settings
Nikolay Vorobyev, FEMTO-ST Institute (France), et al.

In this paper, we describe an original digitally controlled double thermostat system for the quartz crystal oscillator that allows setting the turnover point of crystal oscillator automatically and its characterization. The oscillator optimization was implemented with an EDA software. This simulation included the resonator noise and amplifier noise, which was measured previously for different transistors.

7224 Phase Noise and Jitter in Digital Electronics

Claudio Eligio Calosso, Istituto Nazionale di Ricerca Metrologica (Italy), et al.

We tested a few digital integrated circuits of different technology and families with the ultimate target of understanding low phase noise frequency synthesis. Digital electronics is appealing for its simplicity, reproducibility and cost, in applications where the lower noise of analog circuits is not mandatory. Our work is partially driven by the attempt of reducing the phase noise in two ways. First, by paralleling numerous gates, as in microwave and RF amplifiers . Secondly, to de-alias the output as we did in the Λ divider.

7253 Optimization of a Local Oscillator to Achieve Minimum Impairment of the Receiver by Phase Noise

Michael Nebel, Universität der Bundeswehr München (Germany), et al.

The noise characteristics of a local oscillator have a major impact on the performance of practically every receiver in a communications system. We connect the theory of noise in the oscillator circuit with the concept of phase noise which is usually used in communications engineering. We suggest an appropriate weighted combination of tangential and orbital noise to describe the resulting impairment of the receiver by the stochastic phase noise process. Furthermore, we show how an oscillator is to be optimized to achieve minimum phase noise.

7308 Microwave Phase Noise Properties of Optical Links Involving Small Signal and Gain Saturated Optical Amplifiers

Vincent Auroux, LAAS-CNRS (France), et al.

Optical amplifiers are a major noise source in optical links. It is important to choose the suitable amplifier according to the setup and operating conditions in order to minimize the phase noise. In this work, we studied the performances of an erbium doped fiber amplifier and a semiconductor booster optical amplifier for different saturation state and pump power. Microwave phase noise measurements have been carried out with a correlation setup. Noise spectra differences are explained through the measurement of noise figure and amplitude noise for each amplifier.

7177 Low Noise Master Oscillator LNMO

Gérard Wagner, Orolia Switzerland (Switzerland), et al.

Qualification Test Results of a Low Phase Noise Master Oscillator (LNMO)developped in the frame of an ESA ARTES project. After a short overview of the LNMO design, this paper presents the test results of the qualification tests conducted at the end of the development in 2012/2013. The objective was to validate the design of the Low Noise Master Oscillator versus space environment.

7104 **Preliminary Measurements of Buffer Gas Collisional Clock Frequency Shifts in Cs Vapor Cells in Presence of Xe and He**
Eric Kroemer, FEMTO-ST Institute (France), et al.

We report preliminary measurements of buffer gas collisional clock frequency shifts in Cs vapor cells in presence of Xe and He.

7121 **Development of the Cesium Fountain Frequency Standard, NMIJ-F2**
Akifumi Takamizawa, National Institute of Advanced Industrial Science and Technology (Japan), et al.

We have made much progress on NMIJ-F2, which is our second cesium fountain frequency standard aiming an uncertainty of < 1×10^{-15}. To improve the frequency stability, a cryogenic sapphire oscillator (CSO) using a pulse-tube cryocooler was applied to NMIJ-F2 as a local oscillator, and optical pumping to the Zeeman sublevel mF = 0 was performed. Then, the homogeneous magnetic field in the interrogation region was obtained with magnetic shielding and a solenoid coil. Currently, the estimation of a collisional shift is ongoing. In this presentation, we describe the current status of the development of NMIJ-F2.

7127 **A Frequency-Temperature Compensated Sapphire Loaded Cavity for Satellite Hydrogen Maser**
Nuanrang Wang, Beijing Institute of Radio Metrology & Measurement (China), et al.

To obtain frequency-temperature compensation in a sapphire loaded cavity for hydrogen maser, Dielectrics named SrTiO3 and rutile are adopted whose temperature coefficient of permittivity are opposite to that of sapphire. Based on theoretical analysis and computer simulation, TE011 mode of a sapphire loaded cavity associated with two small rings of SrTiO3/rutile with different thickness is solved, and useful parameters that influence temperature coefficient of cavity are calculated. Finally an experiment is brought forward and its results are very close to computing results. When the height of rutile ring is 5 mm,the temperature coefficient of cavity frequency is decreased from -58.8 kHz/K to 28.99kHz/K,and the quality facotor is 41648.When the thickness of SiTiO3 dielectric is 7 mm and the diameter is 17 mm in configuration b, the temperature coefficient of cavity is decreased from - 58.8 kHz/K to - 8.2 kHz/K and the quality factor is 40248.

7134 **Main Construction Features of the on Board Active Hydrogen Maser for Radioastron Mission**
Alexander Utkin, Vremya-CH (Russia), et al.

Construction and design features of the active hydrogen maser suitable for long operation in space are considered in the article. The special consideration in on-board frequency standard was given to the units responsible for mechanical strength and lifetime in outer space. The most important constructive elements of the frequency standard are shown and some measurement's results are discussed.

7135 Atomic Clocks Continuous Development and Production Capability for Navigation at SELEX ES

Alberto Battisti, Selex ES (Italy), et al.

This paper presents an overview of the atomic clocks time stability central role in a Navigation Satellite System mission , an overview of POP and mPHM main performances and characteristics, the topics of the Selex-ES industrial approach leading to the industrialization of PHM clocks for space and the establishment the manufacturing and testing facilities at Nerviano premises.

7137 Raman Transitions of Free Falling Atoms for an Atomic Gravimeter Developing at KRISS

Sang-Bum Lee, Korea Research Institute of Standards and Science, et al.

we will introduce preliminary results about Raman spectrum including current status of an atomic gravimeter developing at KRISS. We investigated Raman transition spectum and Rabi oscillations between two ground states (F=1, 2) for the free falling Rb87 atoms by co-propagating Raman pulse before obtaining interference fringes in the Mach-Zehnder-type interferometer

7140 Present State of the Primary Frequency Standard SU CsF02

Yury Domnin, All-Russian Scientific Research Institute of Physical-Technical and Radiotechnical Measurements (Russia), et al.

The metrological characteristics of the SU CsF02, the atomic cesium fountain developed at VNIIFTRI in 2008-2011 in the frame of "GLONASS" project, are presented. SU CsF02 is used for the realization of the time scale UTC(SU), which is the basis for legal time in Russia. The metrological investigations of SU CsF02 are in progress. The estimation of the frequency shifts related to the blackbody radiation, cold collisions, the microwave power dependence is given.

7146 Atomic Clock Ensemble in Space

Luigi Cacciapuoti, European Space Agency (Netherlands), et al.

Operated on-board the International Space Station, the Atomic Clock Ensemble in Space (ACES) payload will distribute a clock signal with fractional frequency instability and inaccuracy of 1E-16. ACES is scheduled for a launch to the ISS in the second half of 2016. The ACES mission elements are now approaching flight maturity. Tests on the engineering models have been completed and the manufacturing of the flight models is ongoing. The active H-maser SHM and the science link MWL have recently been tested to evaluate their sensitivity to the ISS environment and flight dynamics. The flight model of the cold cesium clock PHARAO has been delivered by industry and it is presently under test in CNES laboratories. The ACES ground segment is close to completion, with the first two terminals of the ACES microwave link expected to be delivered before the end of 2014. The organization of the ACES science ground segment is being finalized. This paper will present the progress achieved on the ACES mission. Recent test results on instruments and subsystems and the status of the ACES science ground segment will be discussed.

7148 Investigation of Compact Magneto-Optical Sources of Slow Atoms for Fountain Standard Based on 87Rb

Ekaterina Aleinikova, All-Russian Scientific Research Institute of Physical-Technical and Radiotechnical Measurements (Russia), et al.

Two rubidium fountain type frequency standards based on cold 87Rb atoms are developing at VNIIFTRI. The main characteristics of the Compact Magneto-optical sources of slow atoms will be presented. Frequency modulation spectroscopy can be provided as by a direct injection-current modulation, and by an external modulation of the laser. Both methods will be tested to estimate a noise level of error signals.

7152 Absorption 87Rb Cells with Anti-Relaxation Wall Coating with the Ultimately Low TFC Near to the Zero Value for Supporting a High Long-Term Stability of Frequency Standards

Evgeny Pestov, Russian Institute of Radionavigation and Time (Russia), et al.

87Rb cells with ARW coating have an operating temperature region with the ultimately low TFC near to the zero value and allow, using this parameter, to support a high long-term frequency stability of atomic standards and quantum magnetometers.

7153 Absorption Spectroscopy of 85Rb Atoms at 420 nm: Pressure Broadening with N2 Buffer Gas and Saturation Intensity

Xi Zeng, Centre Suisse d'Electronique et Microtechnique SA (Switzerland), et al.

We present absorption spectroscopy measurements of 85Rb in the 420 nm wavelength transition with data on pressure broadening due to N2 buffer gas and absorption saturation due to high optical intensity. To the best of our knowledge, there is no literature on the effects of N2 in this atomic transition.

7154 Recent Progress on Commissioning an Optically Pumped Cesium Beam as Primary Frequency Standard at Brazilian NMI

Luiz Vicente Gomes Tarelho, Instituto Nacional de Metrologia, Qualidade e Tecnologia (Brazil), et al.

This paper describes the recent progress on commissioning an optically pumped Cesium beam frequency standard developed at Instituto de Física de São Carlos and transferred to the Brazilian NMI (INMETRO) in order to be continuously operated as a primary frequency standard. INMETRO is doing a strategic effort to create an infrastructure for time and frequency metrology, in order to guarantee the traceability to the SI of other units by distributing this accurate and stable frequency reference around the Campus.

7036 **Active Optical Frequency Standards Using Cold Atoms: Perspectives and Challenges**

Georgy Kazakov, Technische Universität Wien (Austria), et al.

We consider various approaches to the creation of a high-stability active optical frequency standard, a new type of optical frequency standard where the atomic ensemble itself produces a highly stable and accurate frequency signal. Various effects critical for practical implementations, the main challenges and possible methods of overcoming them will be discussed.

7055 **Polarizabilities of Actinides and Lanthanides**

Alexander Kozlov, University of New South Wales (Australia), et al.

We calculate scalar and tensor polarizabilities for ground and few excited states of lanthanides and actinides. These elements are of the great experimental interest for ultraprecise atomic clocks, searches for variation of fundamental constants and parity non-conservation, application in study of quantum gasses. Calculations for atoms with opened f-shell are very complicated and usually have poor accuracy. There is no published data for most of actinides and lanthanides and the accuracy of unpublished results is not determined. We calculate scalar polarizabilities for ground and first few exited states as well as tensor polarizabilities of ground states of opened f-shell elements.

7060 **Inhomogeneous-Excitation Frequency Shifts of Ytterbium Optical Lattice Clocks**

Ning Chen, East China Normal University (China), et al.

The frequency shifts caused by inhomogeneous excitation in a 171Yb optical lattice clock have been studied theoretically. The dependences of the frequency shift on the temperature of the cold ytterbium atoms and the misaligning angle between the lattice laser and the clock laser, and the ground state fraction are analyzed by the numerical calculations. The results show that the fractional frequency uncertainty of the ytterbium clocks contributed by the inhomogeneous excitation can be reduced to be 10^{-19} or even lower with the certain condition.

7108 **Optical Frequency Standard with Ytterbium Single Ion**

Sergey Chepurov, Institute of Laser Physics SB RAS (Russia), et al.

The largest frequency shift that contributes to the systematic uncertainty of many atomic frequency standards is the interaction of the thermal blackbody radiation with the atomic eigenstates. Presence of two ultra narrow optical transitions in the same thermodynamic environment makes possible implementation of so called "synthetic" frequency standard with suppressed blackbody radiation (BBR) frequency shift1. In 171Yb ion at room temperature the residual BBR shift is estimated to be on the order of 10^{-18} for the "synthetic" frequency which is a combination of the octupole (467 nm) and the quadrupole (436 nm) optical transition frequencies. Thus, the "synthetic" frequency standard based on 171Yb+ can be practically immune to the blackbody radiation shift. We report on the progress in development of a highly accurate optical frequency standard based on the single ion of ytterbium-171 at the Institute of Laser Physics, Novosibirsk.

7118 Progress Report Towards an Al+ Quantum Logic Optical Clock
Stephan Hannig, Physikalisch-Technische Bundesanstalt (Germany), et al.

The PTB is building an aluminium ion optical clock using quantum logic techniques for sympathetic cooling and read-out of the clock ion. We present the clock setup, the ultra-stable cavity, trap characterization and will report on the status of the quantum logic state transfer between two ions.

7119 A Compact 461-nm Laser Source for Sr+ Trapped-Ion Experiments
Thomas Fordell, Centre for Metrology and Accreditation (Finland), et al.

A compact, stabilized source of 461 nm radiation for photoionization of strontium is presented. A 100-mW, 922-nm DBR laser diode is frequency doubled in a PPLN waveguide and stabilized via absorption spectroscopy to a beam of strontium atoms emitted from a strontium dispenser.

7125 A Frequency-Comb-Stabilized Laser for Cooling Sr+ Ions
Thomas Fordell, Centre for Metrology and Accreditation (Finland), et al.

Lasers for Doppler cooling of trapped ions demand light sources with MHz-level frequency accuracy and long term stability. For cooling strontium ions, an 843-nm DFB laser is amplified and doubled to 422nm. Frequency stability is achieved by locking the fundamental to a frequency comb, and absolute frequency is determined via saturated absorption spectroscopy of rubidium.

7130 PTB's Transportable Sr Lattice Clock
Stefan Vogt, Physikalisch-Technische Bundesanstalt (Germany), et al.

We will present the progress on a strontium lattice clock setup, which is designed to be transportable and competitive with today's optical clocks. New kinds of measurements are enabled by transportable clock setups that allow operation at arbitrary locations after a short startup time. As one example applications such as chronometric leveling will become possible between locations where no stationary optical clock is available.

7143 Least-Squares Analysis of Clock Comparison Data to Deduce Optimized Frequency and Frequency Ratio Values
Helen Margolis, National Physical Laboratory (United Kingdom), et al.

In this presentation we describe analysis techniques for processing the results of clock comparison experiments to deduce optimized frequency and frequency ratio values. Our approach is based on that used by CODATA to provide a self-consistent set of internationally recommended values of the fundamental physical constants.

7170 Towards Optical Clocks and Coherent Frequency Transfer in Sweden
Martin Zelan, SP Technical Research Institute of Sweden (Sweden), et al.

Within SPs commitment as a National Metrology Institute (NMI), a research program towards optical clocks and coherent frequency transfer are being initialized. With the aid from Swedish Post and Telecom Authority (PTS), we have recently been able to equip a new laboratory with an optical frequency comb and an ultra-stable laser from Menlo Systems. We will present the research program, the current status, and our future plans within the field.

7184 Ytterbium Lattice Clock Development at RIKEN
Nils Nemitz, RIKEN (Japan), et al.

We have started to convert one of the existing strontium clocks at RIKEN for optional operation with ytterbium. Over the last months, the required laser systems have been constructed and recently a combined strontium/ytterbium oven has been installed. We will present the latest progress in the development of the new ytterbium frequency standard at RIKEN.

7194 Reduction in the Blackbody Radiation Shift Uncertainty of Optical Clock Transitions in 171Yb+
Peter Nisbet-Jones, National Physical Laboratory (United Kingdom), et al.

Work is presented to reduce the systematic uncertainty of the BBR shift in an optical frequency standard based on a single ytterbium ion. Careful thermal design of the trap ensures that the ion is exposed to a known spectral intensity of IR radiation. The magnitude of the shift coefficient can be determined by applying an IR laser of known intensity to induce a measureable frequency shift.

7219 Preliminary Experiment of Sympathetic Cooling a Single Al+ Ion by Ca+ Ions in a Linear Paul Ion Trap
Jian Cao, Wuhan Institute of Physics and Mathematics / Chinese Academy of Sciences (China), et al.

Optical frequency standards have been developed rapidly over the world in recent years because of the fast developing technologies such as laser cooling neutral atoms or single trapped ion, the optical frequency comb and the ultra-narrow-linewidth lasers. While Sympathetic cooling of trapped ions which could hardly be laser-cooled directly because of the UV optical laser transition laser has become an indispensable tool for quantum information processing and precision optical frequency standards.in this paper, we will focused on our recently experiment of sympathetic al+ cooling with ca+ ions in our Lab.

7233 The SOC2 Transportable 171Yb Lattice Clock
Gregor Mura, Heinrich-Heine-Universität Düsseldorf (Germany), et al.

Optical lattice clocks based on elements with two valence electrons like Sr, Hg, Mg and Yb are strong competitors in the quest for next generation time and frequency standards. Recently, a stability and accuracy in the 10^{-18} range has been reported for lattice clocks using Sr and Yb for stationary setups. In the framework of the SOC2 project, we are developing a transportable Yb lattice clock demonstrator, since the development of transportable optical lattice clocks is desirable for both performance evaluation and applications, e.g. in a microgravity environment. To ensure transportability, our setup is based entirely on diode and fiber lasers and features an intra-vacuum enhancement resonator to allow the formation of a large volume lattice using moderate laser power. Here we present a characterization of our clock setup, as well as our plans for a transport of the apparatus from the University of Düsseldorf to INRIM and LSM. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n. 263500.

7235 Atomic Clock Based on Magneto-Dipole Transitions in Highly Charged Ions
Valeriy Yudin, Institute of Laser Physics SB RAS, Novosibirsk State University, et al.

We evaluate the possibility of using magnetic dipole (M1) optical transitions in highly charged ions (HCI) for high-precision atomic clock. Our analysis demonstrates that the atomic clocks based on the optical M1 transitions in HCIs can have very small inherent uncertainties (at the fractional level below 10^{-20} - 10^{-21} for the dominant systematic shifts (such as BBR, electric-quadrupole,

Zeeman and AC-Stark shifts). Moreover, by contrast to the conventional atomic clock based on neutral atoms or singly (weakly) charged ions such HCI clocks are exceptionally sensitive to hypothetical drifts of fundamental constants.

7255 Probing me/mp Variation by Comparison of Near-Resonant Acetylene Reference Lines at 1.5 µm

Florin Lucian Constantin, Centre National de la Recherche Scientifique (France)

Difference frequency of two near-resonant rovibrational transitions has an enhanced sensitivity to the temporal variation of electron-to-proton mass ratio µ. Sensitivity is calculated for reference transitions of isotopic acetylene at 1.5 µm using a rovibrational Hamitonian. Identification of transitions with an enhancement >10^4 is promising to put stringent limits on the variation of µ by comparison of acetylene clocks. The uncertainty of the difference frequency is evaluated for second order Doppler and recoil effects, hyperfine structure and Zeeman effect, black-body radiation shift.

7258 Preliminary Determination of the Magic Wavelength of Magnesium-24

Steffen Rühmann, Gottfried Wilhelm Leibniz Universität Hannover (Germany), et al.

We report on the latest results of the magnesium frequency standard at the Leibniz University of Hanover. Recently, we performed spectroscopy with first estimations of the magic wavelength. We give details on the experimental sequence and measurement methods. First estimations of the magic wavelength have values between 467.6 and 469 nm.

7263 Towards an 27Al+ Ion Optical Clock

Zetian Xu, Huazhong University of Science and Technology (China), et al.

This abstract is about the recent progress in the Al+ optical clock based on quantum logic technique of our group. It will focus on two parts. One is about the development on the sub-Hertz clock laser, and the other is the Raman sideband cooling of 25Mg+ which is one of the most important necessary conditions of applying quantum logic technique.

7266 Ultra-Precise Optical Clock: New Methods and Approaches

Sergey Bagayev, Institute of Laser Physics / Novosibirsk State University, et al.

In the present talk we will review new methods of precision spectroscopy of forbiden transitions with special emphasis on methods developed and studied in Institute of Laser Physics SB RAS, Novosibirsk. The short history and present status of experimental works devoted to optical frequency standards will be observed.

7273 Cavity-Enhanced Non-Destructive Detection of Atomic Populations in Optical Lattice Clocks

Rodolphe Le Targat, Observatoire de Paris (France), et al.

We present a new design of non-destructive detection of atomic populations in an atomic clock. The goal is to recycle the atoms and therefore increase the duty cycle of the clock, opening the way towards increased stabilities. We discuss the practical implementation of this approach in an operational strontium optical lattice clock, as well as the possible impact on its uncertainty budget.

Thursday June 26

08:00 – 18:00 Registration Main Aula
University of Neuchâtel Jeunes Rives

8:00	**Main Aula**		
	Exhibitor presentations Chair: Wolfgang Schäfer		
9:00	**Lecture sessions**		
	Main Aula	**Room R.N.02**	**Room R.E. 48**
	C1L-A – New Concepts in Atomic Clocks & Sensors Chair: Peter Rosenbusch	C1L-B – Ion Clocks Chair: Sébastien Bize	C1L-C – Time Transfer II Chair: Daniele Rovera
10:40	***Coffee break***		
11:00	**Lecture sessions**		
	Mobile Lab – R.O.12	**Room R.O.14**	**Room R.S.38**
	C2L-A – Frequency Combs II Chair: Thomas Südmeyer	C2L-B – Cold Atoms and Clocks Chair: Krzysztof Szymaniec	C2L-C – Galileo and Time Dissemination Chair: Pierre Waller
12:40	***Lunch at the Patinoire***		
14:00	**Poster sessions**		
	Room R.0.14	**Room R.S.38**	**Room R.S.38**
	C3P-E – GNSS & Space Chair: Pascale Defraigne	C3P-G – Microwave Frequency Standards III Chair: Sang Eon Park	C3P-H – Laser Stabilization & Atom Manipulation Chair: Hidekazu Hachisu
15:40	***Coffee break***		
16:00	**Lecture sessions**		
	Main Aula	**Room R.N.02**	**Room R.E.48**
	C4L-A – Fundamental Tests Chair: Ekkehard Peik	C4L-B – Compact Atomic Clocks Chair: Patrick Berthoud	C4L-C – Time Scales & Time Stamping Chair: Felicitas Arias
17:40	***End of the day***		

Note:

For reasons of limited space, only the name and affiliation of the first author of each communication is given in this program booklet. For the full list of authors and affiliations, please refer to the USB drive and online program.

Session C1L-A – New Concepts in Atomic Clocks & Sensors — Main Aula

09:00 ***INVITED* – Atomic Clocks Below the Standard Quantum Limit**
Vladan Vuletic, Massachusetts Institute of Technology (United States), *et al.*

We report on a spin squeezed atomic clock operating on a hyperfine transition in 87Rb that overcomes the standard quantum limit, and discuss an experiment in preparation to demonstrate a spin squeezed optical-transition clock using Yb atoms. We also discuss progress to prepare other entangled states that are potentially useful for clock operation, e.g. non-Gaussian states generated by the detection of a single photon.

09:40 **Rydberg Spin-Squeezing for a Strontium Optical Lattice Clock**
Elizabeth Bridge, Durham University (United Kingdom), *et al.*

We propose a new technique for achieving high levels of spin-squeezing in strontium optical lattice clocks using the long-range Van der Waals interactions between high-lying Rydberg states. We report on our experimental progress towards demonstrating this method.

10:00 **Simultaneous Dual Species Matter Wave Interferometry**
Ernst M. Rasel, Gottfried Wilhelm Leibniz Universität Hannover (Germany), *et al.*

We report on the first realization of a simultaneous 39K-87Rb-dual species matter wave interferometer measuring gravitational acceleration with the aim to test Einstein's Equivalence Principle (EEP). Compared to classical tests such as torsion pendulum experiments and Lunar Laser Ranging, chemical elements suitable for performing matter wave interferometry can provide complementary information. We show the performance of our apparatus and discuss current limitations and future improvements towards highly sensitive matter wave tests of EEP.

10:20 **Atom Chip Based Guided Atom Interferometer for Rotation Sensing**
Carlos Leonardo Garrido Alzar, Observatoire de Paris (France), *et al.*

In this work, the physical aspects as well as the experimental progress towards the realization of a rotation sensor using cold atoms magnetically guided on an atom chip are presented. The design and derivation of the magnetic guiding potential, the expected sensitivity, and the study of a highly efficient matter-wave beam splitter are in detail analyzed. This device is designed taking into account the stringent requirements of inertial navigation. Besides the usual constraints imposed on the physical dimensions and power consumption for the aforementioned application, we also investigate here the on-chip incorporation of keys elements needed in the realization of a cold atom interferometer. In particular, we discuss different strategies to overcome the fundamental limitations of guided and free falling atom interferometer inertial sensors: wire roughness induced decoherence, cloud fragmentation, interrogation time and quantum projection noise.

09:00 **Optical Clock Based on the 171Yb+ Octupole Transition with Uncertainty at the 10^{-18} Level**

Nils Huntemann, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

We aim for the realization of a very accurate optical clock that uses the electric octupole transition of a single laser-cooled 171Yb+ ion at 467 nm as a reference. We have implemented the Hyper-Ramsey excitation scheme that shows a suppression of the previously limiting light shift by 5 orders of magnitude. Recently, we have inferred the differential polarizability of the octupole transition from light shift measurements at various NIR wavelengths. The result allows us to improve the uncertainty blackbody radiation shift correction, which constitutes the leading contribution to the total systematic uncertainty of 5×10^{-18}.

09:20 **Measurement of the Absolute Frequencies of Two Optical Clock Transitions in 171Yb+**

Steven King, National Physical Laboratory (United Kingdom), *et al.*

We report new measurements of the absolute frequencies of two optical clock transitions in a single ion of 171Yb+, referenced to the caesium fountain primary standard NPL-CsF2 via two optical frequency combs. The contributions to the total systematic uncertainty arising from the 171Yb+ apparatus are substantially smaller than in our previously published work, which is mainly attributable to improved compensation for the ac Stark shift induced by the probe laser, better knowledge of the blackbody environment experienced by the ion, and a reduced uncertainty on the cancellation of the quadrupole shift.

09:40 **Measurement of the Static Scalar Polarizability of the 88Sr+ Clock Transition**

Pierre Dubé, National Research Council Canada (Canada), *et al.*

Preliminary results on a method used to determine experimentally the static scalar polarizability of the clock transition of the strontium ion optical frequency standard are reported. The method is based on the relation between the trap frequency at which the micromotion shifts cancel each other and the differential scalar polarizability. The anticipated improvement in this parameter will reduce the evaluated blackbody radiation shift uncertainty of the NRC strontium ion to the 5 mHz level or lower.

10:00 **Agreement Between Two 88Sr+ Optical Clocks to 4 Parts in 10^{17}**

Geoffrey Barwood, National Physical Laboratory (United Kingdom), *et al.*

The frequencies of two nominally identical 88Sr+ trapped single ion optical clocks, based on the 674 nm 5s 2S1/2 " 4d 2D5/2 electric quadrupole clock transition, have been compared over a period of 9 months. The frequency of the two clocks was found to agree within a total fractional uncertainty of 4×10^{-17}, demonstrating that the individual 88Sr+ optical clocks are reproducible at the 3×10^{-17} level.

10:20 Towards Optical Clocks Based on Multi-Ion Systems
Tanja Mehlstäubler, Physikalisch-Technische Bundesanstalt (Germany), *et al.*

In order to exploit their full potential and to resolve frequencies with a fractional frequency instability of 10^{-18}, optical ion clocks need to integrate over many days to weeks. For the characterisation of systematic shifts of the clock, as well as for applications, such as relativistic geodesy, these long times scales pose severe limits. We present our sudies to scale up the number of ions for optical clock spectroscopy to significantly reduce integration times, with a new ion trap with low on-axis micromotion and good control of the dynamics of coupled many body systems.

Session C1L-C – Time Transfer II R.E.48

09:00 Comparison of Cesium Fountain Clocks in Europe and Asia
Aimin Zhang, National Institute of Metrology (China), *et al.*

A remote comparison campaign of cesium fountain clocks from four National Metrology Institutes in Europe and Asia was carried out in May 2013. Six fountains at PTB,VNIIFTRI-SU,NPLI and NIM were compared by Two-Way Satellite Time and Frequency Transfer (TWSTFT) and GPS Carrier Phase (GPS CP) techniques.The measurement campaign and the evaluation techniques will be presented in detail.

09:20 GPS Frequency Transfer with IPPP
Gérard Petit, Bureau International des Poids et Mesures (France), *et al.*

Since many years, the BIPM has been using the Precise Point Positioning (PPP) technique using GPS phase and code observations to compute time and frequency links. We estimate the present uncertainty of our PPP frequency comparisons over 15-30 days to be in the low 10^{-16}, i.e. it is a limiting factor in comparing frequency standards. One main limiting factor comes from the effect on the clock solution of the simultaneous resolution of floating phase ambiguities together with other parameters such as the tropospheric delay and station position. In this paper we study how to improve the frequency transfer using the Integer-PPP (IPPP) technique of CNES.

09:40 Link Calibration Against Receiver Calibration Time Transfer Uncertainty When Using the Global Positioning System
Giovanni Daniele Rovera, Observatoire de Paris (France), *et al.*

We propose a direct comparison between two different techniques for the relative calibration of time transfer between remote time scales when using the signals transmitted by the Global Positioning System (GPS). In the remote sites, the local measurements are driving either the computation of the hardware delays of the local GPS equipment with respect to a given reference GPS receiver, or the computation of a global hardware offset between two distribution reference points of the remote time scales. This last technique is often called a "link" calibration, with respect to the other one, which is a "receiver" calibration. Both techniques do not require the same measurements on site, hence are not leading to similar uncertainty budgets, and we discuss different related issues. We report on one calibration campaign organized during Autumn 2013 between Observatoire de Paris (OP), Paris, France, Observatoire de la Côte d'Azur (OCA), Plateau de Calern, France, and NERC Space Geodesy Facility (SGF), Herstmonceux, UK.

10:00 **Absolute Calibration of GNSS Time Transfer Systems at CNES**
Amale Kanj, Bureau International des Poids et Mesures / CNES (France), *et al.*

Since 2005, French Space Agency (CNES) has developed an absolute calibration technique based on the Naval Research Laboratory (NRL) approach. The results of the application of this technique have shown that accuracy around 1 nanosecond for the whole chain can be achieved. We present several calibration results of GNSS receivers and antennas using the absolute tech-nique. For the antennas, we use a specific transportable anechoic chamber developed last year. Different methods to validate the calibration results are also shown, including the comparison of the results obtained with 2 different types of GNSS simulator.

10:20 **Time Transfer Using a Calibrated GPS-Galileo Receiver**
Pascale Defraigne, Royal Observatory of Belgium (Belgium), *et al.*

This paper will study the combination of GPS and Galileo signals to get a calibrated time transfer solution, using code measurements on the four satellites of the current Galileo In-Orbit Validation (IOV) phase. Both the calibration aspects and the data analysis strategy will be investigated.

Session C2L-A – Frequency Combs II — Main Aula

11:00 ***INVITED*** **– Quantum Cascade Lasers Comb Spectrometers**
Jérôme Faist, ETH Zurich (Switzerland)

The quantum cascade laser has demonstrated the ability to provide gain over a very broad wavelength range. Recently, we have shown that such broadband devices, when operated in continuous wave, emit as a coherent optical comb1 in which the phase relation between the comb modes corresponds approximately to a FM modulated laser. These new comb lasers enables the fabrication of a dual comb spectrometer based on a quantum cascade laser that offers a broadband, all solid-state spectrometer with no moving parts and a ultrafast acquisition time. We discuss recent results in gas spectrosocpy as well as the extension of these ideas to the THz.

11:40 **Photonic Synthesis of Low Noise W-Band Signals**
Tara Fortier, National Institute of Standards and Technology (United States), *et al.*

We demonstrate absolute low noise 90 GHz signals via electronic multiplication of the 10 GHz signal generated via optical frequency division. Using this technique we achieved a phase noise level of -80 dBc/Hz at 1 Hz dropping the an electronically limited noise floor of -130 dBc/Hz at 1 MHz.

12:00 **Passively Phase-Locked Fiber Frequency Comb**
David Fehrenbacher, Universität Konstanz (Germany), *et al.*

We demonstrate a passively phase-stable fiber frequency comb at a repetition rate of 100 MHz suitable for metrology applications. The passive stability of the CEP results in a linewidth below 100 kHz at a wavelength of 1550 nm. Reference-limited repetition rate stabilization to an RF source is achieved with the control of the current of the pump diode. High bandwidth stabilization schemes on optical frequency references are currently under development.

12:20 **Phase-Predictable Tuning of Single-Frequency Optical Synthesizers**
Thomas Puppe, TOPTICA Photonics AG (Germany), *et al.*

Single-frequency optical synthesizers (SFOS) provide an optical field with arbitrarily adjustable frequency and phase which is phase-coherently linked to a reference signal. Ideally, they combine

the spectral resolution of narrow linewidth frequency stabilized continuous wave lasers with the broad spectral coverage of frequency combs in a tunable fashion. We investigate the tuning behavior of a novel type of SFOS by phase comparison of two identical devices. We achieve phase-stable and cycle slip free frequency tuning over 28.1 GHz with a short term rms phase deviation of 55 mrad. In contrast to previous implementations, no comb line order switching is needed.

Session C2L-B – Cold Atoms and Clocks R.N.02

11:00 High-Accuracy Measurement of the Blackbody Radiation Frequency Shift of the Ground-State Hyperfine Transition in 133Cs
Steven Jefferts, National Institute of Standards and Technology (United States), *et al.*

We report a high-accuracy direct measurement of the blackbody radiation (BBR) shift of the 133Cs ground state hyperfine transition. This frequency shift is one of the largest systematic frequency biases encountered in realizing the current definition of the International System (SI) second. Uncertainty in the BBR frequency shift correction has led to its being the focus of intense theoretical effort by a variety of research groups. Our experimental measurement of the shift used three primary frequency standards operating at different temperatures. We achieved an uncertainty a factor of five smaller than the previous best direct measurement. These results tend to validate the claimed accuracy of the recently calculated values.

11:20 Long Term Evolution of Key Physical Parameters in Atomic Fountain Frequency Standards
Jocelyne Guéna, Observatoire de Paris (France), *et al.*

The role of atomic fountain clocks has continuously grown now including demanding long term applications such as TAI, some UTC(k), ACES/PHARAO or fundamental science tests. For 5 years now, the LNE-SYRTE atomic fountain ensemble has been a major contributor to TAI with 3 Cs primary frequency standards and, as a novelty since 2013, FO2-Rb. We take the opportunity to present a long term analysis of key parameters such as the magnetic field, atom density ratio or the verticality of the atom trajectory, which are central to establishing a reliable uncertainty budget.

11:40 Uncertainty Evaluation of the Fountain Primary Standard KRISS-F1(Cs)
Sang Eon Park, Korea Research Institute of Stand. and Science (Korea South), *et al.*

We are developing a Cs/Rb dual fountain frequency standard, KRISS-F1 to contribute to International Atomic Time (TAI) and accurately generate of UTC(KRIS). And We are currently evaluating the cold collision and DCP shifts for an accuracy evaluation of the Cs fountain standard. Other frequency shifts are evaluated to be less than 10^{-16}. We aim for a total uncertainty of KRISS-F1(Cs) at the low 10^{-16} level. We will present our recent results at the conference

12:00 Mitigation of Frequency Shifts in a Cold-Atom CPT Clock
Eric Blanshan, National Institute of Standards and Technology (United States), *et al.*

The performance of a compact cold-atom clock based on lin || lin coherent population trapping with Ramsey spectroscopy and phase-locked DFB/DBR lasers is presented, along with a characterization of primary systematics in the system. Mitigation techniques for the Doppler shift and light shift are discussed along with future plans to improve the stability at long integration times.

12:20 Large Area Cold Atom Gyroscope
Indranil Dutta, Observatoire de Paris (France), *et al.*

I will present the latest results of our cold atom matterwave gyroscope experiment at SYRTE. It consists of an atom interferometer where we aim to reach very high sensitivity to rate of rotation. The experimental apparatus is designed such that we can have an atom interferometric area as big as 11 cm^2. Our setup offers interesting applications in inertial sensing, geodesy and test of fundamental physics.

Session C2L-C – Galileo and Time Dissemination R.E.48

11:00 GPS to Galileo Time Offset Operations
Edward Powers, United States Naval Observatory (United States), *et al.*

The Galileo Program system is expected to announce Early Services by the end of 2014. GNSS users could benefit from this new set of GNSS satellites when used in combination with GPS and GLONASS. Each GNSS system broadcasts synchronizing clock corrections linked to their independent navigation time scale. These independent GNSS navigation time scales are typically traceable to UTC (module whole seconds) to better than 50 nanoseconds. To be useful for a precision navigation solution, this error needs to be reduced to below 5 nanoseconds. Therefore in 2004, GPS and Galileo have agreed to develop and jointly broadcast a GPS-to-Galileo Time Offset (GGTO) message. Working in cooperation, USNO (GPS) and ESA (Galileo) have agreed upon several methods to compute and coordinate the GGTO values. This paper will report the status of GGTO development, performance expectations and initial results.

11:20 Precise Timing with the Galileo Early Open Service
Pierluigi De Simone, European Space Agency (Netherlands), *et al.*

The paper describes the context of Galileo Early Services, introduces the Galileo time dissemination concepts, and discusses implementation of the Key Performance Indicators applicable to timing and organization of the overall service validation phase.

11:40 The Galileo Time Validation Facility: One Year of Real-Time Steering of the Galileo System Time
Ilaria Sesia, Istituto Nazionale di Ricerca Metrologica (Italy), *et al.*

In the last 15 years, the Italian Metrology Institute (INRIM) has been deeply involved in the development of the Galileo project, from the early study phase through all the experimental phases. Recently, INRIM designed and developed the Time Validation Facility (TVF), a key timing element of the ongoing In Orbit Validation (IOV) Galileo phase. This paper presents the main Galileo timing results of the TVF, addressing the Galileo System Time validation over one year of real-time steering.

12:00 Performance Results of the Galileo Precise Timing Facility
Amandine Proia, Thales Alenia Space France (France), *et al.*

The Precise Timing Facility (PTF) is considered as a key element of the Ground Mission Segment (GMS) in the Galileo Global Navigation Satellite System (GNSS). The PTF major purpose is to generate the physical time scale of Galileo, the Galileo System Time (GST) with two main functions: the provision of a very stable time reference for navigation purposes and the metrological timekeeping. The first one is critical for fulfilling the navigation mission. The second function is aimed at steering GST towards International Atomic Time (TAI) and to provide the UTC

timing dissemination service to the user. In addition to the above, PTF is also in charge of computing the Galileo-GPS Time Offset (GGTO) which allows the combined use of signals from both GNSS. The PTF located in Italy is operated in nominal way since February 2013 while the German PTF will be qualified this year. This paper gives an overview of the Galileo Project progress and reports the first performance results of the PTF in Fucino (Italy) after the initial In-Orbit Validation (IOV) phase.

Session C4L-A – Fundamental Tests — Main Aula

16:00 ***INVITED*** **– Muonic Hydrogen and the Proton Radius Puzzle**
Randolf Pohl, Max-Planck-Institut für Quantenoptik (Germany)

In muonic hydrogen, a proton is orbited by a negative muon whose mass (m_mu ~ 200 m_e) results in a 200 times smaller muonic Bohr radius, compared to regular hydrogen, and hence a large sensitivity of energy levels to the size of the proton. Our recent measurement of the Lamb shift in muonic hydrogen yielded a tenfold improvement in the proton charge radius, albeit 7 sigma discrepant from the CODATA world average. New measurements in muonic deuterium and helium-4 will help to understand the "proton radius puzzle".

16:40 **Interspecies Comparisons Between Optical and Microwave Clocks**
Chunyan Shi, Observatoire de Paris (France), *et al.*

We present a series of high resolution extensive comparisons between a strontium optical lattice clock and an ensemble of microwave clocks at LNE-SYRTE comprising a dual Cs and Rb fountain. This work was performed in the context of a long term effort to track reproducibility of the comparison between optical clocks and primary frequency standards, which is a necessary prerequisite for a robust definition of the SI second. Finally, we will present ongoing work to improve the performances of strontium optical lattice clocks. In terms of uncertainty budget, our effort is focused on the control of the temperature experienced by the atomic cloud in order to reduce the uncertainty due to BBR effect. To reach a better stability, we will present progress towards a cavity-based nondestructive detection that can contribute to largely reduce the dead time in the clock cycle.

17:00 ***INVITED*** **– Tests of Fundamental Physics with Atomic Dysprosium**
Nathan Leefer, Helmholtz-Institut Mainz (Germany), *et al.*

In dysprosium there is a pair of long-lived, excited non-Rydberg opposite-parity states of the same total electronic angular momentum (J=10) that are separated in energy, depending on the isotope and hyperfine component, by anywhere between 3 MHz and a few GHz (with energies expressed in frequency units) in the absence of external fields. The near degeneracy allows measuring the difference in the energies of the levels directly by radio-frequency (rf) spectroscopy, enabling sensitive exotic-physics searches with relaxed requirements for the rf source in terms of its fractional frequency stability.

Session C4L-B – Compact Atomic Clocks R.N.02

16:00 ***INVITED*** **– Compact Atomic Clocks Based on Coherent Population Trapping: Technologies and Performances for Applications**
Stéphane Guerandel, Observatoire de Paris (France), *et al.*

The atomic CPT interaction technique allows building all-optical setup microwave clocks with high frequency stability in compact vapor-cell devices. These clocks are suitable for a wide range of applications from industry environment to on-board systems.

16:40 **Pulsed Optical Pumping in a Rb Vapour Cell Using a Compact Magnetron-Type Microwave Cavity**
Songbai Kang, Université de Neuchâtel (Switzerland), *et al.*

We present a first evaluation of pulsed optically pumped Ramsey interrogation of 87Rb atoms using a buffer-gas vapour cell and a very compact magnetron-type microwave resonator. High-contrast Ramsey signals (up to 40% contrast) are observed, yielding an estimated shot-noise limit for the clock stability of around $1x10^{-13}$ at one second of integration time. The results are of interest in view of realizing high-stability optically-pumped Rb cell clocks with reduced size of the physics package.

17:00 **Stabilizing Temperature in Vapor-Cell Atomic Clocks: the "Isoclinic-Point Thermometer"**
Nathan Wells, Aerospace Corporation (United States), *et al.*

In this presentation we introduce our "isoclinic-point thermometer." Briefly, in vapor-cell atomic clocks one of the primary impediments to long-term frequency stability derives from vapor temperature fluctuations. We believe that the isoclinic-point thermometer may be a means of more accurately assessing and stabilizing temperature in these clocks. Here, we review the spectroscopic nature of the isoclinic point, and we outline its use for the thermometry of vapor-phase systems. Additionally, we discuss two possible realizations of the isoclinic point thermometer, our calibration of these realizations to vapor temperature, and their potential sensitivity to vapor temperature variations.

17:20 **Spectroscopy in a Micro-Fabricated Rb Cell with Anti-Relaxation Wall-Coating**
Matthieu Pellaton, Université de Neuchâtel (Switzerland), *et al.*

We report on the spectroscopic evaluation of a microfabricated Rb vapour cell equipped with an anti-relaxation wall coating. The cell employs octadecyltrichlorosilane (OTS) as wall-coating and was sealed using a low-temperature indium bonding technique. We combine results from saturated-absorption and microwave-optical double-resonance (DR) spectroscopy to show that the narrow 9kHz linewidth DR signals observed for the Rb clock transition are due to the presence of the wall coating, and not due to a potentially present buffer-gas contamination. The properties of the DR clock signals obtained are discussed.

Session C4L-C – Time Scales & Time Stamping R.E.48

16:00 ***INVITED*** **– Picosecond Time Drift Characterization of the Laser Megajoule Timing System**
Eric Meyer, Centre National de la Recherche Scientifique / University of Franche-Comté (France), *et al.*

The Laser MegaJoule timing system has to synchronize 176 laser within 40 ps. The time drift of delay measurements (from 5 to 100 μs) must be less than 2 ps over 24 hours, 10 ps over 7 days and 30 ps over a month. The main problem is the control and implementation of the instruments needed to achieve such measurements. The first results provided a measurement method and its associated instruments, using a MASER and high sampling rate digitizers. The results are analysed in terms of stability and accuracy. The method used to supervise the facility time drifts is presented.

16:40 **Performances of UTC(OP) Based on LNE-SYRTE Atomic Fountains**
Michel Abgrall, Observatoire de Paris (France), *et al.*

We present the current realization of UTC(OP) generated at LNE-SYRTE, Observatoire de Paris (OP), Paris, France, which is also the source of French legal time. UTC(OP) is based on a H-maser standard steered on the atomic fountains developed by LNE-SYRTE. The steering algorithm and the prediction of UTC(OP) departure from UTC are described, together with the results of the first year of operation. Since October 2012, the departure of UTC(OP) from UTC remained well below 10 ns.

17:00 **New Level of Advancement of a National Time Scale UTC(SU)**
Sergey Donchenko, National Research Institute for Physical-Technical and Radiotechnical Measurements (Russia), *et al.*

The report provides information on the composition and main characteristics of the formation complex of the national time scale UTC (SU) and represents the prospects of its development. The national time scale of the Russian Federation is reproduced and maintained based on the State standard of time and frequency operated at a facility located in Mendeleevo, Moscow Region.

17:20 Frequency Combining System for Atomic Clock Ensembles
Konstantin Mishagin, JSC Vremya-CH (Russia), *et al.*

Analysis of frequency stability of group signal produced by auxiliary crystal oscillator synchronized to the average frequency of active hydrogen maser ensemble is presented. Real measurements' data, obtained in JSC "Vremya-CH" in 2013, are used for the analysis. Simple modification of frequency control algorithm " quasi-optimal atomic clock frequency combining algorithm is described. The algorithm allows combining atomic clocks of different types, which have different frequency stability characteristics on different averaging times.

Details of Thursday poster sessions (14.00 – 15.40)

Session C3P-E – GNSS & Space R.O.14

7040 Disciplined Oscillator System by UTC(Nim) for Remote Time and Frequency Traceability
Kun Liang, National Institute of Metrology (China), et al.

NIM can provide one low-cost Rubidium oscillator disciplined by UTC(NIM) in real time (UTC(NIM) Disciplined Oscillator, NIMDO) that has the instant and direct traceability to UTC(NIM) as soon as powered on. NIMDO can exempt the user from operating ceaseless some kind atomic clock and periodically calibrating it reference to UTC, which leads to a lot of consuming of manpower, material resources and time. The time and frequency accuracy of NIMDO has been improved thanks to the high level reference time scale and time scale algorithm and its long stability has been ameliorated due to the real-time and short latency steering to UTC(NIM). Referenced to UTC(NIM), we can acquired that the time and frequency accuracy of NIMDO could separately be better than 5 ns and 1e-13 averaging one day, and the time and frequency stability averaging one day could separately be better than 5 ns and 6e-14.Soon we would improve the steering algorithm by applying multiple system including BDS system and real time GNSS carrier phase time and frequency transfer.

7045 Remote Steering of OCA Local Time Scale Using UTC(OP)
Myrtille Laas-Bourez, Géoazur / Université de Nice Sophia-Antipolis (France), et al.

A new time scale in OCA, TA(OCA) based on hydrogen maser has been implemented. The H-maser frequency is daily steered with an microphase stepper taking into account the frequency of the free running maser and the actual time difference between TA(OPC) and UTC(OP). The H-maser phase is monitored with two GPS receivers and one TWSTFT station. The main idea is to keep the time difference between our local time scale TA(OCA) and UTC below 50 ns. Preliminary tests have been carried out with LNE-SYRTE. We plan to implement the automated processing in February-March 2014.

7023 Predicting the Corrections for the Polish Timescale UTC(PL) Using GMDH & GRNN Neural Networks

Lukasz Sobolewski, University of Zielona Góra (Poland)

The lowest values of prediction error was obtained for the GMDH neural networks for time series analysis method and data prepared on the basis of times series ts1. These results were significantly better than the values of prediction error obtained in the COM using analytical linear regression method. In the case of GRNN neural networks the obtained values of prediction error using regression method for the data prepared on the basis of time series ts2 are very close to the values of prediction error obtained in the COM. However, for the data prepared on the basis of time series ts1they reached a very high values.

7200 Implementation of the Real-Time Assessment of Dynamic Allan Deviation and Dynamic Time Deviation

Michal Kasznia, Poznan University of Technology (Poland)

In the paper the methods of the real-time computation of the dynamic parameters are proposed. These methods allow to compute the estimates of the dynamic Allan deviation and dynamic time deviation in the real time, during the time error measurement process, simultaneously for a set of observation intervals. In the paper the results of implementation of these methods in a real joint measurement and computation process are presented and described. Some hardware and software solutions enabling to join the time error measurement and parameters' computation in one effective process are discussed and suggested.

7206 Accurate Time Link Calibration for UTC Time Transfer - Status of the BIPM Pilot Study on the UTC Time Link Calibration

Zhiheng Jiang, Bureau International des Poids et Mesures (France)

In 2011, the BIPM launched a pilot study on the accurate calibration for the UTC time links [1]. The goal is to unify the UTC time link calibration uncertainties ≤ 2 ns. This is attainable using the METODE (MEasurement of TOtal DElay) which is based on a calibration scheme and a delicately designed travelling calibrator (StdB). The participants of the pilot study are the BIPM and the 7 leading UTC laboratories: OP in France, PTB in Germany, AOS and PL in Poland, TL in Taiwan, NMIJ and NICT in Japan. The experiments are first carried out at BIPM and then the calibrator StdB is sent to the above laboratories to further perform the time link calibration experiments to investigate the methodology and related total uncertainty.

7213 Surveillance of NTP-Servers in Customer's Network

Kenneth Jaldehag, SP Technical Research Institute of Sweden (Sweden), et al.

A system where the NTP servers of a large telecom and datacom operator is monitored and logged,is presented. The data is presented on a website together with the estimated uncertainties and other key performance indicators. The presented system demonstrates an implementation of quality assured time dissemintation to external, commercial enterprises.

7114 Dissemination of Time and RF Frequency via an Optical Link in KRISS

Myoung-Sun Heo, Korea Research Inst. of Standards and Science (Korea South), et al.

We implemented a fiber-optic dissemination system of time and frequency between two buildings connected by about 1 km underground optical fiber inside KRISS (Korean Research Institute of Standards and Science). This optical link will be used to confirm stable operations of H-masers which will be relocated to a new building one by one.

7217 A New Steering Strategy for UTC(NTSC)

Shuhong Zhao, National Time Service Center / Chinese Academy of Sciences, et al.

In order to make UTC(NTSC) deviate from UTC as small as possible,and keep high long and short frequency stability as well, A new steering algorithm is proposed. The derived frequency offset is sent to the micro phase stepper automatically with an equal interval,so that the time signal derived from the steered master clock can be accurate, meanwhile its stability is not influenced. Test results show that new master clock steering strategy is right and feasible.

7115 Timing Over 4G Mobile Network

Domas Jokubauskis, Center for Physical Sciences and Technology (Lithuania), et al.

In the present work, we focus on the investigation of timing and synchronization of PC clock over 4G (LTE) mobile network. Mobile Testing System (MTS) was constructed using single-board computer "Raspberry Pi" Model B (RPi) and "Huawei E398" modem connected to the RPi via an USB interface. Second pulses (PPS) generated by UTC(LT) traceable clock were time-stamped according to the internal RPi clock, which was synchronized to the UTC(LT) clock using NTP technology via 3G and 4G mobile networks. Various characteristics of time transfer over 3G and 4G mobile telecommunication networks are investigated.

7225 Decentralization of UTC(NICT) System

Fumimaru Nakagawa, Nat. Inst. of Inform. & Commun. Technology (Japan), et al.

In the NICT, we currently advance a project to decentralize UTC(NICT) system in the various parts of Japan. The purpose of the decentralization is mainly to prepare for future disasters and to improve reliability and precision of UTC(NICT). The decentralization consists of decentralization of atomic clocks, construction of time transfer link, construction of database and installation of standard time generation system. Advancing the decentralization so far, we have installed atomic clocks and measurement system in Kobe and two LF frequency standard transmission stations. Moreover we will generate standard time from each place in this year.

7244 Modular Time Interval Counter

Ryszard Szplet, Military University of Technology (Poland), et al.

In this paper we present the design, operation and test results of a multichannel modular time interval counter that allows for simultaneous measurement of time relations between pulses generated by up to six pulse sources (e.g. clocks) being under test and a single common pulse from a reference, more stable source. The counter contains six independent measurement modules built with the use of precise time counters integrated in programmable FPGA devices Spartan-3 (Xilinx). Integrated time counters are based on two-stage interpolation method that provides wide measurement range (> 1 s) and high resolution (< 45 ps).

7161 Construction of a Secure Clock Location for Alternative Realization of UTC(SP)

Glenn Bideberg, SP Technical Research institute of Sweden (Sweden), et al.

Based on a request from the Swedish Post-and Telecommunications Authority, responsible for the availability and robustness of communications, a cavern was reconstructed to operate as a redundant NMI-level Time and Frequency laboratory and collocate with a fiber network node. The paper intends to describe the construction with aims, and some specific solutions in detail. The laboratories are hosted within an EM-shielded building, more than 15 meters below street level. The paper also briefly describes the time and frequency equipment used for the alternative realization of UTC(SP) and its redundant dissemination.

7298 The Technology Research of Master and Backup Clock Switch
Wei Li, National Time Service Center / Chinese Academy of Sciences (China), et al.

Time and frequency reference is usually established and maintained by the clock ensemble, and the real time physical signal is output by the master clock system. Master clock system include the a high-performance atomic clock selected from the clock ensemble and phase trimming instrument, which output the real time, continuous and stable frequency signal and the second signal; at the same time, when the main clock system have abnormalities, it is needed to switch to a backup clock system to ensure the continuity and stability of time and frequency signal. System contains two separate master clock system, a master one and a backup one run in parallel. In the case of the master clock running, according to the time difference of master clock and the backup clock, the backup clock frequency is controlled to maintain consistency with the master clock through the phase trimming instrument. When the master clock is abnormal, it is switched to the backup clock directly through the switch. In the long process of experiment, master and backup clock frequency and phase is very consistent.

7188 Modeling and Analysis of Navigation Signal Failure Caused by on-Board Atomic Clock Anomalies
Gangqiang Guan, National University of Defense Technology (China), et al.

In GNSS, the atomic clock is the core part of satellite payloads, which provides the time refer-ence for generating and measuring the navigation signal, consequently its performance has a di-rect effect on the accuracy of positioning and timing. The failure model of navigation signal gen-eration caused by atomic clock anomalies is the basis for assessing the navigation signal quality and studying the approach of satellite automous integrity monitoring (SAIM).This paper first analyzes the atomic clock anomalies and establishes the clock signal model, then details the prin-ciples of the on-board time-frequency system. According to the flow of navigation signal genera-tion, the effects of atomic clock anomalies on digital and analog generation parts are studied. Meanwhile we establish the failure transfer model from on-board atomic clock anomalies to navi-gation signal generation. Finally, mathematical simulation and SAIM test platform experiment results show that the provided model is verificated.

Session C3P-G – Microwave Frequency Standards III R.S.38

7159 NPL Primary Frequency Standards: Current Status
Krzysztof Szymaniec, National Physical Laboratory (United Kingdom), et al.

NPL operates an ensemble of two caesium fountain primary frequency standards. One, NPL-CsF2 has been in use for several years and an analysis of its long term behaviour will be presented. Its residual instability is found to be consistent with the declared total type-B uncertainty. Construction of the second fountain NPL-CsF3 has now been completed and an early assessment on its performance will be given.

7162 Evaluation of Microwave Leakage and Magnetic Field Inhomo-Geneity in the Continuous Fountain Atomic Clock FoCS-2
Antoine Jallageas, Université de Neuchâtel (Switzerland), et al.

A carefull investigation of microwave leakages originating from both inside and outside the fountain has been made to avoid uncontrolled frequency shifts. The magnetic field inside the fountain has also been investigated, since its homogeneity is important to guarantee the

efficiency of the state preparation and to avoid Majorana transitions. Finite element simulations of the magnetic field have shown good agreement with in-situ probe measurments and have allowed for the prediction of the magnetic field. The latest results of microwave leakage and magnetic field studies on FoCS-2 will be presented.

7182 Constructive Polarization Modulation for Coherent Population Trapping Clock

Enxue Peter Yun, Observatoire de Paris (France), et al.

Coherent population trapping phenomenon (CPT) can replace the traditional double resonance technique in vapor cell atomic clocks. In CPT clocks the microwave frequency is optically carried, removing the need of a microwave cavity. However optical pumping effects in end Zeeman states limit the available contrast of the resonance in usual CPT schemes using circularly polarized beams. We propose here a new scheme using polarization modulation. With appropriate simultaneous phase modulation of the laser beams there is no more trap states and the resonance contrast is significantly increased.

7228 On Efficiency of Laser Pumping for Selective Hyperfine-Level Population in Cesium Atom

Alexander Magunov, A.M. Prokhorov General Physics Institute of Russian Academy of Sciences (Russia), et al.

The results of theoretical studies of the laser pumping of the lower sublevel for the "clock" transition in a cesium frequency standard are presented.

7261 Broadband Spectroscopic Measurement of Impurity Ions in Crystals Using the Whispering Gallery Modes Technique

Warrick G. Farr, University of Western Australia (Australia), et al.

Impurity ions in crystalline microwave cavities are studied. Rigorous spectroscopy of single-crystal sapphire and rare earth doped YAG and YSO was performed over the frequency range 8-30 GHz, and external DC magnetic fields of up to 0.9 T. Measurements of a high purity sapphire reveal the presence of Fe3+, Cr3+, and V2+ impurities, with quadrupole and hyperfine structure, as well as coupling between spins and photons of up to 6MHz. Also, new transitions in Erbium and Europium doped YSO crystals are ob-served in the strong coupling regime and will be presented at the conference.

7262 Short-Term Stability Improvement of the Microwave Frequency Standard Based on Laser-Cooled 113Cd+ Ions

Jianwei Zhang, Tsinghua University (China), et al.

The fluorescence signal decay during detection is one of the main limits to the short-term frequency stability of the microwave frequency standard based on laser-cooled 113Cd+ ions developed at Tsinghua University. This paper reports recent researches on this problem and the ways to improve the short-term stability of the Cd+ clock.

7283 Influence of the Laser Spectrum on the Form of the Coherent Population Trapping Resonance in Optical Dense Medium

K.A. Barantsev, Saint Petersburg State Polytechnical University (Russia), et al.

The main part of this work is comparison of contrast of the CPT resonances which are excited by wide and narrow laser and calculation of short-term stability. Also, we will optimize the stability by different parameters, such as atomic concentration, laser intensity, etc.

7295 FPGA-Based Triggered-Phase Transient Analyzer
Michael Kazda, Physikalisch-Technische Bundesanstalt (Germany)

We are implementing a phase transient analyzer with coherent averaging utilizing a field-programmable gate array (FPGA) to evaluate and subsequently reduce potential sources of frequency shifts in our caesium fountains. We expect to reach sub-microradian resolution with a measurement time significantly lower than in reported previously.

7311 Push-Pull Optical Pumping with Mode-Locked Laser
Koji Masuda, University of New Mexico (United States), et al.

Coherent population trapping (CPT) resonance in alkali-metal has been studied for frequency standards .We present here the enhancement of the 0-0 CPT resonance excited by a frequency comb, using push-pull optical pumping. The laser repetition rate is set near a sub-harmonic of the ground state splitting of rubidium-87. A high contrast (~30 %) 0-0 CPT resonance is observed when both the repetition rate and the inverse of the delay between RCP and LCP pulses are a sub-harmonic of the ground state splitting.

7312 Generation of a Nested Frequency Comb
Ladan Arissian, University of New Mexico (United States), et al.

A mode-locked Ti:sapphire laser with intracavity Fabry-Perot produces a frequency comb at 7 GHz including a fine structure at 100 MHz. The complex nature of this nested comb is analyzed.

Session C3P-H – Laser Stabilization & Atom Manipulation R.S.38

7005 Compact Semiconductor Laser Modules Designed for Precision Quantum Optical Experiments in Space
Ahmad Bawamia, Ferdinand-Braun-Institut,Leibniz-Institut fuer Hoechstfrequenztechnik (Germany), et al.

We present the design and implementation of a compact, robust and energy-efficient semiconductor laser technology that is suitable for field applications or even for a deployment in space. We concentrate on GaAs-based laser systems engineered for emission at 780 nm, which meet the frequency-stability requirements for precision spectroscopy on ultra-cold rubidium atoms. We further outline the next step in the development of the laser technology discussed above in order to extend the accessible wavelength spectrum from the NIR, across the visible spectrum into the UV.

7007 Multilayer Gas Cells for Compact Optical Frequency Standards
Azad Izmailov, Institute of Physics, Azerbaijan National Academy of Sciences (Azerbaijan)

Possible use of recently proposed multilayer gas cells as the basis for new compact optical frequency standards of high accuracy is analyzed. Such a cell is the compact analog of many plane-parallel beams of optically pumped atoms. Various nontrivial sub-Doppler resonances in absorption of the probe light beam are theoretically investigated both for stationary and nonstationary broadband and monochromatic pumping radiation in given cells. Conditions are determined when the effective three-dimensional selection of slow-speed optically pumped atoms may be realized and corresponding sub-Doppler resonances are most narrow.

7017 Cryogenic Sapphire Optical Cavities

Moritz Nagel, Humboldt-Universität zu Berlin (Germany), et al.

We will present the status of our work on a cryogenically cooled sapphire cavity system, with an estimated thermal noise limited frequency stability of a few 10^{-17} (standard coating) and of a few 10^{-18} (crystalline coating), respectively. In a next step, these resonators will be used in a high-precision experiment to test Lorentz invariance within the 10^{-20} to 10^{-21} regime.

7051 Confirmation of Sisyphus Cooling in a Sigma +-Sigma - MOT with Spin 1/2 Atoms on Route to Building a Lattice Clock

Nikita Kostylev, University of Western Australia (Australia), et al.

We show sub-Doppler cooling of ytterbium isotopes 171Yb and 173Yb (fermions) and efficient cooling of 172Yband 174Yb (bosonic) by use of the 1S0 - 1P1 transition in a magneto- optical trap. Measurements have been carried out with two methods and temperature versus frequency detuning and versus intensity have been made. The temperature for the fermionic isotopes appear to be the lowest yet reported for this single stage of cooling using the 1S0 - 1P1 line, with temperatures well below 400 μK for 171Yb and T < 200 μK for 173Yb. Because F=1/2 in the 171Yb ground state, we show further evidence that the Sisyphus mechanism is acting in σ+ - σ– light-field configuration magneto-optical traps.

7065 Optical Cavity Acceleration Sensitivity Reduction via Feedforward Correction

Ross Williams, National Physical Laboratory (United Kingdom), et al.

We report on the real-time cancellation of acceleration-induced frequency perturbations of a laser locked to a shaken cubic cavity. The feedforward-correction system is based on an array of accelerometers centered on the optical cavity and an FPGA for rapid calculation of the frequency correction, which is applied via an AOM. A 32 dB reduction in the acceleration-induced laser frequency noise power spectral density is achieved.

7088 Experimental Set-Up for Study of Collisions of Cold Mercury Atoms for Optical Frequency Clocks

Marcin Witkowski, Nicolaus Copernicus University (Poland), et al.

We present an experimental set-up of two species mercury-rubidium magneto-optical trap (MOT). The particular attention is given to the measurements of the scattering properties in various isotopes of the mercury atoms, such as thermalization rates, which provide information about the interaction potential, essential to predict the collisional shift of the mercury 1S0-3P0 clock transition. Additionally, in the mercury-rubidium MOT, the presence of cold Rb atoms might be used to broaden the 1S0-3P0 clock transition in bosonic isotopes of mercury.

7096 Compact Fabry-Perot ULE Cavity

Alexandre Didier, FEMTO-ST Institute (France), et al.

Developpment of a compact Fabry Perot cavity. Presentation of the cavity design and 1st results.

7106 Experimental Study on Support-Area-Insensitive Position in Cutout Optical Cavity for an Yb Optical Lattice Clock

Won-Kyu Lee, Korea Research Instit. of Standards and Science (Korea, South), et al.

We experimentally studied support-area-dependence of the position in a cutout optical cavity. We measured the vibration sensitivity varying the axial displacement of the support point with various support area. We used Viton pads instead of balls with diameters of 1 mm, 2 mm and 3 mm to define the support area more accurately. The experimental data are well explained by a sliding-support-model (contact points are only vertically constrained) or a fixed-support-model (contacts points are to-tally constrained) with a very small diameter. There were no dependences of vibration sensitivity and the optimum support position on support area within the experimental reproducibility.

7138 229Th and 232Th Optical Spectroscopy System for Nuclear Frequency Standard

Victor Troyan, National Research Nuclear University MEPhI (Russia), et al.

The results are presented on the comparison of different techniques of producing thorium ions: from solid Th(NO3)4 and ThO2 compounds by the laser ablation, from a nitrate solution of 229Th and 232Th by inductively coupled plasma mass-spectrometry, and also from a metallic thorium by the electron-beam evaporation. The results obtained allow to proceed to the high-precision research on optical and nuclear isomeric emission and absorption spectra of 229Th isotope.

7142 Experimental Treatments for the Investigation of Nuclear Optical Transition in 229Th

Victor Troyan, National Research Nuclear University MEPhI (Russia), et al.

An original preparation technique of the thorium films by electrochemical deposition from thorium nitrate solution on different substrate is reported. It was found that electrochemical deposition of thorium on the metal surface provides the formation of adherent continuous films, while the deposition on the semiconductor substrates leads to the formation of thorium island films. The origin of the observed thorium films formation and the results on the investigation of thorium films on Si(111) and polycrystalline Cu surfaces by XPS and LEIS are discussed.

7156 Residual Amplitude Modulation and Birefringence Effects in EOM and AOM-RN

Viacheslav Baryshev, All-Russian Scientific Research Institute of Physical-Technical and Radiotechnical Measurements (Russia), et al.

AOM-RN, an acousto-optic modulator operating purely in the Raman-Nath diffraction regime, extended the tools employed in laser spectroscopy as optical phase modulators. The comparative analysis of the RAM and birefringence effects in particular case of commercial 20 MHz resonant EOM from Thorlabs and broadband AOM-RN from VNIIFTRI will be presented.

7167 Noise Suppression for the Precise Measurement of Fabry-Perot Cavity with Wide Tunable Range

Radek Smid, Institute of Scientific Instruments of the ASCR, v. v. i. (Czech Rep.), et al.

We present the laser diode working at 1542 nm with 2 nm (400 GHz) tunable range equipped with noise suppression method. It introduces an unbalanced heterodyne fiber interferometer working as the phase noise discriminator. This method ensures the tunability range stayed untouched. The resulted linewidth of the noise suppressed DFB laser is 10 kHz only for 1s averaging time. This result lets reach 10^{-10} uncertainty corresponding to 10 fm with wide tunable range of 100s of GHz corresponding to 1000 nm distance changes. The precision is ensured by refer-encing the DFB laser optical frequency to stabilized optical frequency comb.

7169 Reduction of Residual Amplitude Modulation to 1 x 10^-6 for Frequency-Modulation and Laser Stabilization

Wei Zhang, JILA / National Institute of Standards and Technology and University of Colorado (United States), et al.

Active control and cancellation of residual amplitude modulation (RAM) is essential for achieving the ultimate stability of a laser locked to an ultrastable optical cavity. We employ a waveguide-based electro-optic modulator (EOM) to provide phase modulation and implement an active servo with both DC electric field and temperature feedback onto the EOM to cancel both the in-phase and quadrature components of the RAM. The remaining RAM is comparable to the expected thermal noise limit of optical cavities made from single-crystal silicon and employing low thermal noise crystalline mirror coatings.

7171 Cryogenic Single Crystal Silicon Cavity

Jacques Millo, FEMTO-ST Institute (France), et al.

We are developing an ultra-stable laser with reduced thermal noise, compatible with a fractional frequency stability of 3E-17. This noise floor is improved with respect to the ULE or fused silica cavities by the use of single crystal silicon with a mechanical quality factor higher than 1E7 around 10K. The design of the ultra-stable cavity and the cryocooler will be presented.

7181 An Iodine-Based Ultra-Stable Optical Frequency Reference and its Application in Fundamental Physics Space Missions

Thilo Schuldt, German Aerospace Centre (Germany), et al.

We present the development of iodine based frequency references on elegant breadboard (EBB) and engineering model (EM) level where compactness and robustness were main design drivers. A frequency stability of about $1*10^{-14}$ at an integration time of 1 s and below $5*10^{-15}$ at integration times between 10s and 100s were demonstrated. One potential application is the proposed mSTAR (mini SpaceTime Asymmetry Research) mission, dedicated to perform a Kennedy-Thorndike experiment. By comparing an iodine standard to a cavity-based frequency reference and integration over 2 year mission lifetime, the Kennedy-Thorndike coefficient will be determined with up to two orders of magnitude higher accuracy than the current best ground experiment.

7215 Clock Laser Stabilisation on High-Finesse Cavities
Olivier Morizot, Universite Aix-Marseille (France), et al.

The present work is realized to take advantage of the electric quadrupole transition of calcium ions at 729 nm for clock applications or multi-photon coherent processes. The clock laser is locked onto a vertical ultra-stable high-finesse ULE cavity with an optimized geometry. Evaluation of the lock performances on a second cavity will be presented at the conference.

7223 On the Possibility of Deep Laser Cooling of Magnesium Atoms with Large Ultracold Atomic Fraction
Anatoly Bonert, Institute of Laser Physics SB RAS (Russia), et al.

We propose an approach for obtaining the large number of ultracold magnesium atoms (~10^5, T=5 microK) in MOT. Detailed theoretical analysis of sub-Doppler laser cooling of 24Mg atoms in 1D configuration is presented. The atomic velocity distributions are gained beyond the limits of slow atoms approximation and for arbitrary light field intensity. Optimal parameters to maximize a fraction of ultracold atoms (5-10 microK) are calculated. Large number of ultracold atoms is very important for many applications and fundamental experiments.

7234 Saturated Dispersion Resonances in a Cr2+:ZnSe/CH4 Laser with a "Dry Cooled" Methane Cell
Mikhail Gubin, Lebedev Physical Institute of the Russian Academy of Sciences (Russia), et al.

A goal of the work is development of a highly stable optical/microwave interrogative oscillator, based on saturated dispersion resonances (SDR) of methane (λ ~ 2.4 μm) recorded with a low noise two-mode Cr2+:ZnSe laser and a cryo cooled intracavity methane cell. As compared to a previous stage of research we have applied a compressor type cooler for reaching 80K temperature range in the methane cell. Testing of the whole Cr2+:ZnSe/CH4 system features (gas temperature, vibrations, SDR parameters, registration sensitivity) have confirmed feasibility of the chosen approach to short term frequency stability at the order of (3-5).10^{-16} (at 1 s)

7254 Long-Term Performance of a Cryogenic Silicon-Resonator-Based Laser System
Christian Hagemann, Physikalisch-Technische Bundesanstalt (Germany), et al.

We discuss the performance of a cryogenic single-crystal optical cavity. The temperature of the cavity was stabilized at 124 K within less than 1 K from the zero of its thermal expansion coefficient. Using a frequency comb, the laser frequency is continuously compared to a hydrogen maser that is referenced to a primary caesium fountain standard and during shorter intervals to the 87Sr optical lattice clock at PTB. We were able to achieve variations in frequency of less than 2 kHz over a time span of 400 days.

7299 Thermal Noise in Sphere Optical Reference Cavities
Guanjun Xu, National Time Service Center / Chinese Academy of Sciences, et al.

Thermal noise in optical cavities sets a fundamental limit to the frequency instability of ultra-stable lasers. We estimate the contribution of the sphere spacer using our derived Equation based on Levin's formulation of the fluctuation-dissipation-theorem and strain energy. Focusing on the sphere spacer geometry and the widely used materials, the estimate and simulation of the thermal noise have been carried out. We find that thermal noise of the sphere spacer behaves quite different from cylindrical cavities. The estimate for the sphere spacer by our Equation agrees better with simulation compared with previous equations.

7302 Highly Stable Master Laser for the Interrogation of SYRTE's Sr and Hg Optical Lattice Clocks

Olivier Gobron, Observatoire de Paris (France), et al.

We report on the current developments at LNE-SYRTE to realize an ultra-stable laser based on spectral hole burning spectroscopy of rare-earth doped crystals at cryogenic temperature. Our goal is to realize a cw laser with a stability below 10^{-16}, suitable for quantum projection noise limited interrogation of optical lattice clocks after transfer to optical clocks wavelength via an optical frequency comb. Our laser system currently comprises two 1160nm lasers, one referenced to a pre-stabilization cavity and the second offset phase-locked to the first. After frequency doubling, we obtain spectral hole burning patterns in Eu:YSO near 4K.

Friday June 27

09:15 – 12:30 Visit of the International Watch Museum

La Chaux-de-Fonds (www.chaux-de-fonds.ch/musees/mih, in French only)
Further information on page 28.

08:30 – 18:00 Lab tours

Visits of CSEM, Spectratime and LTF-UniNe will be organised. 20 persons maximum per tour. For registration please consult the WEB page and/or ask to the Reception Desk (first-come, first-served basis).

Preliminary program:

- 09h00-10h30, CSEM T&F labs
- 10h30-12h00, CSEM T&F labs
- 14h00-15h30, Spectratime or CSEM T&F labs or LTF-UniNe
- 16h00-17h30, Spectratime or CSEM T&F labs or LTF-UniNe

08:30 – 16:00 Satellite workshops

There will be two satellite workshops to EFTF. Participation is free of charge and open.

Satellite workshops

Frequency Standards with Trapped Ions

Location:	University of Neuchâtel Faculté des Sciences, Rue Emile-Argand 11
Room:	B103
Date & Time:	June 27, 08:30 - 16:00

The workshop is organized by the project "ion clock" of the European Metrology Research Programme (EMRP) with participation from PTB, NPL, MIKES and CMI. Complementing the scientific program of EFTF, it will address recent developments, techniques and applications related to frequency standards with trapped ions.

Workshop website: www.ptb.de/emrp/ion-clocks-home.html

Programme

Session 1 chaired by Hugh Klein

8:30	**E. Peik, (PTB, Germany)** Welcome, Introduction of EMRP Project Ion Clock
8:40	**S. Brewer (NIST, USA)** Al^+ quantum logic clock
9:20	**K. Matsubara (NICT, Japan)** Ca^+ single-ion clock: progress and plan for reducing its frequency uncertainty
10:00	**Coffee break**

Session 2 chaired by Mikko Merimaa

10.30	**P. Dubé (NRC, Canda)** Sr^+ single-ion clock at NRC
11:10	**Nan Yu (JPL,USA)** JPL trapped ion clock development
11:25	**Zehuang Lu (Univ Huazhong, China)** Raman sideband spectroscopy of Mg^+ for an Al^+ clock
11:40	**N. Scharnhorst (PTB, Germany)** The Al^+ clock at the PTB
11:55	**P. Balling (CMI, Czech Republic)** Ion trap thermal analyses
12:10	**M. Keller (USussex, UK)** Fibre coupled ion trap for precision spectroscopy
12:30	**Lunch break**
14:00	**Poster session**
16:00	**Laboratory visits at UniNE, CSEM and Spectratime**

EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

We would like to acknowledge support of the workshop from Laboratoire Temps – Fréquence (LTF) University of Neuchâtel and the Swiss Space Office.

Atomic Clocks for Industry

Location: University of Neuchâtel
Faculté des Sciences, Rue Emile-Argand 11
Room: *Auditoire Emile Argand (F200)*
Date & Time: June 27, 08:30 - 16:00

Presenting advances and results from the two European Metrology Research Programmes IND 14 and IND 55 we invite participation from industry, government organisations and research institutes.

http://www.frequencystandards.eu/ http://www.inrim.it/Mclocks/

Programme

Welcome by Patrick Gill (NPL)

8:40	**Patrick Berthoud (Oscilloquartz)** Requirements for commercial atomic clocks
9:20	**Jacques Morel (METAS)** Fibre-based optical wavelength standards
9:40	**Uwe Sterr (PTB)** Transportable optical local oscillators
10:00	**Coffee break**
10:30	**Helen Margolis (NPL)** Low noise microwave synthesis from optical femtosecond combs
10:50	**Peter Rosenbusch (LNE-SYRTE)** Atom-referenced microwave standards
11:10	**Salvatore Micalizio (INRIM)** Microwave clocks for industrial applications
11:40	**John Kitching (NIST)** Chip-scale atomic clocks after 10 years: technology development and transfer
12:20	**Discussion** "Frequency standards for industry – State of the art and future needs"
12:30	**Lunch**
14:00	**Poster session (common with EMRP "ion clocks")**
16:00	**Lab tours at LTF University Neuchatel, CSEM or Spectratime**

UNIVERSITÉ DE NEUCHÂTEL

EMRP
European Metrology Research Programme
Programme of EURAMET

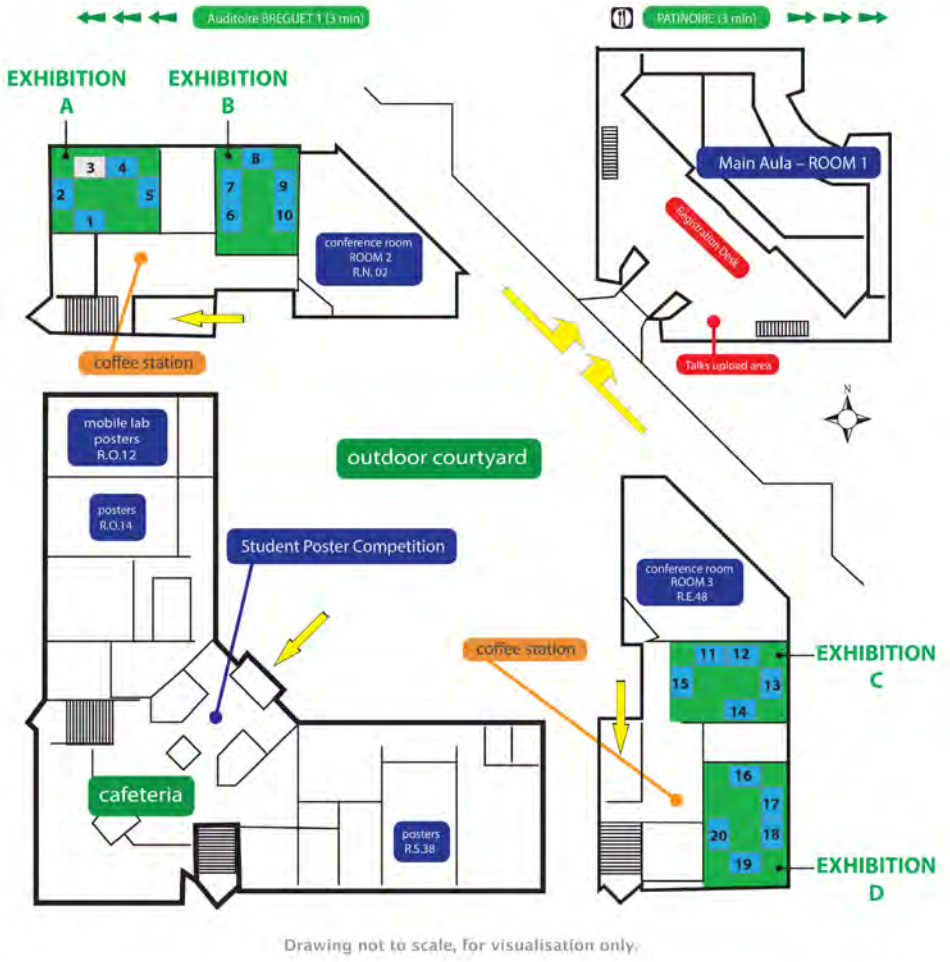
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

EXHIBITION

Opening hours

Location:	University of Neuchâtel Jeunes Rives
Date:	From Tuesday, June 24 to Thursday, June 26
Time:	08:30 – 18:00

Floorplan



Exhibitors

A commercial exhibition will allow companies and institutes to promote their products and raise their visibility at the conference.

Location:	University of Neuchâtel
Date & Time:	Tue / Wed /Thurs, June 24-26, 8:30 – 18:00
Exhibitor presentations:	Thursday, June 26, 08:00 - 09:00, Main Aula
Chair:	Wolfgang Schäfer, TimeTech

BOOTH No 1 – Lange Electronic GmbH

Lange Electronic GmbH, founded in 1977, develops, manufactures and distributes high precision time & frequency systems worldwide. Our systems, which can be designed redundantly if desired, are used in aerospace and on board of ships, in scientific experiments, in time laboratories and testing facilities e. g. the Aviation Gate in Braunschweig.

All of our systems can have special ports tailored to our customers' specifications. The Airborne Time Code Generator product range is designed for operation in harsh environments and is used on aircraft and ships.

We typically employ one or more GNSS time receiver as the basis of the signals we generate. Our precision exceeds +/- 15ns relative to UTC, and our most exact system to date even achieves +/- 2ns.

Our video time and data display inserts time unerasably into a video signal, thus making it tamper proof.

Besides this we represent Spirent Positioning-Technology, the world leader in GNSS simulation equipment, Oktal-SE, a leading mathematical company doing 3D simulation via ray-tracing and several other methods and NavXperience - specialising in navigation and location technologies. Their product range covers high-precision GNSS antennas (GPS + GALILEO + GLONASS + COMPASS).

www.lange-electronic.de

BOOTH No 2 – QuartzCom AG

Product Portfolio: Piezoelectric components like crystal units, quartz oscillators (XO, VCXO, TCXO, VC-TCXO, OCXO), filter (quartz, SAW and ceramic), highly stable precision oscillators for wide operating temperature range in shock-proof and vibrational resistive version.

Company Alignment: **QuartzCom AG** uses its outstanding development and application know-how of its powerful engineering force to be able to understand and optimize the customer´s circuit design already in an early stage. By means of service and customer orientation and by the help of a very broad product range QuartzCom AG wants to offer reliable solutions of high quality.

Services: Technical consulting with design support, training, development and

manufacturing of standard components and customized crystal units, quartz oscillators and filter, fast service, test lab, security stock, logistics, worldwide sales in Europe, Asia and USA.

Target Markets: Telecommunications and data communications (wireline and wireless, infrastructure and terminal equipment), timing & synchronization, measurement equipment, instrumentation, avionics, satellite, navigation, COSPAS-SARSAT, digital audio / video broadcasting, automotive, railway, medical.

www.quartzcom.com

BOOTH No 4 – onefive GmbH

Onefive GmbH, located in Zurich / Switzerland, is a leading supplier of industry-proven, low-noise femtosecond and picosecond lasers for OEM and R&D. The Onefive portfolio contains compact air-cooled maintenance-free lasers and offers a wide choice: UV-IR wavelength range, sub-100fs to 2ns pulse duration, single-shot to GHz repetition rate and nJ to >250µJ pulse energy.

Onefive lasers are well known in research areas like synchrotrons/accelerators and frequency comb applications, where ultra stable pulse trains and/or very low noise synchronization are necessary.

In addition to Metrology and Timing applications Onefive laser systems also enhance procedures and results in Medical applications, Microprocessing, Microscopy and Laser/Optics research.

www.onefive.com

BOOTH No 5 – Piktime Systems sp. Z o.o / Elproma Elektronika Sp. Z.o.o

Piktime Systems sp. z o.o. - satellite techniques and precise time sector company, established in 2007. We are a worldwide leader in precise, long-distance atomic clocks comparison.

Our area of expertise:

- Designing and manufacturing equipment for long-distance precise atomic clocks comparison (time transfer systems),
- Development of time based products and services (navigation, security, data and document exchange, time stamping),
- Advisory on precise time and time scales,
- Time & frequency software and algorithms,
- Time & frequency counters and generators,
- Designing and execution of complete time laboratories on a turn-key basis.

www.piktime.com

Clepsydra Time Systems is a new Time & Frequency brand name from **ELPROMA Electronics** - the specialist in design and manufacturing of professional NTP/PTP Time Servers and time synchronization systems since 1992. This expertise is a result of over than 20 years' experience in: metrology, scientific, telecom, power distribution and financial industry. Elproma takes pride in placing emphasis on three critical factors: Versatility, Compatibility, Reliability. The key to Elproma continued growth and success is its ability to stay at the leading edge of technological innovation paying full attention to the needs of all our customers. Elproma direct caesium time server is one of the most popular products in metrology community today.

www.elproma.com.pl

BOOTH No 6 – GuideTech

Since 1988, **GuideTech** has been the leading innovator of TIA and CTIA Continuous Time Interval Analyzer and high-precision frequency counter instruments, delivering superior performance at over a thousand ATE installations worldwide.

GuideTech's high performance Computer-based Time & Frequency Instruments, GT210 TIC and GT668 CTIA are available in PCI, PCIe, PXI and PXIe bus and can scale-up to 34 channels in one PXI/PXIe chassis.

GuideTech's Femto-Family of multi-channel measurement products are the fastest direct timing analysis systems available with distributed CTIA architecture. Our products are quickly becoming the de facto standard on ATE platforms around the world due to their ability to dramatically reduce test time while improving the quality of critical timing tests in ATE and other critical, high-precision environments.

www.guidetech.com

BOOTH No 7 – Muquans

Muquans is a young start-up company whose project consists in developing a new generation of high precision instruments based on laser trapping/cooling/manipulation of cold atoms.

Muquans is working on the development of the following products:

- An absolute quantum gravimeter capable of measuring gravity with a relative accuracy of 10^-9, dedicated to various applications in geophysics.
- An atomic clock, which provides a time reference signal offering relative stability and accuracy close to 10^-15 and dedicated to time metrology applications.
- Integrated laser systems dedicated to trapping/cooling/manipulation of Rubidium atoms.

Muquans is a spin-off from two academic laboratories (LP2N and SYRTE) specialized in high precision measurements based on quantum manipulation of cold atoms. The technology developed by Muquans therefore benefits from all the experience and know-how resulting from more than 15 years of academic research.

After two years of activity, µQuanS now has 11 employees and plans a commercial launch of its first products in 2015.

www.muquans.com

BOOTH No 8 – Microsemi

Microsemi®, the world leader in precise time solutions, sets the world's standard for time by offering solutions to generate, distribute and apply precise time for the communications, aerospace/defense, IT infrastructure and metrology industries. Customers use Microsemi's advanced timing algorithms, atomic clocks and frequency reference technologies to build more reliable and highly efficient networks. Learn more at www.microsemi.com/time

www.microsemi.com

BOOTH No 9 – M Squared Lasers Ltd

M Squared Lasers is a scientific laser specialist, developing and manufacturing innovative laser sources for the most demanding applications. Sources span the entire performance spectrum, from continuous wave to ultrafast, and from deep ultraviolet to terahertz wavelengths.

With many decades of experience the M Squared team have re-designed the cw Ti:S from first principles with the requirements of scientific users in mind. The resulting SolsTiS cw Ti:S laser is the most advanced source available with hands-free control combined with the lowest noise, narrow linewidth and high stability. Wavelength extension to shorter wavelengths is accomplished by highly efficient second or fourth harmonic generation using the ECD-X or ECD-X-Q resonant cavities.

A fast growing install base means that many of our systems can be found in leading national and academic laboratories worldwide. The company works hard to foster a collaborative approach and has strong links and collaborative projects with a number of local and international research groups, institutions and blue chip partners.

Based in Glasgow, UK, M Squared Lasers provides close sales and service support to its worldwide customer base via a global network of distributors, representatives, and local offices including its subsidiary M Squared Inc in the US.

www.m2lasers.com

BOOTH No 10 – Menlo Systems GmbH

Menlo Systems, a leading developer and global supplier of instrumentation for high-precision metrology, was founded 2001 as spin-off of the Max-Planck-Institute of Quantum Optics. Pioneers of the Nobel-Prize-winning Optical Frequency Comb technology, the Munich based company offers complete solutions based on ultrafast lasers, synchronization electronics and THz systems for applications in industry and research.

www.menlosystems.com

BOOTH No 11 – Femto Engineering

FEMTO Engineering is a technology center located in Besançon – France. It undertakes technological developments in 4 areas of innovation, from lab validation to prototype in operating environment:

- Time & Frequency: ultra-stable oscillators, services in embedded digital systems and ultra-low noise electronic
- Energy: electrical, magnetic, thermal modeling
- Optics: micro and nanomachining with femtosecond laser
- Hybrid microfabrication in clean room facilities (1400 m²): coating, etching, lithography, characterization.

Our scientific backup comes from FEMTO-ST, the largest French public research lab for engineering sciences with 700 people. Markets: watchmaking, energy, transport, telecoms, security and defense, health, space navigation, geodesy, …

www.femto-engineering.fr

BOOTH No 12 – Huber+Suhner

The global Swiss company **HUBER+SUHNER** develops and manufactures components and system solutions for electrical and optical transportation of data and energy. The company serves customers in the Communication, Transportation and Industrial markets with cables, connectors, cable systems, antennas and other passive components relying on its expertise in radio frequency, fiber optics and low frequency technologies.

The products stand out due to their exceptional quality, reliability and durability – even under harsh environmental conditions. HUBER+SUHNER maintains close relationships with its customers in more than 60 countries as the result of its global production network, own group companies and sales offices, as well as numerous distributors. The company captures promising markets with its ground-breaking developments.

www.hubersuhner.com

BOOTH No 13 – Noise XT

Noise XT is a Test and Measurement company focusing on Low Phase Noise devices. Our 22 years of continuous Research and Development gave us a worldwide technical leadership in Ultra Low Phase Noise Analyzers. Capable of all measurement techniques, our products performance can reach about -198 dBc/Hz.

The DCNTS is the State of the Art analyzer from 2 MHz to 140 GHz and the NXA Series bring this high performance into production where ease of use and small footprint matters. Today, Noise XT also offers low phase noise synthesizers that can be compact and affordable or better in performance than any other commercially available signal generator. An amazing -132 dBc/Hz at 10kHz offset on a 10 GHz signal can be obtained with the LNS-18 and small PXI size 7 GHz dual clock synthesizers can always find room on a crawled R&D bench while offering -170 dBc/Hz noise floor. Traditional PN9000 systems are now available with -140 dBc spurious specification, and Frequency stability (Allan Variance) up to 1000 seconds is available in single and dual counter configuration. With 4 Service centers in the world, Noise XT can locally assist you in China, USA, Europe or India.

www.noisext.com

BOOTH No 14 – TimeTech GmbH

TimeTech GmbH was set up in 1990 as a spin off from the University of Stuttgart's Institute for Navigation. The team here is specialized in intercontinental time transfer and very precise satellite positioning services.

TimeTech is a reliable provider of high-tech space systems and ground stations equipment and instruments for precise frequency and time transfer. TimeTech is mainly export-oriented with customers in Europe, North America, Asia and Australia. TimeTech's business areas are subdivided into Project Business and Products. Since November 2012, TimeTech has embarked upon providing systematic and regular two-way link calibration service to our customers primarily the national metrological laboratories.

Project business encompasses scientific studies as well as hardware projects, related to Galileo, Aces, Rosetta, Venus Express and other space projects and ground stations. The Product Business takes care of development, production, testing and installing equipment and complex systems for orbit determination and positioning as well as high precision synchronization and transmission of time and frequency.

Facts & Figures:

- Employees: 22
- Projects: Ground Station for Frequency and Timing in Kourou (French Guiana);
- Atomic Clock Ensemble in Space (ACES) – Microwave Link to ISS;
- Telemetry, Tracking and Command System for ISTRAC (India);
- Frequency and Timing Systems for ESA (Europe)

www.timetech.de

BOOTH No 15 – T4Science SA / Orolia Switzerland SA (Spectratime)

T4science was founded in 2006 in Neuchâtel (Switzerland). T4Science is a leading designer and manufacturer of a full range of advanced, cost-effective and high-performance maser clock solutions. Its products are used in a wide veriety of scientific applications and in the time and frequency industry: Frequency Reference Source, VLBI, SLR, Deep Space Tracking & Navigation, Timekeeping, Navigation, GNSS Satellite Monitoring.

Products – The iMaser is a high-performance, compact active hydrogen Maser. It features advanced phase noise and short term stability for high-precision frequency & timing applications. Passive hydrogen maser offers long term reference with excellent stability and price.

Services – T4Science offers a complete set of first-class services over the product lifecycle for total customer satisfaction. These services, through not limited, include the following: supply and installation, training, remote & on-site maintenance, on-site support.

www.t4science.com

Founded in 1995 in Neuchâtel, Switzerland, **Spectratime** designs, manufactures and markets a full range of high-performance, low-cost crystal, rubidium and maser sources, smart integrated GPS or GNSS reference clocks, and clock testing systems. Its products are used in a wide variety of applications, including telecommunications, defense, navigation, instrument, broadcasting, and space.

The company is a recognized leader in the industries it serves and distributes its products globally through Spectratime's sales offices in Europe, Asia, and United States.

www.spectratime.com

BOOTH No 16 – SpectraDynamics, Inc

SpectraDynamics, Inc. (SDI) was founded in 1994 as a company specializing in high performance time and frequency distribution systems. The company is involved in the research and development of low noise and ultra-stable electronics to support atomic frequency standards and time scales.

SpectraDynamics has developed and patented novel frequency synthesis architectures and time and frequency methods some of which have resulted in products that the company offers.

Our main products are Time and Frequency Distribution Amplifiers, Low Noise Frequency Synthesizers and Noise Measurement Systems. Our featured items are the HROG-5RM a high performance frequency and phase micro-stepper with under 1 fs resolution and the HPDA-15RMi-C an ultra-low noise frequency distribution amplifier.

In addition to the standard products we also provide custom-engineered solutions. Our customers include the National Time and Frequency Laboratories, Government Agencies, Universities, Department of Defense Contractors and Telecommunications companies.

www.spectradynamics.com

BOOTH No 17 – Morion, Inc.

Morion, Inc. is well-known both in Russia and as a worldwide designer and manufacturer of quartz frequency control products (FCP) - quartz oscillators, filters and crystals dedicated for various applications such as telecommunications, navigation, test & measurement, digital broadcasting, search and rescue systems, etc.

You are welcome to view our existing and newly developed products of our company.

morion.com.ru

BOOTH No 18 – Oscilloquartz SA

Oscilloquartz is a pioneer in time and frequency synchronization. We design, manufacture and deploy end-to-end synchronization systems that ensure the delivery and assurance of highly precise timing information over next-generation packet and legacy networks. As an ADVA Optical Networking company, we're creating new opportunities for tomorrow's networks.

For more information, please visit us at: www.oscilloquartz.com and www.advaoptical.com.

www.oscilloquartz.com

BOOTH No 19 – NEL Frequency Controls, Inc.

NEL Frequency Controls is 'Your Silent Partner' for Ultra Low Phase Noise Crystal Oscillators and Synthesizers. NEL specializes in the design and manufacture of lowest phase noise frequency control products in the smallest form factors possible. Provided is a sampling of ultra-low phase noise frequency control offering-

- ULPN Synthesizers– 10GHz+
- ULPN OCXO in SMD package- 10MHz and 100 MHz
- ULPN OCXO up to 1 GHz
- Multi Frequency OCXO Reference Module 10MHz/ 100MHz/ 1000MHz
- ULPN XO, VCXO, TCXO up to 2.0 GHz
- Whitepaper on Phase Noise Testing ULPN OCXO's

Visit the NEL Booth for technical support for your application.

www.nelfc.com

BOOTH No 20 – Terada Co. Ltd and MAXIS 01

TERADA is a manufacturer of industrial adhesive which can be used in indoor and outdoor applications. We also produce functional and processing materials for device and parts manufacturers. Also, a natural-light LED lamp system can be exhibited this time which has been developed by TERADA.

www.trd.co.jp/en/

MAXIS 01 is a manufacturer of Crystal Simulation System and crystal blank measuring systems. Regarding beveling shape and dimension measured by special lens which is used in exposing system.

MAXIS 01 has succeeded to establish his own software technology with FEM/Multiple calculation and other mechanical information coming from Model CA-11 and CA-13 and CA-17. Everybody now can see the streaming of energy and spurious in his imaged picture which can provide all of engineers. What is what and what should be in the design of crystal devices.

www.maxis-01.co.jp

IFCS - EFTF 2015

2015 JOINT CONFERENCE OF THE
IEEE INTERNATIONAL FREQUENCY CONTROL SYMPOSIUM
& EUROPEAN FREQUENCY AND TIME FORUM
April 12-16, 2015 | Colorado Convention Center | Denver, Colorado - USA

2015 Joint Conference of the IEEE International Frequency Control Symposium & European Frequency and Time Forum
April 12-16, 2015
Colorado Convention Center, Denver, Colorado, USA

The IFCS and EFTF are excited to announce the Colorado Convention Center in Denver, CO, USA as the 2015 venue for our continuing biennial joint conference. The Colorado Convention Center is located near the 16 Street Mall, a major Denver attraction, offering pedestrian commerce, restaurants and nightlife.

Ekkehard Peik and Gregory Weaver will be the General Co-chairs of the 2015 joint conference. Gaetano Mileti and Yoonkee Kim will be the Technical Program Co-chairs. The Joint Technical Program Committee will be a composite of the IFCS and EFTF Scientific Committee. Paper topics will be called from the following six technical areas:

Group 1: Materials, Filters, and Resonators
Group 2: Oscillators, Synthesizers, Noise, and Circuit Techniques
Group 3: Microwave Frequency Standards
Group 4: Sensors and Transducers
Group 5: Timekeeping, Time and Frequency Transfer, GNSS and Applications
Group 6: Optical Frequency Standards

Please consider the following timeline when planning for the joint conference:

First Call for Papers (electronic)	Mid-July 2014
Abstract Submission Deadline	Jan. 9, 2015
Author Notification	Feb. 18, 2015
Tutorials and Joint Conference	April 12-16, 2015

We expect the joint conference website to be on-line by July 2014.

2016 IEEE International Frequency Control Symposium

The host city for the 2016 IFCS will be New Orleans, LA, USA. Lute Maleki of OEwaves, Inc. will be the General Chair, and Elizabeth Donley of NIST, Boulder CO. will be the Technical Program Chair.

NOTES


See you next year ...
2015 Joint Conference of the IEEE International Frequency Control Symposium & European Frequency and Time Forum April 12-16, 2015
Colorado Convention Center, Denver, Colorado, USA
Enjoy your stay in Neuchâtel, Switzerland
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