

Advance Program

Optical Frequency/Time Measurement and Generation

Monday, 23 July 2007

ALL SESSIONS WILL BE HELD IN GEVURTZ

9:00 AM - 10:00 AM

Session MC1: ATOMIC FREQUENCY STANDARDS I

Session Chair: TBD

MC1.1 9:00 AM - 9:30 AM (Invited)

Atomic Frequency Standards and Their Impact on the Past, Present and Future of the Second, U. Sterr, *Physikalisch-Technische Bundesanstalt, Braunschweig, Germany*

The uncertainties of optical frequency standards are approaching and even surpassing the best present caesium primary standards. I will present a history of optical frequency standards and discuss prospects and possible applications of optical clocks.

MC1.2 9:30 AM - 9:45 AM

Present Status of the Development of the Yb Optical Lattice Clock at NMIJ/AIST, M. Yasuda, *National Metrology Institute of Japan, Tsukuba, Ibaraki, Japan*

The present status of the development of the Yb optical lattice clock at the National Metrology Institute of Japan (NMIJ) and future prospects are presented.

MC1.3 9:45 AM - 10:00 AM

Direct Two-Photon Resonant Excitation and Absolute Frequency Measurement of Cesium Transitions using a Femtosecond Comb, V. Mbele, J. Stalnaker, *National Institute of Standards and Technology, Boulder, CO, USA*, V. Gerginov, *University of Notre Dame, Notre Dame, IN, USA*, T. M. Fortier, S. A. Diddams, *National Institute of Standards and Technology, Boulder, CO, USA*, C. E. Tanner, *University of Notre Dame, South Bend, IN, USA* and L. Hollberg, *National Institute of Standards and Technology, Boulder, CO, USA*

We measure optical transition frequencies of the $6s\ ^2S_{1/2} \rightarrow 8s\ ^2S_{1/2}$, $9s\ ^2S_{1/2}$, and $7d\ ^2D_{3/2,5/2}$ transitions, in a ^{133}Cs vapor cell with an uncertainty < 100 kHz using a femtosecond laser frequency comb.

10:00 AM - 10:30 AM

COFFEE BREAK

10:30 AM - 11:45 AM

Session MC2: ATOMIC FREQUENCY STANDARDS II

Session Chair: Hirokazu Matsumoto, *National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan*

MC2.1 10:30 AM - 11:00 AM (Invited)

The Yb and Ca Standards: Approaches to High Stability, High Accuracy, and Transportable Optical Atomic Clocks, C. W. Oates, Z. Barber, J. Stalnaker, *National Institute of Standards and Technology, Boulder, CO, USA*, C. W. Hoyt, *Bethel University, St. Paul, MN, USA*, Y. Le Coq, *LNE-SYRTE, Paris, France*, S. A. Diddams, T. M. Fortier and L. Hollberg, *National Institute of Standards and Technology, Boulder, CO, USA*

We describe two different types of neutral atom optical clocks. The first is based on Yb-174 atoms tightly confined in a 1-D optical lattice, while the second is based on freely expanding, laser-cooled calcium atoms. Trade-offs between clock performance and size will be discussed.

MC2.2 11:00 AM - 11:15 AM

Measurement of Acetylene-d Absorption Lines with a Self-Referenced Fiber Laser Frequency Comb, J. Jiang, *University of British Columbia, Vancouver, BC, Canada*, J. E. Bernard, A. A. Madej, *National Research Council, Ottawa, ON, Canada*, S. Drissler, D. J. Jones, *University of British Columbia, Vancouver, BC, Canada* and A. S. Czajkowski, *University of Ottawa, Ottawa, ON, Canada*

Using a self-referenced frequency comb derived from a mode-locked fiber laser we have measured >40 absorption lines within the $2\nu_1$ band of deuterated-acetylene (C_2HD) spanning 195 to 198 THz with a <2-kHz typical uncertainty.

MC2.3 11:15 AM - 11:45 AM (Invited)

Frequency Measurement of an Optical Lattice Clock, F.-L. Hong, Y. Fujii, M. Imae, *National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan*, M. Takamoto, R. Higashi and H. Katori, *University of Tokyo, Bunkyo-ku, Tokyo, Japan*

A frequency measurement system is developed away from a national metrological institute with a frequency link to international atomic time (TAI). The absolute frequency of the $1S_0 - 3P_0$ clock transition of the 87Sr lattice clock is determined to be $429,228,004,229,875(4)$ Hz.

12:00 PM – 1:30PM

LUNCH BREAK

1:30 PM - 3:00 PM

Session MC3: FEMTOSECOND SOURCES AND COMBS

Session Chair: Ronald Holzwarth, *Menlo Systems GmbH, Munich, Germany*

MC3.1 1:30 PM - 2:00 PM (Invited)

Super-Stable Optical Comb and Pulse Generation using Electro-Optic Modulation, T. Sakamoto, T. Kawanishi, M. Tsuchiya and M. Izutsu, *National Institute of Information and Communications Technology, Koganei, Tokyo, Japan*

We review a simple and highly-stable ultra-flat frequency comb generator employing a single-stage electro-optic Mach-Zehnder modulator. Synthesis of a picosecond/sub-picosecond pulse train from the frequency comb using linear/nonlinear pulse compression technique is also reported.

MC3.2 2:00 PM - 2:15 PM

Widely Tunable (1.0-1.7 μm) Yb-doped Fiber Mode-Locked Laser Source with ~ 100 fs Pulse Widths based on Raman Frequency Shift, J. Dawlaty, *Cornell University, Ithaca, NY, USA*

A widely tunable (1.0-1.7 μm) femtosecond laser source based on Raman induced frequency shift in a photonic crystal fiber pumped by a Yb-doped mode-locked fiber laser is presented. The output pulses are ~ 100 fs wide with ~ 0.5 nJ pulse energy.

MC3.3 2:15 PM - 2:30 PM

Quantitative Measurement of the Dynamics of a Mode-Locked Laser, J. Wahlstrand, *JILA, Boulder, CO, USA*, C. R. Menyuk, *University of Maryland Baltimore County, Baltimore, MD, USA*, J. Willits, T. R. Schibli and S. T. Cundiff, *JILA, Boulder, CO, USA*

The linear response of a mode-locked laser to a perturbation of the pump power is measured quantitatively. Relaxation oscillations, frequency pulling, and nonlinear changes in the timing and phase of the pulse train are observed.

MC3.4 2:30 PM - 3:00 PM (Invited)

Er- and Yb-doped Fiber Laser Frequency Combs and Their Applications, I. Hartl and M. E. Fermann, *IMRA America, Inc., Ann Arbor, MI, USA*

The progress in femtosecond fiber laser based frequency combs is reviewed. Recent examples include Er-fiber frequency combs with sub-Hz relative comb tooth linewidths and Yb-frequency combs with $> 10\text{W}$ average power.

3:00 PM – 3:30 PM

COFFEE BREAK

3:30 PM - 5:00 PM

Session MC4: ADVANCED LASER SOURCES

Session Chair: TBD

MC4.1 3:30 PM - 4:00 PM (Invited)

Frequency Comb Generation in a Monolithic Ring Resonator, T. Kippenberg, *Max-Planck-Institut für Quantenoptik, Garching, Germany*
ABSTRACT NOT AVAILABLE

MC4.2 4:00 PM - 4:15 PM

High Power (>150 mW) Electrically Pumped Semiconductor Modelocked Lasers at 1550 nm with Pulse Widths Approaching 6 ps, F. R. Ahmad and F. Rana, *Cornell University, Ithaca, NY, USA*

We report on the generation of stable modelocked pulses from electrically pumped monolithic semiconductor diode lasers with repetition rates > 5 GHz, pulse widths approaching 6 ps, and output powers exceeding 150 mW.

MC4.3 4:15 PM - 4:30 PM

Narrow Linewidth 1.5 μm Sources and the Thermal Limit, W. C. Swann, L. Lorini, J. Bergquist and N. R. Newbury, *National Institute of Standards and Technology, Boulder, CO, USA*

A measured 1 Hz linewidth between a cavity-stabilized, 1535 nm cw fiber laser and the 1535-nm tooth of a stabilized fiber frequency comb is below the thermodynamic limit of the frequency comb.

MC4.4 4:30 PM - 5:00 PM (Invited)

Slab-Coupled Optical Waveguide Devices for Low-Noise Signal Generation, P. W. Juodawlkis, J. J. Plant, F. J. O'Donnell, *MIT Lincoln Laboratory, Lexington, MA, USA* and J. B. Schlager, *National Institute of Standards and Technology, Boulder, CO, USA*

We review the use of slab-coupled optical waveguide amplifiers (SCOWAs) in low-noise mode-locked and single-frequency lasers. We also report a new single-frequency laser cavity incorporating an Er/Yb-codoped waveguide distributed-Bragg-reflector that produces 330-mW power with 75-kHz linewidth.

6:30 PM – 8:00 PM

WELCOME RECEPTION - QUEEN MARIE BALLROOM

Tuesday, 24 July 2007**9:00 AM - 10:00 AM****Session TuC1: OPTICAL ARBITRARY WAVEFORMS I****Session Chair: TBD****TuC1.1 9:00 AM - 9:30 AM (Invited)****Optical Waveform Generation, Measurement and Utilization**, J. Lowell, *Defense Advanced Research Projects Agency, Arlington, VA, USA* and E. Parra, *Booz Allen Hamilton, Arlington, VA, USA*

This talk outlines the DARPA Optical Arbitrary Waveform Generation program. Fundamental application classes are mentioned, and the scientific motivation for each developed to indicate overall goals, prospects for technology development, and insertion into specific devices.

TuC1.2 9:30 AM - 9:45 AM**Optical Arbitrary Pulse Train Generation via Spectral Line-by-Line Pulse Shaping**, Z. Jiang, *University of Illinois at Urbana-Champaign, Urbana, IL, USA*, C.-B. Huang, D. E. Leaird and A. M. Weiner, *Purdue University, West Lafayette, IN, USA*

We demonstrate optical arbitrary pulse generation using spectral line-by-line shaping on a mode-locked fiber laser. The pulse train within each period can be independently controlled as specified.

TuC1.3 9:45 AM - 10:00 AM**Generation of High Repetition Rate Femtosecond Pulse Trains with a High Finesse External Fabry-Perot Cavity**, J. Chen, J. W. Sickler, *Massachusetts Institute of Technology, Cambridge, MA, USA*, T. Wilken, *Max Planck Institute for Quantum Optics, Garching, Germany*, P. Fendel, *MenloSystems Inc., Newton, NJ, USA*, R. Holzwarth, *Menlo Systems GmbH, Munich, Germany*, T. W. Hänsch, *Max Planck Institute for Quantum Optics, Garching, Germany*, E. P. Ippen and F. X. Kaertner, *Massachusetts Institute of Technology, Cambridge, MA, USA*

Generation of 130-fs pulse trains at 1560 nm with 1 GHz repetition rate is demonstrated by locking a fundamentally mode-locked 200MHz repetition rate fiber laser to a high finesse ($F=2100$) external Fabry-Perot cavity.

10:00 AM– 10:30 AM**COFFEE BREAK****10:30 AM - 12:00 PM****Session TuC2: OPTICAL ARBITRARY WAVEFORMS II****Session Chair:** Raman Kashyap, *École Polytechnique de Montréal, Montreal, QC, Canada***TuC2.1 10:30 AM - 11:00 AM (Invited)****High Speed Arbitrary Waveform Generation and Processing using a Photonic Digital-to-Analog Converter**, A. Leven, Y. Yang, R. F. Kopf, A. Tate, T.-C. Hu, J. Frackoviak, R. Reyes, N. G. Weimann, Y.-K. Chen, *Alcatel-Lucent, Murray Hill, NJ, USA*, R. DeSalvo, G. Burdige, G. Deibner, *Harris Corporation, Melbourne, FL, USA*, F. J. Quinlan, S. Gee and P. J. Delfyett, *University of Central Florida, Orlando, FL, USA*

In this paper we report on our recent progress in using photonic digital-analog converters for arbitrary waveform generation. Optical arbitrary waveforms are generated using a time-domain approach based on an interferometric modulator device.

TuC2.2 11:00 AM - 11:15 AM**5-GHz Optical Arbitrary Waveform Generation using > 100 Independently Controlled Spectral Lines from a Compressed Phase-Modulated CW Laser Comb**, C.-B. Huang, *Purdue University, West Lafayette, IN, USA*, Z. Jiang, *University of Illinois at Urbana-Champaign, Urbana, IL, USA*, D. E. Leaird and A. M. Weiner, *Purdue University, West Lafayette, IN, USA*

We demonstrate high-fidelity optical arbitrary waveform generation via spectral line-by-line shaping on more than 100 spectral comb lines selected from a compressed phase-modulated CW laser frequency comb with 5 GHz line spacing.

TuC2.3 11:15 AM - 11:30 AM**Increasing the Mode-Spacing of Stabilized Frequency Combs with Optical Filter Cavities**, S. A. Diddams, *National Institute of Standards and Technology, Boulder, CO, USA*, A. M. Weiner, *Purdue University, West Lafayette, IN, USA*, V. Mbele and L. Hollberg, *National Institute of Standards and Technology, Boulder, CO, USA*

We explore methods and limitations for increasing the mode spacing of a 1 GHz optical frequency comb using a Fabry-Perot filter cavity. Applications to optical and microwave waveform generation are highlighted.

TuC2.4 11:30 AM - 12:00 PM (Invited)

Ultrafast Time Scale Transformation and Recording Utilizing Parametric Temporal Imaging, C. V. Bennett, *Lawrence Livermore National Laboratory, Livermore, CA, USA*

Parametric temporal imaging enables real time transformation of ultrafast waveforms to a time scale accessible by convention recording instruments. Principles and the development of this technology will be reviewed along with recent experimental results.

12:00 PM – 1:30PM

LUNCH BREAK

1:30 PM - 3:00 PM

Session TuC3: FREQUENCY TRANSFER AND METROLOGY

Session Chair: David J. Jones, *University of British Columbia, Vancouver, BC, Canada*

TuC3.1 1:30 PM - 2:00 PM (Invited)

Precise Long-Distance Frequency Transfer and Applications, C. Chardonnet, *University of Paris-North 13, Clement, Villetaneuse, France*

ABSTRACT NOT AVAILABLE

TuC3.2 2:00 PM - 2:15 PM

Large-Scale, Long-Term Stable Femtosecond Timing Distribution and Synchronization Systems, J.-W. Kim, *Massachusetts Institute of Technology, Cambridge, MA, USA*, F. Ludwig, *Deutsches Elektronen-Synchrotron, Hamburg, Germany*, J. Chen, *Massachusetts Institute of Technology, Cambridge, MA, USA*, F. Loehl, *Deutsches Elektronen-Synchrotron, Hamburg, Germany*, F. N. C. Wong, *Massachusetts Institute of Technology, Cambridge, MA, USA*, H. Schlarb, *Deutsches Elektronen-Synchrotron, Hamburg, Germany* and F. X. Kaertner, *Massachusetts Institute of Technology, Cambridge, MA, USA*

We demonstrate large-scale, long-term stable, and femtosecond-precision timing distribution and synchronization systems based on optical pulse trains generated from ultralow-noise mode-locked lasers.

TuC3.3 2:15 PM - 2:30 PM

Optical Frequency Transfer over 38 km of Installed Fiber at Less than 3×10^{-19} Residual Fractional Instability, P. A. Williams, W. C. Swann and N. R. Newbury, *National Institute of Standards and Technology, Boulder, CO, USA*

We transmit a narrow-linewidth cw laser at 1535 nm across 38 km of installed fiber. Through standard Doppler-cancellation techniques, we achieve a residual fractional frequency instability of 4×10^{-17} at 1 second averaging time.

TuC3.4 2:30 PM - 3:00 PM (Invited)

Ultrahigh Dynamic-Range Distance Measurement using a Femtosecond Frequency Comb, K. Minoshima, H. Inaba, H. Matsumoto, *National Institute of Advanced Industrial Science and Technology, Tsukuba, Ibaraki, Japan*, Y. Iino and K. Kumagai, *Topcon Corporation, Tokyo, Japan*

We report a compact optical distance meter using intermode beats of a fiber-delivered frequency comb. We realized micrometer agreement over hundreds of meters to a length-measuring laser interferometer which is the reference standard at NMIJ/AIST.

3:00 PM – 3:30 PM

COFFEE BREAK

3:30 PM - 5:00 PM

Session TuC4: MILLIMETER WAVE AND TERAHERTZ SIGNAL GENERATION

Session Chair: TBD

TuC4.1 3:30 PM - 4:00 PM (Invited)

Techniques for Photonic Generation of Millimeter-Wave Signals, R. Kashyap, *École Polytechnique de Montréal, Montreal, QC, Canada*, J. Yao, *University of Ottawa, Ottawa, ON, Canada*, K. Wu, *École Polytechnique de Montréal, Montreal, QC, Canada* and J. X. J. Zhang, *Concordia University, Montreal, QC, Canada*

This paper reviews various photonic techniques available for the generation of millimeter wave signals, including by direct modulation of lasers, injection locking, beat frequency sources with phase-locked loops, dual wavelength lasers and femtosecond lasers.

TuC4.2 4:00 PM - 4:30 PM (Invited)

The Potential of High Speed UTC-TW Photo Detectors to Generate Sub-MM Wave Signals - Predictions by a New Analytical Model, A. Madjar, *Temple University, Philadelphia, PA, USA* and P. K. L. Yu, *University of California - San Diego, La Jolla, CA, USA*

In this paper we consider generating sub-MM and THz signals by heterodyning optical signals in a UTC-TW photo detector. Use of a novel analytical model predicts that a few mW of output power at frequencies approaching 1 THz may be possible.

TuC4.3 4:30 PM - 4:45 PM

Microwave Photonic Frequency Multiplication for a Tunable Millimeter and Terahertz CW Signal Generator with Improved Spurious Characteristics, H.-J. Song, N. Shimizu, T. Furuta, H. Ito, *NTT Corporation, Atsugi-shi, Kanagawa, Japan* and T. Nagatsuma, *Osaka University, Toyonaka, Osaka, Japan*

In this reports, a microwave photonic frequency multiplication technique for a millimeter and terahertz CW signal generation is described. The proposed scheme shows wideband frequency tunability with low noise, high frequency accuracy, and high frequency stability.

TuC4.4 4:45 PM - 5:00 PM

Microwave Frequency Generation up to 27.5 GHz using a Dual-Wavelength Brillouin Fiber Laser, M. L. Dennis, R. M. Sova and T. R. Clark, *Johns Hopkins University, Laurel, MD, USA*

We demonstrate microwave frequency generation up to 27.5 GHz using a dualwavelength stimulated Brillouin fiber laser. We discuss advantages and limitations of this device as a microwave/millimeter-wave low phase noise oscillator.

END OF PROGRAM