

Contents

Preface

Lute Maleki vii

Symposium History

Jacques Vanier xi

Symposium Photos xv

Part I: Fundamental Physics

Variation of Fundamental Constants from the Big Bang to Atomic
Clocks: Theory and Observations (Invited)

V.V. Flambaum and J.C. Berengut 3

Alpha-Dot or Not: Comparison of Two Single Atom Optical Clocks
(Invited)

*T. Rosenband, D.B. Hume, C.-W. Chou, J.C.J Koelemeij,
A. Bruschi, S. Bickman, W.H. Oskay, T.M. Fortier, J.E. Stalnaker,
S.A. Diddams, N.R. Newbury, W.C. Swann, W.M. Itano,
D.J. Wineland and J.C. Bergquist* 20

Variation of the Fine-Structure Constant and Laser Cooling of
Atomic Dysprosium (Invited)

*N.A. Leefer, A. Cingöz, D. Budker, S.J. Ferrell, V.V. Yashchuk,
A. Lapiere, A.-T Nguyen, S.K. Lamoreaux and J.R. Torgerson* 34

Measurement of Short Range Forces Using Cold Atoms (Invited)

*F. Pereira Dos Santos, P. Wolf, A. Landragin, M.-C. Angonin,
P. Lemonde, S. Bize, A. Clarion, A. Lambrecht, B. Lamine and
S. Reynaud* 44

Atom Interferometry Experiments in Fundamental Physics (Invited)

S.W. Chiow, S. Hermann, S. Chu and H. Müller 53

Space Science Applications of Frequency Standards and Metrology
(Invited)

M. Tinto 62

Part II: Frequency & Metrology

Quantum Metrology with Lattice-Confined Ultracold Sr Atoms
(Invited)

*A.D. Ludlow, G.K. Campbell, S. Blatt, M.M. Boyd, M.J. Martin,
T.L. Nicholson, M. Swallows, J.W. Thomsen, T. Fortier, C.W. Oates,
S.A. Diddams, N.D. Lemke, Z. Barber, S. G. Porsev and J. Ye* 73

LNE-SYRTE Clock Ensemble: New ^{87}Rb Hyperfine Frequency
Measurement – Spectroscopy of ^{199}Hg and ^{201}Hg Optical Clock
Transition (Invited)

*M. Petersen, J. Millo, D.V. Magalhaes, C. Mandache, S.T. Dawkins,
R. Chicireanu, Y. Lecoq, J. Guena, F. Chapelet, P. Rosenbusch,
P. Laurent, M. Abgrall, G.D. Rovera, G. Santarelli, A. Clairon,
S. Bize and M. Tobar* 82

Precise Measurements of S-Wave Scattering Phase Shifts with a
Juggling Atomic Clock (Invited)

S. Gensemer, R. Hart, R. Martin, X. Xu, R. Legere and K. Gibble..... 91

Absolute Frequency Measurement of the $^{40}\text{Ca}^+$ $4s^2S_{1/2} - 3d^2D_{5/2}$
Clock Transition (Invited)

*M. Chwalla, J. Benhelm, K. Kim, G. Kirchmair, T. Monz, M. Riebe,
P. Schindler, A.S. Villar, W. Hänsel, C.F. Roos, R. Blatt,
M. Abgrall, G. Santarelli, G.D. Rovera and Ph. Laurent*..... 100

The Semiclassical Stochastic-Field/Atom Interaction Problem
(Invited)

J. Camparo 109

Phase and Frequency Noise Metrology (Invited)
E. Rubiola, V. Giordano, K. Volyanskiy and L. Larger..... 118

Optical Spectroscopy of Atomic Hydrogen for an Improved
 Determination of the Rydberg Constant
*J.L. Flowers, P.E.G. Baird, A. Evans, H.A. Klein, C.D. Langham, L.
 Mairiniac, H.S. Margolis and B.R. Walton* 127

Part III: Clock Applications in Space

Recent Progress on the ACES Mission (Invited)
L. Cacciapuoti and C. Salomon..... 135

The SAGAS Mission (Invited)
P. Wolf..... 146

Small Mercury Microwave Ion Clock for Navigation and Radio-
 Science (Invited)
J.D. Prestage, S. Chung, R. Thompson, P. MacNeal and T. Le 156

Astro-comb: Revolutionizing Precision Spectroscopy in
 Astrophysics (Invited)
*C.E. Kramer, C.-h. Li, A.G. Glenday, D.F. Phillips, G. Furesz,
 D. Sasselov, A. Szentgyorgyi, R.L. Walsworth, A. Benedick and
 F.X. Kärtner* 116

High Frequency Very Long Baseline Interferometry: Frequency
 Standards and Imaging an Event Horizon (Invited)
S. Doeleman..... 175

Optically-Pumped Space Cesium Clock for Galileo: Results of the
 Breadboard
*R. Ruffieux, P. Berthoud, M. Haldimann, S. Lecomte, V. Hermann,
 M. Gazard, R. Barillet, S. Guerandel, E. De Clercq and C. Audoin* 184

Part IV: Optical Clocks I: Lattice Clocks

Optical Lattice Clock: Seven Years of Progress and Next Steps (Invited) <i>H. Katori, M. Takamoto and T. Akatsuka</i>	191
The Yb Optical Lattice Clock (Invited) <i>N.D. Demke, A.D. Ludlow, Z.W. Barber, N. Poli, C.W. Hoyt, L.S. Ma, J.E. Stalnaker, C.W. Oates, L. Hollberg, J.C. Bergquist, A. Bruschi, T.M. Fortier, S.A. Diddams, T. Heavner, S. Jefferts and T. Parker</i>	200
Optical Lattice Clock with Sr Atoms (Invited) <i>P.G. Westergaard, A. Lecallier, J. Lodewyck and P. Lemonde</i>	209
Development of an Optical Clock Based on Neutral Strontium Atoms Held in a Lattice Trap <i>E.A. Curtis, B. Ovchinnikov, I.R. Hill, G.P. Barwood and P. Gill</i>	218
Decoherence and Losses by Collisions in a ^{88}Sr Lattice Clock <i>J.S.R. Vellore Winfred, Ch. Lisdat, T. Middelman, T. Legero, F. Riehle and U. Sterr</i>	223
Lattice Yb Optical Clock and Cryogenic Cs Fountain at INRIM <i>F. Levi, D. Calonico, L. Lorini, C. Calosso, E.K. Bertacco, A. Godone and G.A. Costanzo</i>	228

Part V: Optical Clocks II: Ion Clocks

$^{171}\text{Yb}^+$ Single-Ion Optical Frequency Standards (Invited) <i>Chr. Tamm, B. Lipphardt, T.E. Mehlstäubler, M. Okhapkin, I. Sherstov, B. Stein and E. Peik</i>	235
---	-----

An Optical Clock Based on a Single Trapped $^{88}\text{Sr}^+$ Ion (Invited) <i>H.S. Margolis, G.P. Barwood, G. Huang, H.A. Klein, S.N. Lea, G. Marra, V. Tsaturian, B.R. Walton and P. Gill</i>	241
A Trapped $^{171}\text{Yb}^+$ Ion Optical Frequency Standard Based on the $S_{1/2} - F_{7/2}$ Transition (Invited) <i>P. Gill, S.A. Webster, G. Huang, K. Hosaka, A. Stannard, S.N. Lea, R.M. Godun, S.A. King, B.R. Walton, H.S. Walton and H.S. Margolis</i>	250
Overview of Highly Accurate RF and Optical Frequency Standards at the National Research Council of Canada (Invited) <i>A.A. Madej, J.E. Bernard, P. Dube and L. Marmet</i>	259

Part VI: Optical Frequency Combs

Extreme Ultraviolet Frequency Combs for Spectroscopy (Invited) <i>A. Ozawa, M. Hermann, A. Vernaleken, Ch. Gohle, B. Bernhardt, T. Wilken, W. Schneider, P. Welter, S. Knuze, V. Batteiger, R. Holzwarth, E. Peters, S. Reinhardt, T.W. Hansch and Th. Udem</i>	271
Development of an Optical Clockwork for the Single Trapped Strontium Ion Standard at 445 THz <i>J.E. Bernard, P. Dube, A.A. Madej, S. Cundy, J.-S. Boulanger, J. Jiang and D.J. Jones</i>	280
A Phase-Coherent Link Between the Visible and Infrared Spectral Ranges Using a Combination of CW OPO and Femtosecond Laser Frequency Comb <i>E.V. Kovalchuk and A. Peters</i>	285
Improvements to the Robustness of a Ti:Sapphire -Based Femtosecond Comb at NPL <i>V. Tsaturian, H.S. Margolis, S.N. Lea, B.R. Walton, G. Marra, D.T. Reid and P. Gill</i>	291

Part VII: Atomic Microwave Standards

NIST F1 and F2 (Invited)

T.P. Heavner, T.E. Parker, J.H. Shirley and S.R. Jefferts 299

Atomic Fountains for the USNO Master Clock (Invited)

C. Ekstrom, S. Peil, T. Swanson and S. Crane 308

The Transportable Cesium Fountain Clock NIM5: Its Construction and Performance (Invited)

T. Li, P. Lin, M. Li, P. Wang, W. Chen, N. Liu and Y. Lin 314

Compensated Multi-Pole Mercury Trapped Ion Frequency Standard and Stability Evaluation of Systematic Effects (Invited)

E.A. Burt, S. Taghavi-Larigani, J.D. Prestage and R.L. Tjoelker 321

Research of Frequency Standards in SIOM – Atomic Frequency Standards Based on Coherent Storage (Invited)

B. Yan, H.D. Cheng, Y.S. Ma, W.Z. Zhang, L. Liu and Y.Z. Wang 329

The PTB Fountain Clock Ensemble Preliminary Characterization of the New Fountain CSF2

N. Nemitz, V. Gerginov, R. Schröder, S. Weyers and R. Wynands 338

The Pulsed Optically Pumped Clock: Microwave and Optical Detection

S. Micalizio, A. Godone, F. Levi and C. Calosso 343

Research on Characteristics of Pulsed Optically Pumped Rubidium Frequency Standard

J. Deng, Z. Hu, L. Li and H. He 348

Status of the Continuous Cold Fountain Clocks at METAS-LTF

A. Joyet, G. Di Domenico, G.K. Gulati, P. Thomann and A. Stefanov 353

Experiments with a New $^{201}\text{Hg}^+$ Ion Clock <i>E.A. Burt, S. Taghavi-Larigani, S.N. Lea, J.D. Prestage and R.L. Tjoelker</i>	358
Optimising a High-Stability CW Laser-Pumped Rubidium Gas-Cell Frequency Standard <i>C. Affolderbach, F. Gruet, D. Miletic and G. Mileti</i>	363
Raman-Ramsey Cs Cell Atomic Clock <i>R. Boudot, S. Guerandel, N. Castagna, O. Kozlova, E. De Clercq, N. Dimarcq and A. Clairon</i>	368

Part VIII: Microwave Resonators & Oscillators

Solutions and Ultimate Limits in Temperature Compensation of Metallic Cylindrical Microwave Resonators (Invited) <i>A. De Marchi</i>	375
Cryogenic Sapphire Oscillators (Invited) <i>J.G. Hartnett, E.N. Ivanov and M.E. Tobar</i>	384
Ultra-Stable Optical Cavity: Design and Experiments <i>J. Millo, S. Bize, E.M.L. English, P. Lemonde and G. Santarelli</i>	393
New Results for Whispering Gallery Mode Cryogenic Sapphire Maser Oscillators <i>K. Benmessai, P.Y. Bourgeois, N. Bazin, Y. Kersalé, V. Giordano, M. Oxborrow, D. L. Creedon, J.G. Hartnett and M.E. Tobar</i>	398

Part IX: Advanced Techniques

Fundamental Noise-Limited Optical Phase Locking at Femtowatt Light Levels (Invited) <i>J. Dick, M. Tu, K. Birnbaum, D. Strekalov and N. Yu</i>	405
---	-----

Microwave and Optical Frequency Transfer via Optical Fibre <i>G. Marra, S.N. Lea, H.S. Margolis and P. Gill</i>	417
Ultra-Stable Laser Source for the $^{88}\text{Sr}^+$ Single-Ion Optical Frequency Standard at NRC <i>P. Dubé, A.A. Madej and J.E. Bernard</i>	422
Clock Laser System for a Strontium Lattice Clock <i>T. Legero, Ch. Lisdat, J.S.R. Vellore Winfred, H. Schnatz, G. Grosche, F. Riehle and U. Sterr</i>	427
Measurement Noise Floor for a Long-Distance Optical Carrier Transmission via Fiber <i>G. Grosche, O. Terra, K. Predehl, T. Hänsch, R. Holzwarth, B. Lipphardt, F. Vogt, U. Sterr and H. Schnatz</i>	432
Optical Frequency Transfer Over 172 KM of Installed Fiber <i>S. Crane, H. Jiang, P. Lemonde, G. Santarelli, F. Kefelian, O. Lopez, A. Amy-Klein and Ch. Chardonnet</i>	437

Part X: Miniature Systems

Chip-Scale Atomic Devices: Precision Atomic Instruments Based on MEMS (Invited) <i>J. Kitching, S. Knappe, V. Gerginov, V. Shah, P.D.D. Schwindt, B. Lindseth, E.A. Donley, Y.-J. Wang, E. Hodby, M. Eardley, R. Jimenez, W.C. Griffith, A. Geraci, J. Preusser, T.C. Liebisch, H.G. Robinson and L. Hollberg</i>	445
CSAC – The Chip-Scale Atomic Clock (Invited) <i>R. Lutwak, A. Rasheed, M. Varghese, G. Tepolt, J. LeBlanc, M. Mescher, D.K. Serkland, K.M. Geib and G.M. Peake</i>	454

Reaching a Few $10^{-13} \tau^{-1/2}$ Stability Level with a Compact Cold Atom Clock <i>F.X. Esnault, S. Perrin, D. Holleville, S. Guerandel, N. Dimarcq and J. Delporte</i>	463
---	-----

Evaluation of Lin Lin CPT for Compact and High Performance Frequency Standard <i>E. Breschi, G. Mileti, G. Kazakov, B. Matisov, R. Lammegger and L. Windholz</i>	468
---	-----

Part XI: Time Scales

Atomic Time Scales TAI and TT(BIPM): Present Status and Prospects (Invited) <i>G. Petit</i>	475
--	-----

Weight Functions for Biases in Atomic Frequency Standards <i>J.H. Shirley</i>	483
--	-----

Part XII: Interferometers

Definition and Construction of Noise Budget in Atom Interferometry (Invited) <i>E. D'Ambrosio</i>	491
--	-----

Characterization of a Cold Atom Gyroscope (Invited) <i>A. Landragin, A. Gauguet, T. Lévèque and W. Chaibi</i>	502
--	-----

A Mobile Atom Interferometer for High Precision Measurements of Local Gravity <i>M. Schmidt, A. Senger, T. Gorkhover, S. Grede, E. V. Kovalchuk and A. Peters</i>	511
--	-----

Demonstration of Atom Interferometer Comprised of Geometric Beam Splitters <i>Hiromitsu Imai and Atsuo Morinaga</i>	517
--	-----

Part XIII: New Directions

Active Optical Clocks (Invited) <i>J. Chen</i>	525
Prospects for a Nuclear Optical Frequency Standard Based on Thorium-229 (Invited) <i>E. Peik, K. Zimmermann, M. Okhapkin and Chr. Tamm</i>	532
Whispering Gallery Mode Oscillators and Optical Comb Generators (Invited) <i>A.B. Matsko, A.A. Savchenkov, W. Liang, V.S. Ilchenko, D. Seidel and L. Maleki</i>	539
Frequency Comparison Using Energy-Time Entangled Photons <i>A. Stefanov</i>	559
List of Participants.....	565