2015 FSM

Frequency Standards & Metrology Symposium

FEMTO-ST Internal Report provided by

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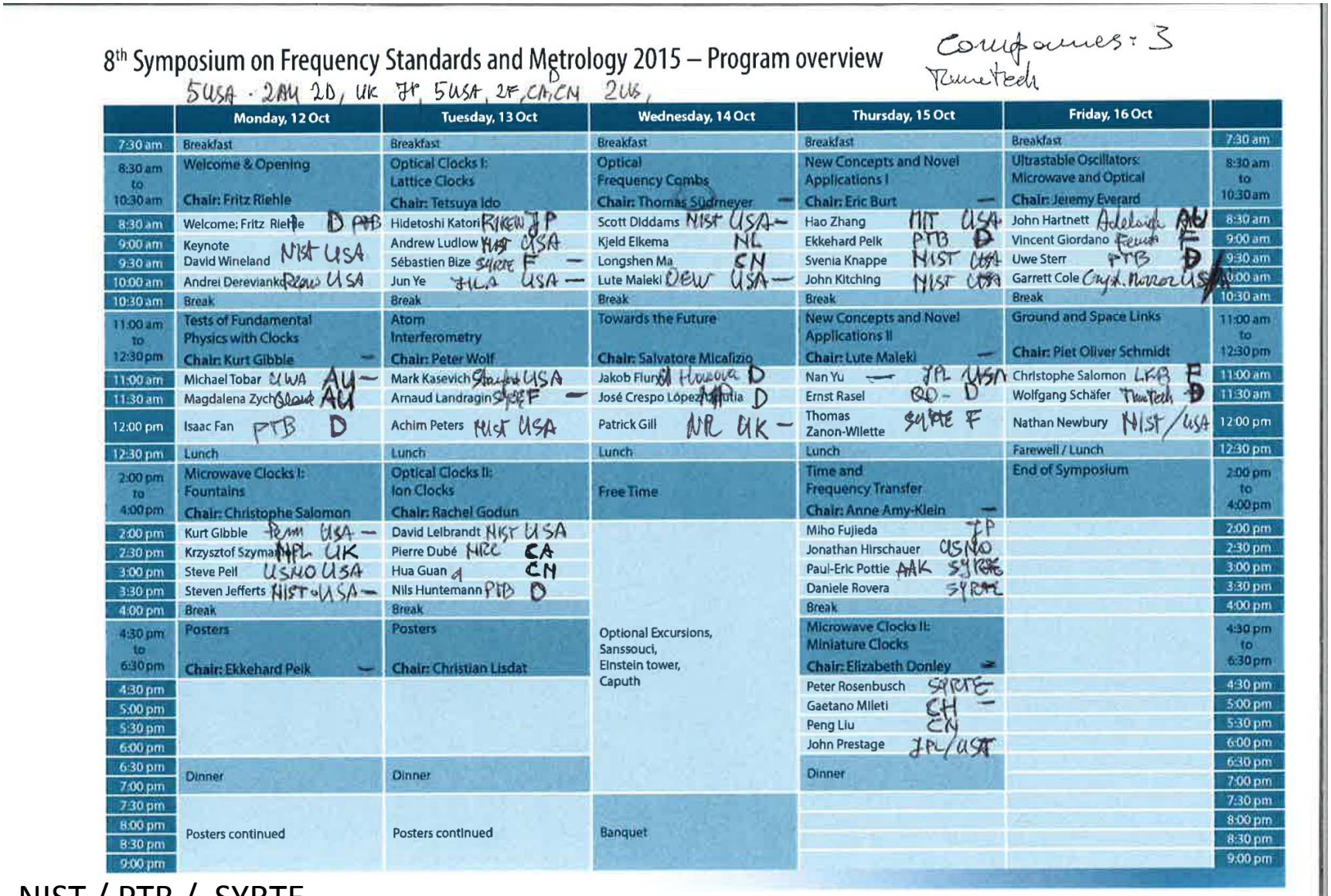
All the FSM Symposia

- 1971 Laval, Quebec, Canada (J. Vanier)
- 1976 Copper Mountain, CO, USA (H. Hellwig)
- 1981 Aussois, France (C. Audoin)
- 1988 Ancona, Italy (A. De Marchi)
- 1995 Woods Hole, MA, USA (J. Bergquist)
- 2001 St Andrews, Fife, UK (P. Gill – September 11)
- 2008 Asilomar, CA, USA (L. Maleki)
- 2015 Potsdam, Germany (F. Riehle)

All the proceedings are on Partages/projects/TF-Ebooks, you all have access
(2015, abstracts only)

Geography and Labs



8th Symposium on Frequency Standards and Metrology 2015 – Program overview

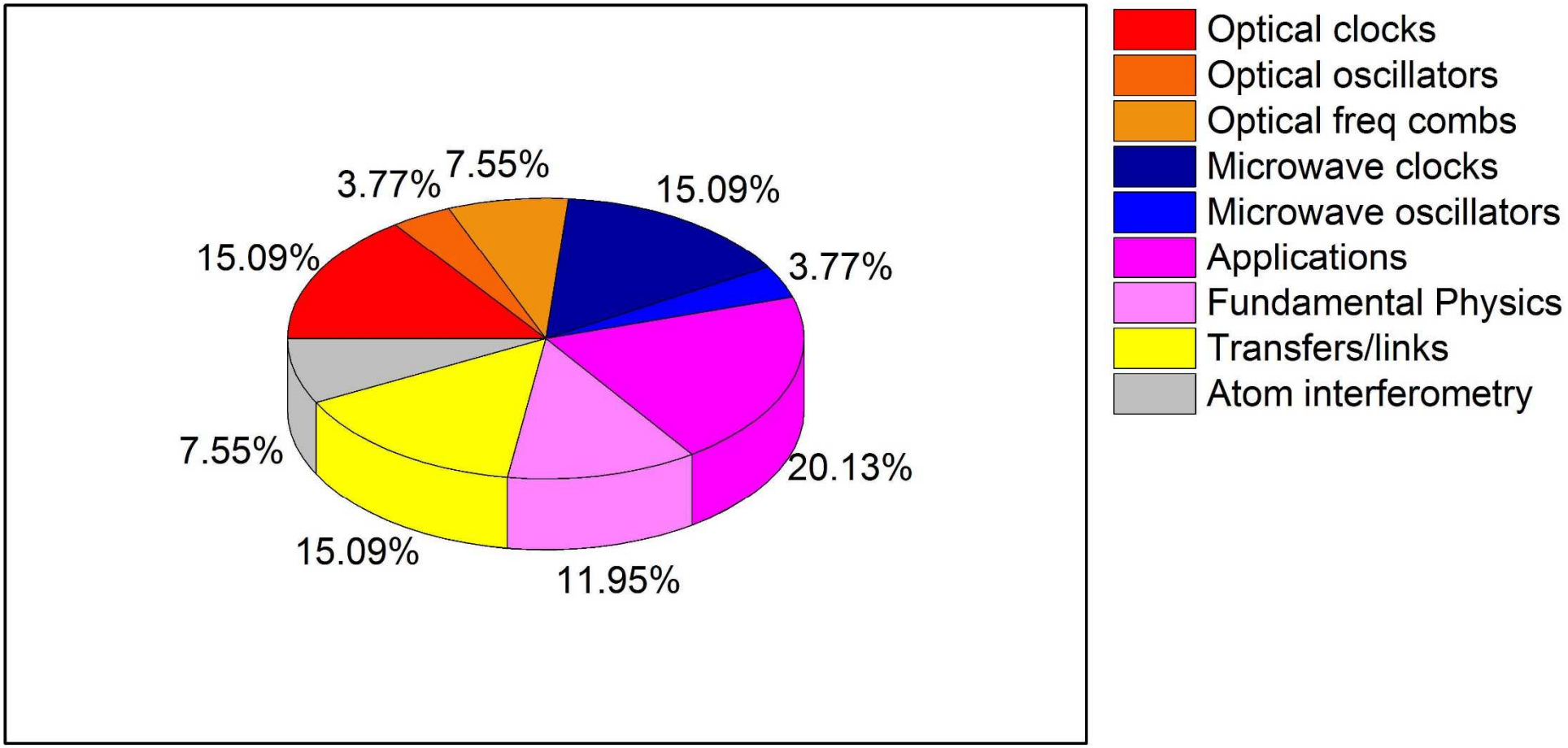
	Monday, 12 Oct	Tuesday, 13 Oct	Wednesday, 14 Oct	Thursday, 15 Oct	Friday, 16 Oct	
7:30 am	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	7:30 am
8:30 am to 10:30 am	Welcome & Opening Chair: Fritz Riehle	Optical Clocks I: Lattice Clocks Chair: Tetsuya Ido	Optical Frequency Combs Chair: Thomas Südmeyer	New Concepts and Novel Applications I Chair: Eric Burt	Ultrastable Oscillators: Microwave and Optical Chair: Jeremy Everard	8:30 am to 10:30 am
8:30 am	Welcome: Fritz Riehle	Hidetoshi Katori	Scott Diddams	Hao Zhang	John Hartnett	8:30 am
9:00 am	Keynote David Wineland	Andrew Ludlow	Kjeld Eikema	Ekkehard Peik	Vincent Giordano	9:00 am
9:30 am		Sébastien Bize	Longshen Ma	Svenia Knappe	Uwe Sterr	9:30 am
10:00 am	Andrei Derevianko	Jun Ye	Lute Maleki	John Kitching	Garrett Cole	10:00 am
10:30 am	Break	Break	Break	Break	Break	10:30 am
11:00 am to 12:30 pm	Tests of Fundamental Physics with Clocks Chair: Kurt Gibble	Atom Interferometry Chair: Peter Wolf	Towards the Future Chair: Salvatore Micalizio	New Concepts and Novel Applications II Chair: Lute Maleki	Ground and Space Links Chair: Piet Oliver Schmidt	11:00 am to 12:30 pm
11:00 am	Michael Tobar	Mark Kasevich	Jakob Fiurášek	Nan Yu	Christophe Salomon	11:00 am
11:30 am	Magdalena Zych	Arnaud Landragin	José Crespo López-Urtia	Ernst Rasel	Wolfgang Schäfer	11:30 am
12:00 pm	Isaac Fan	Achim Peters	Patrick Gill	Thomas Zanon-Wilette	Nathan Newbury	12:00 pm
12:30 pm	Lunch	Lunch	Lunch	Lunch	Farewell / Lunch	12:30 pm
2:00 pm to 4:00 pm	Microwave Clocks I: Fountains Chair: Christophe Salomon	Optical Clocks II: Ion Clocks Chair: Rachel Godun	Free Time	Time and Frequency Transfer Chair: Anne Amy-Klein	End of Symposium	2:00 pm to 4:00 pm
2:00 pm	Kurt Gibble	David Leibrandt	Optional Excursions, Sanssouci, Einstein tower, Caputh	Miho Fujieda		2:00 pm
2:30 pm	Krzysztof Szymaniec	Pierre Dubé		Jonathan Hirschauer		2:30 pm
3:00 pm	Steve Peil	Hua Guan		Paul-Eric Pottie		3:00 pm
3:30 pm	Steven Jefferts	Nils Huntemann		Daniele Rovera		3:30 pm
4:00 pm	Break	Break		Break		4:00 pm
4:30 pm to 6:30 pm	Posters Chair: Ekkehard Peik	Posters Chair: Christian Lisdat		Microwave Clocks II: Miniature Clocks Chair: Elizabeth Donley		4:30 pm to 6:30 pm
4:30 pm				Peter Rosenbusch		4:30 pm
5:00 pm				Gaetano Mileti		5:00 pm
5:30 pm				Peng Liu		5:30 pm
6:00 pm				John Prestage		6:00 pm
6:30 pm	Dinner	Dinner		Dinner		6:30 pm
7:00 pm						7:00 pm
7:30 pm	Posters continued	Posters continued	Banquet			7:30 pm
8:00 pm						8:00 pm
8:30 pm						8:30 pm
9:00 pm						9:00 pm

NIST / PTB / SYRTE

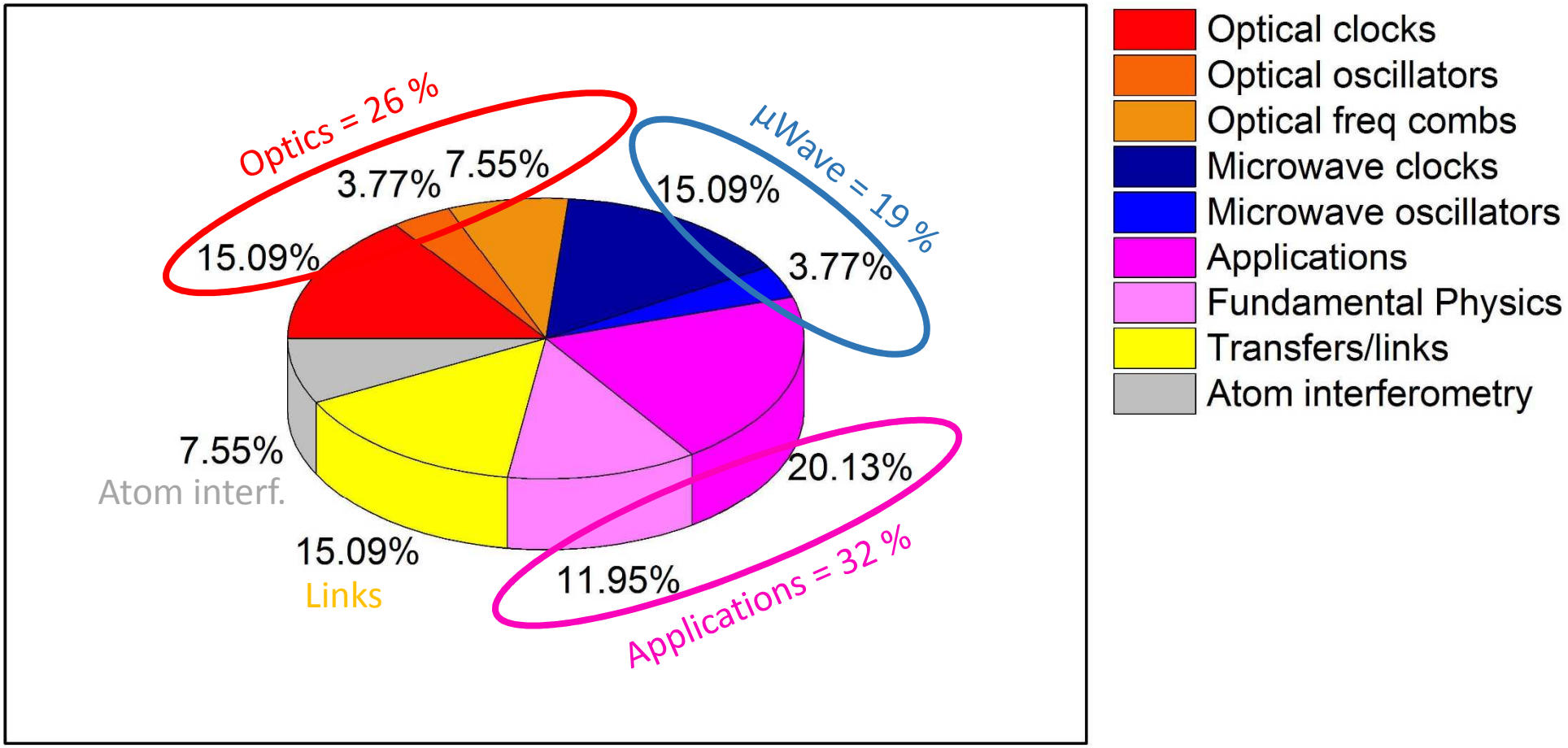
USA / D / F / CN / AU / UK / …

Absents: CH, ES, I, A, …

Topics distribution



Topics distribution



Topics

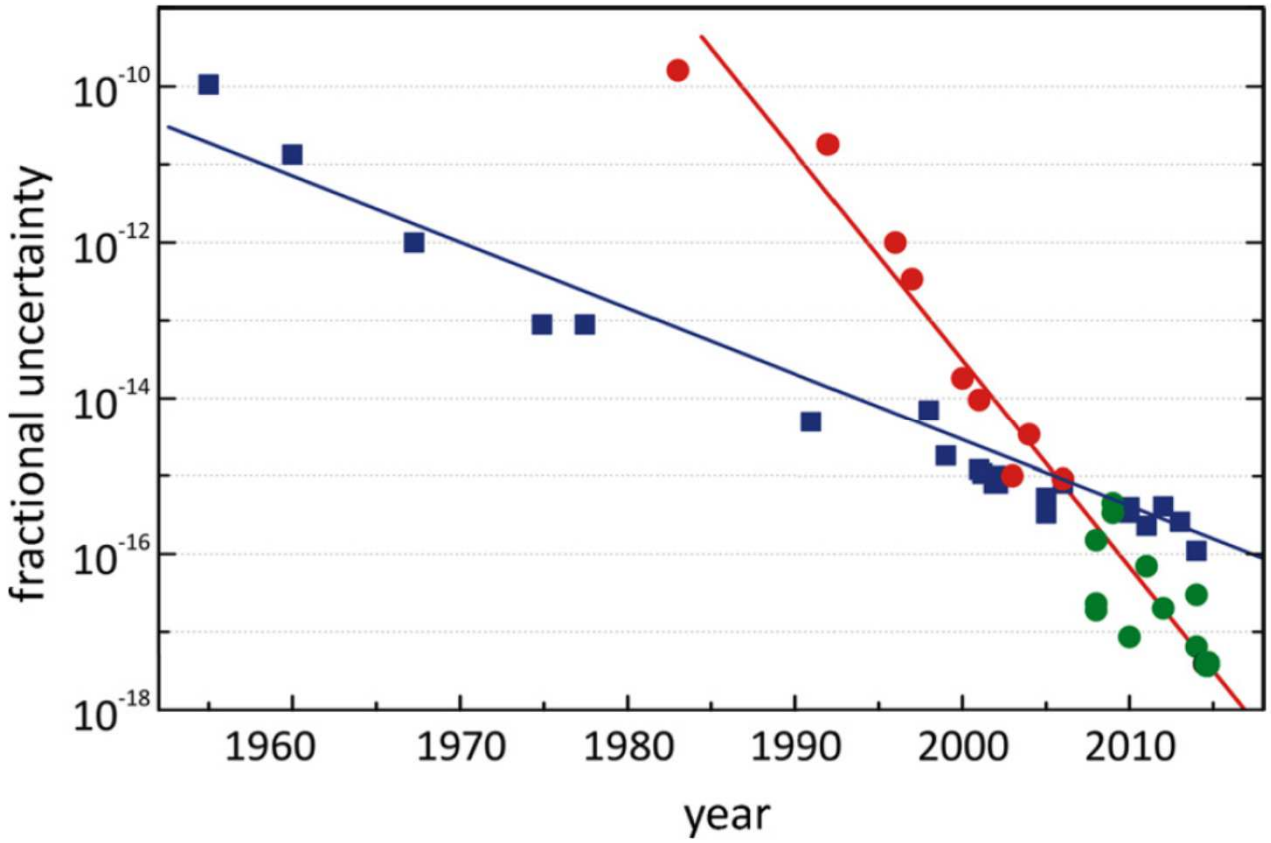
Presents

- Optical clocks
- Lasers
- FP and Combs
- Small optical resonators
- Transfer (most optical)
- Spectroscopy
- Microwave clocks
- CSO
- Nuclear transitions
- General Relativity

Absents

- Noise and AVAR
- Acoustic resonators
- Sensors (w exception)
- Millisecond pulsars
- Spectral Hole Burning
- Ageing of fundamental constants

Atomic clocks – from then to now

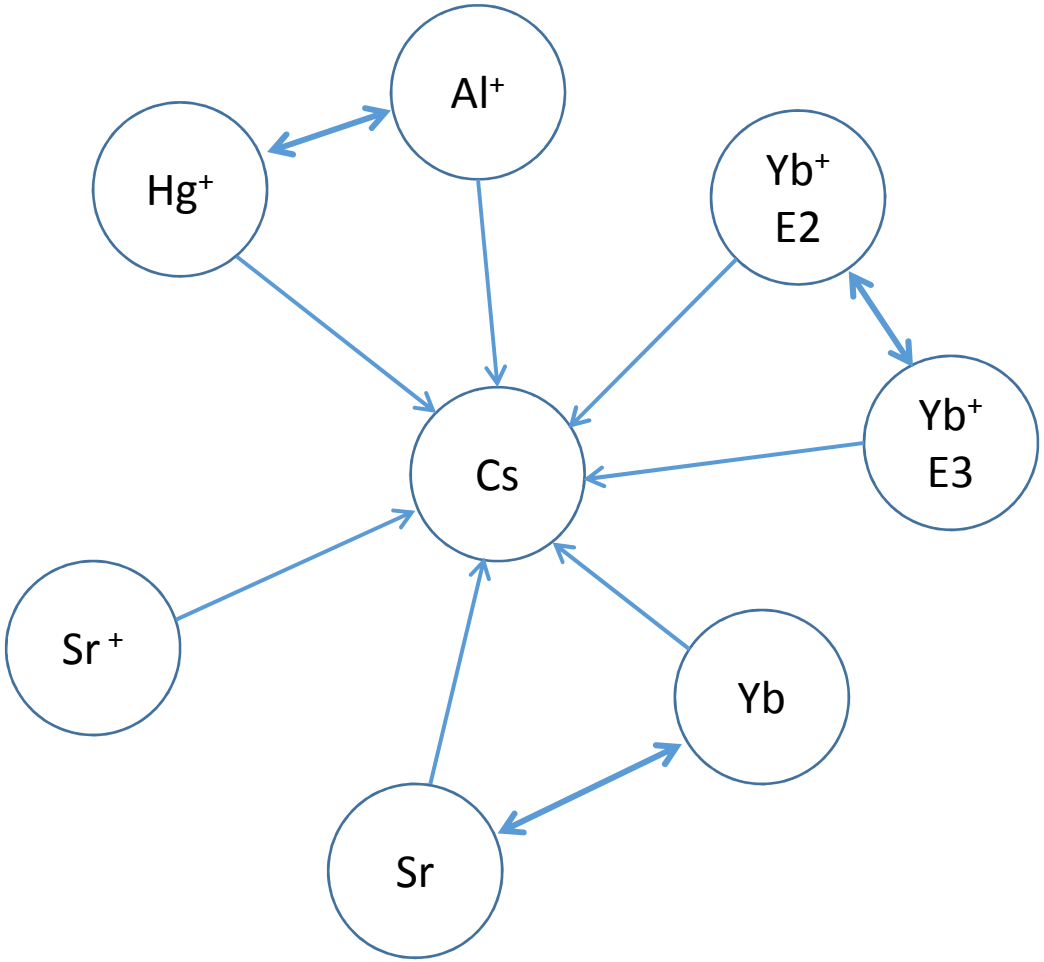


F. Riehle, C. R. Physique 16 (2015) 506-515

The Meaning of Accuracy

- BIPM Guide to Uncertainty in Measurements (GUM)
  - Type A –> statistical (noise)
  - Type B –> system (magnetic, collisions, blackbody…)
- Definition –> ^{133}Cs NMR, ν = 9,192,631,770
  not relying to fundamental constants
- Others
  - ν cannot be calculated
  - u_B does not account for $\Delta\nu$
  - True accuracy relies on the Cs fountain (parts in 10^{-16})
  - Claimed "10^{-18} uncertainty" is misleading

Is it the right time for a redefinition of the second? (P. Gill)



Over-determined set of freq. and freq. ratios measurements => least-square adjustment;
! Correlations bet. measurements need to be taken into account

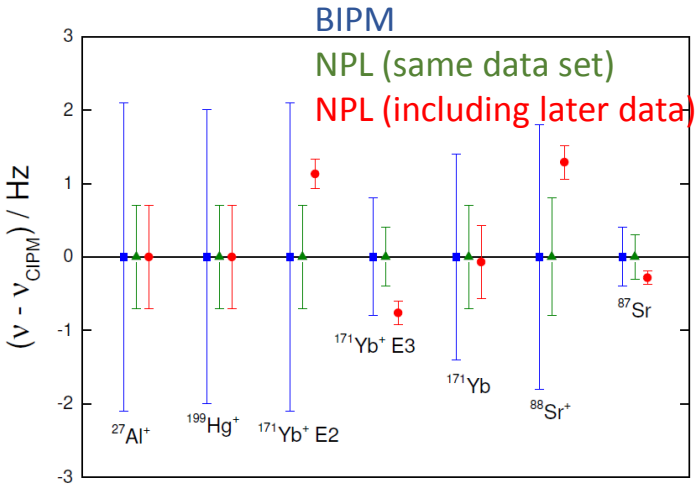


Figure 2. Frequency values obtained for the seven optical secondary representations of the second, calculated using the same input data used by the CCL-CCTF WGFS (green triangles) and with new data included in the analysis (red circles). The present CIPM recommended frequency values are also shown (blue squares).

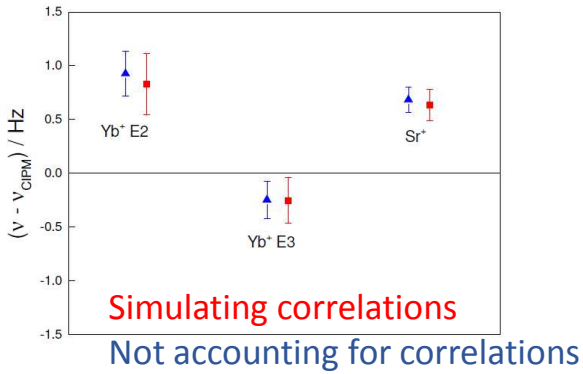


Figure 4. Effect of correlations on the output from the least-squares adjustment for the hypothetical measurement campaign illustrated in figure 3. Blue triangles show the absolute frequency values obtained when correlations are neglected, whilst red squares show the corresponding values obtained when correlations are included.

From Margolis and Gill, Metrologia 52(5), 2015

Microwave Clocks (2 sessions)

- Mature technology
- Progress in understanding systematic uncertainty
- Many clocks at USNO
  (behavior and problems of a large set)
- Miniaturization
- No change in paradigm

Thorium: looking for a nuclear atomic clock (Peik)

Why nuclear?

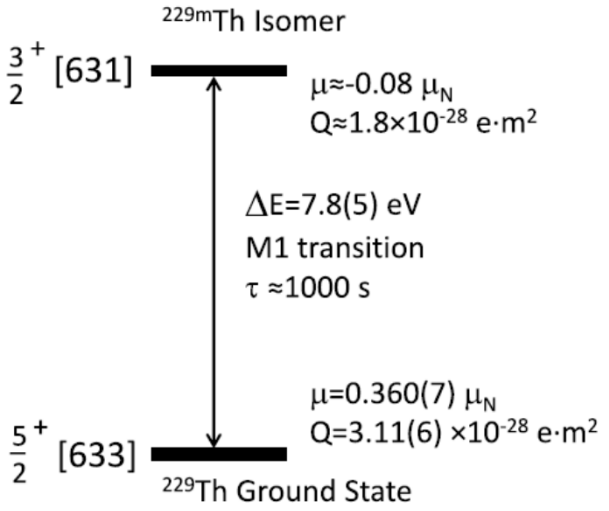
- Higher accuracy through smaller freq. shifts
- Higher stability in a solid-state optical clock
- Higher stability through higher reference frequency

Why Thorium?

- Low energy isomeric transition around 7,8 eV (±0,5eV !!), ie 160 nm, accessible w/ current technology
- Life time = 1000 s.
- Q factor = 2×10^{19}

Challenges :

- 160 nm ± 10 nm, Q factor = 2×10^{19}
- Energy levels hardly known



Peik and Okhapkin, C.R. Physique 16, 516-523 (2015)

Peik → $^{229}Th^{3+}$

Alternative –> full solid state

Future trends

- Optical clocks
- 3-D lattices
- Highly charged ions – Emerging
- Nuclear transitions – Will come
- Space-time applications – Emerging
- Re-definition of the SI second (P. Gill)
  - Delayed
  - Changing the atoms w/out leap in understanding does not add that much
- The quest for 10^{-19} (1 mm in the g potential)

Clock —> Applications

- Fundamental physics
  - Dark Matter
  - Squeezing
  - GR
  - Atomic physics
  - Gravitational waves
- Relativistic geodesy
- Spectroscopy

Dream for 10^{-19} Path and Applications

- New optical clocks
- Highly charged ions
- Nuclear transition
- (rely the resonances to the standard model)

- Space time framework 1.08×10^{-16}/m at gnd level
- Search for gravitational waves