

Atomic clocks

General

- Optical atomic clocks
, N. Poli et al., arXiv:1401.2378v2 (2014)
- Optical atomic clocks
, A.D. Ludlow et al., Reviews of modern physics **87** (2015)
- Fritz Riehle, Frequency Standards, WILEY-VCH Verlag GmbH & Co. KGaA, 2004

Elements

- Best Clock so far (Stand 11/2016)
<http://www.nature.com/nature/journal/v506/n7486/pdf/nature12941.pdf>
doi:10.1038/nature12941
- Systematic Evaluation for this <http://www.nature.com/articles/ncomms7896.pdf>
- Best Clock Comparison so far (Stand 11/2016) Comparison of Two Independent Sr Optical Clocks with 1×10^{-17} Stability at 10^3 s:
[physrevlett.109.230801.pdf](https://arxiv.org/abs/1603.02026)
- **Mercury:**
 - Comparing a mercury optical lattice clock with microwave and optical frequency standards
, R. Tyumeney et al., arXiv:1603.02026v2 [physics.atom-ph] 13 Nov 2016

Cavities

[Summary of the best cavities](#)

- Mercury (Paris) cavity:
 - Ultrastable lasers based on vibration insensitive cavities
, J. Millo et al., PR A **79**, 053829 (2009)
 - Laser locking to the Hg199 π 1– π 3 clock transition with $5.4 \times 10^{-15}/\sqrt{\nu}$ fractional frequency instability
, J. J. McFerran et al., Optics Letters Vol. **37**, No. 17, 3477-3479 (2012)

General

- Making optical atomic clocks more stable with 10–16-level laser stabilization
, V. Jiang et al., Nature Photonics **5**, 158-161 (2011)

Relevant effects influencing frequency stability

- **Pund-Drever-Hall (PDH):**

- Laser Phase and Frequency Stabilization Using an Optical Resonator
, R. W. P. Drever et al., Appl. Phys. B **31**, 97-105 (1983)

- **Vibration:**

- Simple vibration-insensitive cavity for laser stabilization at the 10^{-16} level
, J. Keller et al., Appl. Phys. **B 116**, 203-210 (2014)
- <https://journals.aps.org/pr/abstract/10.1103/PhysRevA.79.053829>

- **Thermal-Noise:**

- Thermal-Noise Limit in the Frequency Stabilization of Lasers with Rigid Cavities
, K. Numata et al., PRL **93**, 250602 (2004)
- Thermal noise in optical cavities revisited
, T. Kessler et al., J. Opt. Soc. Am. B Vol. **29**, No. 1 (2012)

- **Residual amplitude modulation:**

- Reduction of residual amplitude modulation to 1×10^{-6} for frequency modulation and laser stabilization
, W. Zhang et al., Optics Letters Vol. **39**, No. 7 (2014)
- Investigation and cancellation of residual amplitude modulation in fiber electro-optic modulator based frequency modulation gas sensing technique
, Z. Li et al., Sensors and Actuators B **196**, 23-30 (2014)
- Residual amplitude modulation in interferometric gravitational wave detector
, K. Kokeyama et al., J. Opt. Soc. Am. A Vol. **31**, No. 1 (2014)
 - Residual Amplitude Modulation in Interferometric Gravitational Wave Detectors
, K. Kokeyama et al., arXiv:1309.4522v1 [gr-qc] 18 Sep 2013

- **ULE compensations rings:**

http://www.quantummetrology.de/quest/fileadmin/quest/sub_hz_lasers/paper/leg10.pdf

Length

- **7 cm:**

- Compact, thermal-noise-limited optical cavity for diode laser stabilization at 1×10^{-15}
, A. D. Ludlow et al., Optics Letters Vol. **32**, Issue 6, pp. 641-643 (2007)

- **10 cm:**

- A compact, robust, and transportable ultra-stable laser with a fractional frequency instability of 1×10^{-15}
, Q. F. Chen et al., REVIEW OF SCIENTIFIC INSTRUMENTS **85**, 113107 (2014)

- **48 cm:**

- 8×10^{-17} fractional laser frequency instability with a long room-temperature cavity
, S. Häfner et al., Optical Letters Vol. **40**, No. 9 (2015)

Mirror layers

- **Crystalline coatings:**

- Tenfold reduction of Brownian noise in high-reflectivity optical coatings
, Garrett D. Cole et al., Nature Photonics **7**, 644–650 (2013)

Other geometries

- **Cubic geometry:**

- Force-insensitive optical cavity
, S. Webster et al., Optics Letters Vol. **36**, Issue 18, pp. 3572-3574 (2011)
 - PTB took the NPL-design and updated it for a better longterm stability (see Häfner PHD-thesis, Chapter 4.2)

- **Cryogenic single-crystal optical cavities:**

- Ultrastable laser with average fractional frequency drift rate below $5 \times 10^{-19}/s$
, C. Hagemann et al., Optics Letters Vol. **39**, No. 17 (2014)
 - A sub-40-mHz-linewidth laser based on a silicon single-crystal optical cavity
, T. Kessler et al., Nature Photonics Vol. **6**, 687-692 (2012)

Applications

- **Transfer of stability:**

- Providing 10–16 Short-Term Stability of a 1.5- μm Laser to Optical Clocks
, C. Hagemann et. al., IEEE Transactions on instrumentation and measurement, VOL. 62, NO. 6 (2013)

Application of Clocks

- Realization of a timescale with an accurate optical lattice clock:
optica-3-6-563.pdf

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