

# Steffen Sauer

## Lasertreiber

- [Laserdriver\\_Mg](#)
- Leiterplatten: <https://www.multi-circuit-boards.eu/index.html>
  - Login-Nummer: 162258
- 10 MHz Mail: 10mhz@iqo.uni-hannover.de
  - passwort: pAd98Y24
- [Metamirror](#)

## Paper Sammlung

### General

- Making optical atomic clocks more stable with 10–16-level laser stabilization  
, V. Jiang et al., Nature Photonics **5**, 158-161 (2011)
- High-precision laser stabilization via optical cavities  
, M. Martin and J. Ye
- [guidelines\\_for\\_developing\\_optical\\_clocks\\_with10\\_18fractional\\_frequency\\_uncertainty.pdf](#)

### Relevant effects influencing frequency stability

#### Noise calculation

- 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)
- **Reduction of thermal noise limit**
  - **Higher-order mode locking:**
    - Thermal noise limited higher-order mode locking of a reference cavity  
, X. Y. Zeng et al., arXiv:1801.05026v1 (2018)

#### Pound-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)
- EOM-Temperature

## 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/pra/abstract/10.1103/PhysRevA.79.053829>

## Residual amplitude modulation

- Reduction of residual amplitude modulation to  $1 \times 10^{-6}$  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., aXiv:1309.4522v1 [gr-qc] 18 Sep 2013

## Temperature/CTE

- **ULE compensations rings:**
  - Tuning the thermal expansion properties of optical reference cavities with fused silica mirrors  
, T. Legero et al., J. Opt. Soc. Am. B Vol. **27**, No. 5 (2010)

## Spacer geometries / Cavity types

- **Vertical geometry:**
  - **Length: 2.5 cm:**
    - Compact, thermal-noise-limited reference cavity for ultra-low-noise microwave generation  
, J. Davila-Rodriguez et al., Opt. lett. Vol. 42, No. 7 (2017)
  - **Length: 7 cm:**
    - Compact, thermal-noise-limited optical cavity for diode laser stabilization at  $1 \times 10^{-15}$   
, A. D. Ludlow et al., Optics Letters Vol. **32**, Issue 6, pp. 641-643 (2007)
  - **Length: 10 cm:**
    - A compact, robust, and transportable ultra-stable laser with a fractional frequency instability of  $1 \times 10^{-15}$   
, Q. F. Chen et al., REVIEW OF SCIENTIFIC INSTRUMENTS 85, 113107 (2014)
  - **Length: 48 cm:**

- $8 \times 10^{-17}$  fractional laser frequency instability with a long room-temperature cavity  
 , S. Häfner et al., Optical Letters Vol. **40**, No. 9 (2015)
- A strontium lattice clock with  $3 \times 10^{-17}$  inaccuracy and its frequency:  
[a\\_strontium\\_lattice\\_clock\\_with\\_310\\_-17\\_inaccuracy\\_and\\_its\\_frequency.pdf](#)
- **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:**
  - **Length: 6 cm:**
  - **Length: 21 cm:**
    - 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)
    - <https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.118.263202>
- **Mercury (Paris) cavity:**
  - Ultrastable lasers based on vibration insensitive cavities  
 , J. Millo et al., PR A **79**, 053829 (2009)
  - Laser locking to the Hg199  $^101-^103$  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)
- **Core (Achim Peters):**
  - [iqec-2011-i991-2.pdf](#)

## Measurement/characterization techniques of ultra-stable lasers

- Characterization of electrical noise limits in ultra-stable laser systems  
 , J. Zhang et al., Review of Scientific Instruments 87, 123105 (2016)
- Phase noise characterization of sub-hertz linewidth lasers via digital cross correlation  
 , X. Xie et al., Vol. 42, Issue 7, pp. 1217-1220 (2017)

## Applications

- **Transportable cavities:**
  - Single-ion, transportable optical atomic clocks  
 , Marion Delehaye & Clément Lacroûte, Journal of Modern Optics, 65:5-6, 622-639 (2018)
- **Lorentz invariance for the electron:**
  - Achim Peters: CORE
- **time:**

- riehle.pdf

## Noise

- [power spectral density of Brownian noise](#)
- Noise to frequency stability:

dawkins.pdf

## Material-Konstanten

- [Mechanical Loss I](#)
- [Mechanical Loss II](#)

## Coating

- **Crystalline coatings:**
  - Tenfold reduction of Brownian noise in high-reflectivity optical coatings  
, Garrett D. Cole et al., Nature Photonics **7**, 644–650 (2013)
    - Anhang von Cole 2013
  - Optical performance of large-area crystalline coatings  
, M. Marchito et al., Opt. Exp. 6114, Vol. 26, No. 5 (2018)

## Doppelbrechung in kristallinen Spiegelschichten

- ada83.pdf
- bab92.pdf
- jew87.pdf
- Anhang des Cole 2013 Papers

## RAM Optimierung

- zha14.pdf

## Ab wann ist ein Spiegel ein Supermirror?

- Supermirrors:  $R > 99.9999\%$  (<https://www.rp-photonics.com/supermirrors.html>)

## Metamirror

- [Thermal noise of Etalon](#)

## Transfer-Stabilität

- Providing 10–16 Short-Term Stability of a 1.5- $\mu\text{m}$  Laser to Optical Clocks  
, C. Hagemann et. al., IEEE Transactions on instrumentation and measurement, VOL. 62, NO. 6 (2013)
- <https://arxiv.org/pdf/1902.07012.pdf> Transfer-stability von Mehlistäubler zu Siliizum (über zwei Gebäude mit Ethernet-Kabel)

## Kamm-Kamm-Vergleich/Frequenzkamm-Limitierung

- <https://arxiv.org/pdf/1910.04261.pdf>

## Finesse Messung

- Ringdown von Cole:  
supermirror-high-performance-near-and-mid-infrared-crystalline-coatings.pdf

## Frequenzverdopplung

- S. Herbers:  
oe-27-16-23262.pdf

## Darkmatter

- Allgemein  
derevianko\_2016\_j.\_phys.\_conf.\_ser.\_723\_012043\_1\_.pdf
- Cavities  
1808.00540.pdf
- clocks and cavities  
eaau4869.full\_1\_.pdf
- Fiber links  
srep11469.pdf
- GPS  
s41467-017-01440-4.pdf

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