MenloSystems

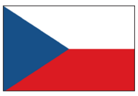
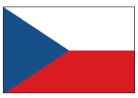
Application Note

5 Metrology Lasers, 3 Countries, 3 Days, 1 SmartComb

Authors: Benjamin Sprenger (Menlo Systems), Martin Wolferstetter (Menlo Systems), Michael Matus (BEV Vienna), Roman Fira (SMU Bratislava), Petr Balling (CMI Prague)

DESCRIPTION

Menlo Systems went on tour to three national metrology institutes (NMIs) to demonstrate the capability of the SmartComb for laser calibration. The device was boxed up, and driven 1500 km from Munich to Vienna to Bratislava to Prague and back. A total of five metrology lasers were calibrated during the tour.

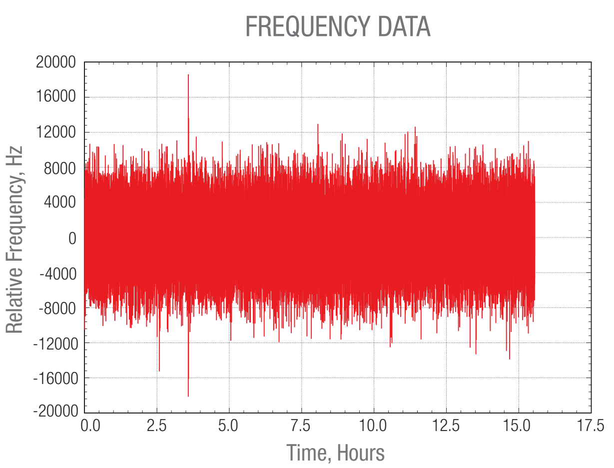
COUNTRY	INSTITUTE	LASER TYPE
	BEV, Vienna	Präzisions-Messtechnik Iodine-stabilized HeNe
	BEV, Vienna	Winters Model 100 Iodine-stabilized HeNe
	SMU, Bratislava	Agilent 5519B Zeeman-stabilized HeNe
	CMI, Prague	CMI Iodine-stabilized HeNe (f and d transitions)
	CMI, Prague	Acetylene-stabilized DFB laser at 1542 nm

The definition of the meter has been realized via Iodine-stabilized Helium-Neon lasers over the past few decades [1]. NMIs worldwide use these lasers either directly in interferometric length measurements, or they are used to calibrate other commercial and cheaper lasers, such as Zeeman-stabilized Helium-Neon lasers. Several transitions in $^{127}I_2$ (iodine) vapor overlap with the 1 GHz gain band of the Helium-Neon gas mixture, and preferably the a_{16} or "*f*" component of the R(127) 11-5 transition is used to define the meter. Since this stabilized laser frequency can drift a few kHz over several months, it is necessary to have comparisons and calibrate the absolute value. Optical frequency combs have been used for almost two decades to measure the frequency against the SI-unit of the second, by locking the comb to a Cesium clock.
Recent advances in frequency comb technology at Menlo Systems have shrunk the size from complicated frequency chains that required an entire optical lab in the 1990s, to Ti:Sapphire based combs, to fiber-based combs, all the way to a compact 19" 3U SmartComb device including all electronics and optics necessary for measurement of the 633 nm light from such a Helium-Neon laser.

FIRST STOP: VIENNA

The first stop of the SmartComb Tour was BEV in Vienna (Bundesamt für Eich- und Vermessungswesen). Dr. Michael Matus and his colleagues started out with the first commercial Ti:Sapphire comb from Menlo Systems back in 2002, followed by nearly ten years of using an FC1500-250 from Menlo Systems to regularly calibrate Helium-Neon lasers. Their two commercial iodine-stabilized Helium-Neon lasers were measured (Präzisions-Messtechnik Dr. Ulrich Hoppe PMT-HE-96 "BEV-1", and Winters Electro-Optics Model 100 "BEV-2"). The SmartComb was connected to the local 10 MHz Hydrogen Maser reference, which is regularly calibrated against their Cesium clock. A measurement was conducted over 16 hours over night on BEV-1 as shown in **Fig. 1**. The result showed +3.088(27) kHz as compared to the recommended value of 473 612 353 604 kHz, which had previously been confirmed in a measurement using the FC1500-250 resulting in +3.139(75) kHz. A similar measurement was conducted on BEV-2 over a 70-minute measurement of the transition, confirming the previously measured value.

SIXTEEN HOUR MEASUREMENT OF BEV-1 f-TRANSITION



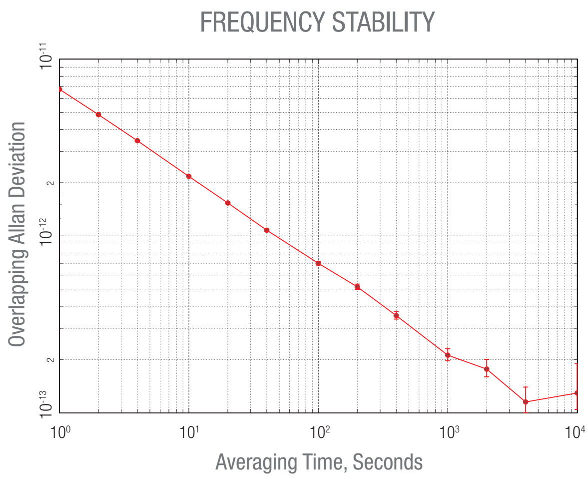


Fig. 1: Left: Raw data, Right: Allan Deviation

SECOND STOP: BRATISLAVA

Dr. Roman Fira has been working in length metrology for many years at the Slovak Institute of Metrology (SMU, Bratislava). Since their Winters Model 100 Iodine-stabilized laser was currently being refurbished, instead a direct measurement of a Zeeman-stabilized Helium-Neon laser was conducted (Agilent 5519B). This laser is well-known in commercial interferometers, and direct calibration could be very convenient. The 6 mm wide beam was coupled into a single-mode PM fiber, and then directly connected to the SmartComb. The proof-of-principle demonstration was limited by the stable quartz which was used as a 10 MHz reference, since the Cesium clock was not available. Nonetheless we could confirm the previously calibrated value which was performed several years earlier against an Iodine-stabilized HeNe laser. The SmartComb made the measurement so easy, that the intermediate step of measuring a beat with a laser which itself is calibrated to the comb is unnecessary. Plugging into the SmartComb and measuring only takes a few minutes, making these extra steps unnecessary. Prior knowledge of the laser frequency to 50 MHz allows a direct measurement using the SmartComb. Alternatively, the mode number that is being used for the measurement can be determined using a wavemeter or the SmartComb itself by measuring with two different repetition rates and solving for the mode number *n*. [2]

THIRD STOP: PRAGUE

Finally, the SmartComb was used in two labs at the Czech Metrology Institute (CMI, Prague) under the supervision of Dr. Petr Balling. A homebuilt Iodine-stabilized Helium-Neon laser was set to the f-transition, and later to the d-transition as a second test.
The SmartComb was referenced to a stable Rubidium-clock, which is disciplined to GPS for long-term stability and traceability to the SI second. The offset from the recommended value was identical to that measured with Dr. Balling's Ti:Sapphire frequency comb from Menlo Systems. The fifth metrology laser to be measured was a $^{13}C_2H_2$ (acetylene)-stabilized DFB laser at 1542 nm. The Erbium femtosecond laser in the SmartComb has fundamental light at this wavelength, so simply plugging in the fiber resulted in a strong beat that could be counted as shown in **Fig. 2**. The recommended value for such a stabilized laser is 194 369 569 384 kHz [3]. The calibration showed a tiny offset of -1.918(207) kHz from this value in literature, thereby demonstrating the SmartComb capabilities and the fiber laser performance.

MEASUREMENT OF ACETYLENE-STABILIZED DFB LASER

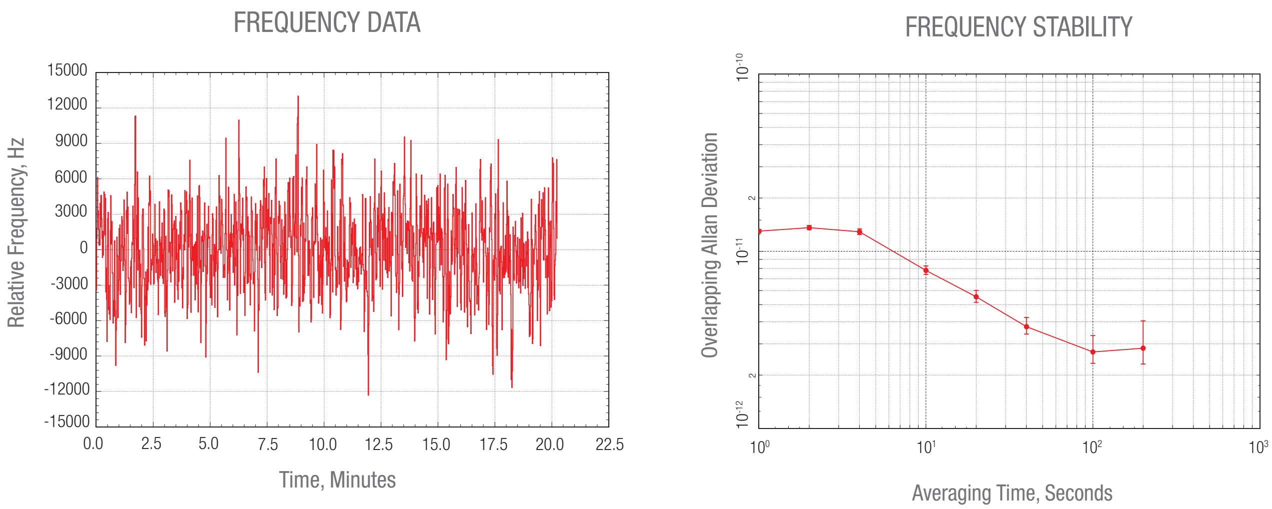


Fig. 2: Left: Raw data, Right: Allan Deviation

The first few visits have shown that the SmartComb is a versatile and robust tool, that makes calibration of lasers as easy as using a wavemeter, nevertheless providing a direct link to the SI second. Simply plug in a fiber-coupled laser, and start the calibration measurement. Rough roads and a night in the 5°C car didn't harm the SmartComb at all.
Please contact us to have a live demonstration in your lab.

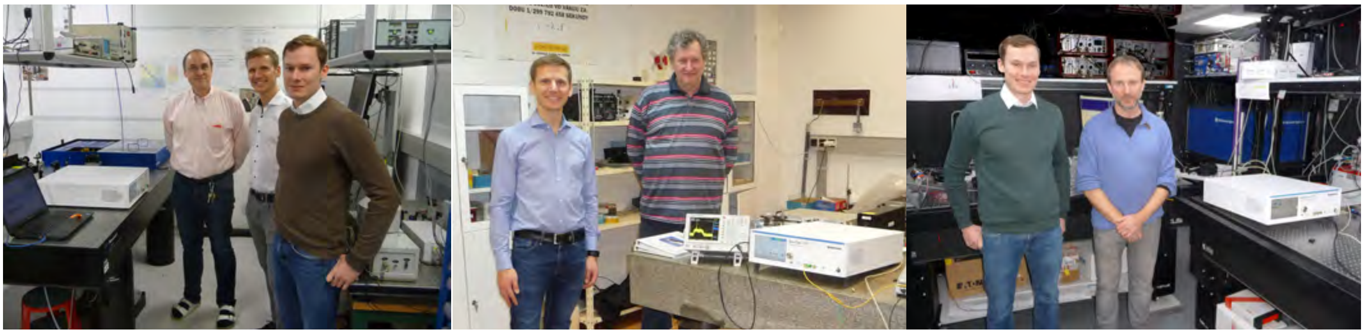


Fig. 3: The SmartComb in the labs of:
Dr. Michael Matus at BEV in Vienna (left), Dr. Roman Fira at SMU in Bratislava (middle), and Dr. Petr Balling at CMI in Prague (right).

PUBLICATIONS

[1] "Practical realization of the definition of the metre, including recommended radiations of other optical frequency standards (2001)," T. J. Quinn, Metrologia 40, 103 (2003)

[2] "A new method to determine the absolute mode number of a modelocked femtosecond-laser comb used for absolute optical frequency measurements," L. Ma et al., IEEE J. Sel. Top. Quantum. Electron. 9, 1066 (2003)

[3] "Recommended Values of Standard Frequencies for Applications Including the Practical Realization of the Metre and Secondary Representations of the Second, Acetylene," BIPM 2007,
https://www.bipm.org/en/publications/mises-en-pratique/standard-frequencies.html

WEBLINKS

Institutes websites:

BEV in Vienna (Bundesamt für Eich- und Vermessungswesen) www.bev.gv.at

Slovak Institute of Metrology (SMU, Bratislava) www.smu.sk

Czech Metrology Institute (CMI, Prague) www.cmi.cz

CONTACT

Contact person: Dr. Benjamin Sprenger
Email address: b.sprenger@menlosystems.com
www.menlosystems.com

Menlo Systems GmbH
Am Klopferspitz 19a
D-82152 Martinsried
Germany
T: +49 89 189 166-0
F: +49 89 189 166-111