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White Paper

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Menlo Systems' Optical Reference System (ORS): Design and Performance

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System description

The Optical Reference System (ORS) consists of a laser locked to a stable high-finesse cavity made of ultra low expansion (ULE) glass. In the ORS1500 range fiber lasers are used and in the ORS-DL range interference filter cateye design external cavity diode lasers from MOGLabs are used. The compact design allows for integration of high vacuum, temperature stabilization, vibration and acoustic isolation into a 19" system while delivering state-of-the-art laser linewidth and stability. Additionally, the system design includes a mechanical locking feature which allows for transportation of the system without the need to readjust the beam coupling into the cavity, once the mechanism is disengaged.

The system features:

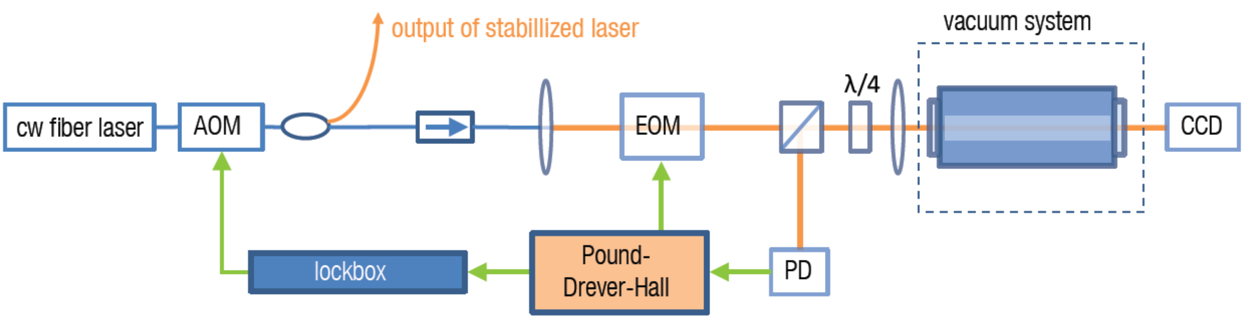
- ultra high finesse cavity (spacer and mirrors) made out of ULE glass
- temperature stabilization of the cavity
- complete ConFlat flange sealed Ultra-High Vacuum (UHV) system
- mechanical transportation lock which allows for setting up and displacing the system without optical readjustment
- active vibration isolation platform
- acoustic isolation
- SYNCRO lockbox using the Pound-Drever-Hall locking scheme

Specifications:

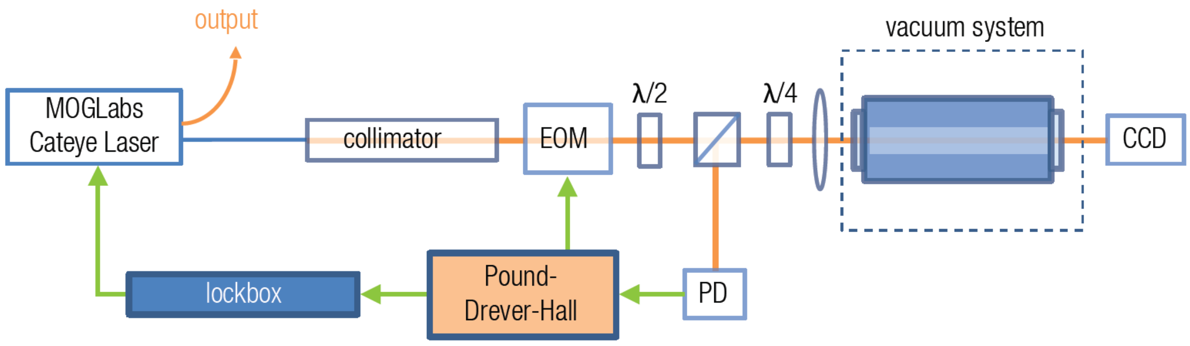
	ORS1500	ORS-DL
wavelength	1542 and 1064 nm, others on request	657, 689, 698, 729 nm, and many others from 400 nm to 1650 nm*
output power	> 5 mW	> 10 mW
finesse of cavity	> 250 000	> 250 000
linewidth of stabilized laser	< 1.0 Hz	< 1.0 Hz
stability: Allan deviation (1 s)	$< 2\times10^{-15}$	$< 2\times10^{-15}$
linear drift rate	approx. 150 mHz/s	approx. 150 mHz/s
pressure in vacuum system	$< 1\times10^{-7}$ mbar	$< 1\times10^{-7}$ mbar

*for a complete list please refer to: www.moglabs.com/cateye-diode-laser.html

ORS1500 system schematic

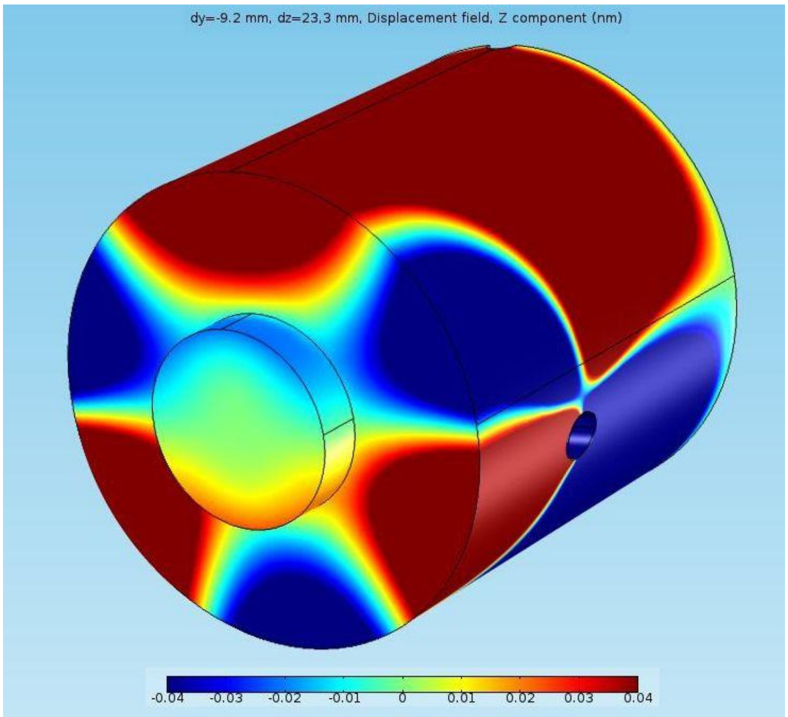


ORS-DL system schematic



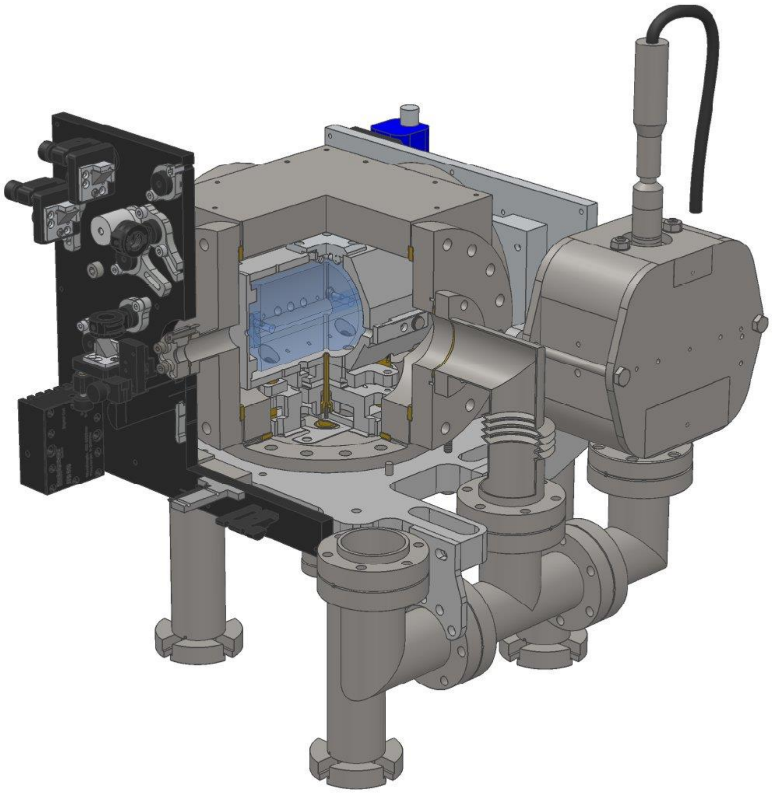
FEM simulation of suspension points of ULE cavity

The plot below shows the result of a Finite Element Method (FEM) simulation of one half of the ULE cavity assembly. The length change in axial direction due to the influence of 1 g of vertical acceleration is color coded, with regions which expand towards the mirrors shown in red. The numeric scale is nanometers. With the four suspension points (only one is visible in the plot) being at their ideal positions, the relative distance of the two opposing mirrors is minimal with respect to a change in vertical acceleration.



Assembly drawing of the ORS system

The ULE cavity is held in the center of a DN100 vacuum chamber, being surrounded by an active thermal shield. Parts of the incoupling and Pound-Drever-Hall optics are visible on the left side. The 10 l/s ion getter pump is mounted in an upright position.



Pictures of the control electronics and cavity system:

Dimensions:

Control rack: 12 U (rack unit) 19”

Cavity system rack: 600×600×1000 mm^3 (width × depth × height)

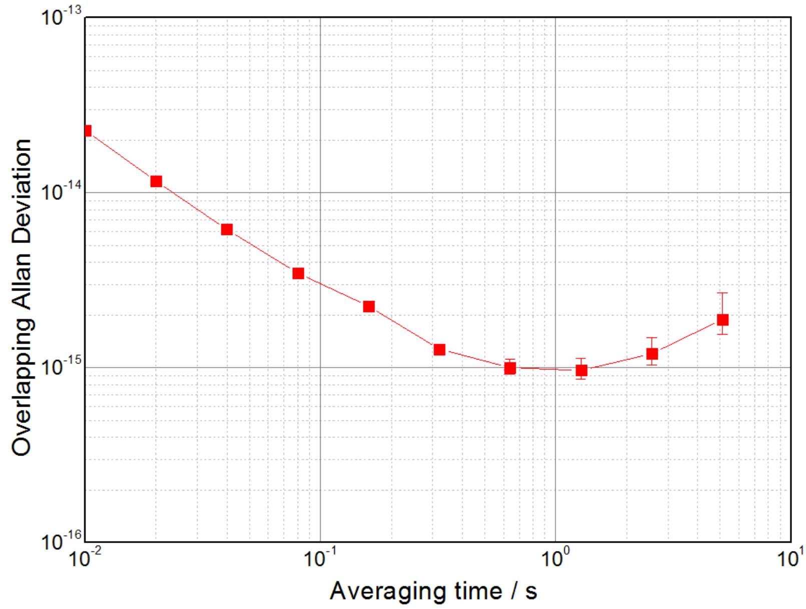
The control rack consists of: oscilloscope, ion getter pump controller, LCD displaying the output of the beam camera, a SYNCRO lockbox, PDH electronics and laser controller. In the ORS1500 system the cw laser and the AOM are also included in the control rack.

The cavity system rack consists of: vacuum system with optical incoupling and outcoupling platforms (see assembly drawing for details), MDF box for acoustic and thermal isolation and active vibration isolation platform.

Performance of the ORS: Comparing an ORS1500 (1542 nm) against an ORS-DL (698 nm)

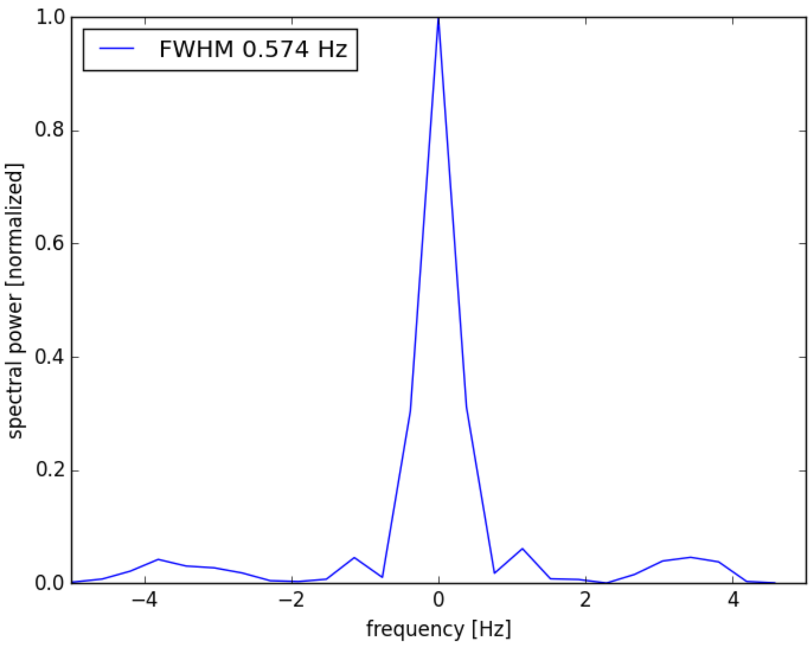
Stability

Below the stability of the optical beat between an ORS1500 (1542 nm) and an ORS-DL (698 nm) can be seen. The purity of the ORS1500 was transferred to 698 nm using an FC1500-250-ULN Ultra Low Noise Optical Frequency Comb. The beat was mixed to 10 MHz, bandpass filtered (bandwidth: 3.8 MHz) and subsequently counted with a K + K FXE counter (10 ms gate time). The Allan deviation at 1 s is $< 2\times10^{-15}$ (linear shrinking drift of the cavities removed).



Linewidth

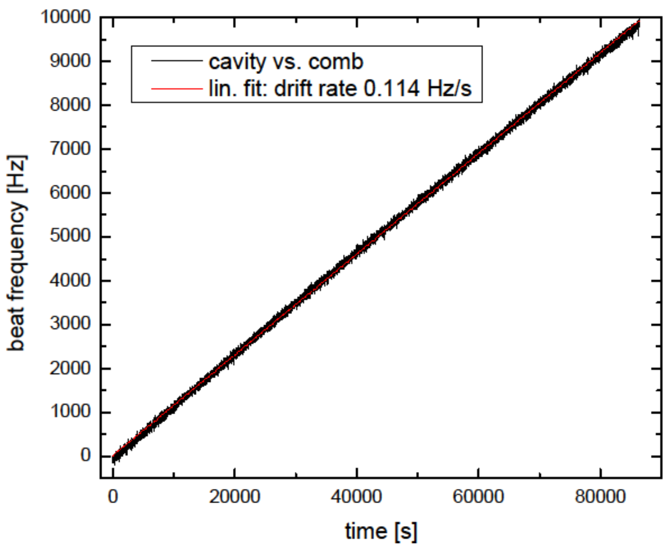
The linewidth of beat was measured by mixing it down 5 kHz and subsequently sampling and FFT analyzing it. The linewidth of the ORS1500 (1542 nm) and the ORS-DL (698 nm) beat is < 0.6 Hz (see graph below).



The beat of two ORS1500 systems at 1542 nm gives a linewidth of < 0.3 Hz.

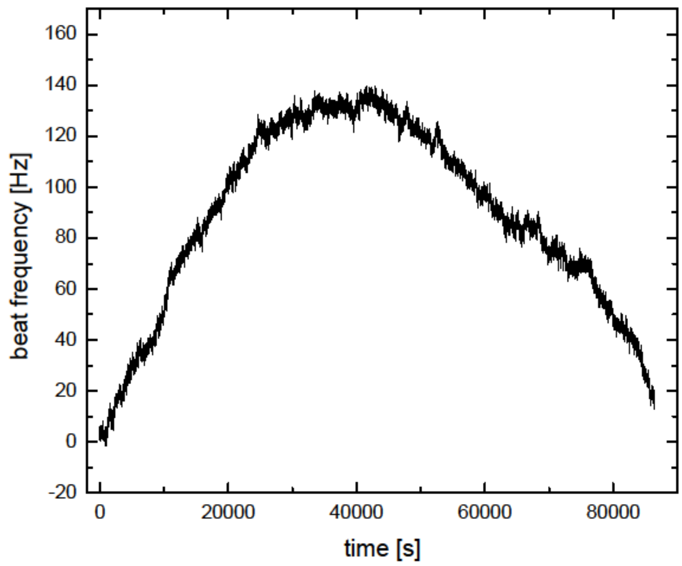
Linear drift rate

The graph below shows a beat measurement during one day of an ORS1500 against a comb which was referenced by a hydrogen maser. The linear drift behavior is typical for ULE glass, which shrinks due to a recrystallization process. In this system, the average linear drift rate was found to be 114 mHz/s.



Long term stability

The graph below shows a beat measurement between two ORS1500 systems. A differential linear drift rate of 85 mHz/s was removed. There is a remaining nonlinear drift of 130 Hz peak-peak over one day which comes from the temperature change in the laboratory of 1-2 °C over one day.



CONTACT INFORMATION

Author

Maurice Lessing is the product manager of the ORS series. He received his PhD from the University of St Andrews and the National Physical Laboratory, where he developed his expertise in frequency metrology. He has several years of experience in low noise microwave synthesis using optical frequency combs and in time- and frequency transfer via optical fiber links.

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