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Miniaturized optical frequency reference enabled by additively manufactured technical ceramics

The FBH develops miniaturized physics packages towards portable and robust quantum sensing devices, ready to be used outside the lab. By integrating optical and electrical components as well as atomic systems into compact and stable platforms, field-deployable quantum technologies are enabled for a wide range of applications – from precision sensing and timekeeping to quantum control and fundamental research.

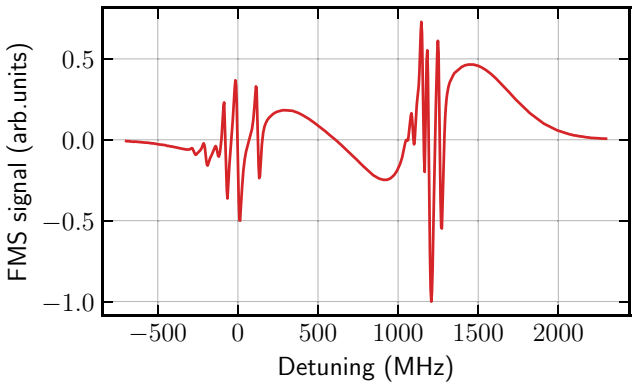
A compact optical frequency reference module

CerAMRef is a fiber-coupled optical frequency reference module providing a doppler-free spectrum of the rubidium (Rb) D2-line at 780 nm for convenient laser locking.

The spectroscopy system is micro-integrated on a 3D-printed Al_2O_3 micro-optical bench with a Rb vapor cell. The compact design includes photodiode and readout-electronics. In operation, the device consumes just ~1 W electrical power for temperature stabilization and electronics. With a laser stabilized onto the CerAMRef using frequency modulation spectroscopy, a relative frequency instability of 3 x 10^{-12} at 1 s averaging time is demonstrated – well suited for a broad range of applications in quantum technologies.

Features

- system volume & mass: 6 ml, 15 g
- convenient system integration & signal generation
- rel. frequency instability < 3 x 10^{-12} @ 1 s shown
- adaptable to other alkali gas species



Doppler-free frequency modulation spectrum of the Rb D2 line, obtained with the CerAMRef reference module and plotted over the frequency detuning. This spectrum exhibits features from the ^{87}Rb D2 F = 2 → F′ and ^{85}Rb D2 F = 3 → F′ transitions.

Micro-integrated CerAMRef spectroscopy module. The micro-optical bench and enclosure lid are 3D-printed from Al_2O_3 ceramics.

Applications

- cold atom quantum sensors
- optical atomic clocks
- frequency metrology
- optical calibration

Profile

The Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) researches electronic and optical components, modules and systems based on compound semiconductors. In the field of III-V electronics, it manufactures high-frequency devices and circuits for communications, power electronics, and sensor technology. Moreover, FBH develops light sources from the visible to the UV spectral range: high-power diode lasers, UV light sources, and hybrid laser systems. Applications range from medical technology, materials processing and sensors to optical communications in space and integrated quantum technology. In close cooperation with industry, its research results lead to cutting-edge products.

The institute is a member of the Leibniz Association and part of Research Fab Microelectronics Germany (FMD).