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AN ULTRA-STABLE FREQUENCY REFERENCE FOR SPACE APPLICATIONS BASED ON MOLECULAR IODINE

Abstract

Future space missions require for ultra-stable optical frequency references. Examples are the gravitational wave detector LISA/eLISA (Laser Interferometer Space Antenna), the SpaceTime Asymmetry Research (STAR) program, the aperture-synthesis telescope Darwin and the GRACE (Gravity Recovery and Climate Experiment) follow on mission exploring Earth's gravity. As high long-term frequency stability is required, lasers stabilized to atomic or molecular transitions are preferred, also offering an absolute frequency reference. Frequency stabilities in the 10^{-15} domains at longer integration times (up to several hours) are demonstrated in laboratory experiments using setups based on Doppler-free spectroscopy. Such setups with a frequency stability comparable to the hydrogen maser in the microwave domain, have the potential to be developed space compatible on a relatively short time scale.

We present the development of ultra-stable optical frequency references based on modulation-transfer spectroscopy of molecular iodine. Noise levels of $2{\cdot}10^{-14}$ at an integration time of 1 s and below $3{\cdot}10^{-15}$ at integration times between 100 s and 1000 s are demonstrated with a laboratory setup using an 80 cm long iodine cell in single-pass configuration in combination with a frequency-doubled Nd:YAG laser and standard optical components and optomechanic mounts. The frequency stability at longer integration times is (amongst other things) limited by the dimensional stability of the optical setup, i.e. by the pointing stability of the two counter-propagating beams overlapped in the iodine cell.

With the goal of a future space compatible setup, a compact frequency standard on EBB (elegant breadboard) level was realized. The spectroscopy unit utilizes a baseplate made of Clearceram-HS®, a glass ceramics with an ultra-low coefficient of thermal expansion of $2{\cdot}10^{-8}\mathrm{K}^{-1}$. The optical components are joint to the baseplate using adhesive bonding technology. This setup ensures a higher long-term frequency stability due to enhanced pointing stability. Also, it takes into account space mission related

criteria such as compactness, robustness, MAIVT and environmental influences (shock, vibration and thermal tests). We present first measurements of the EBB setup and a first design of an iodine frequency standard on engineering model (EM) level. The EM-setup is based on the EBB experience, but features smaller dimensions by using a multipass iodine cell and less optical components.

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