Laser frequency reference for 1064 nm based on molecular iodine – towards space qualification

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Optical frequency references are essential tools for future space missions using laser interferometric detection and ranging, such as e.g. GRACE-FO/NGGM or eLISA/NGO. Besides optical cavities, transitions in atoms or molecules are excellent for laser frequency stabilization to the noise levels required by these missions, below 100 Hz/√Hz at Fourier frequencies of 1 Hz to 1 mHz.

For laser frequency stabilization, we frequency double the radiation of a Nd:YAG laser at a wavelength of 1064 nm using fiber-coupled waveguide SHG modules and stabilize the laser to hyperfine transitions in molecular iodine near 532 nm. With the goal of a space qualified frequency reference, we have realized an engineering model (EM) of an iodine spectroscopy setup. The optical assembly is realized on a baseplate made of fused silica with dimensions of $38\times18\times4$ cm^3 using an adhesive bonding technology with a space-qualified two-component epoxy. A special designed multipass-cell allows for an effective absorption length of 90 cm in a compact design, which provides balanced detection of the spectroscopy signal, detection of residual amplitude modulation and power detection.

We report on environmental tests applied to the EM, including vibrational loads of 25 g_{rms} and thermal cycling between -20 °C and +60 °C. Further we report on the performance before and after the environmental tests.

The frequency stability achieved with this setup is determined from beat note measurements with a similar setup and a cavity stabilized laser system. The relative frequency stability is better than 1×10^{-14} at 1 s and averages down to below 5×10^{-15} at 10 s averaging time, the frequency noise already fulfils the requirements of the GRACE-FO and LISA mission (Fig 1).

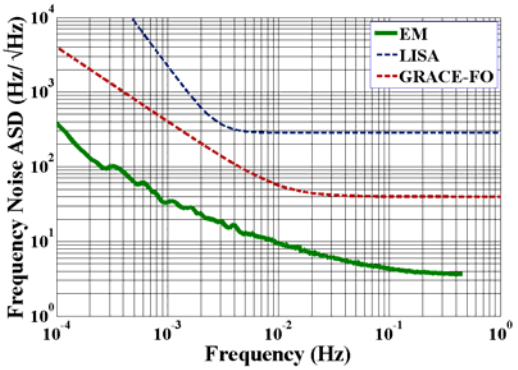

Fig. 1: Frequency noise amplitude spectral density of the beat note between two Nd:YAG lasers stabilized to the EM and an optical cavity, respectively.

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