Towards Compact, Robust and Highly Stable Optical Frequency References for Space Applications

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State-of-the-art optical frequency references like ion clocks have demonstrated frequency stabilities at the 10^{-18} level and below [1]. With these new technologies, many applications will benefit for either time or distance measurements. In terrestrial applications, optical references are already replacing microwave references, but for space applications, optical references are not yet as widely used because reliability, size, weight, and power budgets are key considerations in addition to the performance.

One technology already being used for space missions is optical cavities. Optical cavities can offer high short-term stability, small volumes, low power consumption and comparable low complexity, making them suitable for communication applications or interferometry. With current frequency stabilities at the 10^{-17} level on short timescales for terrestrial applications and 10^{-15} for space applications there is still a need for development. In addition, cavities have the disadvantage of being relative references, which limits their suitability to applications where long-term stability or absolute frequency knowledge is not required. Here, absolute frequency references are the technology of choice, based on the principle that a laser is stabilized to an atomic or molecular transition, resulting in high long-term stability and absolute frequency knowledge, but at the cost of reduced short-term stability and more complex setups.

At the DLR Institute of Quantum Technologies, in cooperation with the Universities of Bremen and Ulm, frequency references covering both, short- and long-term stability are currently under development with a focus on space compatibility. One well known - and compared to ion clocks less complex technology of an absolute reference - is doppler-free spectroscopy of molecular iodine. This technology already demonstrated frequency stabilities at the 10^{-15} level for integration times > 100 s in laboratory experiments, has been flown on a sounding rocket and is currently being further developed to be launched within the COMPASSO project to the ISS Bartolomeo platform in 2025, becoming the first optical clock in space [2]. On the other hand, the further development of a high finesse optical cavity towards space compatibility is ongoing, which should fulfill the requirements of future gravity missions and global navigation satellite systems. Both technologies together can form, in a near future, a so-called hybrid lock, which would offer the advantages of both technologies and would thus be an enrichment for many applications, as a next step [3].

We will present the ongoing development of both, the cavity setup towards space compatibility as well as a broad outline of our evolution of the iodine technology towards the COMPASSO project. Finally, a brief overview of the hybrid lock will complete this presentation.

References

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