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SATELLITE TEST OF THE SPECIAL AND GENERAL RELATIVITY THEORY: A PROPOSAL

Abstract

We propose a small satellite mission that aims for testing the foundations of special relativity. It will perform a Kennedy-Thorndike (KT) experiment, where a potential boost anisotropy of the velocity of light is measured by comparing a length reference (i.e. a highly stable optical resonator) with a molecular frequency reference. This experiment in space increases its sensitivity significantly (factor of >100) with respect to an equivalent terrestrial test. A sensitivity of 10^{-18} in the measurement of the Kennedy-Thorndike coefficient is targeted.

The experiment uses state-of-the-art laser technology. For realizing a small satellite compatible payload, the use of diode-laser technology is favorable and currently already under investigation with respect to other space experiments. A laser wavelength of 1030/1016nm is foreseen as its second harmonics accesses narrow linewidth transitions in molecular iodine. For the KT experiment, one laser is stabilized to a high finesse cavity and a second laser is frequency doubled to a wavelength of 515/508nm and stabilized to a hyperfine transition in molecular iodine. Both lasers are directly compared in a beat measurement and analyzed with respect to a possible boost dependency of the speed of light.

In the last years, we realized an iodine-based frequency reference at a wavelength of 532nm on elegant breadboard (EBB) level where a frequency stability of 10^{-15} at 1000s integration time was demonstrated in a beat measurement with a laboratory-type cavity setup. In a current activity the iodine frequency reference is further developed with respect to compactness and thermal and mechanical stability. A compact iodine setup on engineering model (EM) level is currently developed. This setup uses a fused

silica baseplate with dimensions of 18cm x 38cm x 4cm where the optical components are directly glued to. This setup uses a 10cm x 10cm iodine cell in nine-path configuration and will be subjected to environmental tests such as vibration and thermal cycling.

In a parallel activity, the development of a space compatible optical resonator setup with a finesse of 10^5 of the resonator and a controlled temperature stabilization of $\sim 1\mu$K is planned.

Techniques for laser frequency stabilization are key technologies not only for the proposed KT experiment mission but also for a variety of other future space missions such as LISA/NGO, GRACE-FO, and missions using aperture-synthesis such as Darwin/TPF.