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IN-ORBIT-VERIFICATION OF OPTICAL CLOCK TECHNOLOGIES

Abstract

Optical frequency references are an essential tool for many applications in space, including Earth observation, fundamental physics and navigation and ranging. They are either needed as light source for a high-sensitivity inter-spacecraft optical metrology system, as part of a payload enabling tests of fundamental physics or as a high accuracy timebase for global navigation satellite systems (GNSS). Examples are the space-based gravitational wave detector LISA (Laser Interferometer Space Antenna), future missions measuring the Earth's gravitational field within the NGGM (Next Generation Gravity Mission) program and the proposed space-based test of Special Relativity BOOST (BOOst Symmetry Test). Furthermore, new concepts for satellite navigation foresee optical frequency references in combination with optical links used for synchronization, communication and ranging.

Technology development for future operation of optical frequency references in space is currently carried out where crucial design parameters are compactness and rigidity. First setups of iodine-based frequency references on Elegant Breadboard (EBB) and Engineering Model (EM) level have been realized in a cooperation of DLR Bremen, University of Bremen and Humboldt-University Berlin and a compact iodine reference was successfully flown on a sounding rocket within the project JOKARUS, lead by HU Berlin. A long-term stable cavity-based system is currently developed at DLR Bremen/ University of Bremen in the context of the BOOST mission; development of an Engineering Model in the context of NGGM and as clock laser for an optical clock is currently ongoing within the OSRC (Optical Stabilizing Reference Cavity) project by ESA. Optical terminals are commercially provided by Tesat GmbH, developed in cooperation with DLR Oberpfaffenhofen.

We present a specific mission concept for in-orbit verification of optical frequency references on a small satellite in low-Earth orbit, called COFROS (Compact Optical Frequency References on a Satellite). The payload consists of an iodine- and a cavity-based frequency reference, together with an optical frequency comb and a GNSS receiver and, eventually, an optical terminal. The optical frequency references are operated at a wavelength of 1064 nm and directly compared in a beat measurement. Additionally, both references are compared to GNSS (GPS; Galileo) via the optical frequency comb and the GNSS receiver. The optical link is used for synchronization of a ground-based oscillator to the space-based optical frequency reference. A first mission scenario was worked out and a preliminary budget estimation shows compatibility with the DLR compact satellite bus.