A microwave-optical local oscillator for future applications in space

I. Ernsting[1], Q.-F. Chen[1], M. Cardace[1], A. Nevsky[1], S. Schiller[1],
U. Sterr[2], Th. Legero[2], B. Lipphardt[2], S. Häfner[2], H. Schnatz[2]

[1]Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany
[2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany

E-mail: alexander.nevsky@uni-duesseldorf.de

Future atomic clocks in space will need optical radiation with ultra-stable frequency that is transformed to ultra-stable microwave radiation for transmission of the frequency information of an optical clock to ground, or for delivering a low-noise local oscillator to a microwave clock. A system of this type, composed of cavity-stabilized laser, 1.5 µm fiber frequency comb, and microwave generation subunit, has been proposed for the STE-QUEST mission. A specification of this system is a 9.5 GHz signal with phase noise of -90 $dBrad^2/Hz$ at 1 Hz offset, and -115 $dBrad^2/Hz$ at 100 Hz.

Here, we present the development of a breadboard demonstrator of such a system. The ultra-stable laser is a Nd:YAG laser stabilized to a 10 cm long ULE cavity with a finesse of 500 000. A special frame holding the resonator and a compact vacuum chamber were developed in order to achieve low vibration sensitivity and tolerate a rocket launch. A compact and rigid optical setup for laser frequency stabilization including is assembled on a miniature breadboard and attached to the vacuum chamber. The frequency instability was less than 3×10^{-15} for integration times below 20 s, determined using a three-cornered-hat method with two additional resonator-stabilized lasers.

In order to generate the microwave, we phase-lock a fiber comb to the 1064 nm laser wave. The comb's repetition rate is detected using a highly linear photodiode. The microwave signal (9.5 GHz) is a 37^{th} harmonic of the frequency comb repetition rate. A DRO is phase-locked to it and generates a high-power signal S1. In order to characterize precisely the phase noise of the microwave generation process, we have developed a second microwave generation system, based on a Ti:Sapphire frequency comb and locked to the same 1064 nm wave. A high-power microwave signal S2 is generated in a similar way as before. The relative phase noise between the two signals S1, S2 will indicate the quality of the generation process. The results of this measurement in progress will be reported at the meeting.

The research leading to these results has received funding from the Bundesministerium für Wirtschaft und Technologie (Germany) under project no. 50OY1201.