OPTICAL FREQUENCY STANDARD DEVELOPMENT IN SUPPORT OF NASA'S GRAVITY-MAPPING MISSIONS

W.M. KLIPSTEIN, D.J. SEIDEL, AND B.C. YOUNG
Jet Propulsion Laboratory, Pasadena, California

We have begun constructing all-solid-state laser systems at 778 nm and at 532 nm in support of a satellite-based gravity-mapping mission tentatively planned to fly in 2007. In each case the lasers will be stabilized at short times to high-finesse Fabry-Perot cavities similar to those of Ref. 1. At longer times the 778 nm laser will be stabilized to the 2-photon transition in rubidium [2,3]. In the 532 nm system, a frequency-doubled Nd:YAG laser with a non-planar ring oscillator (NPRO) design will be frequency-locked to a molecular iodine line [4]. By developing two separate candidate systems with proven performance we intend to maximize the probability of success for this mission-critical system development.

The EX-5 mission is a follow-on to NASA's Gravity Recovery and Climate Experiment (GRACE), which will map changes in the Earth's mass distribution due, for example, to changes in the polar ice caps, large aquifers, and major ocean currents over its five-year mission lifetime. The map is generated by precise ranging between two satellites separated by 50-100 km and flying in a low earth polar orbit. The GRACE metrology uses a microwave source derived from a 5 MHz quartz crystal oscillator specified to have Allan deviation $< 2 \times 10^{-13}$ from 1-100 s and $< 5 \times 10^{-13}$ out to 1000 s. The resolution of the metrology is expected to be limited by an on-board accelerometer as well as by oscillator noise. Improved performance of EX-5 will derive from an improved accelerometer design and an improved intra-satellite optical link. To support this improvement the lasers should have Allan deviation $< 1 \times 10^{-13}$ from 1-1000 s, but with the goal of significantly improved stability, carried out well beyond an orbit (5500 s). There is essentially no requirement on accuracy for these systems.

References:

[1] B.C. Young, F.C. Cruz, W.M. Itano, and J.C. Bergquist, "Visible Lasers with Subhertz Linewidths," *Phys. Rev. Lett.* **82**, p. 3799 (1999).
[2] D. Touahri, *et al.*, "Frequency measurement of the $5S_{1/2}(F=3) - 5D_{3/2}(F=5)$ two-photon transition in rubidium," *Optics Comm.* **133**, p. 471 (1997).
[3] J.E. Bernard, *et al.*, "Absolute Frequency Measurement of a laser at 1556 nm locked to the $5S_{1/2} - 5D_{5/2}$ two-photon transition in ^{87}Rb," *Optics Commun.* **173**, p. 357 (2000).
[4] J.L. Hall, *et al.*, "Stabilization and Frequency Measurement of the I2-Stabilized Nd:YAG Laser," *IEEE Trans. Instrum. Meas.* **48**, p. 583 (1999).

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Corresponding author:
William Klipstein
MS 298-100
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
USA
phone 818 354 2245
Fax 818 393 6773
klipstein@jpl.nasa.gov