FY24 Strategic Initiatives Research and Technology Development (SRTD)

Laser and Optical System for Miniaturization and Space Qualification of Quantum Sensors

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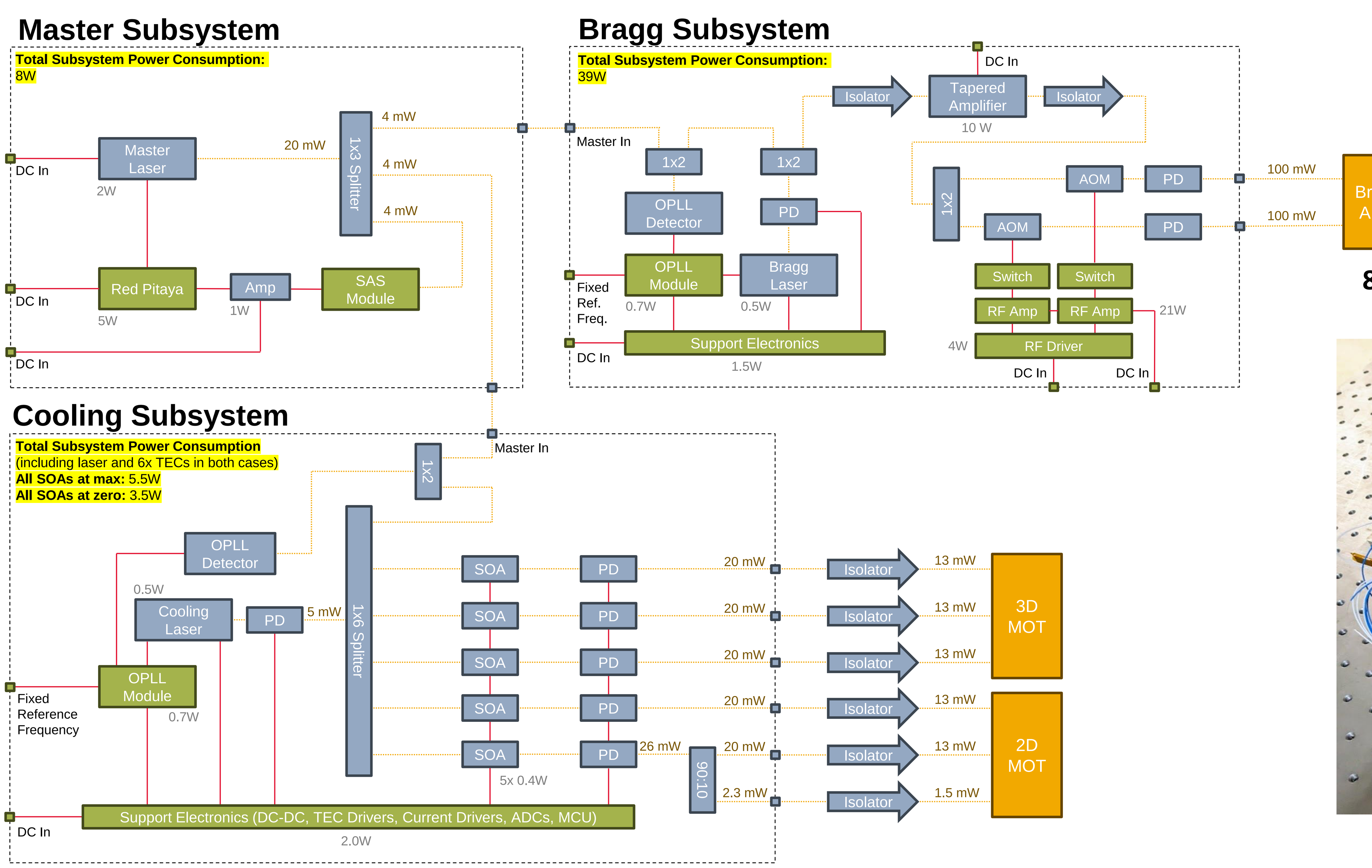
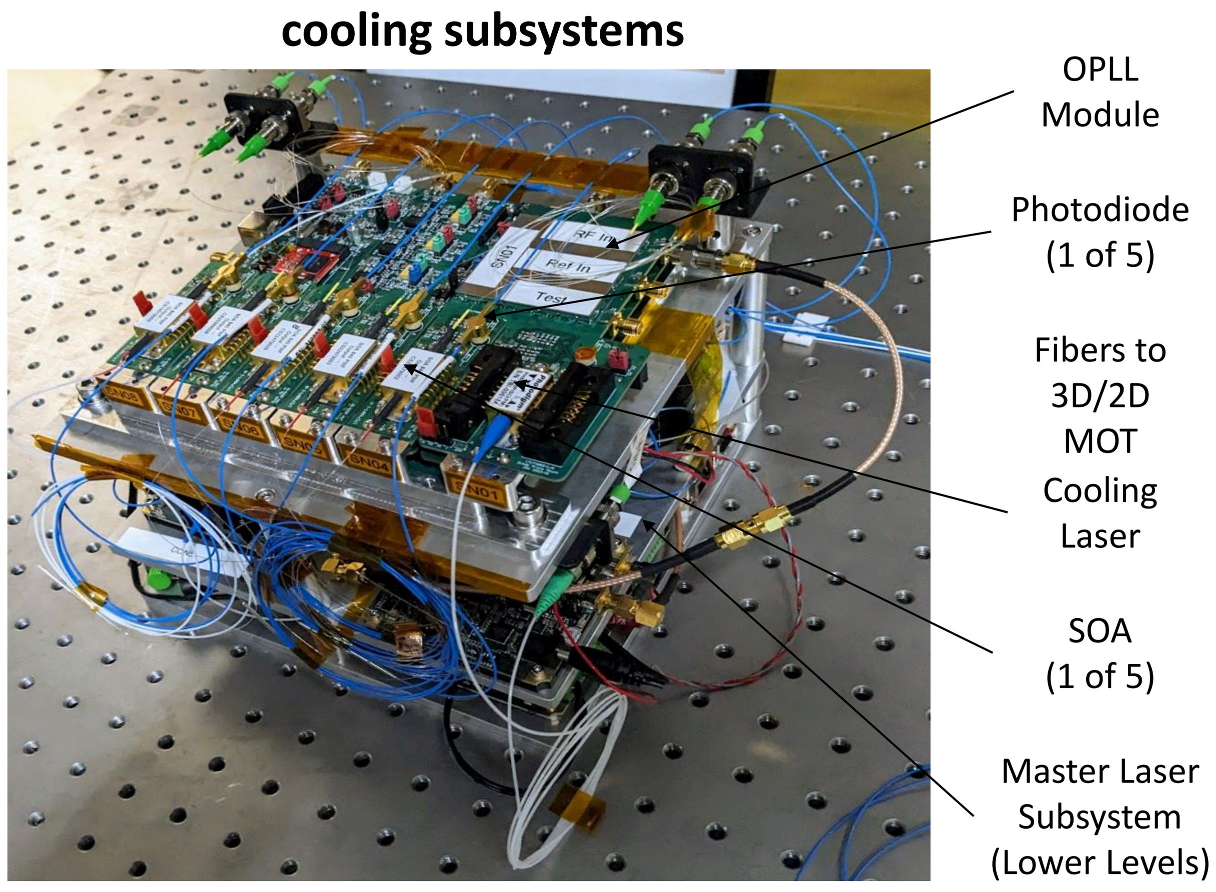
Strategic Focus Area: Quantum Sensing for Science Missions **| Strategic Initiative Leader:** Edward T Chow

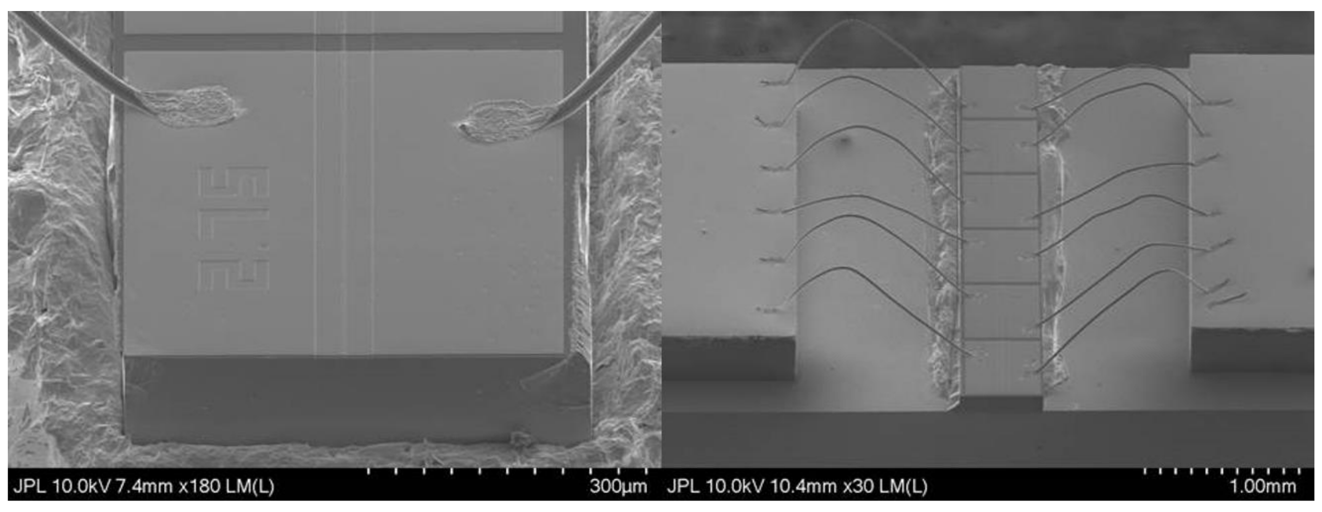
Objectives: This effort seeks to develop a robust, low-SWaP semiconductor-based laser and optical system (LOS) to support cold-atom quantum sensors. This LOS is targeted for application of an atom-interferometer-based gravimeter, which will enable high-precision remote gravity measurements, while its architecture is readily applicable to other cold-atom instruments such as clocks and Rydberg radar. The target volume is <0.01 m 3 , and the total power consumption requirement is <100 W, compared to >250 W typically needed in current experiments including NASA/JPL's Cold Atom Lab (CAL). Through this effort, we have matured a novel system architecture that supplies eight frequency-locked beams for 2D and 3D magneto-optical trap formation and interferometry. Each beam is targeted for operation around 852 nm for a Cesium atom interferometer-based gravity gradiometer, and achieves narrow laser linewidth (<150 kHz), wavelength referencing using a miniaturized atomic vapor cell, frequency tunability of >5 GHz, and rapid frequency agility of ~100s of MHz in <1 ms, as well as intensity and path control, and integration with custom path-to-flight drive electronics. Current efforts are focused on integration of auxiliary functionalities for atom interferometry and maturation of novel constituent component technologies, targeting maturation of current laboratory-scale atom interferometer experiments into a compact path-to-flight module.



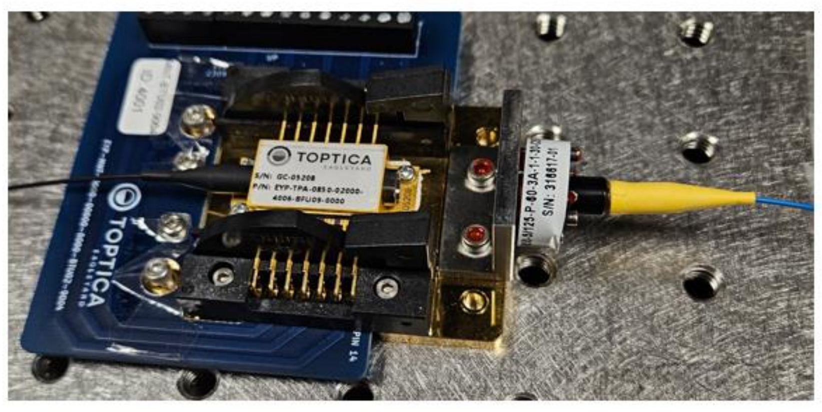
Left: Block diagram for the laser and optical system including three main subsystems including master subsystem for absolute frequency referencing, cooling subsystem for 2D and 3D magneto-optical trap control, and Bragg subsystem which generates high-power frequency-locked optical pulses for interferometry. Below: Photograph of LOS prototype.

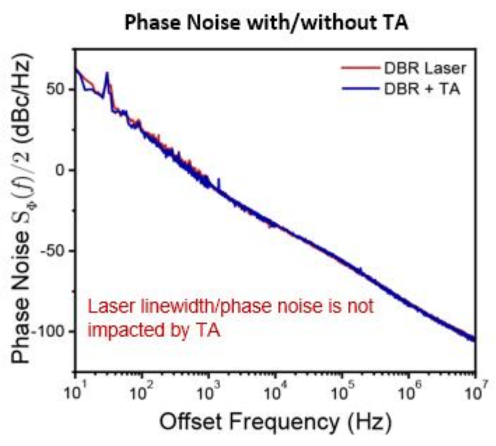
8x8x6 inch cube containing master and cooling subsystems





Electron micrographs of high-power 852 nm semiconductor amplifier/laser chips fabricated at JPL's Microdevices Laboratory.





(left) Butterfly-packaged tapered amplifier (TA) with custom fiber-coupling of the output beam for generation of optical powers up to 500 mW with small form-factor. (right) Experimental measurements showing that the seed laser phase noise level is maintained by the TA.

Currently, the new control electronics for the Bragg subsystem are implemented as an add-on mezzanine board, which includes DDS signal generator, preamplifier, and RF power amplifiers to drive two acousto-optic modulators for pulse synthesis.

Publications: Mahmood Bagheri, Jonathan Hunacek, Eric Kittlaus, Mehdi Langlois, Hani Nejadriahi, Firat Yasar, Sheng-wey Chiow, Nan Yu, and Siamak Forouhar, "All-semiconductor-based systems for atom interferometry experiments in space," JOSA B 41(9) 1979-1986 (2024).

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