quency mixing is proportional to Q^3. Therefore, it is important to know both the maximally achievable finesse and quality factor values of a resonator.

Whispering gallery mode (WGM) resonators are capable of achieving larger finesse compared to FP resonators. For instance, fused silica resonators with finesse 2.3×10^6 and 2.8×10^6 have been demonstrated. Crystalline WGM resonators reveal even larger finesse values, $\mathscr{F} = 6.3 \times 10^6$, because of low attenuation of light in the transparent optical crystals. The larger values of $\mathscr{F}$ and Q result in the enhancement of various nonlinear processes. Low-threshold Raman lasing, optomechanical oscillations, frequency doubling, and hyper-parametric oscillations based on these resonators have been recently demonstrated. Theory predicts a possibility of nearly 10^{14} room-temperature optical Q-factors of optical crystalline WGM resonators, which correspond to finesse levels higher than 10^9. Experiments have shown numbers a thousand times lower than that. The difference occurs due to media imperfections.

To substantially reduce the optical losses caused by the imperfections, a specific, multi-step, asymptotic processing of the resonator is implemented. The technique has been initially developed to reduce microwave absorption in dielectric resonators. One step of the process consists of mechanical polishing performed after high temperature annealing. Several steps repeat one after another to lead to significant reduction in optical attenuation and, as a result, to the increase of Q-factor as well as finesse of the resonator which demonstrates a CaF_2 WGM resonator with $\mathscr{F} > 10^7$ and $Q > 10^{11}$.

This work was done by Lute Maleki of OE Waves and Anatoliy Savchenkov, Andrey Matsko, and Vladimir Iltchenko of Caltech for NASA's Jet Propulsion Laboratory.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Management Office–JPL. Refer to NPO-45053.

Ultra-Stable Beacon Source for Laboratory Testing of Optical Tracking

A prototype laser beacon assembly provides reference for testing tracking and pointing systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

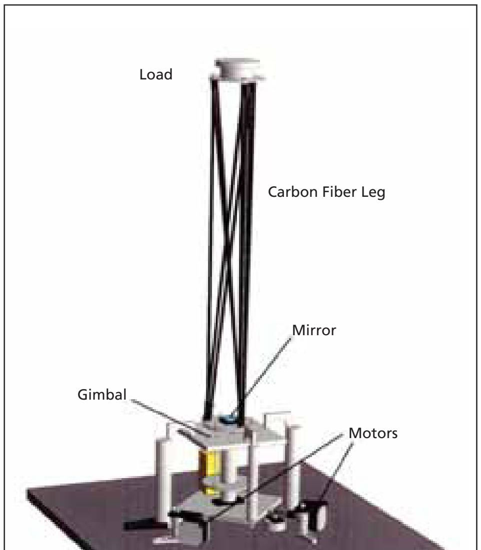
The ultra-stable beacon source (USBS) provides a laser-beam output with a very low angular jitter and can be used as an absolute angular reference to simulate a beacon in the laboratory. The laser is mounted on the top of a very short (≈1 m) inverted pendulum (IP) with its optical axis parallel to the carbon fiber pendulum leg. The 85-cm, carbon fiber rods making up the leg are very lightweight and rigid, and are supported by a flex-joint at the bottom (see figure). The gimbal-mounted laser is a weight-adjustable load of about 1.5 kg with its center of rotation co-located with the center of percussion of the inverted pendulum. This reduces the coupling of transverse motion at the base of the pendulum to angular motion of the laser at the top.

The inverted pendulum is mounted on a gimbal with its center of rotation coinciding with the pivot position of the inverted pendulum flexure joint. This reduces coupling of ground tilt at the inverted pendulum base to motion of the laser mounted at the top. The mass of the top gimbal is adjusted to give the pendulum a very low resonant frequency (≈10 mHz) that filters transverse seismic disturbances from the ground where the base is attached.

The motion of the IP is monitored by an optical-lever sensor. The laser light is reflected by the mirror on the IP, and then is detected by a quadrant photo-detector (QPD). The position of the beam spot on the QPD corresponds to the tilt of the IP. Damping of this motion is provided by two coil and magnet pairs.

The bottom gimbal mount consists of two plates. The IP is mounted on the second plate. The first plate is supported by two posts through needles and can be rotated about the axis connecting the tips of the needles. The second plate hangs from the first plate and can be rotated about the axis perpendicular to the first plate. As a result, the second plate acts as a two-axis rotation stage. Its center of rotation is located at the effective bending point of the flex-joint. The second plate is pressed against two screw actuators by the weight of the IP. The screw actuators are orthogonal to each other and are used to adjust the inclination of the second plate. The actuators are driven by stepper motors.

The whole IP system is housed in a box made of Lexan plastic plates to provide isolation from air currents and temperature variations. The signals from the sensors are processed and recorded with a PC using the xPC Target realtime environment of MathWorks. The control algorithms are written using the Simulink package from The MathWorks.



In the **Inverted Pendulum** configuration, an additional gimbal is mounted at the top with a laser at the center of rotation. The laser provides the outgoing beacon source.

This work was done by Yoichi Aso and Szabolcs Marka of Columbia University and Joseph Kovalik of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45127.