A Chip-scale Optomechanical Accelerometer for Inertial Navigation Suitable for Small Satellites

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High-precision inertial sensing and gravity sensing are core technologies that enable oil exploration, mapping, obstacle avoidance, navigation, and are widely used on space vehicles (SVs). Modern navigation systems integrate signals from a Global Navigation Satellite System (GNSS), such as the global positioning system (GPS), with an inertial navigation system (INS), and signals of opportunity, which complement each other for correct attitude and velocity determination. However, as the SV orbit is higher above the surface of the Earth, having access to GNSS signals become more challenging, and is subject to availability. Therefore, the navigation system should rely more on the INS and especially on the sensors that it integrates. The core of the INS is the inertial measurement unit (IMU), which is composed of accelerometers and gyroscopes used to measure the specific forces and angular rate in the vehicular inertial reference frame. High performance accelerometers and inertial sensors usually require big masses and weights, as this is proportional to the measured force, and do not scale well with size. Therefore, IMUs used in projects like the Apollo Missions (i.e. ST-124) used to weight tens of pounds. Current trends in miniaturization and microfabrication have improved this setup, and strapdown IMUs like the ones from recently missions to Mars have a weight of less than 9 pounds, but this value is still larger compared to the requirements for small satellites.

In order to achieve a high performance INS/IMU that could be used in systems with strict weight and size requirements, here we present an optomechanical inertial accelerometer sensor with 8.2-μ*g*/Hz$^{1/2}$ velocity random walk (VRW) at acquisition rate of 100 Hz and 50.9 μ*g* bias instability. The presented solid-state implementation uses coherent readout and provides advantages such as high sensitivity and narrow linewidth, compared to previous techniques. When driven into optomechanical sustained-oscillation, the optomecahnical accelerometer's slot photonic crystal cavity provides radio-frequency readout of the optically-driven transduction with enhanced sensitivity. When compared to other techniques, the current representation of the optomechanical accelerometer measures the optomechanically-stiffened oscillation shift produces by the parametric driving optical field, instead of the resonance shift in the optical transmission.