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A COLD ATOM INTERFEROMETRY SENSOR PLATFORM BASED ON DIFFRACTIVE OPTICS AND INTEGRATED PHOTONICS

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***Abstract*— We report the current progress in the development of a compact, deployable cold atom interferometry sensor platform towards atomic sensors for position, navigation, and time (PNT) applications. A simplified atomic sensor head with diffractive optics, an alignment-free optical package, and photonic-integrated-circuit (PIC) compatible laser architecture [1] are essential for its compactness and deployability. This cold atom sensor platform can be generally applied to gravimeters, accelerometers, gyroscopes, and clocks, and the sensor platform includes significant engineering efforts in the development of grating-mirror magneto-optical traps (G-MOTs), vibration-immune structural design, custom titanium vacuum package with passive pumping, silicon photonics multi-channel on-chip single sideband modulators, and a feedforward technique to extend the dynamic range of the atom interferometer inertial sensors.**

Keywords—atom interferometer; cold atoms; magneto-optical trap; integrated photonics)

We demonstrated a rubidium grating-mirror MOT (GMOT) [2] with Sandia-fabricated grating chips and measured the microwave response of the GMOT with Doppler-sensitive Raman beams. Sub-Doppler cooling process and high data-rate measurement (40Hz) [3,4] were demonstrated in a custom Ti vacuum chamber (Fig. 1). We are pursuing cold atom interferometry experiments with the PIC-compatible laser architecture with four fiber-optic channels using fiber-coupled commercial off-the-shelf (COTS) devices such as IQ modulators, optical amplifiers, and second harmonic generator frequency doubler, which minimizes optical channels and requisite components. In addition, there are significant efforts in the development of heterogeneously integrated PICs for the cold atom sensor platform with silicon photonics, amplification with III-V gain materials, and second harmonic generation. We demonstrated a four-channel optical single sideband (SSB) modulator on a silicon PIC at 1560 nm with a high extinction ratio and a high carrier-injection modulation [1], which can dynamically control laser frequencies and intensities during the experimental sequence of a cold atom interferometer. A software-based modulator bias controller regulates the drift of cascaded dual-parallel Mach-Zehnder modulators within the SSB modulator. We envision in a fully integrated system, in which 30 on-chip SSB modulators can be applied to a 6-degree-of-freedom (DOF) matterwave inertial measurement unit (IMU). For high dynamic conditions, we also explore atom interferometry feedforward control with a 6-DOF IMU cosensor to estimate atomic states and compensate potential

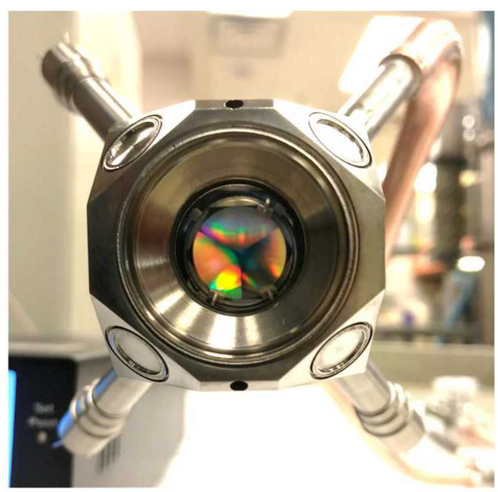

Fig. 1. Fig 1. (above) Image of the custom titanium vacuum chamber looking through the window to show the grating for the G-MOT. The clear apperture of the window is 1.9 cm.

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issues such as reduced signal, increased calibration errors, and null-detection events due to Doppler shift and lateral atomic motion.

These on-going efforts toward a compact, deployable cold atom interferometry sensor platform will enable matterwave inertial navigation sensors and could find use in other cold-atom sensors.

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