# Performance of a Point Source Atom Interferometer Gyroscope

Azure Hansen [1], Yun-Jhih Chen [1,2], Moshe Shuker [1,2], Rodolphe Boudot [1,3], Eugene Ivanov [1,4], Gregory W. Hoth [1,2 *], Bruno Pelle [1,2 †], John E. Kitching [1], Elizabeth A. Donley [1]
1. Time and Frequency Division, National Institute of Standards and Technology, Boulder, CO 80305 USA
2. University of Colorado Boulder, Boulder, CO 80309 USA
3. FEMTO-ST, CNRS, 26 Rue de l'Epitaphe, 25030, Besançon, France
4. University of Western Australia, Perth, WA, Australia

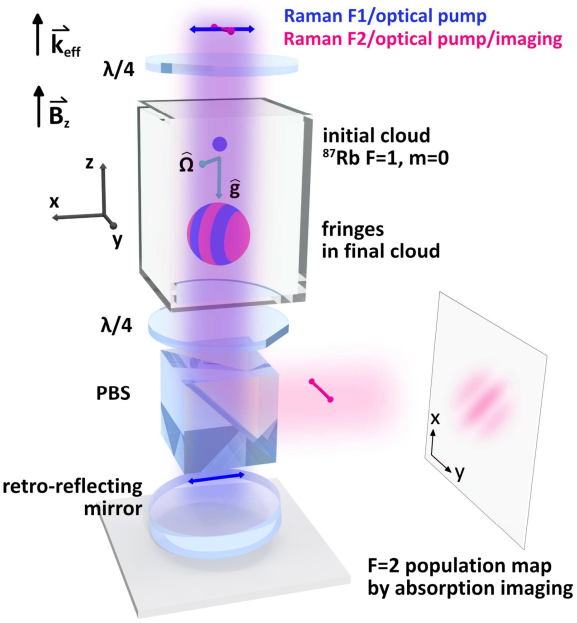
*Abstract*—**Point source atom interferometry, employing optical Raman pulses and a cold atom source, enables measurements of rotation and acceleration in a compact experimental package. This system is uniquely sensitive to rotations in the plane perpendicular to the Raman beamline. Here we discuss our experiment's sensitivity, stability, systematic errors, and other performance-limiting factors both fundamental and technical. Our current measurements for the sensitivity to the magnitude and direction of the rotation vector are 0.6 mrad/s and 5 mrad, respectively.**

***Keywords—quantum sensors, atom interferometry, gyroscope***

Matter wave interferometry facilitates precision measurements of fundamental physics, but its utility in practical devices has been limited due to the size and complexity of such instruments until recently. The development of a compact gyroscope for navigation that is sufficiently sensitive and precise remains an important goal. The technique of point source atom interferometry (PSI) [1] is promising for a gyroscope device, as the setup is simplified (see Figure 1) compared to other light atom interferometer pulse gyroscope systems. It has the additional advantage that the measurement inherently measures two axes of rotation and one axis of acceleration simultaneously.

PSI makes use of the ballistic expansion of the cold atom cloud to generate a fringe pattern from which rotation and acceleration are measured. Three collinear and counter-propagating Raman pulse pairs (see Figure 1) act as optical beamsplitters and mirrors, creating a Mach-Zehnder-like interferometer for each atom, which accumulates a phase dependent on its velocity vector and the inertial forces applied to the system. When the cloud is imaged, these parallel interferometers generate a phase gradient across the atom cloud, leading to fringes in the atomic spin state population. The orientation and frequency of the fringes measures the component of the rotation vector in the plane perpendicular to the Raman beams, as shown in Figure 2. The phase of the fringes measures the acceleration parallel to the Raman beams.

Fig. 1. Illustration of the compact point source atom interferometer gyroscope setup. The Raman beamline is oriented along gravity (z axis) and the magnitude and direction of rotation is measured in the plane perpendicular to the beams (xy plane). Rotations can be simulated by tilting the piezo-driven retro-reflecting mirror. The atom cloud is imaged onto a camera and the fringe pattern indicates the magnitude of acceleration along z and the magnitude and orientation of the rotation vector in the xy plane.



The performance of our compact PSI-based device is limited by a variety of effects, including the interrogation time of the interferometer Raman pulse sequence, the phase noise of the Raman beams (90 mrad at 1 s), the vibrations of the Raman optics (62 mrad at 1 s), the dead time of the experiment, systematic errors relating to the atom cloud not being an ideal point source, and others [2]. For our current experimental setup and parameters, the measured sensitivity to the magnitude and direction of the rotation vector is 0.6 mrad/s and 5 mrad, respectively. Our estimates of the shot-noise-limited performance for an ideal point source gyroscope are 2 µrad/s and 50 µrad at 1 s.

[*] Present address: Department of Physics, University of Strathclyde, Glasgow, United Kingdom.

[†] Present address: MUQUANS, Institut d'Optique d'Aquitaine, rue François Mitterrand, 33400, Talence, France.

Our current work focuses on measuring, modeling, optimizing, and correcting for performance-limiting effects with the goal of creating a compact atom interferometer gyroscope in mind. Improvements being pursued include creating a smaller and more uniform initial atom cloud with an optical dipole trap, the reduction of the Raman laser phase noise with a different frequency chirping scheme, active vibration isolation, and modeling the effect of initial cloud size and shape on the scale factor.

Fig. 2. Absorption images of interference fringes generated by simulated rotation. Left: $\Omega_y$ = 35 mrad/s. Center: $\Omega_x = \Omega_y$ = 25 mrad/s. Right: $\Omega_x$ = 89 mrad/s.

## ACKNOWLEDGMENT

A. H. was supported under an NRC Research Associateship award at NIST. R. B. was supported by the NIST Guest Researcher Program and the Délégation Générale de l'Armement (DGA). This work was funded by NIST, a U. S. government agency, and is not subject to copyright.

## REFERENCES

[1] S. M. Dickerson, J. M. Hogan, A. Sugarbaker, D. M. S. Johnson, and M. A. Kasevich, "Multiaxis inertial sensing with long-time point source atom interferometry," Phys. Rev. Lett. **111**, 083001 (2013).

[2] G. W. Hoth, B. Pelle, S. Riedl, J. Kitching, and E. A. Donley, "Point source atom interferometry with a cloud of finite size." Appl. Phys. Lett. **109**, 071113 (2016).