Enhancing atom-interferometric inertial sensors in dynamic environments using robust control

R. P. Anderson
J. C. Saywell, M. S. Carey, P. S. Light, S. S. Szigeti, A. R. Milne, K. Gill, M. L. Goh, V. S. Perunicic, N. M. Wilson, C. D. Macrae, A. Rischka, P. J. Everitt, N. P. Robins, M. R. Hush, M. J. Biercuk

Q-CTRL Pty. Ltd., Sydney, NSW Australia

russell.anderson@q-ctrl.com

We experimentally demonstrate tailored light pulses that improve the sensitivity of a cold-atom interferometric accelerometer. We designed and implemented these error-robust pulses in software using quantum control techniques to mitigate noise sources that can severely inhibit operation in dynamic environments inherent to onboard applications. Our results show that these robust pulse sequences improve the fringe visibility of an order-3 Bragg-pulse atom interferometer by a factor of 3X over conventional Gaussian pulses, using an atomic source with a broad momentum width of nearly two photon recoils. We also verified their scale factor through absolute measurements of Earth's gravity with 2X enhanced precision. Furthermore, when we introduced laser intensity noise that varied up to 20% from pulse-to-pulse to mimic the effect of lateral platform accelerations, our robust control solution preserved phase sensitivity while the utility of the Gaussian pulses collapsed. This improvement delivered a 10X increase in measurement precision of an applied acceleration. These results show for the first time that software-defined quantum sensing can preserve the useful performance in operating regimes where conventional operation is severely degraded, providing a pathway to augment the performance of current and next generation cold-atom inertial sensors in real fielded settings [1].

References

[1] J. C. Saywell, *et al.*, arXiv:2303.03683 (2023)

Figures

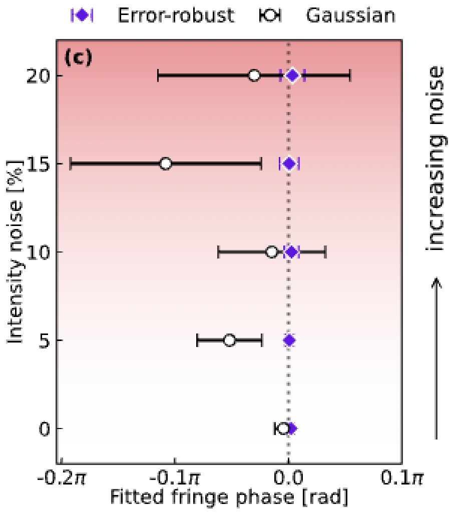

Figure 1: Measured phases of a T = 5 ms order-3 Bragg atom interferometer for different values of applied intensity noise using conventional pulses (black) and error-robust pulses (purple).

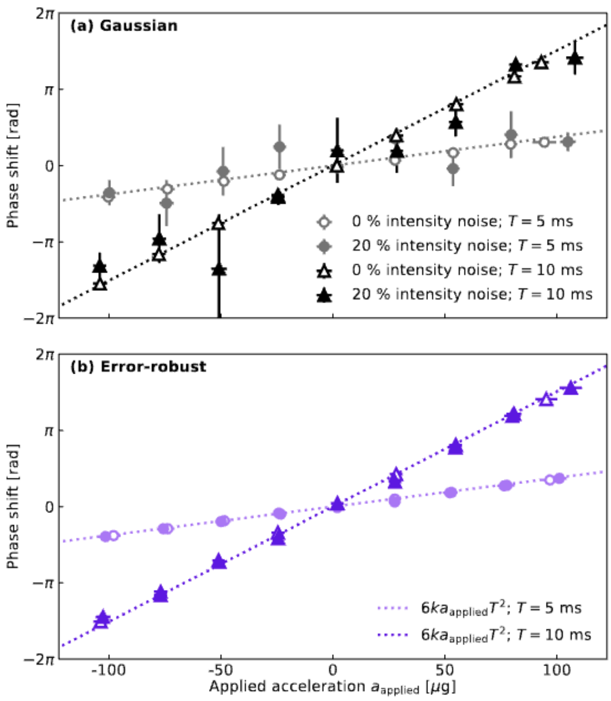

Figure 2: Measured phases of an order-3 Bragg atom interferometer for variable applied acceleration in the presence of 0 and 20% laser intensity noise, using conventional (black) and error-robust (purple) interferometer pulse sequences with T = 5 and 10 ms.