Dual-species atomic interferometric sensor for simultaneous inertial measurement and clock operation

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Positioning, navigation and timing technologies play a crucial role in various applications [1]. Quantum devices utilizing atomic interference, including gyroscopes, accelerometers and clocks [2-5], offer notable advantages such as high sensitivity, precision, and independence from external signals, thereby exhibiting substantial potential for PNT applications.

In this paper, we propose a scheme utilizing dual-species atoms that integrates atomic interferometric inertial sensors and the atomic clock into a unified system. The counter-propagating atomic beams both comprise two Rubidium isotopes. Specifically, the counter-propagating ^{87}Rb atomic beams enable Mach-Zehnder interference for measuring the rotation rate and acceleration, while the ^{85}Rb atomic beam in one direction serves as the Ramsey clock.

We conducted the Mach-Zehnder interference experiment based on one side of the atomic beam and obtained the interference signal. The atomic beam interacts with three Raman beams, which are spatially separated and can be modulated independently in terms of frequency or phase. By scanning the phase of the first Raman beam, we achieve interference fringes with a contrast of C=0.05, given the spacing of L = 0.27 m between the Raman beams and an interrogation time of T=1.4 ms. The preliminary experimental results have confirmed the system's capability to perform subsequent inertial measurements, thus establishing a foundation for further experiments.

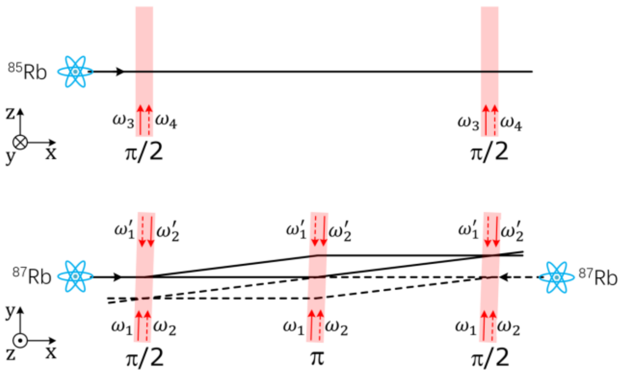

Fig.1. Schematic diagram of the interferometric configuration, including the Ramsey interferometry and the Mach-Zehnder interferometry in two perpendicular planes.

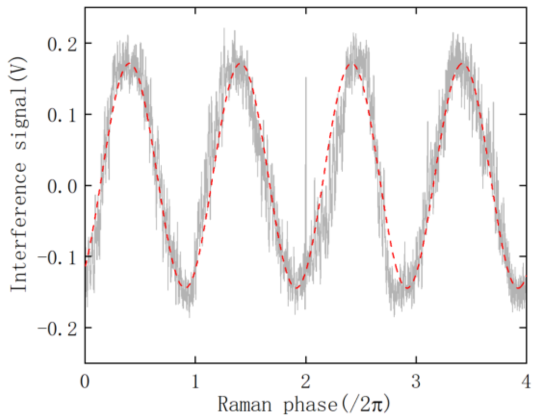

Fig.2. The Mach-Zehnder interference signal obtained by scanning the first Raman beam.

References

[1] Morton, Y. Jade, et al., eds. Position, navigation, and timing technologies in the 21st century: Integrated satellite navigation, sensor systems, and civil applications, volume 1. John Wiley & Sons, 2021.

[2] Gustavson, T. L., A. Landragin, and M. A. Kasevich. "Rotation sensing with a dual atom-interferometer Sagnac gyroscope." Classical and Quantum Gravity 17.12 (2000): 2385.

[3] Takase, Ken. Precision rotation rate measurements with a mobile atom interferometer. Diss. Stanford University, 2008.

[4] Savoie, Denis, et al. "Interleaved atom interferometry for high-sensitivity inertial measurements." Science advances 4.12 (2018): eaau7948.

[5] Kwolek, J. M., and A. T. Black. "Continuous Sub-Doppler-Cooled Atomic Beam Interferometer for Inertial Sensing." Physical Review Applied 17.2 (2022): 024061.