Development of a cold atom absolute airborne gravimeter

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Abstract

Cold atoms inertial sensors are quantum instruments capable of measuring inertial quantities such as gravity, accelerations, or rotations with unprecedent stability, sensitivity and accuracy. Their operating principle is based on atom interferometry.
A gas of atoms is cooled and trapped by lasers to temperatures around the micro-Kelvin in a 3D-MOT and used as the matter wave source in the interferometer.
The atoms are then released from the trap in free fall (in our case) and undergo a series of Raman pulses, $\pi/2$-π-$\pi/2$, that splitdeflect and then recombine the matter wave. The phase at the output of the interferometer allows to access the inertial quantity of interest such as gravity. Several prototypes of onboard cold atom gravimeters were developed and improved over the years leading to numerous campaigns of measurement on ships [1] and planes [2]. The last campaign achieved gravity measurements with a precision of around 1 mGal, equivalent to 10^{-5} m/s^2 [3]. In these demonstrations, a quantum accelerometer was placed on a gyro-stabilized platform that dynamically maintained the sensor's verticality.

Currently, we are seeking to develop a new generation of cold atom gravimeter based on "strap-down" operation, meaning without a gyro-stabilized platform. The advantage of such a system would be to benefit from a lighter, smaller, less expensive, and potentially more precise instrument. The long-term objective is to achieve one or even two orders of magnitude improvement in precision ($10^{-6}/10^{-7}$ m/s^2). Achieving such precise gravimetric measurements would enable to be sensitive to dynamic variations (i.e., temporal variations) in the gravity field, opening up applications in volcanology, groundwater monitoring, earthquakes, and seismic activities, ...

The new configuration of the cold atom gravimeter requires the use of a fiber for the Raman beam in order to use two orthogonal polarizations for the Raman transitions. These two polarizations need to be completely stable over time and stay properly orthogonal for the interferometer to work well. I studied the impact of the vibration of a fiber on the phase noise in multiple configurations to see if the error on the phase could lead to a significant error on the measure of g.

Another part of my work during my first year of thesis, which is an ongoing work, is to characterize the wavefront of the beam and the wavefront aberrations caused by the different optics that will be used in the new gravimeter. While they are being reflected or transmitted by optical elements, such as wave plate, window or mirror, laser beams tend to be distorted and their wavefront is then modified.
The idea is to use a Shak-Hartmann wavefront analyzer to characterize those wavefronts and see if the error could be significant for the measure of g.

References

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