Multi-axis quantum sensor for inertial navigation

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Inertial navigation systems integrate the rotation rates and accelerations from triads of accelerometers and gyroscopes to compute their trajectory in time and determine their position. They are typically limited by bias drifts of their inertial sensors. Our team aims to create mobile bias-free quantum inertial sensors that will, in the future, revolutionize commercial inertial guidance systems by enabling accurate long-term navigation without feedback from satellite-based GPS.

The exploitation of quantum physics allows the development of matter waves interferometers. Like classical optics, the idea is to split and recombine coherently these wave packets thanks to light pulses, to create multiple interfering paths. The phase of the fringes is sensitive to inertial effects due to the mass of the atoms. These quantum sensors have excellent measurement noise and long-term stability which make them candidates for a technological breakthrough in the field of inertial navigation.

Nowadays, substantial technical developments have been done and have allowed to bring to market atom gravimeters and clocks enabling static long-term measurements. Nevertheless, the use of cold atoms sensors for navigation and positioning still needs to solve a lot of scientific and technological challenges such as compliance with onboard applications, compactness, measurement continuity and operation in relevant environments. The research activities of the Joint Laboratory iXAtom bring together the knowledge of a French very high technology company iXblue, expert in photonics and very high-performance inertial navigation systems – and a public laboratory specialized in atom interferometry at the highest worldwide level – LP2N.

After successfully building a multi-axis cold atom interferometer measuring the three components of the acceleration vector, this quantum sensor needs to be fully hybridized with a classical inertial navigation system (INS) to form a new generation of INS without the usual limitation due to the bias drift of the mechanical accelerometers. The hybridization with classical accelerometers and gyroscopes allows in particular to avoid dead times and increase the dynamic range of the quantum sensor to be compliant with inertial navigation.

Moreover, unlike in the laboratory, residual accelerations (vibrations) and rotations of the vehicle can cause strong losses of contrast of the atom interferometer. For this reason, different solutions need to be evaluated, especially for the rotations such as rotating dynamically the reference mirror. Concerning the vibrations, the goal is to implement a real-time hybridization technique relying on the laser phase correction through an FPGA board. The complete hybrid quantum accelerometer is currently being tested on vibrations and rotations platforms before taking it out of the lab and perform on-field measurements.