Sensitivity functions and phase scaling in light-pulse atom interferometers

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We are currently constructing two novel atom interferometers. The first is designed to measure the perturbation caused by a nearby Foucault pendulum, and the second is to demonstrate improved scaling with interferometer time.

Atom interferometers are now firmly established as devices that can measure inertial forces with exquisite precision and stability. These devices are now making the transition from the pristine environment of a laboratory to the more difficult field environment. The field environment presents a long list of challenges that need to be overcome for these devices to be useful. One such challenge is attempting measurements on moving platforms, restricting the averaging time.

We are developing an atom interferometer to address exactly some of the design challenges associated with making precision measurements with limited time. We are constructing the interferometer next to a Foucault pendulum, whose period is about 10.5 seconds. The interferometer is oriented vertically and is designed such that we can conduct experiments over a range of baselines and at any desired position relative to the pendulum. In this way, we can explore the trade-off between making sensitive measurements and sensor size. A longer interferometer will average over an increased fraction of the pendulum swing. Also, the pendulum is not synchronized to the launching of the interferometer, so that averaging over many pendulum cycles will simply average the signal to zero.

To aid in the optimization of the interferometer, we have developed a novel sensitivity function, designed to highlight frequencies to which the interferometer is most sensitive.

We are also constructing a so-called T^3-light pulse interferometer, in which the phase sensitivity scales as T-cubed, where T is the time between laser pulses. Ordinary gravimeters based on atom interferometers have a phase scaling of T^2 but assume the acceleration the atoms experience in each arm is the same. This assumption is valid for most interferometers that use magnetically insensitive transitions; however, we apply a constant magnetic field gradient and use magnetically sensitive transitions, leading to different accelerations in each arm. We know from magnetism theory, a vertical field gradient leads to horizontal field gradients. Crucially, the interferometer must close not only along the vertical direction, but also horizontally. We have developed high-resolution, realistic magnetic models to simulate the field inside our vacuum chamber and utilized our cold atoms to provide verification. We use these models to characterize the open nature of our interferometer.