Quadrature phase detection in atom interferometry

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Cold atom interferometers are among the most sensitive instruments in measuring inertial forces, such as gravity and gravity gradients, accelerations and rotations. The interferometer phase ϕ, representing the inertial measurement, is usually found from its two output ports, $C \pm A\sin(\phi)$. As such, dynamic range is limited to phases of $\phi = [-\pi/2, \pi/2)$, and sensitivity is greatly reduced away from mid-fringe ($\phi = 0$). These limitations challenge the usage of atom interferometers in field conditions.

We present here new interferometer and measurement schemes which together enable full quadrature phase detection, $C \pm A\sin(\phi)$ and $C \pm A\cos(\phi)$ [Fig. 1], in a single experimental run and with a single atomic ensemble.

The scheme relies on replacing the final Raman π/2-pulse with a combination of Raman and microwave pulses [Fig. 2], which result in four output ports in phase quadrature. It is thus applicable to Raman atom interferometers in any configuration, including large momentum transfer. Velocity- and state-dependent detection allows measurement of all four outputs.

Advantages of quadrature detection are numerous: it doubles the dynamic range with constant sensitivity for all phases; it allows complete fringe parameters estimation from a single experiment run, improving robustness to drifts and removing the need for recurring fringe calibration; and it is expected to enhance precision of ellipse-fitting in gravity gradiometer instruments.

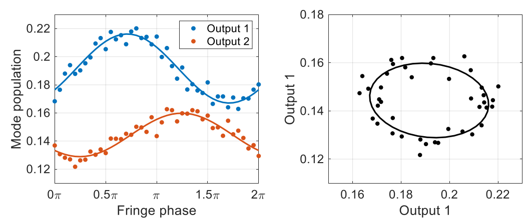

Figure 1: Measurement of two interferometer outputs with π/2 phase shift between them, shown each vs. absolute fringe phase (left) and each vs. the other (right).

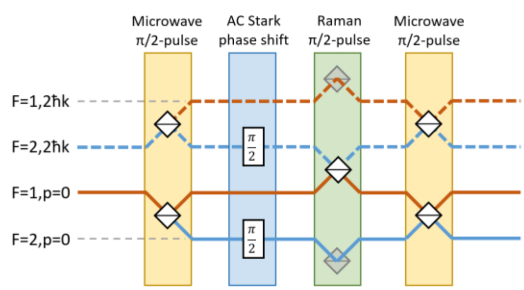

Figure 2: Our composite beam splitter, which creates four quadrature output signals in four atomic states, separated in momentum and internal state.

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