Contribution ID: **5** Type: **not specified**

Gravitational wave detection using cavity-assisted atom interferometry

Friday, 2 March 2018 14:30 (20 minutes)

Atom interferometers employing optical cavities to enhance the beam splitter pulses promise significant advances in science and technology, notably for future gravitational wave detectors. Long cavities, on the scale of hundreds of meters, have been proposed in experiments aiming to observe gravitational waves with frequencies below 1 Hz, where laser interferometers, such as LIGO, have poor sensitivity. The Atom Interferometry group at the Birmingham Institute of Gravitational Wave Astronomy has explored the fundamental limitations of two-mirror cavities for atomic beam splitting, and established upper bounds on the temperature of the atomic ensemble as a function of cavity length and three design parameters: the cavity g-factor, the bandwidth, and the optical suppression factor of the first and second order spatial modes. A lower bound to the cavity bandwidth which avoids elongation of the interaction time and maximizes power enhancement was found. An upper limit to cavity length is also found for symmetric two-mirror cavities. These key limitations impact the feasibility of long-baseline detectors, which suffer from a naturally larger bandwidth and worse optical suppression of higher order optical modes. Our findings will aid the design of current and future experiments using this technology, such as the MIGA experiment in France. In the future we aim to fully model the effect that the imperfect (but cavity-filtered) optical wavefronts have on the atomic transitions.

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Session Classification: Development of Enabling Technologies for Gravitational Wave Detectors