Einstein–Podolsky–Rosen Entangled Interferometers

Daniel W. Gould[a], Vaishali B. Adya[b], Min Jet Yap, Dennis Wilken[c], Robert L. Ward, Bram J. J. Slagmolen[a], David E. McClelland[a], Michle Heurs[c]

[a]*Centre for Gravitational Astrophysics, Australian National University, Canberra, Australia.*

[b]*Department of Applied Physics, KTH Royal Institute of Technology, Stockholm, Sweden.*

[c]*Max Planck Institute for Gravitational Physics, Albert Einstein Institute, Hannover.*

Interferometry has been proposed as the test bed for a range of fundamental physics experiments. Tests of quantum gravity [1, 2], the quantisation of space-time [3] and searches of non-baryonic dark matter [5]. Confirmation of which would be a breakthrough for our understanding of modern physics. These detectors, along with a recent proposal of a large scale interferometer for gravitational wave detection [4], utilize interferometer design and, or are compatible with, heterodyne readout. We investigate methods of quantum enhancement via Einstein–Podolsky–Rosen (EPR) squeezed states in a twin sensor type experiment, a design compatible with many aspects of these proposals.

Two carrier heterodyne interferometry matches the sensitivity performance of homodyne readout. With careful choice of readout frequency it can avoid any low frequency noise sources on the local oscillator. Noise such as, scatter, control noise or any experimental control signals. In this work we aim to enhance the signal to noise ratio of such a readout scheme by the injection of an EPR squeezed state. Each sensor receives one of the entangled pairs such that the signals encoded onto the optical carrier of each sensor can be detected together against an engineered, low noise, quantum state. This allows us to avoid the difficult task of generating squeezed light at low frequencies, instead using high frequency squeezing to enhance low frequency signals.

The science goals of the experiment are to inform and investigate the quantum enhancement of interferometric type detectors with continuous wave EPR squeezed states. However the techniques may have implications not only in the the aforementioned detection techniques, but also in the fields of quantum multiplexing, quantum lithography and space based gravitational wave detection.

[1] Chou, A., *et al.*, *Class. Quantum Grav.* 34 065005 (2017)

[2] Pradyumna, S.T., *et al.*, *Commun Phys.* 3, 104 (2020).

[3] Vermeulen, S. M., *et al.*, *Class. Quantum Grav.* 38 085008 (2021)

[4] Zhang, T., *et al.*, *Phys. Rev. Lett.* 126, 221301 (2021).

[5] Martynov, D. and Miao, H., *Phys. Rev. D*, 101, 095034 (2020)