Laser Interferometer Gravitational Wave Detectors : (Quantum) Opto-Mechanics on the Large Scale

David McClelland
Director, ANU Centre for Gravitational Physics

Research School of Physics and Engineering
The Australian National University
Canberra, 0200, Australia.

ABSTRACT

Gravitational wave detectors using laser interferometry which will begin operation in the next decade will be limited by quantum noise over most of their detection band – quantum radiation pressure noise at low frequencies, quantum shot noise at high frequencies. At the frequency where quantum radiation pressure noise and shot noise are equal in magnitude, the so-called standard quantum limit (SQL) is achieved. Quantum optical techniques such as squeezing will play a major role in improving their sensitivity. Injecting a squeezed vacuum produces entangled light fields in the interferometer arms. At the SQL the position-momentum uncertainty of the mirrors becomes correlated with the quadrature uncertainty of the reflected optical field. Entanglement between the 40 kg scale mechanical system and the optical system may then be observable! Eventually, two such mirrors might be projected via entanglement swapping into an entangled state. This opens the possibility for further studies of the peculiarities of quantum physics on a macroscopic scale.

Such physics using gravitational wave detectors is more than a decade away. To date, no observation of quantum radiation pressure noise has been reported let alone the SQL reached. Gravitational wave researchers are actively building smaller (gram) scale interferometers with a view to observing firstly quantum radiation pressure noise and then the SQL ahead of cooling such gram size mechanical systems to a quantum ground state.

In this talk I will report on progress towards second and third generation gravitational wave detectors and towards the realization of quantum optical effects in smaller gram scale experiments, with a focus on the issues which currently limit performance in such systems.