World Academy of Science, Engineering and Technology
International Journal of Nuclear and Quantum Engineering
Vol:12, No:02, 2018

Using Squeezed Vacuum States to Enhance the Sensitivity of Ground Based Gravitational Wave Interferometers beyond the Standard Quantum Limit

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Abstract : This paper reviews the impact of quantum noise on modern gravitational wave interferometers and explains how squeezed vacuum states are used to push the noise below the standard quantum limit. With the first detection of gravitational waves from a pair of colliding black holes in September 2015 and subsequent detections including that of gravitational waves from a pair of colliding neutron stars, the ground-based interferometric gravitational wave observatories LIGO and VIRGO have opened the era of gravitational-wave and multi-messenger astronomy. Improving the sensitivity of the detectors is of paramount importance to increase the number and quality of the detections, fully exploiting this new information channel about the universe. Although still in the commissioning phase and not at nominal sensitivity, these interferometers are designed to be ultimately limited by a combination of shot noise and quantum radiation pressure noise, which define an envelope known as the standard quantum limit. Despite the name, this limit can be beaten with the use of advanced quantum measurement techniques, with the use of squeezed vacuum states being currently the most mature and promising. Different strategies for implementation of the technology in the large-scale detectors, in both their frequency-independent and frequency-dependent variations, are presented, together with an analysis of the main technological issues and expected sensitivity gain.

Keywords : gravitational waves, interferometers, squeezed vacuum, standard quantum limit
Conference Title : ICQMA 2018 : International Conference on Quantum Metrology and Applications
Conference Location : London, United Kingdom
Conference Dates : February 15-16, 2018