OPTICAL PARAMETRIC AMPLIFICATION USING NONLINEAR OPTICAL EFFECT FOR THE NEXT GENERATION GRAVITATIONAL WAVE DETECTOR

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A Gravitational wave was predicted by A. Einstein's General Theory of Relativity in 1916 and was observed directly in 2015 by the advanced LIGO, which consists of two widely separated interferometers. The gravitational waves are generated by accelerated masses. However, the amplitude of them is extremely small because of the weak interaction between them and a matter and it is hard to detect them directly. Therefore, various techniques to improve the measurement sensitivity have been employed in the gravitational detectors such as LIGO, GEO600, Virgo, and KAGRA.

The squeezing is one of the effective techniques to improve the sensitivity of the high-frequency band of the gravitational wave detector. The quantum background noise is suppressed by injecting the squeezed vacuum from the anti-symmetric port of a Michelson interferometer, and GEO600 achieves a squeezing level of 5.7 dB. However, optical losses due to scattering and absorption at mirrors cause the degradation of the squeezing level and it becomes an obstacle for improving the detector sensitivity.

We suggest a new method beyond the standard quantum limit using an optical parametric amplification (OPA) in a signal recycling cavity (SRC) for the next generation gravitational-wave detector. This method has an advantage of improving the detection sensitivity in a high-frequency band. The OPA technique with a nonlinear crystal realizes a stiff optical spring without increasing the circulating laser power and exceeds the standard quantum limit in the high-frequency band even under losses.

We constructed an experimental setup for a signal amplifier by putting a periodically poled KTiOPO4 in the SRC. By using the amplification of the signal in the cavity and the effect of the optical spring, we performed a verification experiment for the sensitivity improvement beyond the standard quantum limit in the high-frequency band. We will present the experimental details of the OPA and optical spring setups in the cavity.