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Development of a signal amplification system using nonlinear optical effects for next-generation gravitational wave detectors

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Optical squeezing is a well-known technique to reduce quantum noise. This technique has been implemented in actual gravitational wave detectors such as LIGO or Virgo. On the other hand, an opto-mechanical method using an optical spring generated by slightly displacing the signal recycling mirror from its resonant position, i.e. detuning, has also been investigated to increase the sensitivity of gravitational wave detectors. To improve the sensitivity of high-frequency signals, a new method has been proposed in which the optical spring is enhanced by optical parametric amplification: OPA, a kind of nonlinear optical effect, and the resonance of the optical spring amplifies the high-frequency gravitational wave signals.

The optical spring binds the suspended mirror and changes its mechanical behavior. Therefore, the signal amplification method combining OPA and optical spring can be verified by measuring the transfer function of the optical system. For this purpose, we constructed a signal recycling Michelson interferometer: SRMI, composed of a suspended mirror, and stably controlled it with a digital system. We also measured the transfer function of the SRMI and confirmed the generation of the optical spring. In addition, we realized the OPA inside the SRMI by injecting strong pump light into a nonlinear optical crystal installed inside the SRMI and performed coherent control of the OPA. In this presentation, I will report the details of these experiments.

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