論文の内容の要旨

論文題目
Multi-Color Interferometry for Lock Acquisition of Laser Interferometric Gravitational-wave Detectors
（レーザー干渉計型重力波検出器における動作点引込みのためのマルチカラー干渉技術）

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There have been worldwide efforts to directly detect gravitational-wave (GW) for the first time. The highest sensitivity to mid-frequency GWs at around 100 Hz has been achieved by the laser interferometric detector. However the direct detection has not been yet achieved. To increase the detection rate by enlarging the observable volume in the universe, the km-scale interferometers are currently being upgraded or constructed. It is expected that those interferometers will be able to detect GWs with a sufficient detection rate of a few events per year.

The modern GW interferometer is a variant of the Michelson interferometer enhanced by the addition of the optical cavities in the arms as well as the input and output sides of the Michelson. The optical lengths of those cavities must be controlled against the seismic vibration such that the proper interferometric condition is always maintained.

In the operation of such a complicated interferometer, one of the big challenges is lock acquisition, in which the interferometer is brought from the initial state, where the lengths are at arbitrary values and hence a random interference happens, to the final state, where the lengths are interferometrically controlled at the operating points. During lock acquisition essentially there are no reliable optical signals that provide the proper lengths information until all the lengths are simultaneously on the operating points. This is due to the fact that the response of the interferometer is highly nonlinear and also the optical cavities are coupled to each other. These facts lead to two probabilistic processes, which strongly hinder the lock acquisition progression. Thereby they can potentially result in a serious reduction in the observational duty cycle.

In order to avoid the probabilistic processes, a new multi-color interferometric technique has been proposed. In the technique frequency-doubled auxiliary lasers, phase locked to the main interferometer laser, is introduced to serve as sensors which can readout only the length of the arm Fabry-Perot cavities. This technique enables us to control the arm lengths independently of the condition of the rest of the interferometer. Therefore it decouples the arm cavities from the rest of the interferometer and consequently enables us to perform a more deterministic and repeatable lock progression.

In this thesis an experimental demonstration of the multi-color interferometric technique, conducted in a 40-meter baseline prototype interferometer, is presented. It is shown that the resultant stability in the arm length successfully surpasses the requirement. In addition to it, the other important function, arbitrarily tuning the length of the arm cavity, is demonstrated. A noise study has been also performed by utilizing a noise model. Based on the noise study the feasibility of the technique in the km-scale interferometer is discussed and confirmed. Thus the use of this technique should allow for a significantly higher duty cycle in the upcoming km-scale interferometers.