MOLECULAR ADSORBED LAYER FORMATION ON COOLED MIRRORS AND ITS IMPACTS ON CRYOGENIC GRAVITATIONAL WAVE TELESCOPES

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ABSTRACT

Cryogenic mirrors have been introduced to the KAGRA gravitational wave telescope in Japan, and are also planned to be used in next-generation gravitational wave telescopes to further improve their sensitivity. Molecular gases inside vacuum chambers adhere to cold mirror surfaces because they lose their kinetic energy when they hit cryogenic surfaces. Finally, a number of adsorbed molecules form an adlayer, which will grow with time.

The growing adlayer functions as an optical coating and changes the properties of the underlying mirror, such as reflectance, transmittance, and absorption, which are carefully chosen to maximize the detector sensitivity. The adlayer possibly affects the gravitational wave detector sensitivity. To characterize these changes, a high-finesse Fabry-Perot cavity was introduced to a KAGRA cryostat, and the finesse of the cavity was monitored for 35 days under cryogenic conditions. We confirmed that the molecular adlayer was formed on a cold mirror and caused an oscillation in the finesse. The measured finesse was shown in the figure 1 with the theoretical estimation. The results of the analysis indicate that the real and imaginary parts of the refractive index of the adlayer were 1.26 ± 0.073 and $2.2 \times 10^{-7} \pm 1.3 \times 10^{-7}$, respectively. These are considered to be those of H_2O molecules. The formation rate of the molecular adlayer was 27 ± 1.9 nm/day.

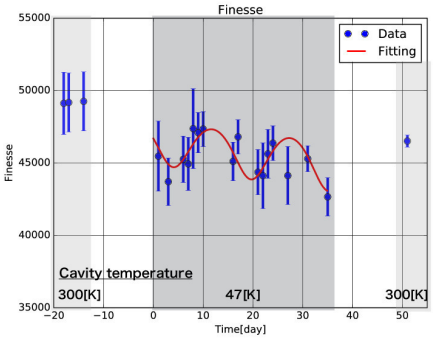

FIGURE 1. Measured finesse oscillations. Depending on the thickness of the adlayer on the cooled mirror, the finesse of the optical cavity which was put inside the KAGRA cryostat changed.

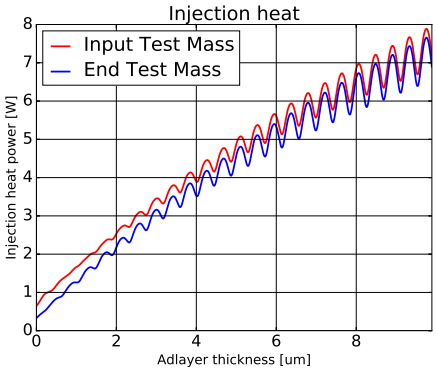

FIGURE 2. The estimated heat injection to the test masses in KAGRA. An adlayer absorbs a part of circulating laser, and it causes the additional heat to the test masses.

The formation of an adlayer affects to the sensitivity of a gravitational wave detector. The change of the reflectance of arm FP cavity leads to the change of the quantum noise. At the same time, an molecular adlayer absorbs a part of circulating laser as shown in the figure 2, and that additional heat warms test masses up which are cooled down to reduce the thermal noise.

The effects of an adlayer are important to construct stable and high sensitive detectors. To construct the next generation gravitational wave detectors, the simulation or estimation of the adlayer effects are essential to design the vacuum and the cryogenic system. Furthermore, the system to compensate the adlayer formation must be developed.

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