

A study of cooling time reduction of interferometric cryogenic gravitational wave detectors using high emissivity coating

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supported by KAGRA cryogenic group



Abstract

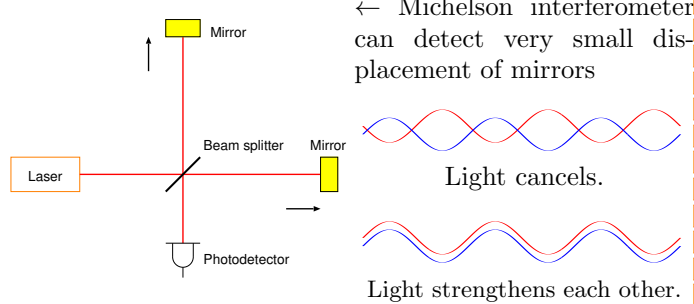
KAGRA is a Japanese project to construct an interferometric cryogenic gravitational wave detector. Its mirrors and their suspension system (payload) is planned to be cooled down in order to reduce thermal noise, one of fundamental noise sources. It takes time (\sim months) to cool the payload since the payload has large mass (several hundred kg in total) and is thermally isolated. To reduce the cooling time, we adopt high emissivity coating (DLC coating). This coating enhances heat transfer by radiation. Here, we report experiment to verify the effect of DLC coating on the reduction of the cooling time. In this experiment, the cooling time of metal spheres with and without DLC coating was examined. As a result, the cooling is comparable to the calculation model. The effect of DLC coating has been verified.

1. Introduction

★ Gravitational waves (GWs)

- Ripples of space time predicted by general relativity

★ Detection of GWs



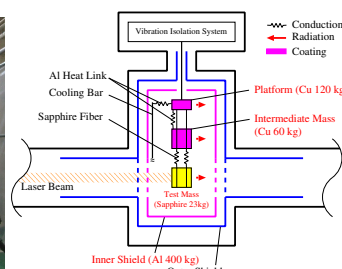
- Mirrors suspended as test masses
- GWs change differential length of arms
- Displacement is proportional to arm length



★ KAGRA:

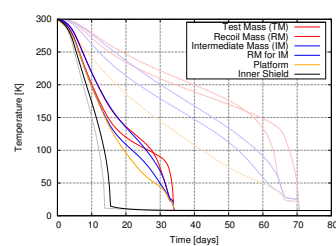
- Interferometer (3 km arms)
- Kamioka underground (small seismic motion)
- **20 K mirrors** (reduce thermal noise)

★KAGRA cryostat



★ How to reduce cooling time

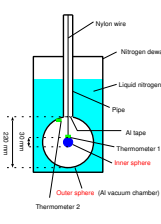
- Gas cooling
 - o Mechanism to close and open holes of shields
- Heat switch
 - o Mechanism to contact and detach payloads
- **Radiation (promising)** using DLC coating (Diamond Like Carbon)
 - o High emissivity 0.41 cf. aluminum, copper 0.03
 - o Calculation of cooling **2 months \rightarrow 1 month**
 - o **Experimental verification necessary**



Thick: With coating Thin: No coating

2. Method

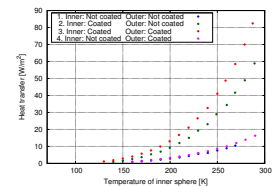
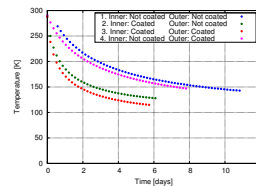
★ Experimental test of effect of DLC coating



- Inner sphere (copper) is suspended inside outer sphere (aluminum)
- Pressure $< 10^{-3}$ Pa
- Outer sphere kept at 77 K using liquid nitrogen

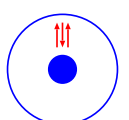
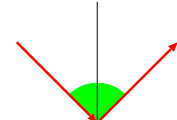
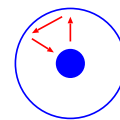
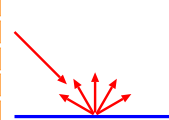
3. Result

★ Coating inner sphere has large effect on cooling time



★ Model of heat transfer via radiation

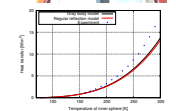
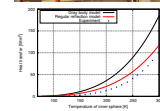
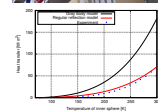
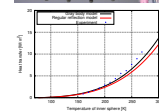
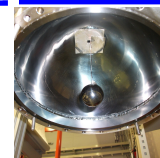
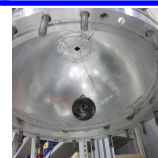
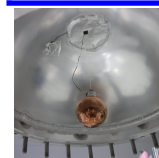
- Gray body model
 - o Rays reflected to all angle
 - o Some rays reflected by outer sphere more than twice
- Regular reflection model
 - o Rays reflected to same angle
 - o All rays reflected alternatively by outer and inner sphere



★ Comparison with two models

- **Regular reflection model is better**
 - o Surfaces are flat planes at wavelength of radiation $\sim 10 \mu\text{m}$

1	2	3	4
Inner: Not coated Outer: Not coated	Inner: Coated Outer: Not coated	Inner: Coated Outer: Coated	Inner: Not coated Outer: Coated



4. Summary

- ★ Cooling time of KAGRA is calculated
- ★ Small experiment has verified effect of DLC coating
 - Results comparable to regular reflection model
- ★ Large-scale experiment (KAGRA cryostat) is underway