# Birefringence measurement of a sapphire mirror for KAGRA

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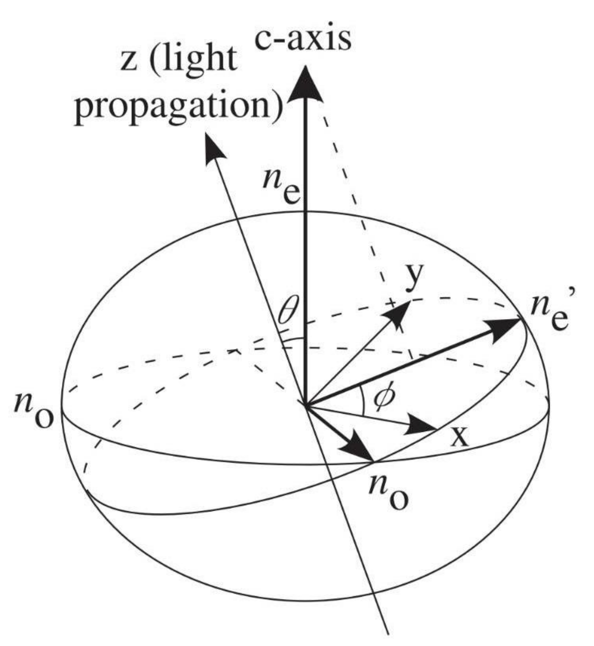
## • Introduction

- The presence of birefringence in the Input Test Masses (ITM) is a big problem for KAGRA. The laser used in the interferometer has almost pure S-polarization, however, when passing through the ITMs, due to their birefringence, a portion of laser power is converted into P-polarization. This conversion leads to a degradation in sensitivity. In addition, the ITM's birefringence properties are not spatially homogeneous, and this issue cannot be solved easily. The purpose of this poster is to present a plan to measure the non-uniformity of the ITM's birefringence properties.

## • Birefringence

- Sapphire is uniaxial, which means that there is a light axis, along which a linearly polarized light beam propagates with the same phase speed regardless of its polarization direction.




This figure shows the different refractive indexes for different polarization states.[1]

## • Measurement1

- It's a simple measurement method using PBS.
- Observe how the polarization changes after passing through the sample.
- Using two waveplates, we can input any polarization state.

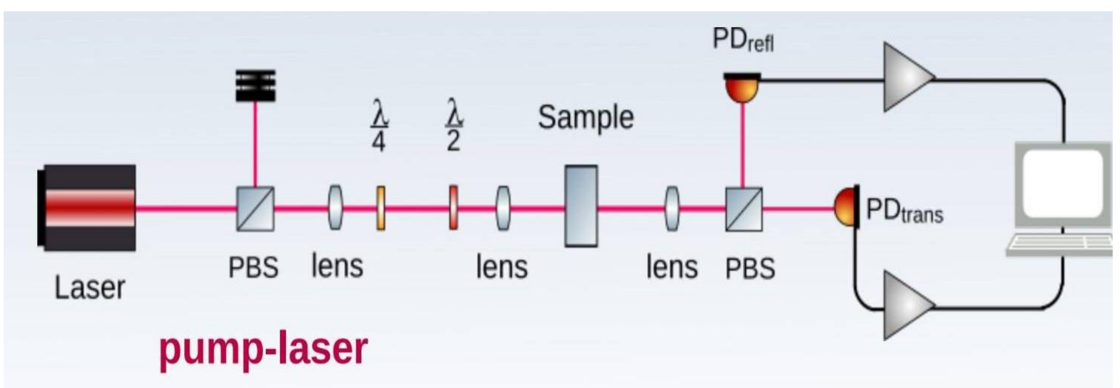
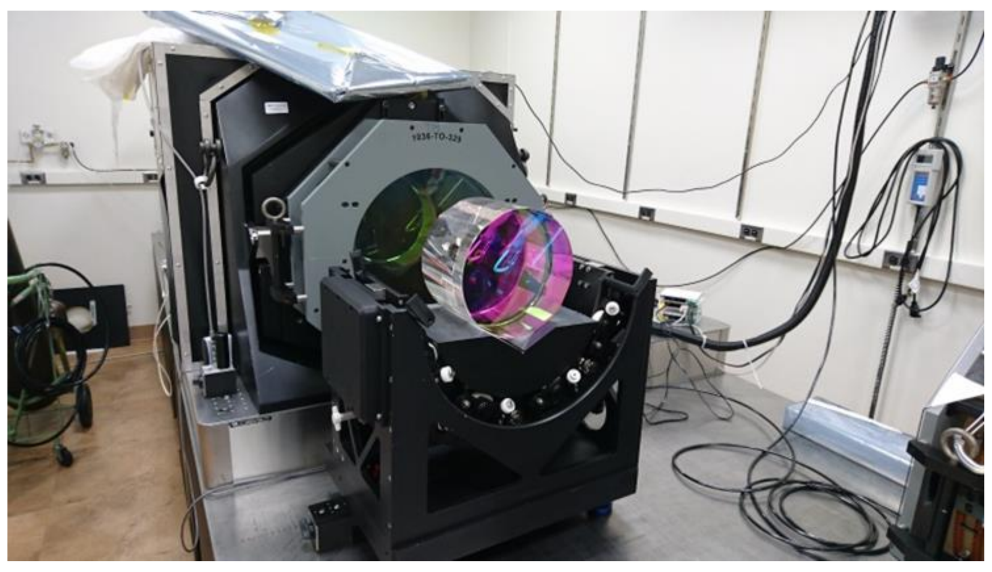



Image of set up for measurement

## • Measurement2

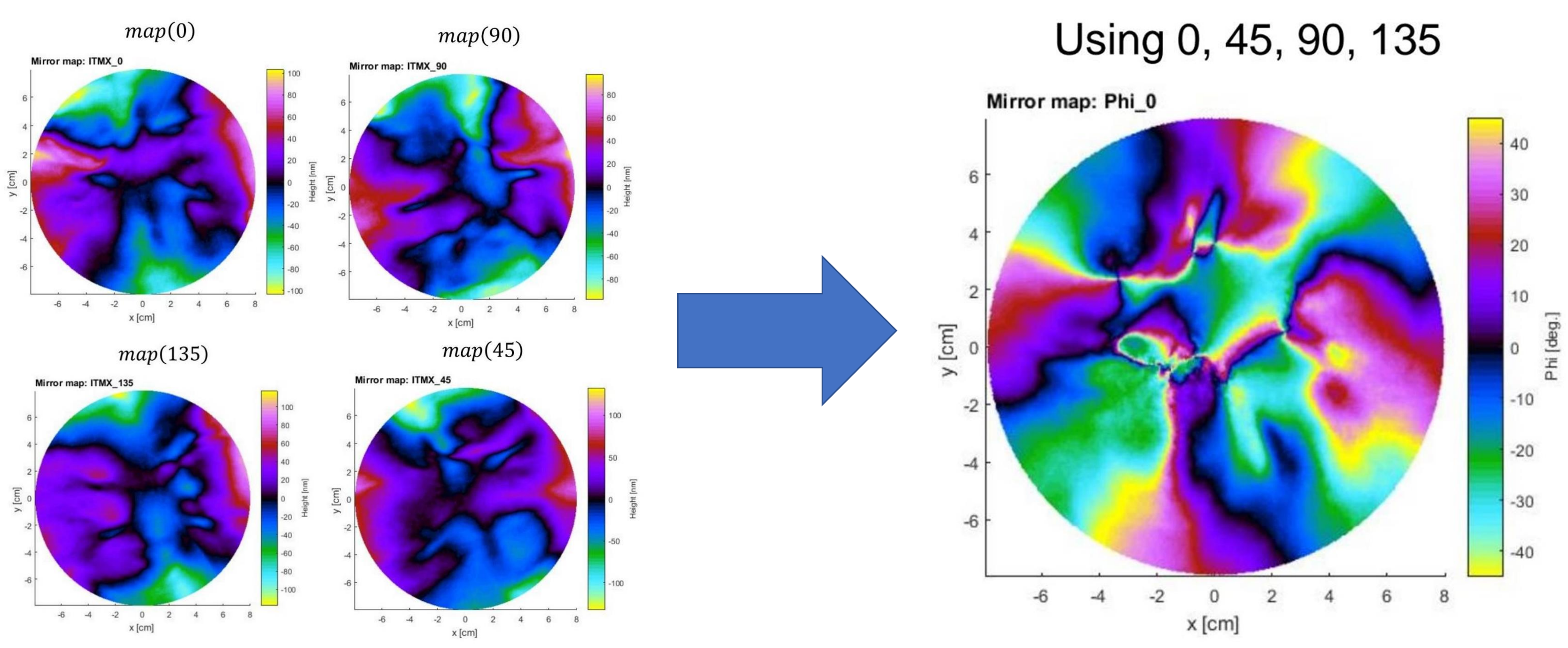
- Fizeau interferometer is a device to measure thickness. However, the birefringence rotates the polarization and changes the optical path length. Therefore, the TWE map contains the information of birefringence. By rotating the sample, multiple TWE maps are made and the magnitude of birefringence is calculated.
- Using the four TWE maps, the inclination of the c-axis can be calculated from the following equation.
- $\phi = -\frac{1}{2}\tan^{-1}\frac{TWE[45^\circ]-TWE[135^\circ]}{TWE[0^\circ]-TWE[90^\circ]}$

($TWE[\theta]$ shows how much the optical path lengths differ.[nm])



Fizeau interferometer at CALTECH

An example of birefringence map production




## • Comparing two methods

- Measurement1 is a measurement method based on the definition of birefringence, and we believe that the results are correct except for the error of the instrument.
- On the other hand, measument2 involves a lot of complicated operations, and it is doubtful that it will give correct results. However, if measurement2 is correct, there will be no need to measure new data since the TWE maps data of ITMs already exists, and future investigation of the mirror characteristics will be easier.

## • Conclusion

- We will use two methods to make accurate birefringence measurements.
- In particular, if measurement2 works well, we can efficiently investigate the characterization of the mirror.
- By considering the birefringence, we will be able to create a more accurate TWE map and improve the quality of the polishing.

## • Bibliography

- [1] Masao Tokunari et al '' Optical properties measurement of an Al2O3 mirror substrate for the Large-Scale Cryogenic Gravitational Wave Telescope (LCGT)''2010 Class. Quantum Grav. 27 185015