（別紙様式2）

フォトンサイエンス国際卓越大学院プログラム（XPS）

光科学特別実習　報告書

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研究機関・企業名	● 19th International Workshop on Low Temperature Detectors ● Princeton university
日程	西暦　2021年　7月　19日　～　西暦　2021年　7月　29日

The small aperture telescopes of the Simons Observatory experiment employ a cryogenic sapphire half-wave plate rotating at 2 Hz on a superconducting magnetic levitating bearing. I am participating in the Simons observatory experiment, and in particular I am in charge of the development and performance evaluation of this hardware.
I performed the following two studies.

● 19th International Workshop on Low Temperature Detectors (LTD19)

In LTD19, I presented on the development and performance of a LC sensor that measures both the 3D position and temperature of a continuously rotating cryogenic half-wave plate in a completely contactless manner (Fig. 1). This is a technology that has not been realized in the conventional rotation mechanism of the low-temperature half-wave plate in CMB observations, and will play a role in investigating the cause of the noise synchronized with the rotation of the half-wave plate.

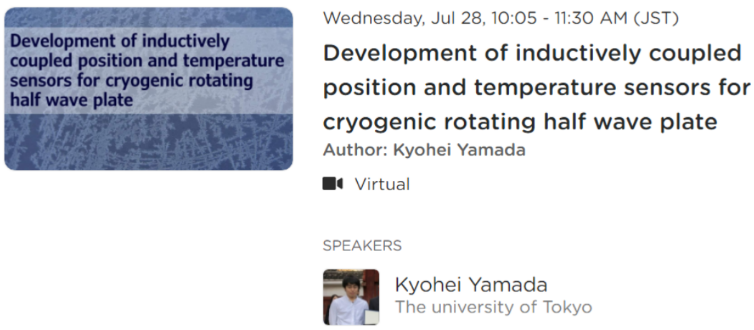

Fig1. Presentation of contactless LC sensors for CHWP

In this presentation, we reported the design and the performance of the LC sensor. This sensor has many advantages such as being contactless, passive, being less susceptible to stray impedance, operating at cryogenic temperatures and being able to measure position and temperature with the same probe, This sensor acts as a position-sensitive eddy sensor when it couples to the metal parts on the edge of rotating half-wave plate while it acts as a thermometer when it resonantly couples to the temperature sensitive resonator on the edge of rotating half-wave plate. We demonstrated that the sensitivity of the position sensor is O (0.1) mm and that of the temperature sensor is less than 1 K. Through the discussions at the conference, I was able to gain a new perspective on how to optimize the parameters of the sensor and how to evaluate its performance. We plan to reflect these results in the further development of these sensors.

The following two presentations were particularly helpful for me.

“Development of low-cost readout electronics for resonator-based multiplexing detector arrays”

In our study, we proposed a simple method to read out three LC resonators with a resonance frequency of 100 kHz. While in this study, the readout electronics can handle 512 readout channels within a 1 GHz bandwidth. This presentation was really helpful for further improvement of a multichannel measurement.

“Magnetic Shielding Measurements for the Simons Observatory Universal Multiplexing Module.”

The CHWP rotators that I am developing use magnets in the superconducting magnetic bearings. However the detector and readout for the CMB observation, especially TES and SQUID amplifiers, are sensitive to the magnetic field, so the performance of magnetic field shielding is important for mitigating the systematics. From the amount of magnetic field leakage from the CHWP system and the performance of this magnetic shield, we could quantitatively account for one of the systematics from the CHWP system.

- ## **Collaborative research with Princeton university**

The development and testing of the cryogenic half-wave plate (CHWP) rotator at UTokyo was scheduled to be completed by the summer of 2021, and shipped to Princeton University in the U.S. for the integration test with the telescope receiver and detectors.

Due to schedule delays, the integration test at Princeton University has not yet been conducted, but We are making good progress on the development of the CHWP rotator and the performance testing at UTokyo. Meetings with Princeton University are underway to prepare for the integration test this fall.

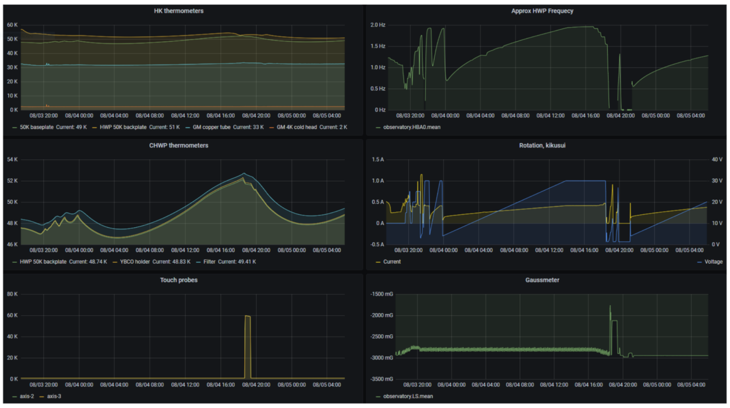

Fig2. Monitoring system for cryogenic half wave plate rotator

Development of CHWP rotator system

The development of control electronics and monitoring software for the CHWP is in progress (Fig 2.) and now we are integrating it into the control system at Princeton University. Also, the softwares developed to evaluate the performance of CHWP are planned to be included in the collaboration's shared library.

Performance testing

In the tests conducted in Tokyo, the essential tests, the rotational performance test, thermal test, and vibration test, were completed. We confirmed that our system achieves fast enough rotation speed and the rotation encoder’s accuracy satisfies the requirement. We measured the amount of vibration from the rotating CHWP. The effect of vibration on the CMB detector will be evaluated in more detail in the integration testing

Future study

I am planning to go to Princeton University in the fall of 2021 to assemble and integrate the cryogenic half-wave plate rotator with the telescope receiver that is being built at Princeton university. I will also be doing integration tests of the entire receiver to evaluate the overall performance of the entire receiver.

Through this collaboration research, we will be able to evaluate the thermal performance of the entire receiver. Also, by combining the performance studies of CHWP in UTokyo and the integration study in Princeton, we will be able to decompose the noise caused by the cryogenic half-wave plate rotator into electrical noise, vibration noise and magnetic noise. In addition, using the detectors at Princeton University, we will be able to evaluate optical performance, including half-wave plates, which was not possible at UTokyo.