Thermometry Integration & Calibration for the Simons Observatory

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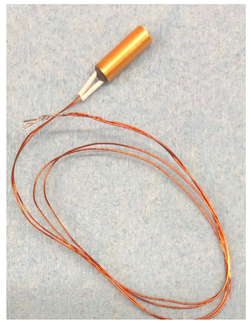
Abstract

The Simons Observatory experiment is a next generation CMB experiment, fielding arrays with up to 30,000 detectors. Amongst goals like measuring neutrino masses and discovering dark matter via gravitational lensing, the Simons Observatory will also search for direct evidence of inflation in the B-mode polarization pattern. In order to make sensitive measurements, the Simons Observatory detectors must be cooled down to 100mK with dilution refrigerators, with intermediate cold stages of 80K, 40K, 4K, and 1K. In addition, it is crucial that we map any temperature fluctuations at the 100mK stage that cools the detectors. This requires the construction of temperature sensors that can be placed at different stages of the cooling process, ranging from 80K down to 100mK. At Yale, about 250 temperature sensors are currently being constructed, where the data from these sensors are analyzed using readout systems in development for the Simons Observatory.

Introduction

There are two types of temperature sensors, the DT-670 silicon diode and the Ruthenium Oxide (ROX) sensor. The diode will be used at "warmer" cooling stages (80K, 40K, 4K. 1K), and the ROX will be used at 1K and 100mK stages. The sensors must be soldered and potted to provide optimal thermal coupling.

DT-670 Silicon Diode



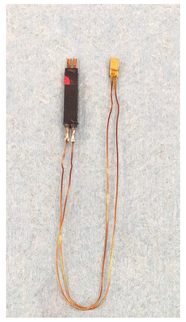
ROX 102A

Soldering

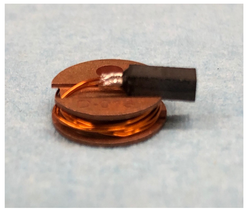
Soldering steps for diodes are more involved than ROX's. Diodes must be tinned and soldered to copper wire before connected and placed inside a bobbin.

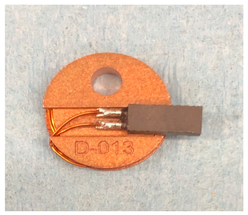
Diode

Temperature sensor connector



Diode and connector soldered to copper wire

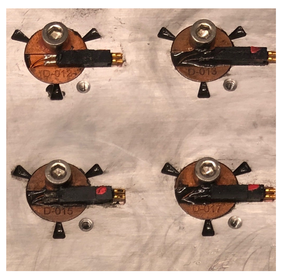




Bobbin

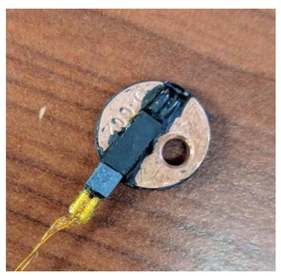
Potting

An epoxy encapsulant (Stycast) mix is injected into the bobbin using a bobbin mold. The Stycast mix takes 18-24 hours to cure before the sensors can be released from the mold. Once successfully potted, the sensors are ready for liquid nitrogen dunk tests.



Bobbin mold filled with sensors and Stycast mix

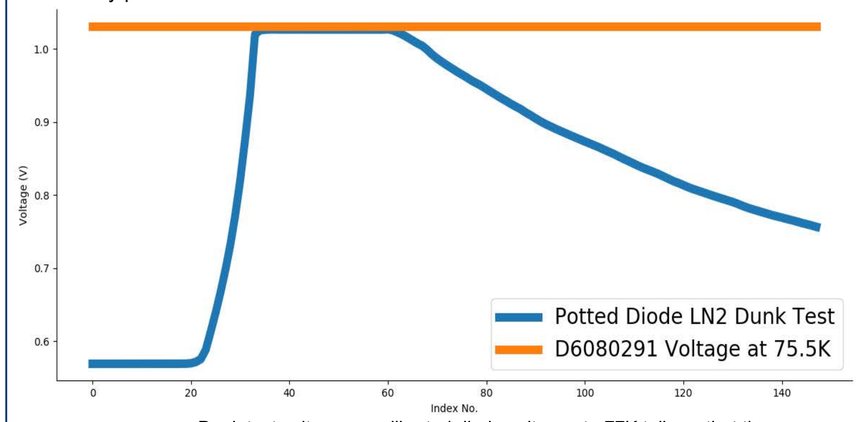
Potted temperature sensor



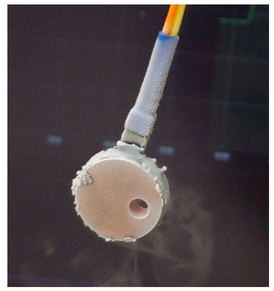
Sensor ready for LN2 dunk test

Liquid Nitrogen Dunk Tests

LN2 dunk tests are an important intermediate step before sensor calibration. They tell us how well the sensors were potted. We measure the temperature of diodes as a function of voltage, and ROX's as a function of resistance. Because the temperature of liquid nitrogen is held constant at 77K, we compare the voltage of a calibrated diode at ~77K with that of our newly potted diodes.



Dunk test voltage vs calibrated diode voltage at ~77K tells us that the uncalibrated diode was potted successfully.



Potted diode just after being dunked in LN2

Lakeshore 240, a readout system for diode sensors

Calibration

Once LN2 dunk tests are successful, the potted sensors can then be calibrated using a cryostat.

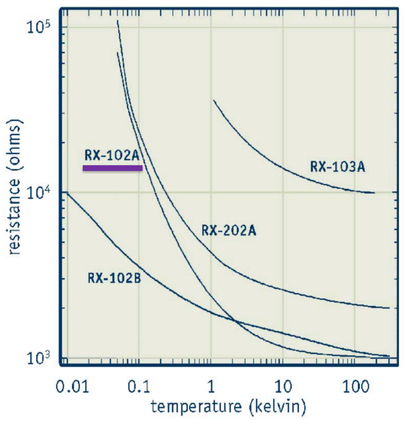
Diode

The cryostat cools the diode sensors down to ~2.5K in 1 hour. Diode calibration occurs over a 30 hour warm-up period (warming up to room temperature, 300K) once the cooldown is completed.

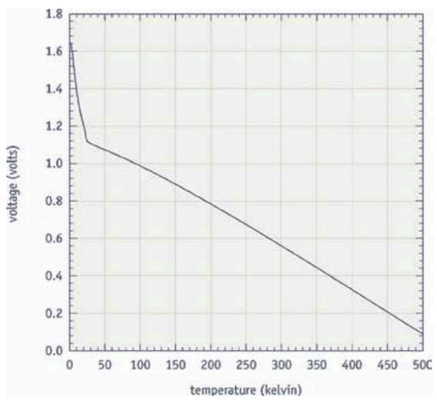
ROX

ROX's are intended to be calibrated down to 50mK. Calibration steps are more involved for ROX's and involve a separate readout system (Lakeshore 372 rather than the Lakeshore 240 that's used for diodes).

Typical Rox™ resistance



Typical DT-670 diode voltage



Conclusions & Applications

Because purchasing ***one*** potted calibrated sensor costs ***over $1000***, a great budget-saving technique is to manually pot silicon diode and Ruthenium Oxide sensors in-house and calibrate them using readout systems and software in development for the Simons Observatory. Potting sensors allows us to measure any temperature fluctuations in intermediate cooling stages to ensure that our detectors can make sensitive measurements at the 100mK level.

References

DT-670 Silicon Diodes. Lake Shore Cryotronics, Inc. 2018. Print.
Ruthenium Oxide Sensor | Lake Shore Cryotronics, Inc. 2018. Print.
Limon, Michele. *Simons Observatory Thermometer Potting Procedure*. 2018. Print.

Acknowledgements

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