Improving the Cryogenic Performance of the Optics Tube and Design, Construction, and Testing of New Optical Windows of Simons Array

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Abstract

The mission of the POLARBEAR-2/Simons Array experiment is to study the early universe by measuring the Cosmic Microwave Background, using the Huan Tran Telescope in the Atacama Desert. In this project we designed, constructed and tested the new optical window of Simons Array and improved the cryogenic performance of Simons Array Optics tube cryostats. We also fabricated the mechanical clamp of the window, designed and machined parts for the optics tube cart.

POLARBEAR-2 CMB

- POLARBEAR-2 will map Cosmic Microwave Background polarization with unprecedented sensitivity to constraint cosmology parameters.
- Simons Array will consist of 3 POLARBEAR-2 telescopes (PB-2a, PB-2b, PB-2c) at multiple frequencies for galactic foreground rejection.
- Located at 5200m in the Atacama Desert of Chile for thin, dry atmosphere and access to 80% of the sky.

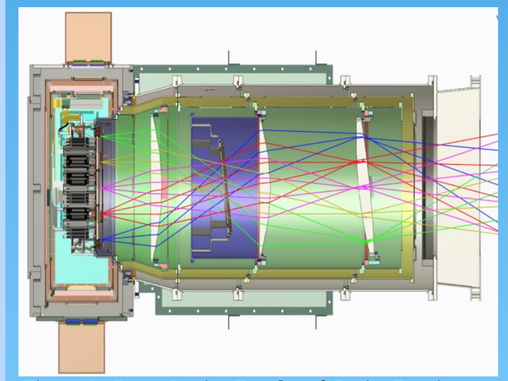


Figure 1: Cross-Section Render of Optics Receiver

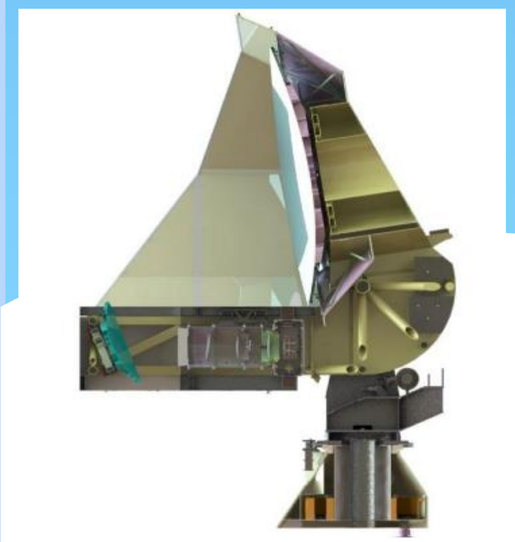
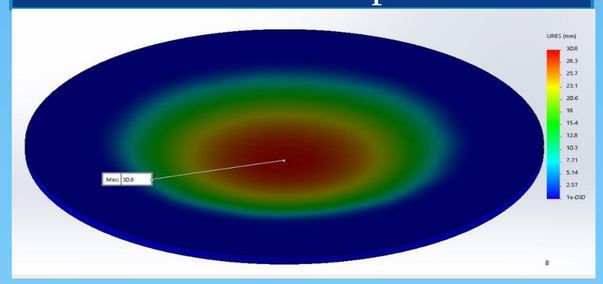


Figure 2: Cross Section render of PolarBear Telescope

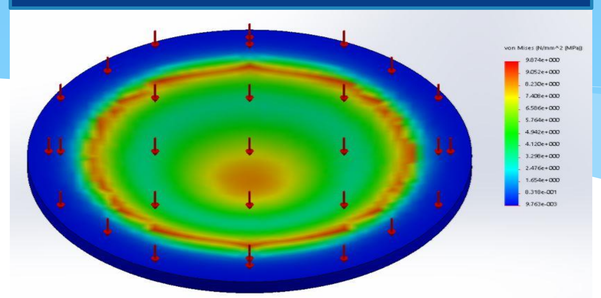
UHMWPE(Ultra High Molecular Weight Polyethylene) Window Stress Simulation

- PB-2A original window design relied on window as a vacuum stop to in-band photons and blocks far & Mid-IR.
- Problem – Scattering at window creates side lobes – even for PB-2A, there is a ~2% Scattering at the window.
- UHMWPE (Plastic) Option is proven technology from QUIET, SPIDER, CLASS and more.
- UHMWPE expects higher Far – and Mid-IR loading onto 50K stage as bulk plastic does a much worse in blocking infrared.
- Determine plastic AR + Thickness
  (Optimal Case) e = 1.55, t_ar = 461.8um,
  plastic = 4.20mm
- Total Reflection (90GHz, 150GHz, total)

4mm Window Displacement



4mm Window Stress Simulation



Ultra High Molecular Weight Polyethylene Optical Properties

- UHMWPE chosen for window material because it allows for thinner window and has less effect on optics.
- Transmission function: Allowed us to determine the transmission properties of High Density Polyethylene, determine which material possesses ideal optical properties and facilitate the mechanical design of the optics tube window by simulating the optical properties for different thicknesses of the material.

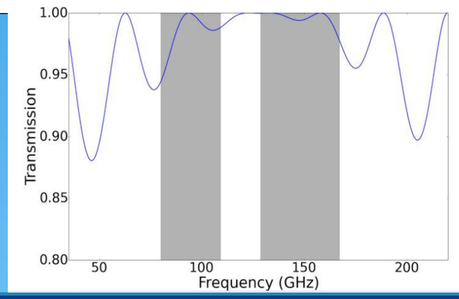


Figure 3: Transmittance V.S. Frequency (Transmittance Simulation)

Improving Cryogenics of the Optics Tube

To improve the performance of the optics tube 4K and 5K shells we collaborated with UC San Diego Polar Bear team to develop a method to increase the thermal conductivity of the cryostat. The new method is being developed to apply a heat shield to the outer surfaces of each tube to help with uniform thermal conductivity thought-out the entire tube. We used 6N Aluminum as the heat shield being applied to the cryostat because it is 99.9999% pure aluminum and it is a great heat conductor. We had to developed a new layout of the tube because they are cylindrical as where the San Diego method was for flat panel strips.

Figure 4: Cryostats before and after application of 6N aluminum strips

Designs and Methods

- The clamping mechanism for the optical window had to be designed with 12 equally spaced clearance holes which allowed a strong connection and did not break vacuum.
- The Optics tube cart design was modified to improve weight distribution and to minimize the risk of failure when subjected to large forces.
- 6N Aluminum strips were applied to cryostats to facilitate axial thermal uniformity.

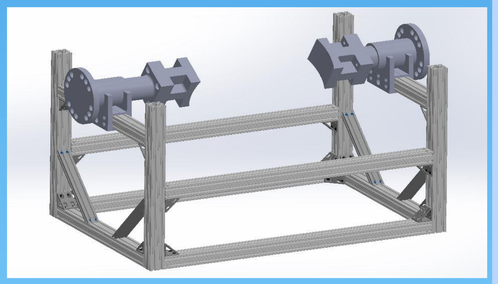


Figure 5: Optics Tube Cart CAD render

References

1) HS Hou. Method for optimized design of dielectric multilayer filters. Applied optics, 13(8):1863–1866, 1974.
2) Multimedia LLC. MS Windows NT kernel description.
3) A Suzuki, P Ade, Y Akiba, C Aleman, K Arnold, C Baccigalupi, B Barch, D Barron, A Bender, D Boettger, et al. The polarbear. Journal of Low Temperature Physics, 184(3-4):805–810, 2016
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