Design, Fabrication and Characterization of the Performance of the Simons Array Optics Tubes

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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.

Introduction

- The cosmic microwave background is the remnant radiation from the Big Bang and has been a fundamental tool for experimental cosmology since its accidental discovery by Penzias and Wilson in 1964.
- POLARBEAR-2/Simons Array is the next generation upgrade to the successful POLARBEAR telescope in the Atacama Desert of Chile, mapping the polarization of the cosmic microwave background in the southern sky.
- We want to measure the faint primordial B-mode signal, which puts tighter constraints on inflation models and energy levels of inflation.
- Inflation is the period of time during the Big Bang which exponentially expanded the size of the universe.
- The sensitivity and multi-frequency (90 and 150 GHz) observation will allow us to precisely characterize the inflationary and lensing B-mode signals.
- In this project we made improvements to the design of the optics tube to optimize cryogenic and optical performance

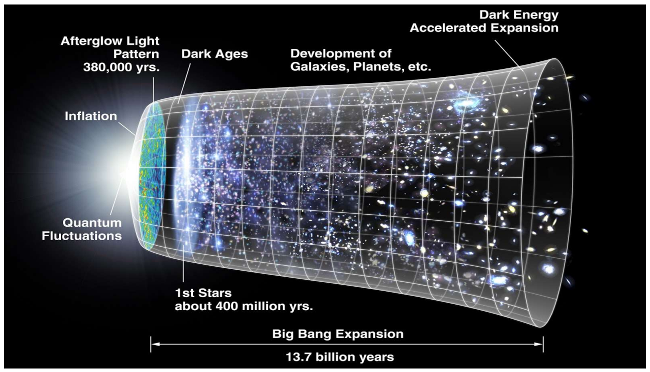

Figure 1: The expanding universe

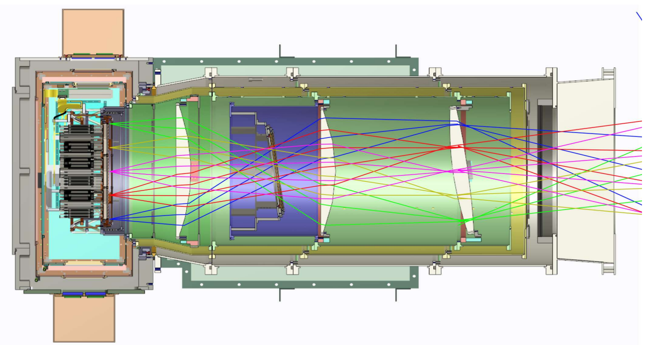

Figure 2: A cross-section drawing of the POLARBEAR receiver.

Simulations

- Transmission function:
  - Allowed us to determine transmission properties of High Density Polyethylene and Ultra High Molecular Weight Polyethylene
  - Helped determine which material possesses ideal optical properties
  - Facilitated the mechanical design of the optics tube window by simulating the optical properties for different thicknesses of the material
- Stress test:
  - Allowed us to determine mechanical properties of the window
  - Simulated the pressure conditions and predicted performance of the window assembly
  - Helped determine the optimal thickness for the window

Results

- UHMWPE chosen for window material because it allows for thinner window and has less effect on optics
- A thickness of 4mm of UHMWPE provides a sufficient safety factor of slightly greater than 1 and minimal absorption loss

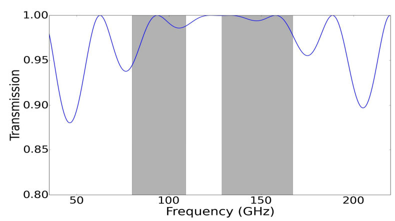

Figure 3: 4mm UHMWPE transmittance data for observation band

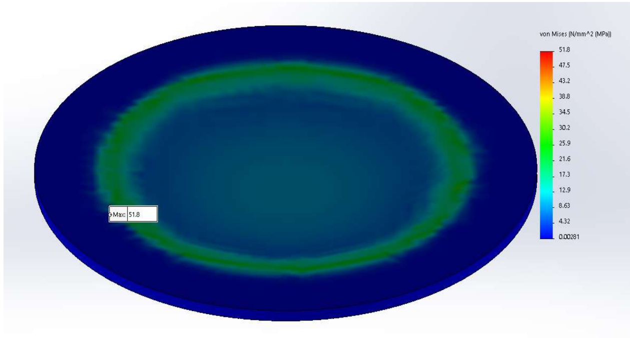

Figure 4: 4mm UHMWPE window stress simulation results

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

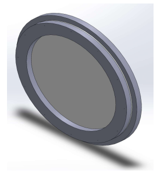

Figure 5: Optical window test setup design

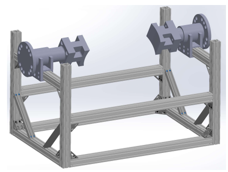

Figure 6: Optics tube cart

Figure 7: Cryostats before and after application of Aluminum strips

References

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