PIPER

- **What:** Primordial Inflation Polarization Explorer
- **How:** A balloon-borne experiment designed to detect polarization in the Cosmic Microwave Background on a large angular scale.
- **When:**
  - 2010: Design and Testing
  - 2011: Assembly and Integration
  - 2012: Launch

How? The detection of the B-mode polarization and curl of gravity waves would support inflation theory.

To develop techniques and technology for a space mission

PIXIE

- **What:** Primordial Inflation Explorer
- **Why:** A satellite dedicated to the detection of primordial gravity waves through polarization in the Cosmic Microwave Background (CMB).
- **How:** Similar in purpose to PIPER, PIXIE will use different detection techniques.

When? A proposal to NASA headquarters is currently in the works.

Why? A space-based instrument, free of atmospheric interference, will allow for even more sensitivity to the faint CMB signal.

How? Using 4 harp bolometers to measure relative intensity.

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Polarization grids are a key component of PIPER’s variable polarization modules. Since PIPER’s instruments are cooled, all optical elements must be able to withstand the cold temperatures inside the dewar. My project involved creating a sample polarization grid to ensure that the winding method was feasible and reliable. To do this, I modeled the experimental setup in SolidWorks, and designed several connecting pieces. Then, I used a computer-controlled milling machine to wind the stainless steel wire around a cylindrical mandrel.

Left: CAD design for winding polarization grids. Above: 1-mm stainless steel wire and grid holders.

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The proposal for PIXIE discussed using a Winston Cone to concentrate the polarized signal of the Cosmic Microwave Background. Testing needed to be done, however, to ensure that the parabolic shape of the cone did not scramble the polarization. To do this, I constructed an optical path with a miniature Winston Cone, two polarizers, an LED light source, and an occlusion disk to ensure only beams glancing the edge of the cone entered the lux meter. The final results showed that the Winston Cone to be an effective concentrator with minimal effect to the polarization.

Left: The experimental set-up. The optical path was placed in a box with walls covered in black felted paper to reduce any scattered light. To the right sits the lux meter, clock, amplifier, and the beam splitter. Right: Graph of the polarization cone using an annotated Winston Cone.

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**Objective:** Determine the resistivity of printed circuit board (PCB) copper traces at 4K.

**Why:** The literature is somewhat incomplete and there is a large uncertainty for the value of ρ for Cu at 4K due to variations in the purity of Cu at these detector temperatures. We must know with high precision the resistivity of the PCB Cu so we can design the detector read-out so that the signal we are trying to measure is not attenuated.

**Given:**
- **ρ** = 0.16 μΩ·cm
- **L** = 1 cm
- **W** = 1 cm (PCB design by Luke Lowe)

**Procedure:**
- Measure the resistance using a 4-wire measurement with an alternating current source (to minimize errors).
- Obtain this measurement a conductivity board with eight traces was used either at constant length or constant R.
- Conductivity tests were conducted at room temperature (~300 K), liquid nitrogen temperature (~77 K), and liquid helium temperature (~4 K).

**Result:**
- Left: Graph of resistance for different temperatures. Right: Solid state conductance band to break-out board.