Cryogenic LED mapper for microwave kinetic inductance detector

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Abstract

We present work done towards the development and calibration of instrumentation for studying the cosmic microwave background (CMB) in millimeter and submillimeter wavelengths. We designed a cryogenic wafer mapper made of light emitting diodes (LED) for mapping an array of microwave kinetic inductance detectors (MKIDs). The light from the LED array will be collimated and passed through feedhorns onto the MKID array. By using the LED array we can correspond each MKID pixel to its measured resonance frequency. The MKID array eventually will be assembled in the Cerro Chajnantor Atacama Telescope (CCAT-Prime) located on Cerro Chajnantor at an elevation of 5600 meters (18,400 feet) overlooking the ALMA plateau in Chile.

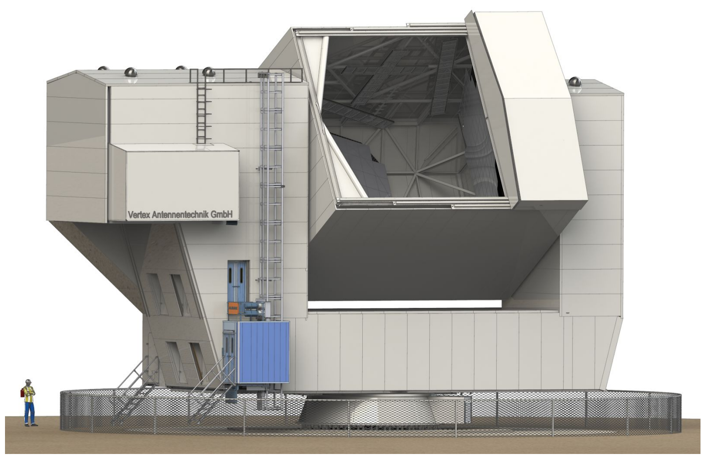

Figure 1: Cerro Chajnantor Atacama Telescope (CCAT-PRIME)

1. Introduction

By using low-temperature resonators such as Microwave Kinetic Inductance Detectors (MKIDs), the rapid progress in Cosmology and Galactic Science has been enabled. Using MKID arrays follows with increasing the mapping speed of future instruments such as the Cerro Chajnantor Atacama (CCAT-Prime), a wild-field-of-view Telescope that is capable of scanning a large range of the sky rapidly and operates at millimeter and submillimeter wavelengths.

2. Background

2.1. *MKID array*

Cryogenic microwave kinetic inductance detectors (MKIDs) are the most preferred technology in frequency detection for astronomical observations over the electromagnetic spectrum, *Figure 1*. MKIDs are a type of superconducting photon detector that is very sensitive and easy to multiplex into large arrays. Additionally, MKIDs are able to operate in temperatures as low as

100 mK. These devices use frequency domain multiplexing to read thousands of pixels over a single microwave cable. It is essential for a large MKIDs array to correspond each physical pixel to its measured resonance frequency.

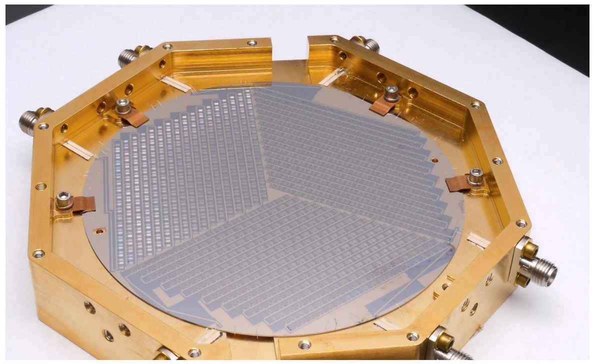

Figure 1: microwave kinetic inductance detectors array

2.2. ***LED array***

For designing the cryogenic LED mapper (*Figure 2*) we are utilizing computer-aided design software SolidWorks. The LED array is used to determine the resonator frequency shift in a single pixel on the MKID array. Each element is individually addressed and are able to perturb each pixel on the MKID array distinguishing it from other unperturbed pixels. Also, the LEDs are easy to use because they are low-cost and able to emit light at extremely low temperatures.

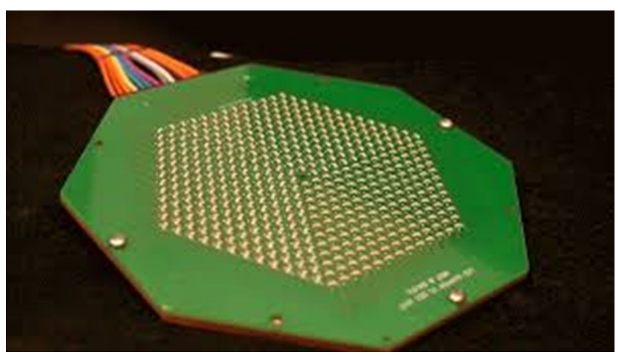

Figure 2: Hexagonal cryogenic wafer mapper based on light emitting diodes (LED).

3. Methodology

I have contributed my work in designing and editing the feedhorn array and the pixels array in Solidworks, which will be beneficial for making the cryogenic wafer mapper for the MKIDs array. For fabricating the LED array, small and efficient LEDs that are closely packed in a hexagonal-shape scheme on a printed circuit board (PCB), will be used. The LEDs should be able to work in extremely low temperature with a low optical power so it would be possible to have a measurable frequency shift in the resonator. The horn array, which have the same pattern as the LED array and is made of aluminum alloy, is created to collimate the visible light emitted from the LEDs onto the pixels on the MKID wafer individually. In the next step, MKID wafer, horn array and the cryogenic LED array on the PCB will be aligned together, and mounted on the mixing chamber stage in a dilution refrigerator .

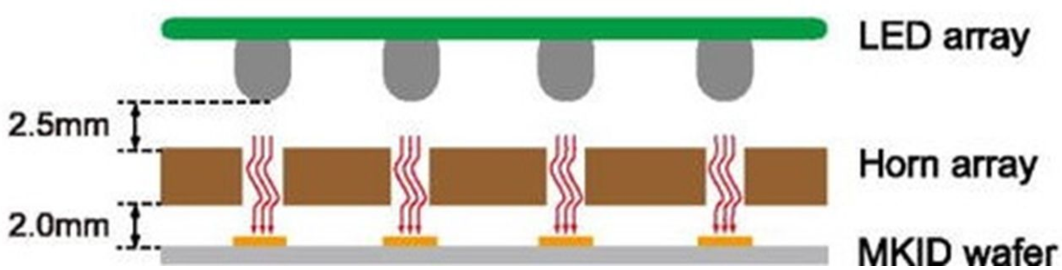

Figure 3: The Assembly Alignment

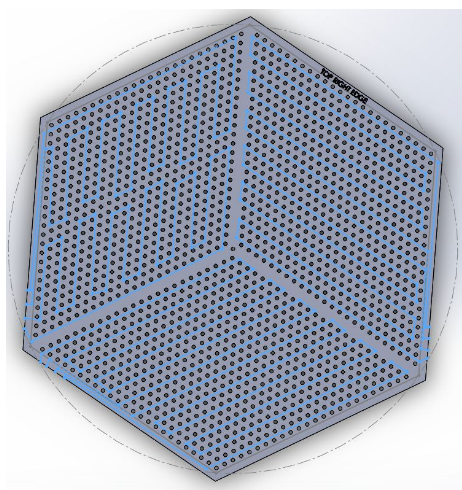
Figure 4: Hexagonal Detector Wafer Designed by Using Solidworks

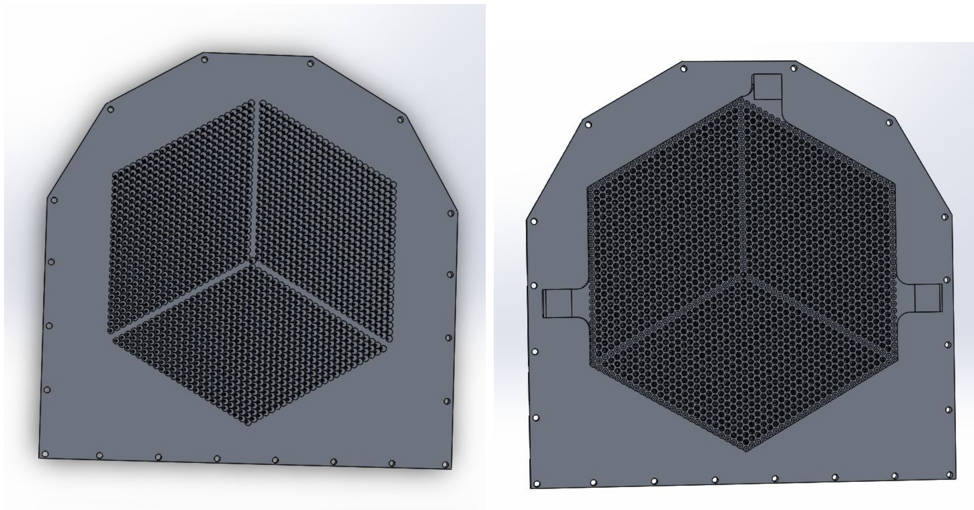

Figure 5 : Feedhorn Block, Designed by using Solidworks

4. Summary

I contributed my work in designing and editing the parts that will support the fabrication of the cryogenic LED array and MKID wafer which will be beneficial for mapping the physical pixels in the order of their frequency and determining the possible errors and uncertainties. The next step is designing the PCB board and using minimal possible DC wires to connect the LEDs and prepare the assembly to work in Dilution Refrigerator (DR). After testing the pixels, the MKID array will be prepared for installation in CCAT-Prime.

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