Large Aperture Telescope Optical Coupling Design Optimization

A CMB-S4 Research and Development Letter of Intent

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Between the CDT concept assumptions and the DSR reference design, the large aperture receiver coupling optics has evolved significantly. By scaling from the Simons Observatory coupling optics and detector array geometries, we find that the number of detectors required per LAT has increased by almost a factor of two (from 68k in the CDT to 123k in the DSR). The additional detector array costs, readout costs, and data volume associated with this change is significant. Improvements to the coupling optics designs have the potential to reduce the number of detectors required. Specifically, optimizing the designs of smaller diameter optics tubes with only one detector wafer per tube (e.g. Niemack Applied Optics 2016, Gallardo et al. SPIE 2018, and Dicker, Gallardo, et al. SPIE 2018) and working with DOE engineers to assess how densely the optics tubes can be packed in a large aperture receiver *could lead to similar sensitivity performance with significantly fewer detectors.*

The notional CMB-S4 project schedule will require pre-CD1 decisions on the large-aperture cryostat optics tube diameter and pixel spacing, because they directly impact any CMB-S4 detector design and prototyping that will need to occur pre-CD1. Given the high-risk that the detector fabrication and throughput will have on the CMB-S4 project schedule, the start of detector fabrication of production arrays in CD-1 / CD-3a will significantly burn-down project risk. This then requires that the design and prototyping of CMB-S4 detector and readout arrays begin several years earlier, which will require decisions on the pixel spacing and optics tube diameter well-before CD-1; work that will be directly addressed by this proposal.

In this LOI, we propose to further develop the large-aperture cryostat concept, focusing on optimizing the pixel spacing and optics tube diameter to 1) maximize the overall sensitivity, 2) help determine the sensitivity versus cost tradeoffs for different optics tube sizes and detector spacings, and 3) enable an earlier start to CMB-S4 detector designs and prototype fabrication.

Resources: FNAL: 0.25 FTE of engineering. Cornell: Support for ~½ postdoc (Patricio Gallardo), travel to CMB-S4 meetings.

Context in the field: The proposed work would build directly on optics studies that Niemack and Gallardo developed collaboratively with the Simons Observatory. The constraints are different for S4 than Simons Observatory, which is why the optimal optics design and detector packing may differ. As part of this study, we would present detailed comparisons between the new large aperture telescope optics configurations we develop (which will not be used for Simons Observatory) and the Simons Observatory configuration.