Letter of Intent for CMB-S4 R&D: metal mesh filters

Brookhaven National Laboratory[1], University of Michigan[2], SLAC[3], Stanford[4]

Brief description:

We propose to develop the capability within the U.S. to design and manufacture photolithographed, multilayer metal mesh filters (MMFs) for use in the optical path of CMB-S4 telescopes. As outlined in Sec 3.3 of the S4 Technology handbook, IR blocking filters are a critical component of CMB-S4 and MMFs are a universal choice -- every Stage-III experiment uses one. As discussed in Sec 3.3.1, however, while the MMF technology status level is 5, the production status level is only 3, because "production needs have [until now] been spread out over time. Depending on receiver design for CMB-S4, the project may require a large number of metal mesh filters in a short amount of time." There is currently no capability within the collaboration to produce MMFs, which could result in delays of schedule and being forced to deploy suboptimal filters (e.g. polarized systematics or in-band optical efficiency). Developing the ability within DOE to produce and test MMFs would help retire this risk. The fabrication process can also be adapted to manufacture bandpass filters, allowing their use without the assumption of similar risks.

Project scope:

Year 1: Design, fabricate, and test a small diameter MMF that, if scaled up, would meet S4 science requirements. Microwave design responsibilities will be split between BNL and UMich. Fabrication will take place at BNL in conjunction with the Center for Functional Nanomaterials (CFN). Characterization will occur between BNL and UMich. Stanford and SLAC will consult. This phase will not require significant capital expenses.
Years 2-3: Scale up the design to the required diameters; fabricate and test. This phase would require some custom equipment (e.g. large a evaporator) in order to scale the production process to large form factor filters.

Collaborator expertise:

McMahon and Sheehy have collaborated on the successful RF design, fabrication, testing, and fielding of low frequency antennas for 21-cm studies, which share design methodology with the proposed research; both are proficient in HFSS. BNL has access to the CFN user facility, whose leadership have agreed to take on this project in conjunction with the cosmology group. (Suzanne Staggs recently met with CFN researchers and helped outline the main challenges.) McMahon and his group have extensive experience designing, fabricating, and testing cold optics for CMB, including characterizing MMFs. SLAC and Stanford designed and fabricated the laser ablated MMFs used by BICEP3.

Requested resources in FY2019:

2 FTEs to be split between institutions, with at least 1 to be reserved for BNL for fabrication
~$20-30k for capital expenses (polypropylene substrates, granite blocks, machining, etc.)

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