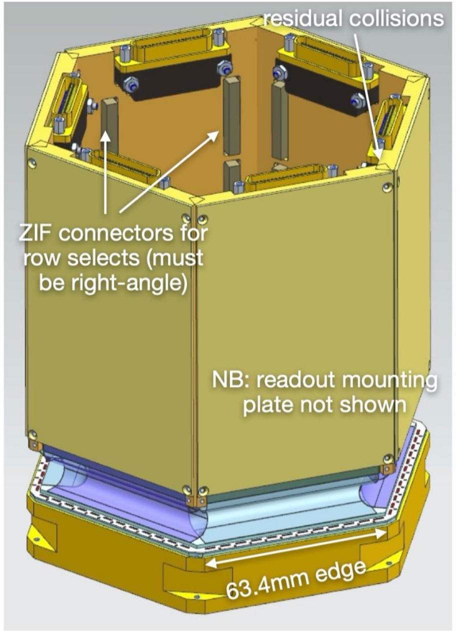
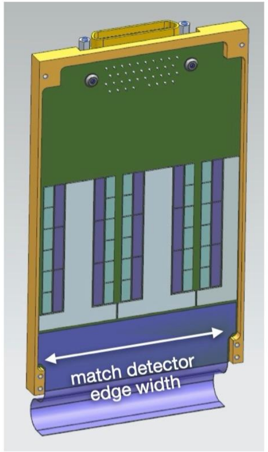
Modules & Testing (MAT) Report Back

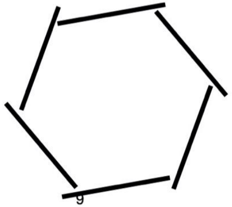
Brad Benson (L2 scientist) for WBS 1.05

Plenary Session, Friday, March 12, 2021

Readout Boxes - v2 in progress



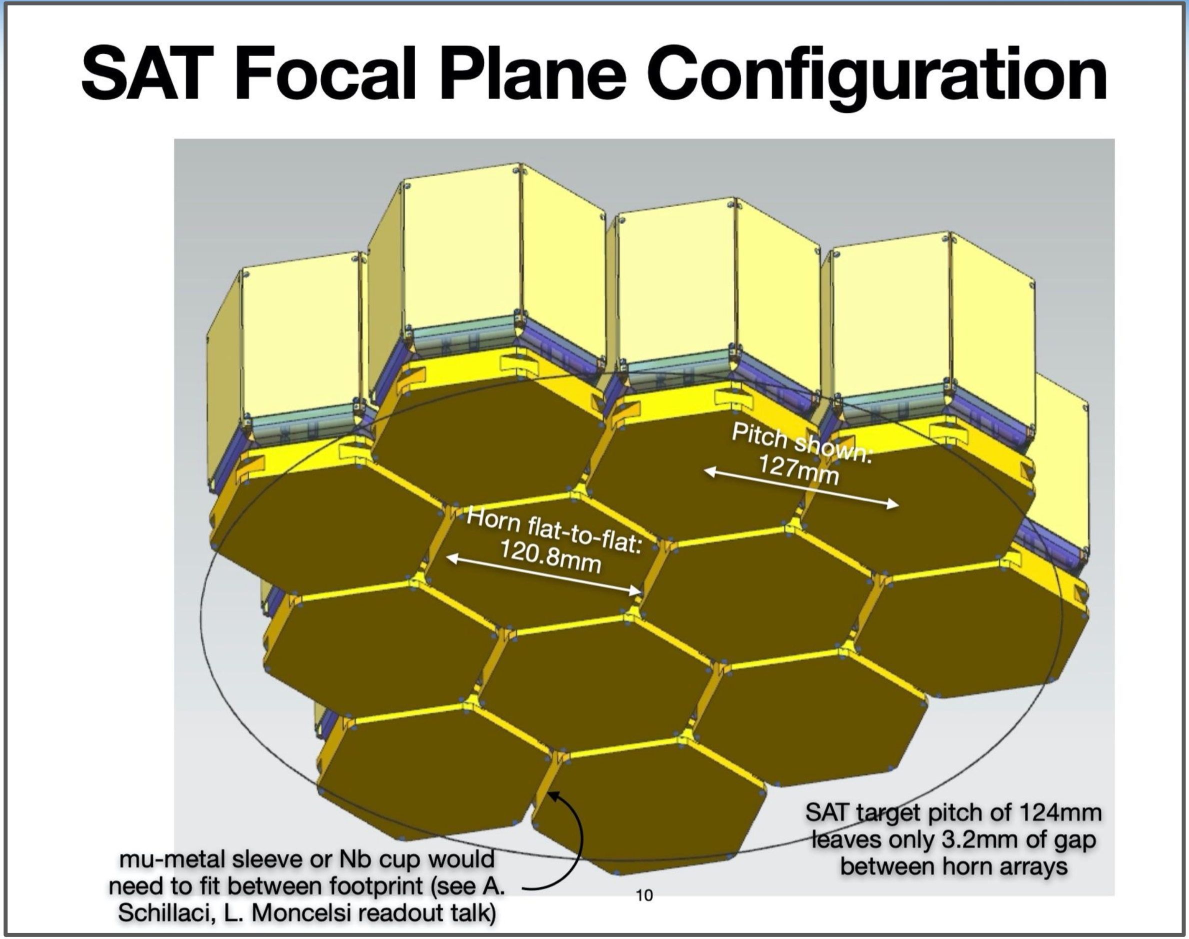




- Achieved significant reduction in box width with denser wiring chips, corrected MUX chip dimensions (90mm -> 65mm)
- Flex cables drastically shortened, eliminated twisting/ routing problem
- Final layout/dimensions of readout box pending final MUX column wiring chip configuration (see G. Haller readout talk)
- Residual collisions in corners, resolve with some combination of fine-tuning box width, removing material, and "pinwheel" orientation
- Include springs on readout mounting plate as on previous slide

- Discussed ease and possibility to add in RF and Magnetic shielding into new v2 Module Design.
- Readout modules will include their own shielding, combination of Nb and A4K u-metal.
- Cylinder around each module could be challenging given separation specification of modules.
- Also noted that it will be important to set requirements on shielding, shielding could be made arbitrarily good but would add additional physical constraints.

See A. Anderson's MAT Parallel Talk

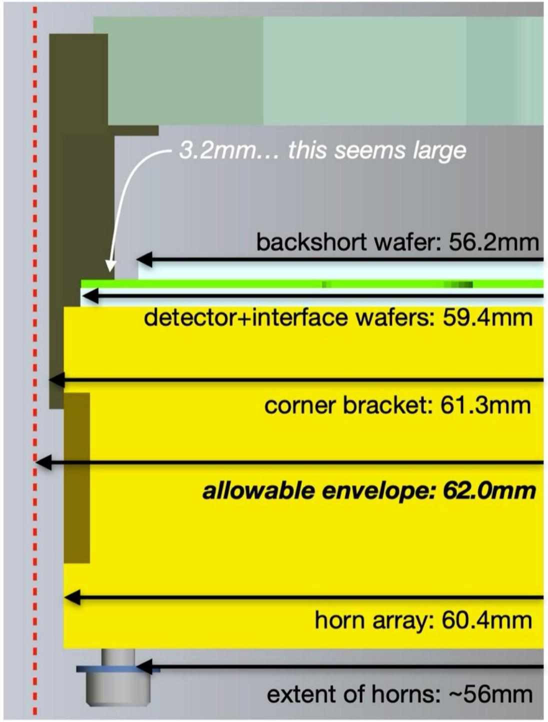


- Discussed challenges of SAT module packing requirements, a couple mm of tighter req. makes a big difference in current design.
- Discussed options for gaining ~2-mm in module spacing.
- Reduce SAT pitch; mapping speed decreases by 1% per 2-mm increase in wafer pitch.
- Discussed option of hard attaching modules without interconnecting 100 mK plate on SAT.
- Could create mechanical challenges, e.g., support for for focal plane weight through readout boxes could be challenge for thermal gradients, FEA / mechanical strength, etc., but is worth further study.

See A. Anderson's MAT Parallel Talk

SAT Pitch Problem

Important radial distances:



- In current design, there is 1.6mm or 0.7mm clearance for focal plane plate + magnetic shield, modulo precise locations. Seems inadequate.
- Possible solutions:
  - Relax 124mm pitch: reduces SAT mapping speed.
  - Shrink detector+interface wafers and horn array, holding backshort and horn array by ~2mm. *No impact to optics*. Reduces area for bondpads and mechanical support of outer horn wall.
  - Eliminate focal plane plate, and expand horn arrays to bolt directly into each other. Probably too radical, but arguably not insane.

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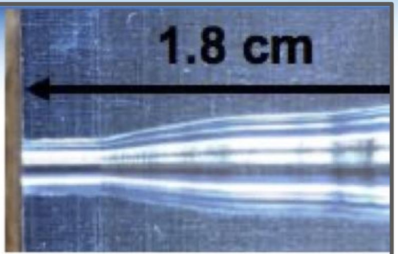
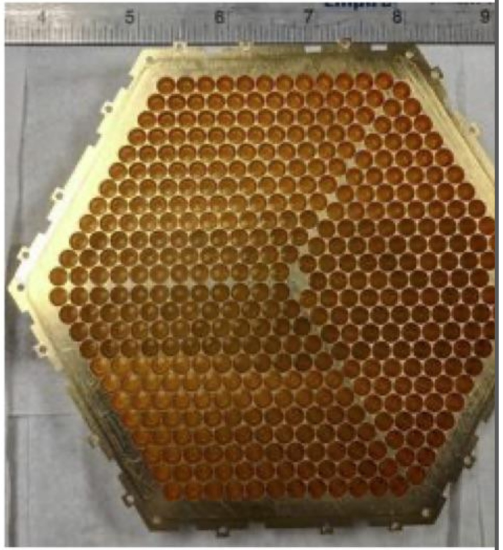
- Also discussed shrinking diameter of detector wafer, by reducing size of bond pads, etc.,
- Toki said he would study potential options to get more quantitative and could be part of report back to CDFG on this overall issue.

See A. Anderson's MAT Parallel Talk

Feedhorn Arrays

- Spline profiles optimized for performance requirements→ simulated estimates of systematic effects, efficiency
- Fabrication experience/testing from Simons Observatory
- Test arrays can use quick/less-optimized designs
- Final design requires set inputs:
  - Set pixel size
  - Defined waveguide cutoff and bands
  - Aperture stop angle
  - Any mechanical constraints (e.g. length)
  - Set input requirements
- Will need to decide when inputs are frozen



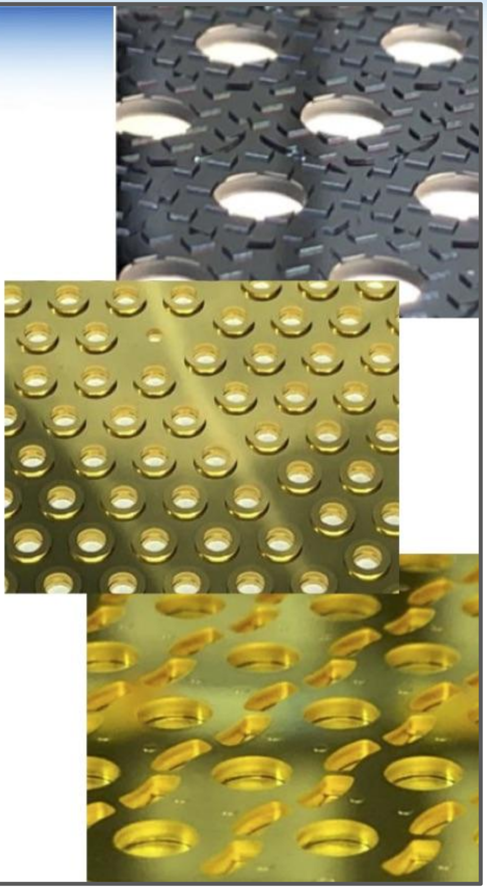


- Discussed optimizing feedhorn designs for different frequency bands, in particular trade-offs on horn length vs beam-symmetry and efficiency for different bands.
- Coordinating horn design studies underway to align with ongoing in-parallel Detector Module and SAT design efforts

See S. Simon's MAT Parallel Talk

Interface Wafers

- Identifying commercial vendors
  - NIST made previously, handing off process
  - NIST could produce a few for early optical tests depending on available resources
- Process Overview:
  - Vendor 1: DRIE etch, inspection, and cleaning of the wafers→ RFI in progress
  - Vendor 2: TiCu seed layer (likely same vendor NIST uses)
  - Fermilab: Assemble WIP and choke into a single piece
  - Vendor 3: Cu/Au coating with gap filling (likely same vendor NIST uses)
  - Fermilab: Integration with detector wafer
- Process could be costly→ also considering alternatives to baseline



- Talked about ongoing challenges with Interface wafer production, however clear near term path of RFI and engaging alternate vendors
- Discussed moat design and if that should be revisited / resimulated in future.

See S. Simon's MAT Parallel Talk

Measurement Req.

From PBDR

Table 3-4: Testing measurement requirements

Title	Requirement	Origin	Test
NET	Noise equivalent temperature of the detecotr module	Flowdown from sensitivity requirements in each band	In-transition noise and efficiency measurements looking into a cold-load during dark testing.
Yield	Percentage of detectors that can be readout per module	Flowdown from sensitivity requirements in each band	IV measurements of TES during dark testing
TES time constant	Time constant of the TES detector in the transition	Flowdown from sensitivity and systematic requirements in each band	TES response to voltage bias step and flashed-optical source during dark testing
TES properties	Saturation power, superconducting transition temperature, normal resistance of the TES	Flowdown from sensitivity and systematic requirements in each band	IV measurements of TES during dark testing
TES stability	Stability of the TES while in-transition	Flowdown from sensitivity and systematic requirements in each band	In-transition noise looking into a cold-load during dark testing.
RF pickup	RF response of the detectors	Flowdown from systematic requirements in each band	Sweep of RF source around cryostat during dark and optical detector testing
Magnetic pickup	Magnetic response of the detectors	Flowdown from systematic requirements in each band	Sweep of magnetic field around cryostat via Helmoltz coil during dark and optical detector testing
Bandpass	Frequency response of the detectors	Flowdown from sensitivity and systematic requirements in each band	Fourier transform spectroscopy measurements during optical testing.
Beam shape	Spatial response of the detectors	Flowdown from systematic requirements in each band	Beam-shape measurements of horns via VNA setup, with spot checks of modules during optical testing
Cross-polarization	Cross-polarization response of the horn arrays and detectors	Flowdown from systematic requirements in each band	Cross-polarization measurements of horn arrays via VNA setup, with spot checks of modules during optical testing

- Will need to continue to develop testing requirements and measurement procedures for next stages of testing.
- Instrument flowdown will affect what type of test equipment is required, e.g.,
  - Required frequency band accuracy would affect what we build to measure bandpasses
  - Magnetic and RF shielding requirements.
  - Warm VNA+CMM measurements of horns.
- More "testing and measurement requirements" documentation will have to be prepared ahead of CD-1

CMB-S4

CMB-S4 Collaboration Meeting, March 8-12, 2021

- Discussed measurement requirements for testing detector modules, a couple missing tests.
- Suggestion to simplify measurement requirements focusing on key detector module performance parameters (e.g., NET, Psat)

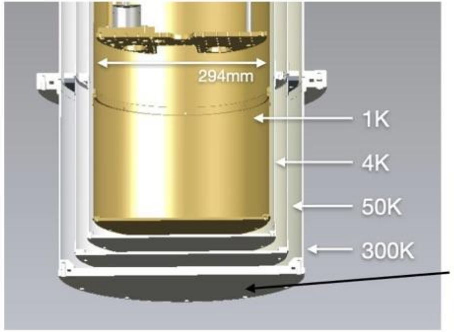
See B. Benson's MAT Parallel Talk

Module Testbeds: FY21 DRM R&D

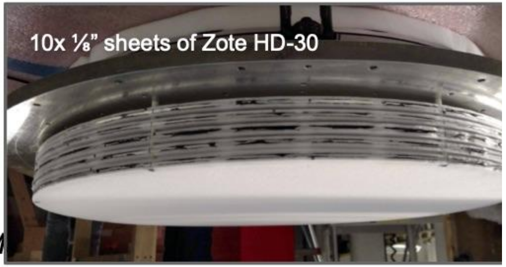
- Also later in 2021, would like to expand some testbeds to have optical capability.
- Requires ~20-cm diameter optical window, very similar to what's being developed for LATR optics tube
- Expecting to be able to leverage aspects of LATR design to make mostly plastic IR filter design
- Can be effectively identical across our Bluefors and Oxford testbed

material	*T sink [K]*	*T filter [K]*	*thickness [mm]*	*power in [W]*
Blackbody	290	290	N/A	N/A
HDPE window	290	290	10	5.8
zotefoam filter stack (10 layers)	290	282-164	10x 3.175	4.7 - 0.46
HDPE	40	42.7	10	0.37
nylon	40	43.9	1	0.025
nylon	3	4.3	4	1.76e-3
metal-mesh (200 GHz cutoff)	3	3.0	1	7.7e-7
gold (emissivity of 0.01) with 16 horns of radius 3.5mm with effective area $\lambda^2 = 4\mathrm{mm}^2$ and emissivity of 1	0.1	0.1	N/A	5.0e-8

Table 1: Baseline all-plastic filter configuration.



All bottoms of radiation shields are removable—replace these with plates that have holes and clamping for filter components



- Discussed commonalities in detector module test setups, with SAT and LATR camera designs.
- Suggestions of coordinating designs and R&D on vacuum window, infrared filtering material, and IR stack variations, since filter layout and material technology will be similar
- See MAT notes at: https://docs.google.com/document/d/147DTwHa2qDfxlHHTN0zPOF79ekOyeTk_M17elxZfON0/edit

See B. Benson's MAT Parallel Talk