The Simons Observatory uMux focal plane modules

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JSAC talks
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The Simons Observatory (SO) Collaboration

Collaboration
• 40+ institutions
• 160+ researchers
• 10 countries

Funding
• Simons Foundation
• Heising-Simons Foundation
• University Contributions

SO collaboration meeting, July 2020, virtually at Princeton

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Simons Observatory


- First light in the first small aperture telescope (SAT) in 2021

- **One large aperture telescope** (LAT) for high-l science

- **Four small aperture telescopes** for low-l science

- **60,000 detectors** in 6 frequency bands centered between 27 GHz and 270 GHz

  (three SATs will be deployed initially)


LATR and SATs

Zhu et al. (2018)
arXiv:1808.10037

LATR at University of Pennsylvania

SAT 1 at University of California, San Diego

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SO focal planes

LAT optics tube focal plane
(3 arrays x 7 optics tubes)

SAT focal plane (7 arrays x 4 SATs)

49 focal plane modules

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uMUX focal plane modules

- Leading testing and microwave SQUID multiplexing (uMUX) focal plane module design at Princeton
- uMUX readout and the focal plane module are major technical developments for SO in conjunction with SLAC and NIST.
- Designed to multiplex 1000 TES bolometers per pair of coaxial cables
- Current CMB experiments use a multiplexing factor of ~70
- Module design allows for efficient focal plane use, with readout electronics in a compact assembly that lies directly behind the detector array.

I will present the evolved design and status here.
uMUX focal plane modules

- Implement the uMUX readout scheme for TES bolometers for SO at 1000 or 2000 multiplexing
- Provide bias circuitry for TESs
- Mechanical housing for uMUX
- Low noise and RF quiet environment
- Occupy the same footprint as detector arrays
SO readout overview

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uMUX

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SO universal focal plane module (UFM): detectors and readout

Exploded view of focal plane parts

UFM assembled with (top) and without (bottom) magnetic and RF shield
Cold readout

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Exploded view of focal plane parts

Readout components measured independently
Architecture

- 28 mux chips
  - 66 channels per multiplexer chip
  - 2 x 4-6 GHz resonators
  - 1848 readout channels (1764 detectors)

- Wafer(s)
  - Connect RF lines in series
  - Contain TES bias circuitry
Readout demonstration

- Left: Noise spectrum from a demonstration of 500x multiplexing in prototype SO module meeting baseline spec with a median noise of 62 pA/rt(Hz) with 94% initial resonator yield.

- Right: most recent prototype with additional grounding has improved Qis > expect even lower noise.
(Preliminary) Demonstration with first detector array

- Right: IV curve of an example MF detector in prototype SO focal plane module.
- Left: Integrated SO module. Visible is the sealed module lid and walls.
Underway: SO first light arrays

• Initial arrays being built: characterization underway.

• Further improvements in readout: frequency placement, noise, and overall yield.

• (Re)validating detector arrays: assume 99% detector yield as with AdvACTPol.

• *Putting together what has previously been demonstrated* > multiplexing and detectors.

• Arrays will be sent for integration to first SAT this fall and LATR shortly thereafter.

• First light in 2021.
Summary

- Successfully designed an assembly that places 2000 channels of readout behind a 6” detector wafer.
- Demonstrated low rate of frequency collisions and high yield.
- Readout noise measurements have met SO baseline spec. at 500 multiplexing, moving toward 1000x.
- Demonstrated detector operation and characterization in SO focal plane modules.
- *Putting it all together* > first focal plane modules going to field are beginning testing now.
- First light in 2021.
Back up
Assembly

Module designed to make integration of readout components and detector array feasible.

Assembly is crucial to RF/readout performance.

Assembly and integration steps: inspection, diebond, RF and DC bonding, mechanical packaging

Necessary to create automated, robust and repeatable assembly and integration processes to produce 49 readout and detector assemblies.

Li et al. (2019)
SO testbeds at Princeton

The two dilution refrigerator testbeds at Princeton

Two stage cold amplification

SMuRF

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Qi requirements

- Pseudo noise floor as a function of number of probe tones for varying resonance depths.
- With a 5 dB depth and a 1000 multiplexing factor, the noise floor correspond to 50 pA/rt(Hz), below SO baseline.

- Resonance depth versus Qi for resonators designed to have 100 kHz bandwidth and resonances at 4, 5, 6, and 7 GHz.
- The shaded region corresponds to the 4 GHz resonance.