Advanced ACTPol Low Frequency Array: Readout and Characterization of Prototype 27 and 39 GHz TESes

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Introduction

Advanced ACTPol (AdvACT) is a third generation polarization sensitive upgrade to the Atacama Cosmology Telescope (ACT). AdvACT contains three sets of multichroic detectors, referred to as high-frequency (HF, 220/270 GHz), mid-frequency (MF, 90/150 GHz) and low-frequency (LF, 27/39 GHz). The addition of the LF array will enable mapping synchrotron emission and radio sources across a large fraction of the sky to understand the foreground complexity and inform future projects such as Simons Observatory and CMB-S4.

The increased spectral coverage of AdvACT will enable improvements in a wide range of science, such as improving constraints on dark energy, the sum of the neutrino masses, inflationary parameters and potentially the energy scale of inflation. The LF array will be deployed for the 2018 season. Here we present the design and characterization of the first LF prototype detectors for AdvACT.

Advanced ACTPol

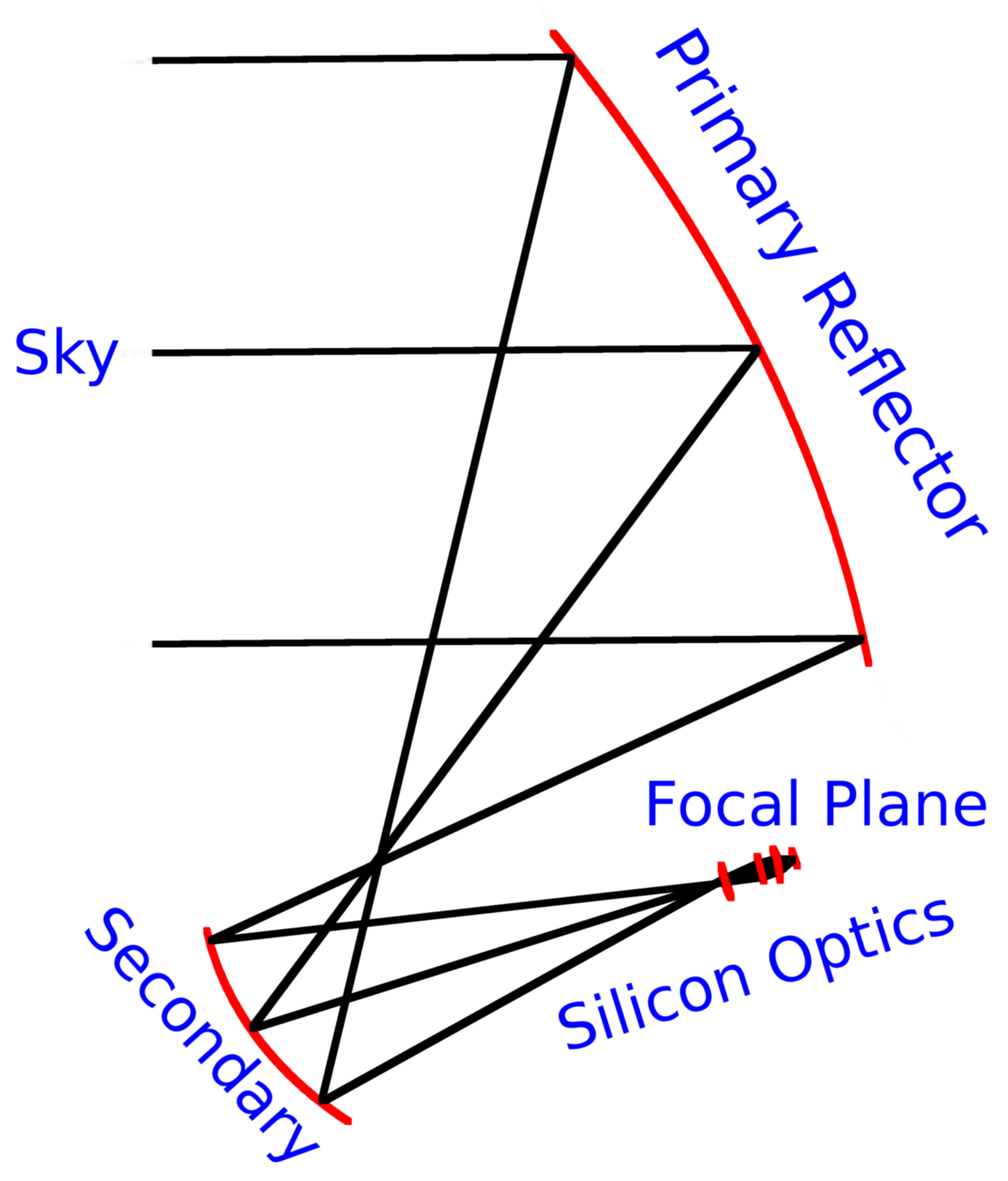

Figure 1: Ray trace of ACTPol [5].

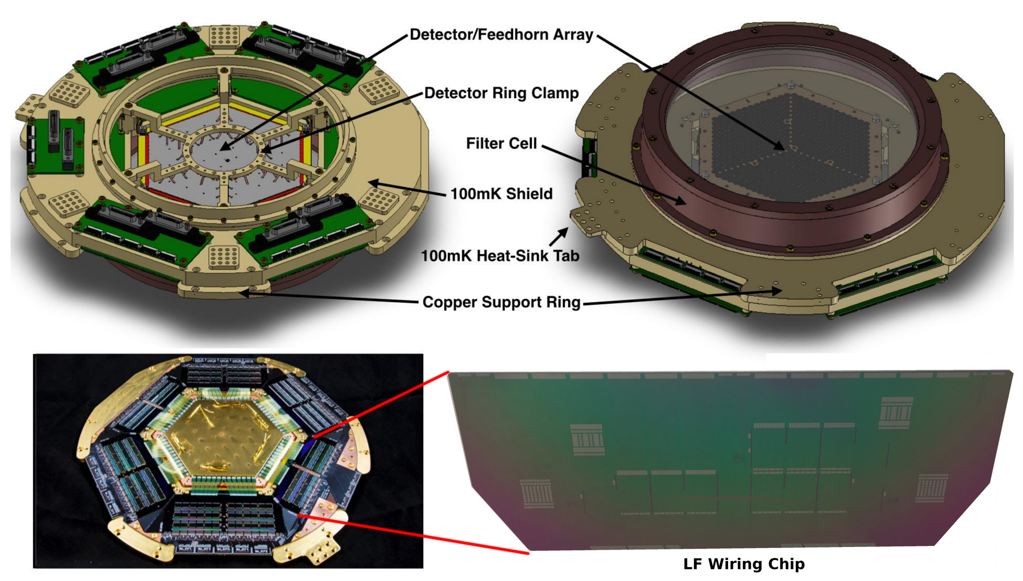

Figure 2: AdvACT HF array package and new LF Wiring Chip [4].

LF Readout and Detector Array

- Similar to HF and MF readout [1]
- Time Division Multiplex (TDM) on warm Multi-Channel Electronics (MCEs)
- Identical readout PCB as HF/MF arrays
- New 100 mK interface board interfaces existing MF/HF electronics with low LF pixel count
- Simplified TDM architecture compared to already implemented MF and HF readout
- 24 Rows, 16 Columns, 376 TESes readout
- Multiplexing factor of 24:1

LF Prototype Devices

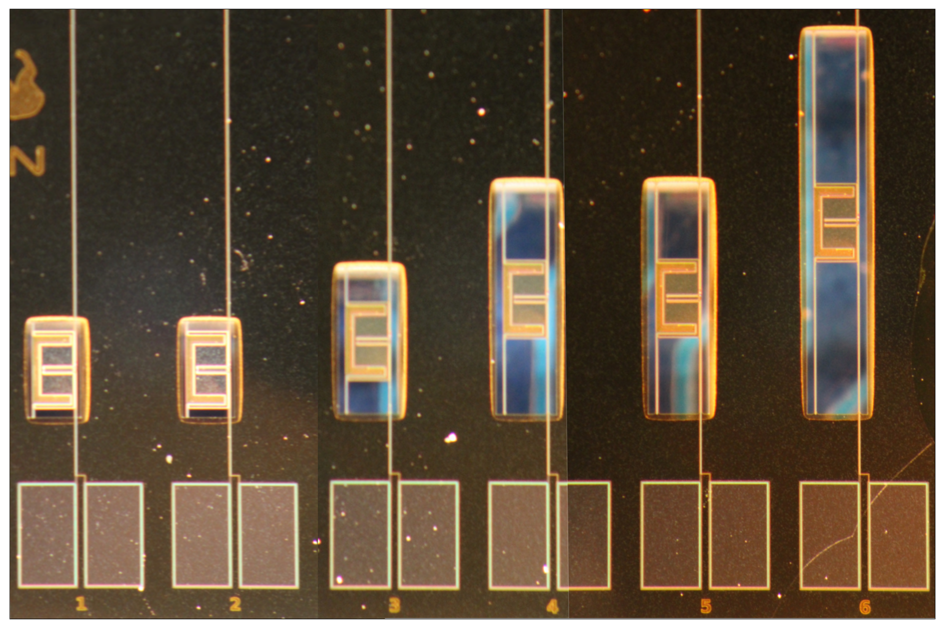

Figure 3: LF prototype TESes - leg variations.

Device	Freq [GHz]	w[μm]	l[μm]
1	39	14.4	61.0
2	39	12.1	61.0
3	27	10.0	219.8
4	27	10.0	500.0
5	27	15.0	500.0
6	27	10.0	1000

Table: Leg length and width variations tested.

- Determine different detector P_{sat}
- Changes in the legs change the thermal coupling to the bath, changing the P_{sat}
- Target 1.5 pW and 7.8 pW for 27 and 39 GHz bands

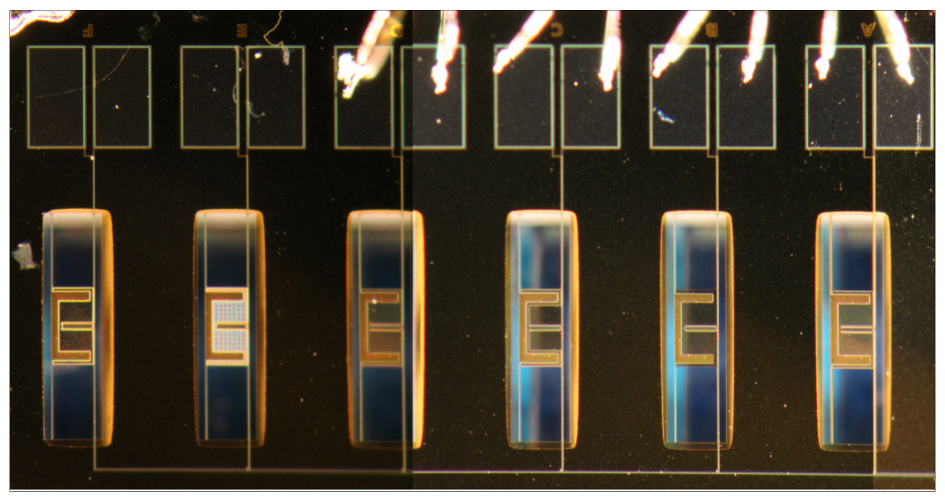

Figure 4: LF prototype TESes - BLING variations.

6 AlMn and PdAu variations to explore detector response speed parameter space:

- PdAu "BLING" adds heat capacity, changing the response of the detectors
- Target f3dB in range [81 Hz, 275 Hz] for 35%-70% R_n across range of expected P_{bias}

Device Characterization Results

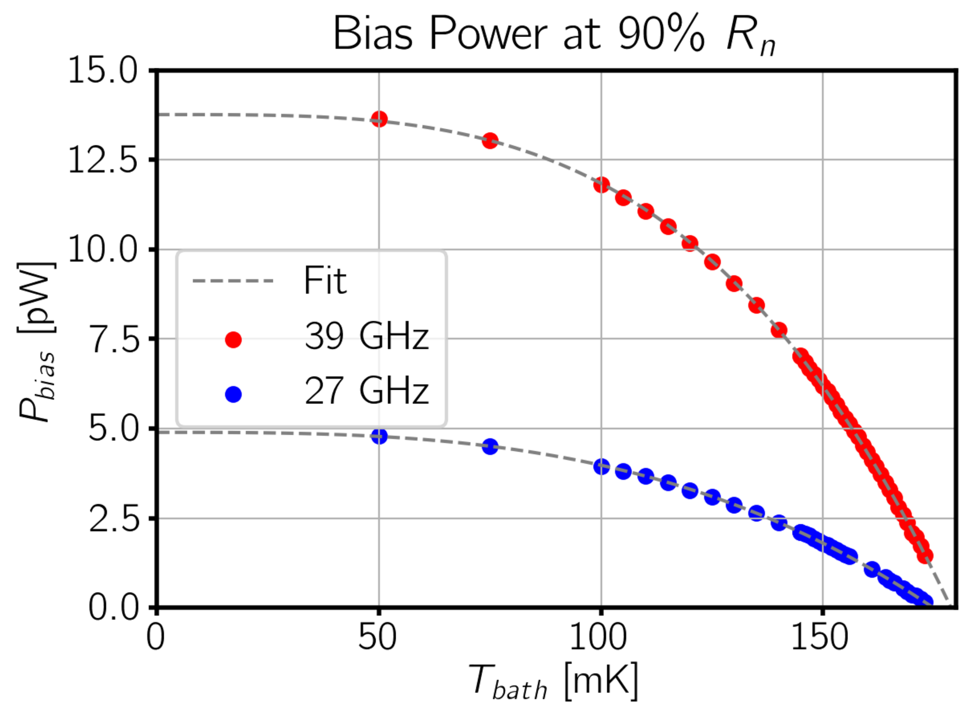

Figure 5: P_{bias} vs T_{bath} from IV curves for 27 and 39 GHz device. Fit to Eqn. (1).

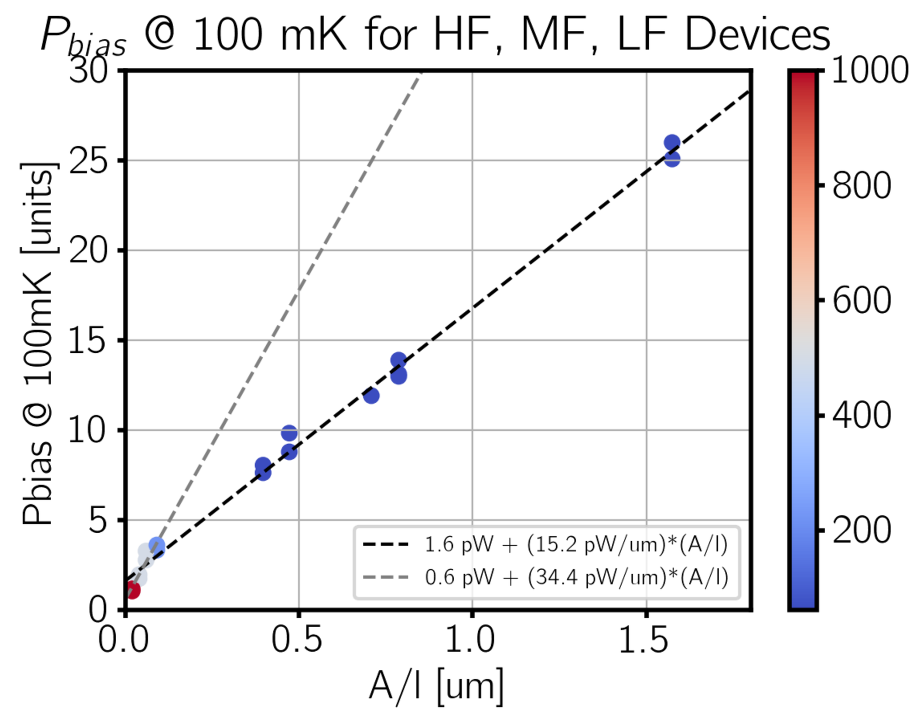

Figure 7: P_{bias} at 100 mK vs cross sectional area over length of the TES leg. Includes HF, MF, and LF detectors. T_c rescaled to 165 mK.

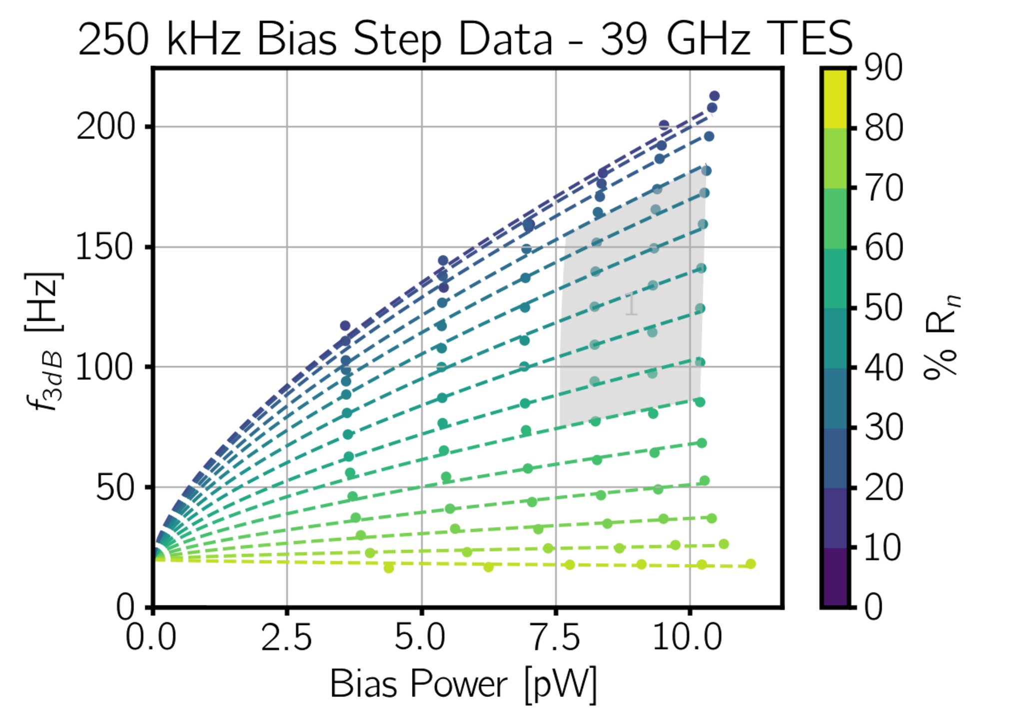

Figure 6: 250 kHz bias step results for a 39 GHz TES. Grey region indicates predicted operating range.

- IV curves performed at many T_{bath}
- Fit to Eqn. (1) and (2) to determine P_{sat}, G, K

$$P_{sat} = K(T_c^n - T_{bath}^n) \quad (1)$$
$$G = nKT_c^{n-1} \quad (2)$$

- Fast sampled (250 kHz) voltage steps on TES bias line used to characterize detector response speed, fit to two-fluid model in [3],

$$f_{3dB} = A + BP_{J0}^{2/3}, \quad (3)$$

where,

$$A = \frac{G}{2\pi C}, \quad (4)$$

$$B = \frac{3}{4\pi C T_0 (1+\beta_I)} \left(\frac{(c_r R_n - R_0) c_I^2 I_{c0}^2 R_0}{c_R R_n} \right)^{1/3}. \quad (5)$$

LF Array Device Parameters

Freq[GHz]	PdAu vol[μm^3]	AlMn vol[μm^3]
27	0	24846
39	23473.3	36112.8

Table: LF PdAu and AlMn parameters for fabrication.

Measured Device Parameters

Device	T_c[mK]	P_{sat}[pW]	G[pW/K]	R_n[mΩ]
1	177.7	12.5	282.9	7.9
2	177.8	10.5	230.2	7.8
3	172.3	4.1	87.0	7.5
4	169.9	2.1	40.9	7.5
5	171.6	3.5	74.9	7.5
6	160.6	1.0	20.3	7.5

Table: Measured LF leg-variation prototype detector properties

Freq[GHz]	w[μm]	l[μm]
27	10	628
39	12.1	61

Table: LF leg geometries for final LF array fabrication.

References

[1] Henderson et. al., LTD16 (2015).
[2] Irwin and Hilton (2005).
[3] Irwin et. al., JAP, 83, 3978-3985 (1998) - doi:10.1063/1.367153.
[4] Ward et. al., SPIE 991416 (2016).
[5] Fowler et. al., Appl. Opt. 46, 3444-3454 (2007).

Acknowledgments

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Conclusions

- Lowest P_{sat} TESes fabricated yet for AdvACT
- Demonstrates capability to achieve target P_{sat}
- Plan to deploy LF array in 2018