PICO Noise Model

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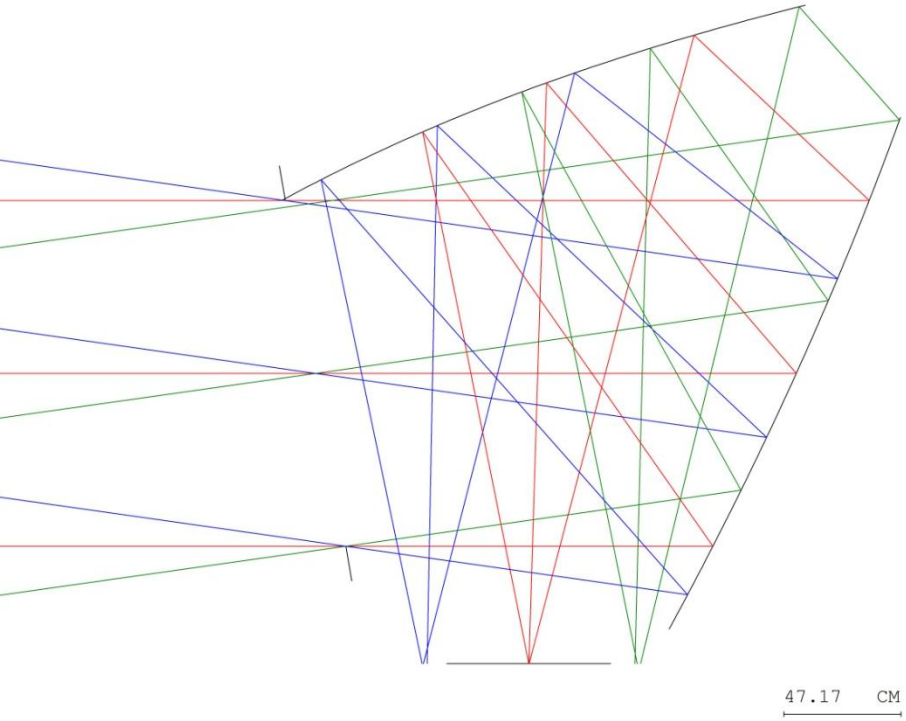
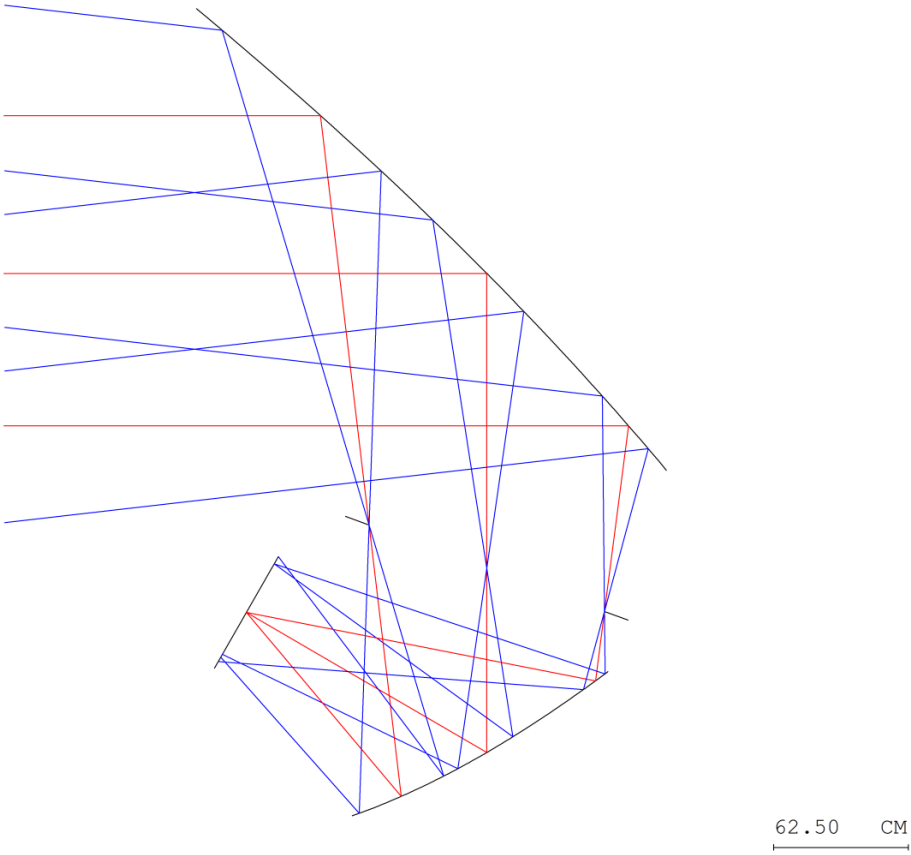
PICO Noise Model

- Goal: calculate noise as a function of focal plane configuration
- Step 1 (today): develop noise model per single detector
- Today's summary:
  - 1st iteration of noise model exists
  - Spillover vs. wavelength not yet implemented correctly for multi-chroic pixels (MCP)
  - Iterating on FDM readout noise with Dobbs
- Next steps:
  - Compare performance with bath temperature
  - Extend to MCP
  - Include full focal plane: all detectors, filters as emissive elements along light path
  - Compare with O'Brient's model

Optics options studied



Crossed Dragone
30 K mirrors
30 K stop



Open Dragone
30 K primary
4 K stop
4 K secondary

Examples and explanation on next pages. Final numbers in separate google docs sheet, https://docs.google.com/spreadsheets/d/1XIygkHSCQj4TGHTtVj52Amb13qQuqYqxJIlyYaYYQFE/edit?usp=sharing

Summary of loading and noise calculation code

- Overview: Calculate in band power absorbed by the detector, P_{opt}. From P_{opt} calculate bolometer properties, then NEP by source, then total NET per detector.
- Assumptions
  - Throughput for detector = lambda ** 2
  - Spillover is terminated on the stop
  - Mirror emissivity scales as sqrt(frequency); value at 150 GHz = 1% (TBC)
  - All power (CMB and emission from warm surfaces) is unpolarized
  - Gaussian beam emitted by detector
  - Photon correlation noise =1
  - Bolometer temperature is transition temperature Tc
  - Bolometer Tc is optimal for given Psat.
  - FDM readout noise assumes x16 FDM boards, not new ICE boards.
    - Bias frequency = 500 kHz
    - Gains are; carrier = 2, nuller = 1, demod = 0
    - SQUID trans-impedence 320 ohm, R_feedback = 5 kohm

Inputs to the code, Open Dragone

Parameter	Value		
Band (top hat, no out of band loads)	21 bands, 21 GHz to 800 GHz		
Edge taper of detector beam on stop	10 dB		
Telescope aperture	140 cm		
F-number	1.5		
Bolometer attributes (same for all optics cases)			
Psat to Popt safety factor	2.5		
T_bath	250 mK		
thermal power law index (n)	3 (will change to 2 as measured in EBEX)		
Bolometer normal resistance	1.33 Ohms		
Bolometer loopgain	25		
Bolo time constant	10 ms		
Optical element properties	**Reflection loss**	**Emissivity**	**Temperature (K)**
Bolometer absorption efficiency	0.3	0	0.25
Mirror (secondary)	0	0.01	4
Stop	0	1	4
Mirror (primary)	0	0.01	30
CMB	0	1	2.725

Outputs, Open Dragone

- Power emitted by each element.
- Power absorbed by detector from each element
- Total power absorbed by detector
- NEP total and by type (photon, phonon, johnson, readout)
- Total NET, this is temperature sensitivity of a single bolometer. NOT polarization sensitivity.

Example at 155 GHz, Open Dragone

element	emissivity	Temperature (K)	power_emit (W)	Transmission per element	Cumulative efficiency	Power absorbed (W)
Pol_y/n	0	0	0	0.5	1	0
Bolometer absorption efficiency	0	0.25	0	0.7	0.5	0
Mirror	0.010157	4	1.50E-14	0.989843	0.35	2.25E-15
Stop	1	4	1.47E-12	0.901722	0.034048	2.15E-14
Mirror	0.010157	30	2.87E-13	0.989843	0.312397	3.84E-14
CMB	1	2.725	5.61E-13	1	0.309224	7.44E-14

Output, all bands page 1/2, Open Dragone

Band	Center (GHz)	nu_low (GHz)	nu_high (GHz)	spill_eff	illum_eff	FWHM (')	total_power (W)
1	20.8	18.2	23.4	0.902	0.898	40.88	1.24E-13
2	25	21.9	28.1	0.902	0.898	34.01	1.44E-13
3	30	26.3	33.8	0.902	0.898	28.29	1.67E-13
4	36	31.5	40.5	0.902	0.898	23.62	1.91E-13
5	43.2	37.8	48.6	0.902	0.898	19.68	2.17E-13
6	51.8	45.4	58.3	0.902	0.898	16.40	2.42E-13
7	62.2	54.4	70	0.902	0.898	13.67	2.68E-13
8	74.6	65.3	84	0.902	0.898	11.39	2.91E-13
9	89.6	78.4	100.8	0.902	0.898	9.49	3.08E-13
10	107.5	94.1	120.9	0.902	0.898	7.91	3.18E-13
11	129	112.9	145.1	0.902	0.898	6.59	3.22E-13
12	154.8	135.4	174.1	0.902	0.898	5.49	3.19E-13
13	185.8	162.5	209	0.902	0.898	4.58	3.09E-13
14	222.9	195	250.8	0.902	0.898	3.81	2.98E-13
15	267.5	234	300.9	0.902	0.898	3.18	2.92E-13
16	321	280.9	361.1	0.902	0.898	2.65	3.00E-13
17	385.2	337	433.3	0.902	0.898	2.21	3.26E-13
18	462.2	404.4	520	0.902	0.898	1.84	3.71E-13
19	554.7	485.3	624	0.902	0.898	1.53	4.33E-13
20	665.6	582.4	748.8	0.902	0.898	1.28	5.06E-13
21	798.7	698.9	898.5	0.902	0.898	1.06	5.82E-13

Output, all bands page 2/2, Open Dragone

Band	NEP_total (W / rt(Hz))	NET_total (K_cmb / rt(Hz))	NEP_poisson (W / rt(Hz))	NEP_photon (W / rt(Hz))	NEP_phonon (W / rt(Hz))	NEP_johnson (W / rt(Hz))	NEP_readout (W / rt(Hz))
1	6.0E-18	9.6E-05	1.9E-18	2.5E-18	4.1E-18	2.1E-18	3.0E-18
2	6.5E-18	8.8E-05	2.2E-18	2.8E-18	4.4E-18	2.3E-18	3.2E-18
3	7.1E-18	8.0E-05	2.6E-18	3.2E-18	4.7E-18	2.4E-18	3.5E-18
4	7.7E-18	7.3E-05	3.0E-18	3.6E-18	5.1E-18	2.6E-18	3.7E-18
5	8.3E-18	6.6E-05	3.5E-18	4.1E-18	5.4E-18	2.8E-18	4.0E-18
6	8.9E-18	6.1E-05	4.1E-18	4.6E-18	5.7E-18	2.9E-18	4.2E-18
7	9.6E-18	5.6E-05	4.7E-18	5.2E-18	6.0E-18	3.1E-18	4.4E-18
8	1.0E-17	5.2E-05	5.4E-18	5.8E-18	6.2E-18	3.2E-18	4.6E-18
9	1.1E-17	4.8E-05	6.0E-18	6.4E-18	6.4E-18	3.3E-18	4.7E-18
10	1.1E-17	4.6E-05	6.7E-18	7.0E-18	6.5E-18	3.4E-18	4.8E-18
11	1.2E-17	4.5E-05	7.4E-18	7.6E-18	6.6E-18	3.4E-18	4.8E-18
12	1.2E-17	4.6E-05	8.1E-18	8.2E-18	6.5E-18	3.4E-18	4.8E-18
13	1.2E-17	5.0E-05	8.7E-18	8.8E-18	6.4E-18	3.3E-18	4.7E-18
14	1.3E-17	5.9E-05	9.3E-18	9.4E-18	6.3E-18	3.2E-18	4.6E-18
15	1.3E-17	8.0E-05	1.0E-17	1.0E-17	6.2E-18	3.2E-18	4.6E-18
16	1.4E-17	1.3E-04	1.1E-17	1.1E-17	6.3E-18	3.3E-18	4.7E-18
17	1.6E-17	2.5E-04	1.3E-17	1.3E-17	6.6E-18	3.4E-18	4.9E-18
18	1.8E-17	6.1E-04	1.5E-17	1.5E-17	7.0E-18	3.6E-18	5.2E-18
19	2.1E-17	2.0E-03	1.8E-17	1.8E-17	7.6E-18	3.9E-18	5.6E-18
20	2.4E-17	8.7E-03	2.1E-17	2.1E-17	8.2E-18	4.2E-18	6.1E-18
21	2.7E-17	5.4E-02	2.5E-17	2.5E-17	8.8E-18	4.5E-18	6.5E-18