Semiconducting Pop-Up Bolometers for Far-Infrared and Submillimeter Astronomy

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Abstract.

This condensed version of the paper contains the SHARC II bolometer prescription.

1. Bolometers for SHARC II

For SHARC II, we are constructing an AC-biased readout (Wilbanks et al. 1990) with an optical signal band of approximately 0.1 to 50 Hz.

Table 1. SHARC II Bolometer Design Constraints

Operating temperature	0.32 K
Background power (Q)	75 pW
NEP_{elec}(sky)	4.4×10^{-16} W $Hz^{-1/2}$
NEP_{elec}(detector)	$\leq2.0\times10^{-16}$ W $Hz^{-1/2}$
e_n(amplifier, 50 Hz)	6 nV $Hz^{-1/2}$
R_{load}	400 MΩ at 2.0 K
Signal bandwidth	f = 0.1 to 50 Hz

The resistance of the doped silicon thermistors is modeled well by the variable range hopping mechanism, where:

$$R = R_0 \exp(\sqrt{\frac{T_0}{T}}). \quad (1)$$

The dependence of T_0 on doping density is extreme, while the dependence of R_0 is weak (Zhang et al. 1993).

The temperature dependence of the thermal conductance in the silicon links is:

$$G = G_0 T^3 \quad (2)$$

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Table 2. SHARC II Bolometer Design

Parameter	Target	Acceptable Range	Units
R_0	1430	400-2000	Ω
T_0	40	31-43	K
G_0	8.0	1.5-9.5	nW K^{-1}
implant area	1		mm^2
time constant	1.5	less than 10	ms

Table 3. Calculated Bolometer Characteristics

Parameter	Value	Units
V(bias)	820	mV
V(bolometer)	20	mV
I	2.0	nA
R	10.0	MΩ
Z	5.1	MΩ
T	0.51	K
G	1.1	nW K^{-1}
S	1.2	10^8 V/W
NEP_{elec} (phonon)	0.89	10^{-16} W $Hz^{-1/2}$
NEP_{elec} (bol. Johnson)	1.03	10^{-16} W $Hz^{-1/2}$
NEP_{elec} (bol. 1/f, 0.1 Hz)	1.10	10^{-16} W $Hz^{-1/2}$
NEP_{elec} (load Johnson)	0.22	10^{-16} W $Hz^{-1/2}$
NEP_{elec} (amplifier)	0.50	10^{-16} W $Hz^{-1/2}$
NEP_{elec} (detector total)	1.84	10^{-16} W $Hz^{-1/2}$
e_n	22	nV $Hz^{-1/2}$

To determine the required accuracy of the bolometer fabrication, we considered the range for each parameter separately for which we achieve our goal of $NEP_{elec}(\text{detector}) \leq 2.0 \times 10^{-16}$ W $Hz^{-1/2}$. This range has also been included in Table 2.

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