Characterizing the PAR Detectors

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All data from Simon, Phillip, et al. at UPenn
The UPenn Array
The TESs are Small!
The Ideal Model
A Better Model

Bulk Silicon \( T_b = 300 \text{ mK} \)

\[ C_a \]

\[ G_{ap}(T) \]

\[ C_p \]

\[ G_{ep}(T) \]

\[ G_{pb}(T) \]
Estimating Parameters

Bulk Silicon $T_b = 300 \text{ mK}$
Estimating Parameters

• The TES and phonon heat capacities are calculated from published values of heat capacities for Mo, Au, and Silicon.

  \[ C_e = 160 \text{ fJ/K}, \quad C_p = 650 \text{ fJ/K} \]

• The electron-phonon thermal conductance is also estimated from the literature, but there is about a factor of 10 uncertainty in the actual number.

  \[ G_{ep} = 5-50 \text{ nW/K @ 480 mK} \]
Estimating Parameters

- The thermal conductance to the silicon substrate, $G_{pb}$, is calculated from fitting the bias power vs bath temperature curve.

- $G_{pb} = 140 \text{ pW/K } @ 480 \text{ mK}$
Power vs Bath Temperature

![Graph showing the relationship between TES Bias (Joule heating) Power [pW] and Bath Temperature Tb [mK].]
Circuit Parameters

- $R_L = 0.55$ mOhm
- $L = 74$ nH
- $R_n = 7.3$ mOhm
Fitting to $R_{\text{TES}} = 0$ Data

- Impedance [mOhm]
- Frequency [Hz]

- GBTsuper Re\{Data\}
- GBTsuper Im\{Data\}
- GBTsuperRe\{Model\}
- GBTsuperIm\{Model\}

Inductor

$R_L$ (shunt resistor)
\[ \alpha = \frac{T}{R} \left. \frac{\partial R(T,I)}{\partial T} \right|_{I=\text{const}} \]

\[ \beta_i = \frac{I}{R} \left. \frac{\partial R(T,I)}{\partial I} \right|_{T=\text{const}} \]
# Results before fitting

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_e$ (TES)</td>
<td>160 fJ/K</td>
<td>$C_a$ (Bi) (est: 1.6-2.2 pJ/K)</td>
</tr>
<tr>
<td>$C_p$ (Si)</td>
<td>650 fJ/K</td>
<td>$G_{ap}$</td>
</tr>
<tr>
<td>$G_{ep}$</td>
<td>5 nW/K</td>
<td>alpha</td>
</tr>
<tr>
<td>$G_{pb}$</td>
<td>140 pW/K</td>
<td>beta</td>
</tr>
<tr>
<td>$T_c$</td>
<td>484 mK</td>
<td></td>
</tr>
<tr>
<td>$T_b$</td>
<td>298 mK</td>
<td></td>
</tr>
<tr>
<td>$R_n$</td>
<td>8.28 mOhm</td>
<td></td>
</tr>
<tr>
<td>$R_{L\text{(shunt)}}$</td>
<td>.055 mOhm</td>
<td></td>
</tr>
<tr>
<td>$L$ (inductor)</td>
<td>74 nH</td>
<td></td>
</tr>
</tbody>
</table>
The Data

- GBT9000 Re{Data}
- GBT9000 Im{Data}
- GBT10000 Re{Data}
- GBT10000 Im{Data}
- GBT11000 Re{Data}
- GBT11000 Im{Data}
- GBT12000 Re{Data}
- GBT12000 Im{Data}
The Fits

The graph shows the impedance [mOhm] against frequency [Hz] for different models, with the frequency range from $10^0$ to $10^4$ Hz. The models include:

- GBT9000 Re{Model} 37% Bias
- GBT9000 Im{Model}
- GBT10000 Re{Model} 47% Bias
- GBT10000 Im{Model}
- GBT11000 Re{Model} 57% Bias
- GBT11000 Im{Model}
- GBT12000 Re{Model} 68% Bias
- GBT12000 Im{Model}
Width of data suggests a decoupled absorber
X-ray position-sensitive TES impedance data
Distributed Absorbers!
Distributed Model

Bulk Silicon $T_b = 300$ mK

$C_e$, $C_a$, $C_p$, $G_{ep}(T)$, $G_{ap}(T)$, $G_{pb}(T)$
## Modeling Results

<table>
<thead>
<tr>
<th>Calc. Pars</th>
<th>Values</th>
<th>Fitted Pars</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_e$ (TES)</td>
<td>160 fJ/K</td>
<td>$C_a$ (Bi)</td>
<td>4 pJ/K</td>
</tr>
<tr>
<td>$C_p$ (Si)</td>
<td>650 fJ/K</td>
<td>$G_{ap}$</td>
<td>8.7 nW/K</td>
</tr>
<tr>
<td>$G_{ep}$</td>
<td>5 nW/K</td>
<td>alpha</td>
<td>170</td>
</tr>
<tr>
<td>$G_{pb}$</td>
<td>140 pW/K</td>
<td>beta</td>
<td>0.9</td>
</tr>
<tr>
<td>$T_c$</td>
<td>484 mK</td>
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<td></td>
</tr>
<tr>
<td>$T_b$</td>
<td>298 mK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_n$</td>
<td>8.28 s mOhm</td>
<td>Values at operating point</td>
<td></td>
</tr>
<tr>
<td>$R_{L\text{(shunt)}}$</td>
<td>0.055 mOhm</td>
<td></td>
<td></td>
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<td>$L$ (inductor)</td>
<td>74 nH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Variation as func. of $G_{ep}$
Time Constants

4-6 ms decay time, depending on loading
Noise

Energy Resolution = 102.19 eV FWHM
NEP

Energy Resolution = 102.19 eV FWHM

Frequency [Hz]

NEP [W/√Hz]

$10^{-19}$

$10^{-18}$

$10^{-17}$

$10^{-16}$

$10^{-15}$

$10^{-14}$

$10^{-13}$

$10^{-12}$