Detection chain readout development and modeling for next-generation Cosmic Microwave Background observations

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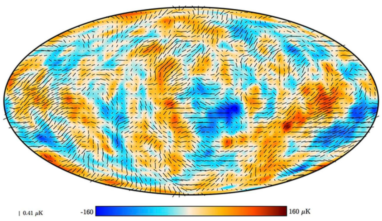
CMB B modes

CMB : Cosmic **M**icrowave **B**ackground is a leftover radiation of the Big Bang, of microwave wavelength

- Many CMB measurements from past experiments thoroughly investigated the temperature anisotropies of CMB
- Cosmology today : detection of the **B polarization mode of CMB** a few nK signal surrounded by a the background at ~ 3K



- Scientific applications : inflationary models, gravitational waves and particle physics

Hard to observe such small signal drowned in a background

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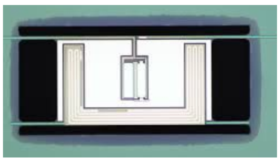
Superconducting cryogenic devices

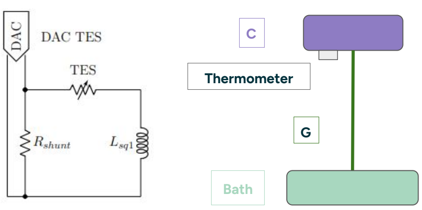
- Quantum Cryogenic detectors **TES** (**T**ransition **E**dge **S**ensor) at 100 mK

TES image from NIST array



- Read and multiplexed by **SQUIDS** (**S**uperconducting **QU**antum **I**nterference **D**evice at 100mK and 4K via TDM

TES : *Transition Edge Sensor*



TES theory

- Exploits the transition between the superconducting to normal state

Hard to measure the transition because of the thermal coupling to the bath (G)

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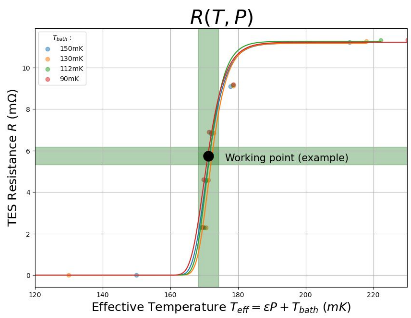
No direct access to TES temperature

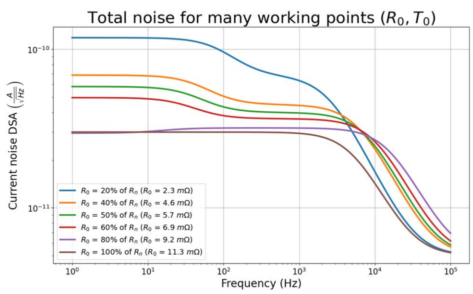
- Reconstructing the transition from raw measurements : from a current- voltage characteristic, to saturation power fit
- Superconducting transition
- Fitting the measurements with a form of Richard function

$$R(T,P) = \frac{R_n}{\left[1 + e^{-\frac{T - T_c + \epsilon P}{\Delta T}}\right]^p}$$



Fit of a reconstructed superconducting transition R(T,P) : taking in account the thermal processes in the TES leads to define an effective temperature

How is the **total noise spectrum** modified when we move across this transition ?



Being high in the transition means a lower noise level! How about the SNR ?

NOISE model and measurements

Noise contributions as **transfer functions**

TES

$$H_{tes}(f) = K_{tes} \cdot K' \cdot \frac{1 - i\frac{f}{f_T}}{\left(1 - i\frac{f}{f_T\ \gamma_t}\right)\left(1 - i\frac{f}{f_{el}}\right)}$$

Shunt Resistance

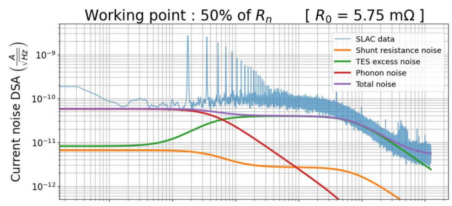
$$H_{shunt}(f) = K_{shunt} \cdot K' \cdot \frac{1 - i\frac{f}{f_{th}}}{\left(1 - i\frac{f}{f_{th}\ \gamma}\right)\left(1 - i\frac{f}{f_{el}}\right)}$$

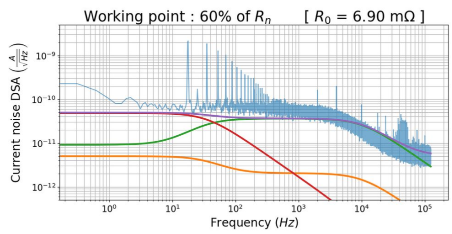
Phonon noise

$$H_{ph}(f) = K_{ph} \cdot K' \frac{1}{\left(1 - i\frac{f}{f_1}\right)\left(1 - i\frac{f}{f_{el}}\right)}$$

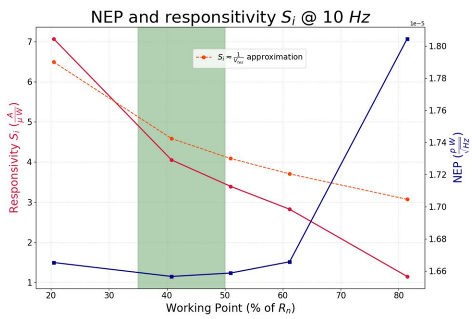
Prediction of the noise contribution levels and characteristic frequencies with the transfer functions

- Measured noise spectrum for different superconducting transition working points (in collaboration with SLAC) :





- The responsivity and NEP



Compromise between NEP and responsivity!

(Current noise doesn't give the full information)

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Grenoble