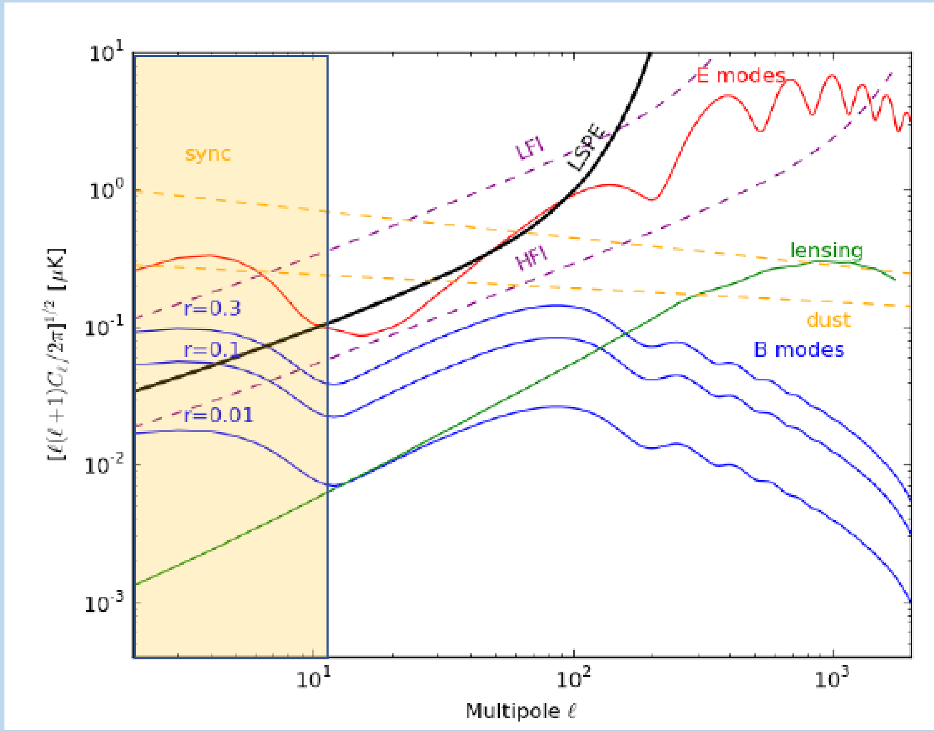
Large Area Superconducting TES Spiderweb Bolometer for CMB Polarisation Measurements for the LSPE balloon borne telescope

B. Siri[1,2], M. Biasotti[1,2], L. Ferrari Barusso[1,2], G. Gallucci[2], F. Gatti[1,2]
[1]University of Genoa, [2]INFN Genoa, Italy

Abstract: Detecting B-mode polarization at large angular scales of the Cosmic Microwave Background (CMB) is one of the main challenges in modern observational Cosmology. Superconducting TES Bolometers are a suitable detector choice for the 10^{-17} $WHz^{-1/2}$ range requirement on NEP. We present the development status of a large area spider-web bolometer for CMB measurements for the LSPE telescope. The bolometer has a 10-mm diameter suspended Si_3N_4 membrane with a mesh size of 250 µm suspended with a thin leg structure. The TES sensor is a Ti/Au bilayer with T_C tuned in the 500-550 mK range electronically coupled with a Bi/Au microwave absorber. Fine tuning of detector's parameters, heat capacity C and thermal conductivity G, has been made in order to reduce the time constant τ of the bolometer.

LSPE/SWIPE experiment[1,2]

The SWIPE instrument of Large Scale Polarization Explorer is a stratospheric balloon borne telescope aimed at measuring the B-mode CMB polarization at large angular scale.
Its primary target is to improve the limit on the tensor to scalar perturbations amplitude ratio down to r=0.03, at 99.7% confidence level.
The mission is optimised for large angular scales, with coarse angular resolution (about 2 degrees FWHM) and wide sky coverage (25% of the sky).
The full LSPE project is composed of two instruments: SWIPE (balloon-borne telscope) and STRIP (ground base telescope Tenerife).



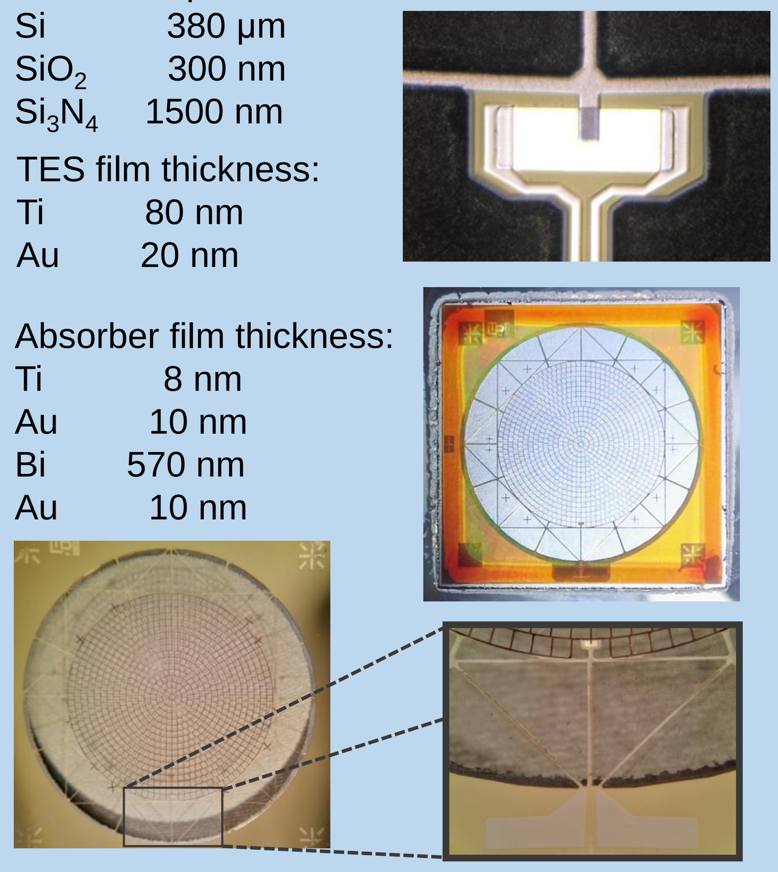
SWIPE telescope will fly in a circumpolar long duration balloon mission during the polar night. It will use an array of 326 spiderweb TES bolometer, cooled at 300 mK. Large throughput multi-mode bolometers and rotating Half Wave Plates (HWP), to survey the sky in three bands at 140, 220 and 240 GHz.

Fabrication Process

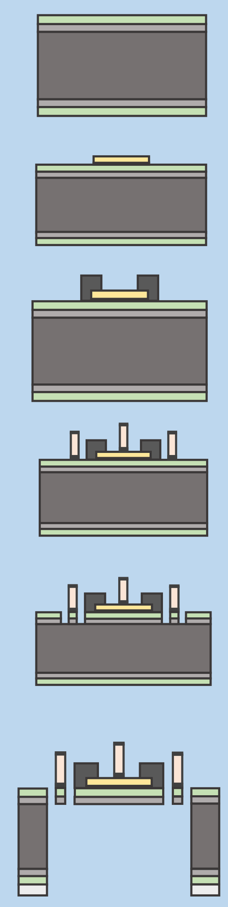
Wafer composition
Si 380 µm
SiO_2 300 nm
Si_3N_4 1500 nm

TES film thickness:
Ti 80 nm
Au 20 nm

Absorber film thickness:
Ti 8 nm
Au 10 nm
Bi 570 nm
Au 10 nm

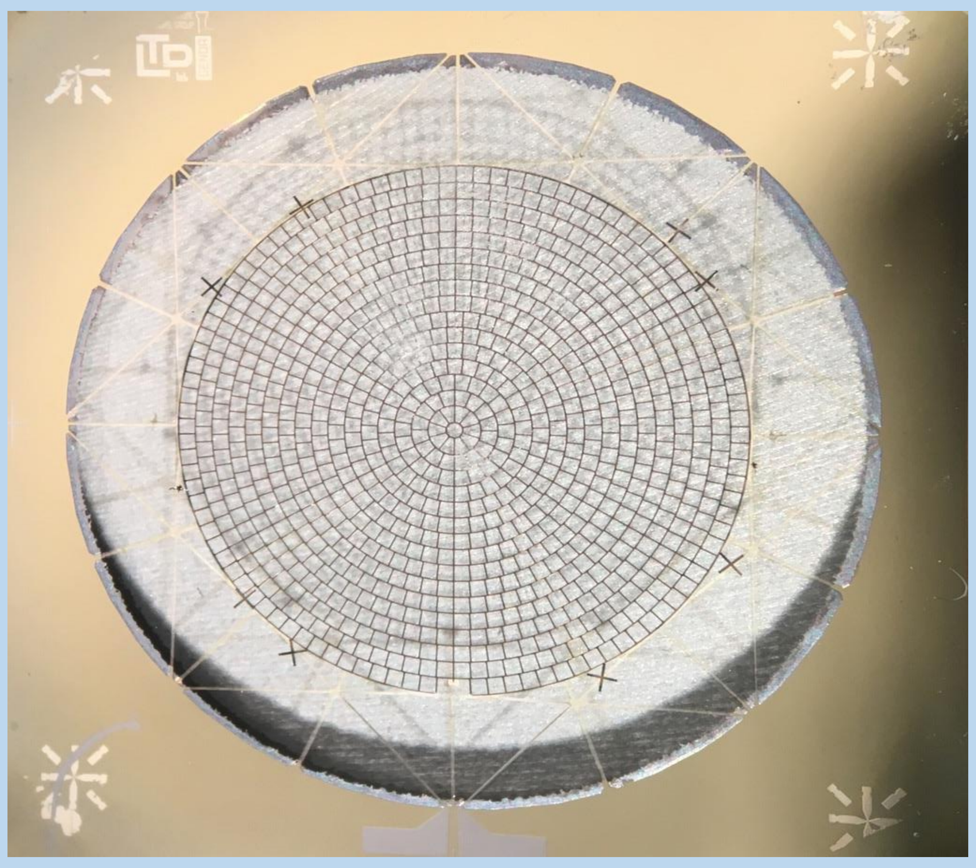


1 - Starting Si wafer
2 - TES deposition
3 – Electrical contact deposition
4 – Absorber deposition
5 - Membrane etching in RIE
6 - Backside RIE etching and membrane suspension

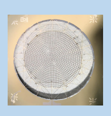


Spider Web geometry

A large area absorber is necessary for multimode detection

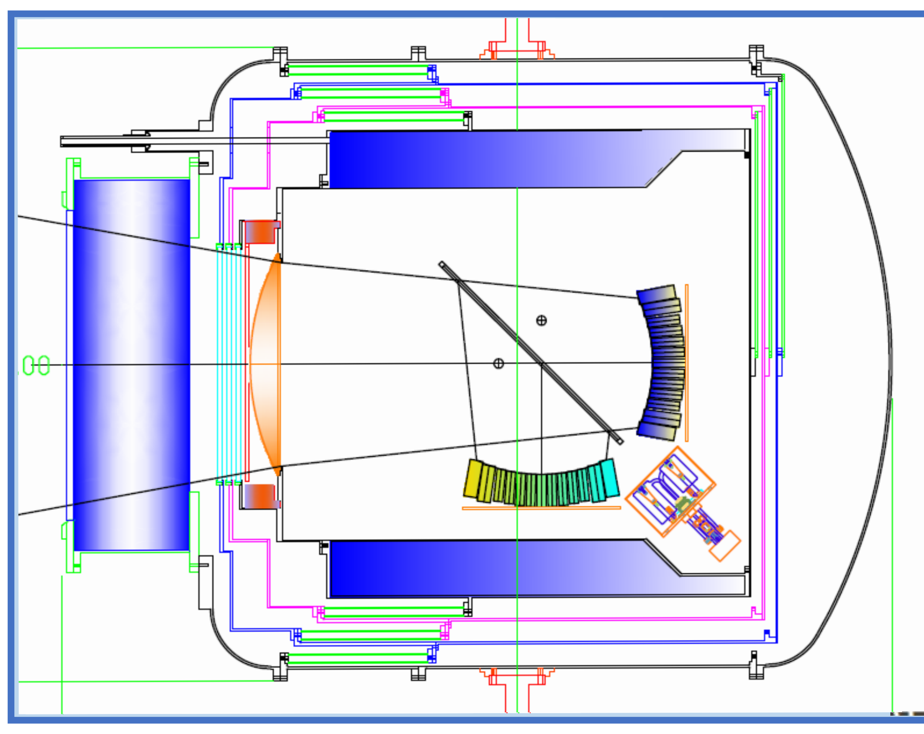


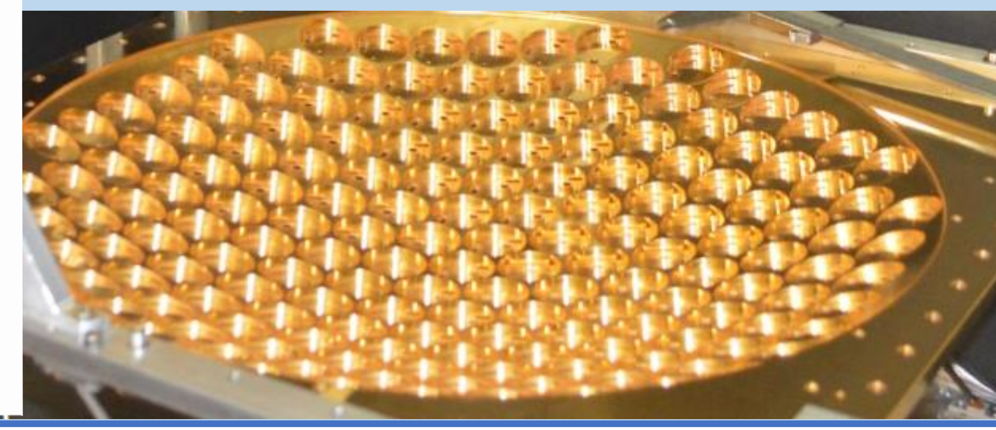
Absorber diameter
8 mm
SW mesh size
250 µm
Chip dimension
15 x 15 mm^2



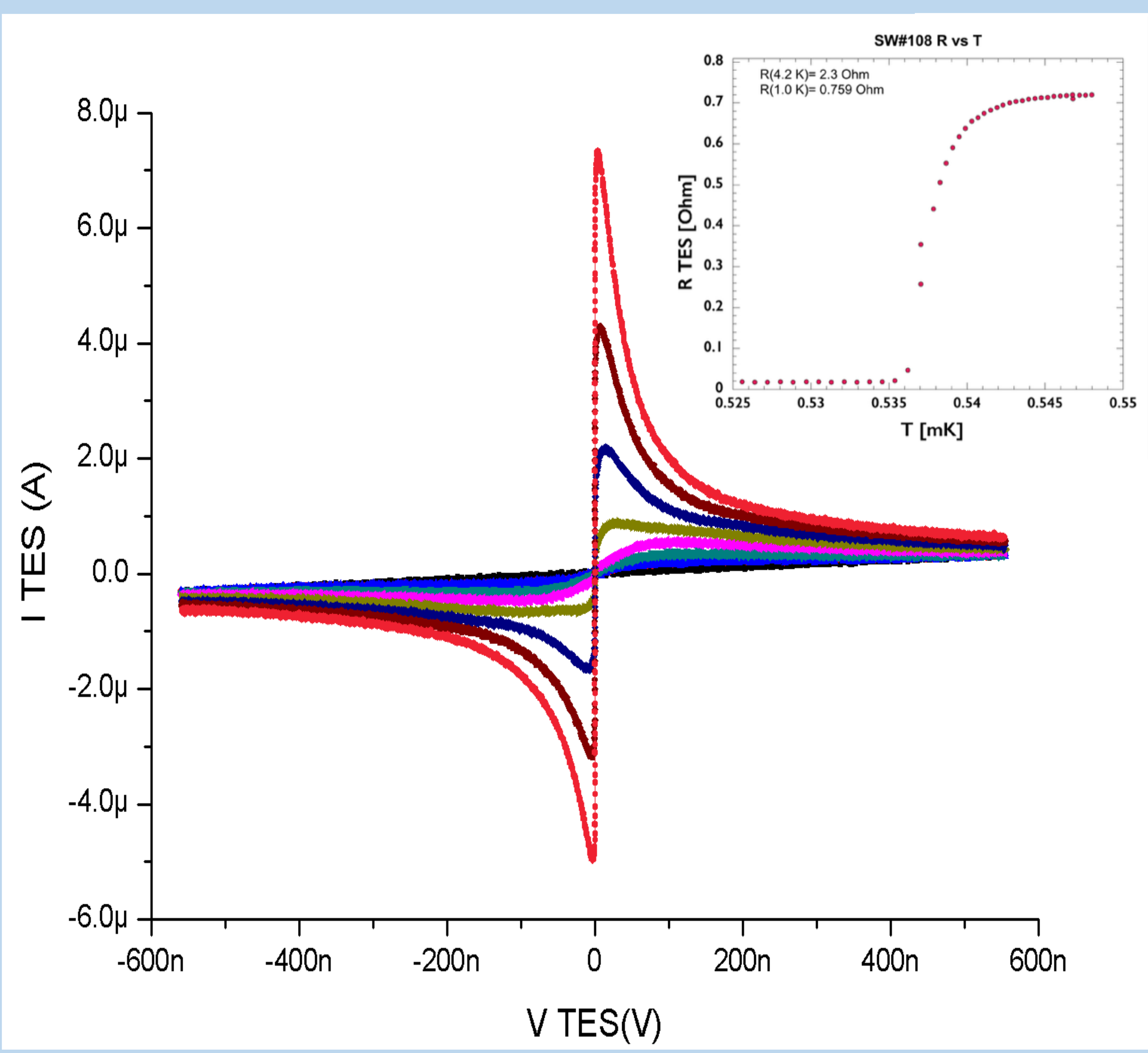
Lifesize image

SWIPE telescope



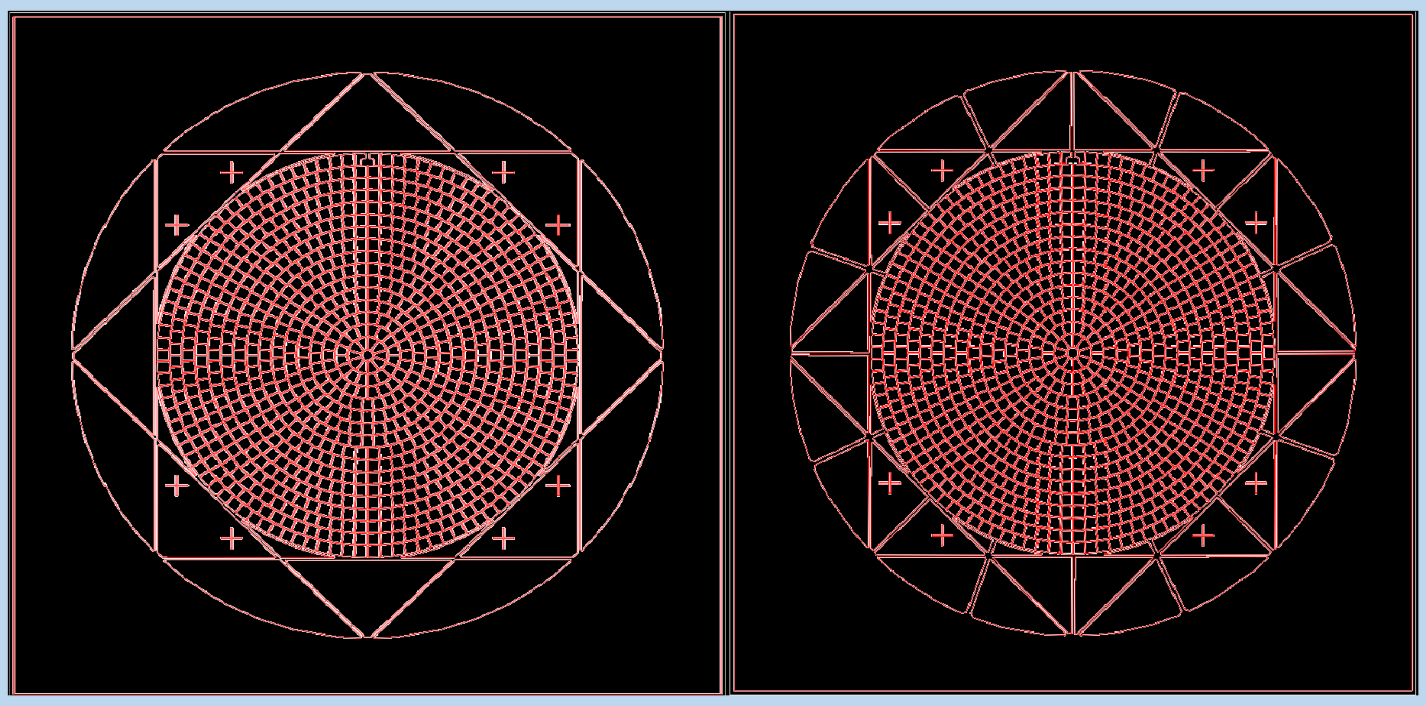


IV curves at different temperatures



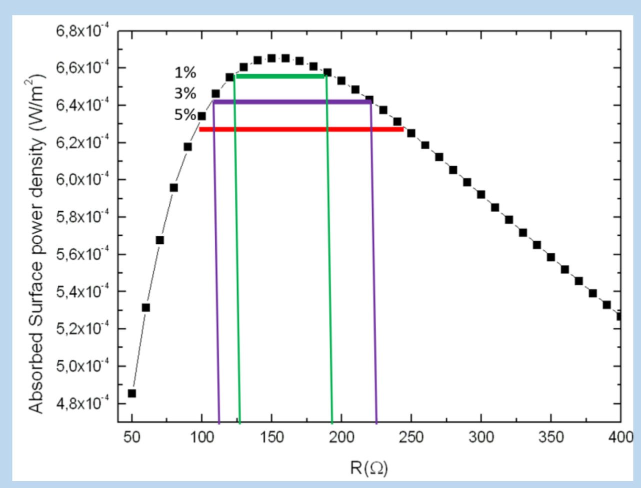
Thermal time constant tuning

Detector test at low temperature have shown a thermal time constant of at least factor 5 above the requirements. There is sufficient room for improvements and several possibilities of tuning the detector's time constant. We have focused mainly on thermal conductance and heat capacity tuning.



Thermal conductance has been increased by a factor 2: a bolometer design upgrade has been made doubling the supporting beams. This change in thermal conductance has an impact on the NEP that increases accordingly with a factor $2^{1/2}$

The heat capacity of the absorber has also been considered as a possibility to tune the time constant.
One constraint in this case is the requirement on EM matching impedance. In figure the HFSS simulation of the matching impedance of gold film on a Si_3N_4 membrane. Allowing a tiny impedance mismatch of up to 3% allows us to gain in heat capacity.



Another way to improve heat capacity is to reduce film thickess: in order to do this and keep the correct impedance matching some adjustments needs to be done.
We increased the residual resistance ratio (RRR) of our film and we doubled the width of the absorber's mesh.

Material	Gamma J/cm^{3}K^2	Rho (300 K) ohm m	Meas. (300 K) ohm m	Meas. (4.2 K) ohm m
Au	6.8 e -5	2.2 e -8	4.5 e -8	2.0 e -8
Bi	4.0 e-7	1.1 e-6	2.1 e-6	1.4 e-6
Ratio	170	51	47	70

From the original design which included a gold absorber we studied and realized some prototypes with bismuth absorber. We can expect a speed up of the bolometer of about a factor 5 to 7.

[1] P. de Bernardis *et al.*, "The Large-Scale Polarization Explorer", arXiv:1208.0281, (2012); [2] P. de Bernardis *et al.*, "SWIPE: a bolometric polarimeter for the Large-Scale Polarization Explorer", arXiv:1208.0282, (2012).