Bismuth-Gold absorber for large area TES spiderweb bolometer

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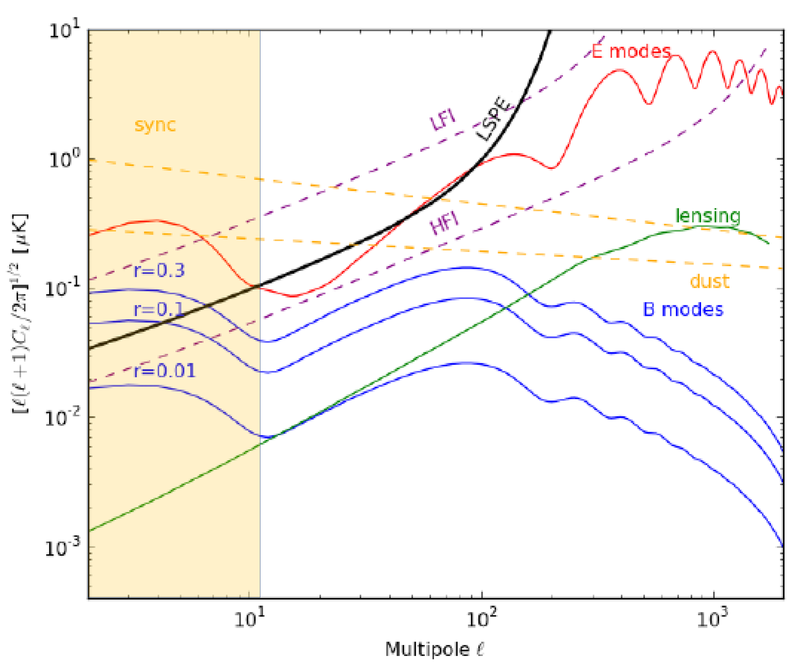
Abstract: Large area spiderweb bolometer of about one centimetre diameter are required for matching multimode or quasi-optical cavities in microwave antenna for CMB measurements as proposed for the Large Scale Polarization Explorer balloon borne sky survey at 140, 220, 250 GHz. Possible applications at low frequencies, 40 GHz or less, in single mode are also foreseen. The main drawback of such large absorber is the achievement of an optimal trade-off among the thermal properties, like fast internal thermal diffusivity, heat capacity and milli-second recovery time and EM characteristics, like the matching impedance and EM power dissipation. In parallel with standard micropatterned gold film absorber deposited onto silicon nitride membrane, we have tested the Bismuth Gold in order to reduce the heat capacity even if with an increase of resistivity. Films of Bismuth Gold may have low resistivity under application of a proper post-production thermal cycle. We present the fabrication method of Bismuth Gold films for our microwave absorbers and the bolometer characterization at low temperature.

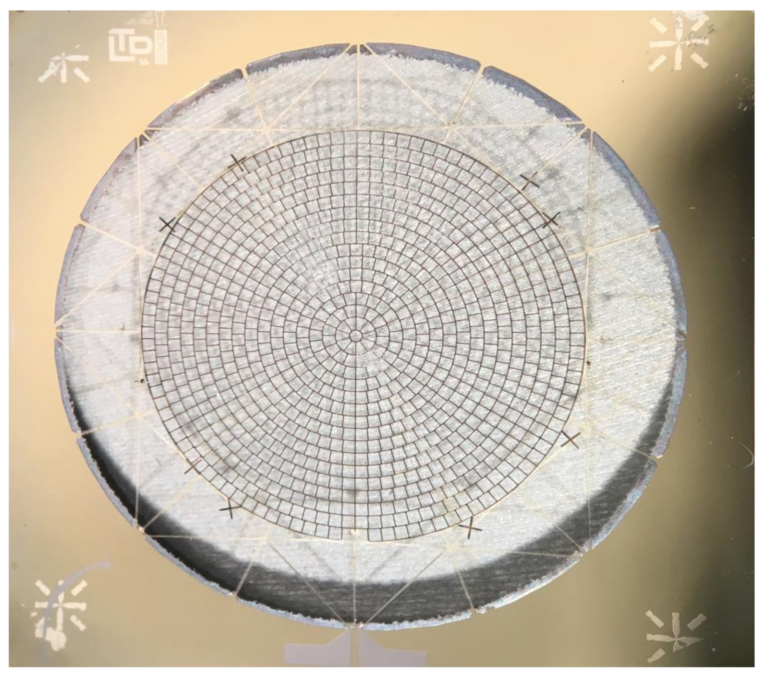
LSPE/SWIPE experiment[1,2]

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.

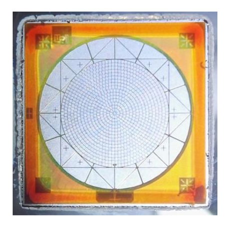
Spider Web Fabrication



Wafer composition
Si 380 µm
SiO_2 300 nm
Si_3N_4 1500 nm

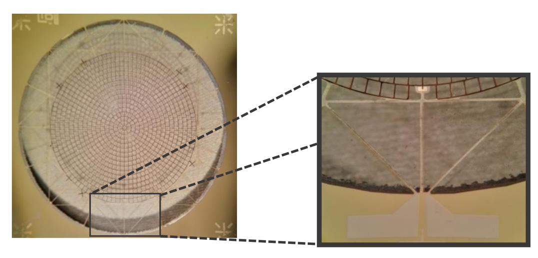
TES film thickness:
Ti 80 nm
Au 20 nm

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

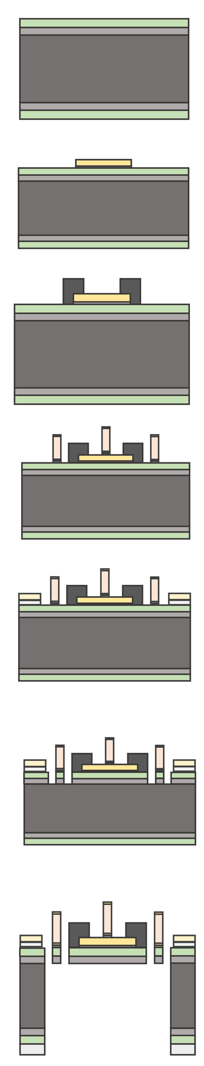


A large area absorber is suitable for multimode detection

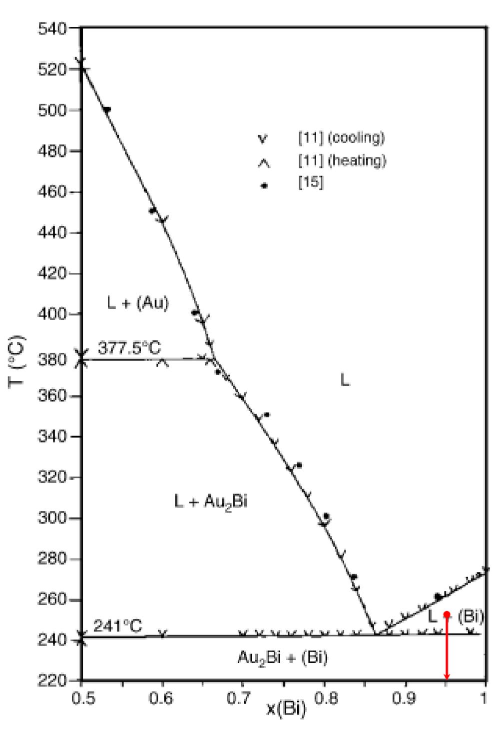
Absorber diameter **8 mm**
SW mesh size **250 µm**
Chip dimension **15 x 15 mm²**



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



Bismuth-Gold Absorber

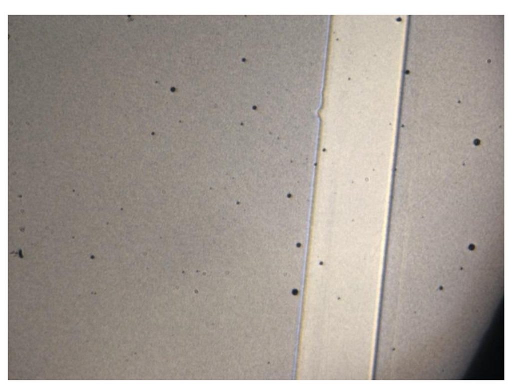


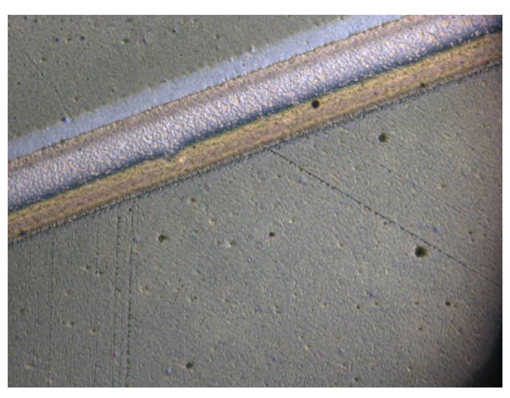
In order to tune the time constant of the bolometer we decided to improve the heat capacity of the absorber. An improvement can be obtained by increasing the residual resistance ratio of the film, allowing us to reduce the film thickness and consequently the heat capacity. The original design of the detector included a gold absorber. Among other possible candidates as absorber the most promising was Bismuth, in particular Bi-Au.

Left: phase diagram for the Au-Bi binary system, the red arrow shows the Bi-Au ratio and the annealing temperature chosen for the absorber film.

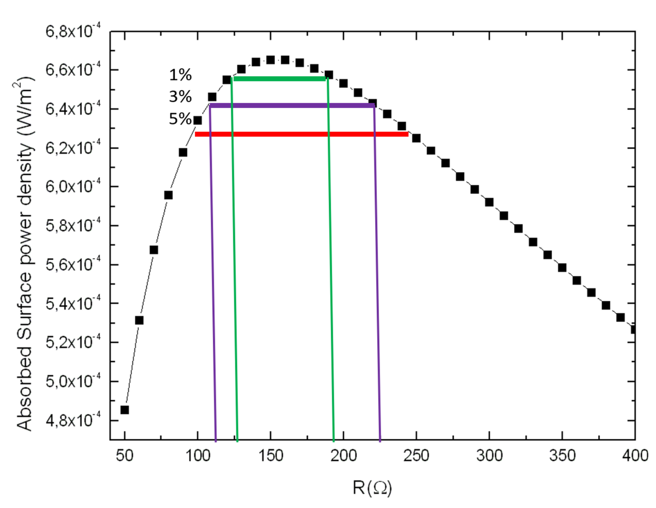
Material	Gamma J/cm³K²	Rho (300 K) ohm m	Meas. (300 K) ohm m	Meas. (4.2 K) ohm m
Au	6.8 e -5	2.2 e -8	4.5 e -8	2.0 e -8
Bi	4.0 e-7	1.1 e-6	2.1 e-6	1.4 e-6
Ratio	170	51	47	70

Parameter for Bi over Au	Expected/measured factor	Effect on heat capacity
Resistivity ratio	50 (exp.) - 70 (meas.)	3.4 (exp.) – 2.4 (meas.)
Specific heat ratio	1/170	
G factor	2	
Expected Tau factor	7 (exp.) - 5 (meas)	





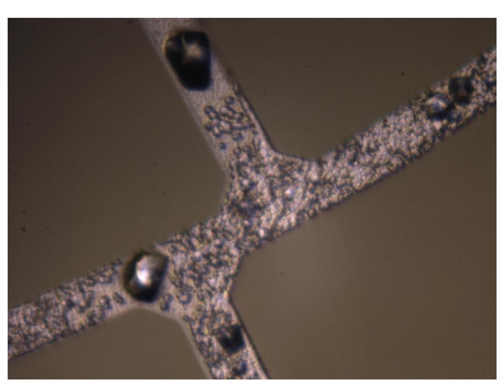
BiAu bilayer test sample, before (left) and after (right) annealing at T=251 °C in Ar atmosphere. In both pictures it is visible the shadow of a 100 um tungsten wire.

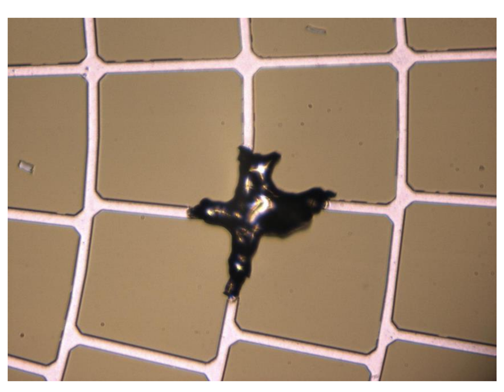


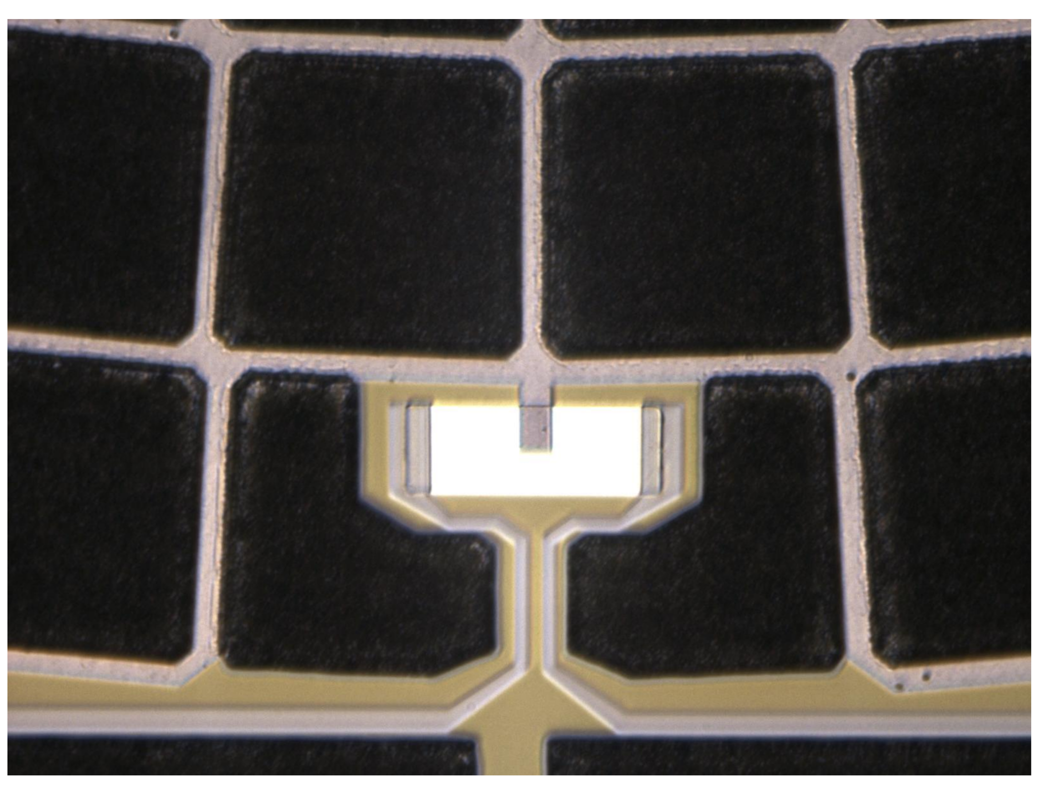
HFSS simulation of the matching impedance of a gold film on a Si_3N_4 membrane.
Allowing an impedance mismatch of up to 3% also allows us to gain in heat capacity without losing too much signal.

Parameters for Gold	Expected/measured factor	Effect on heat capacity
RRR	1.5	1.5
3% matching factor	1.8	1.8
G factor	2	-
Expected tau	5	-

We deposit a Ti sticking layer followed by a thin Au layer and then the BiAu bilayer. All films are deposited by thermal evaporation using a thickness monitor. There is no direct control on the substrate temperature during deposition but it is below 80 °C.
The film is very sensitive to temperature changes during the annealing process which can lead to both formation of Bi crystals and contamination of the gold film of the TES.

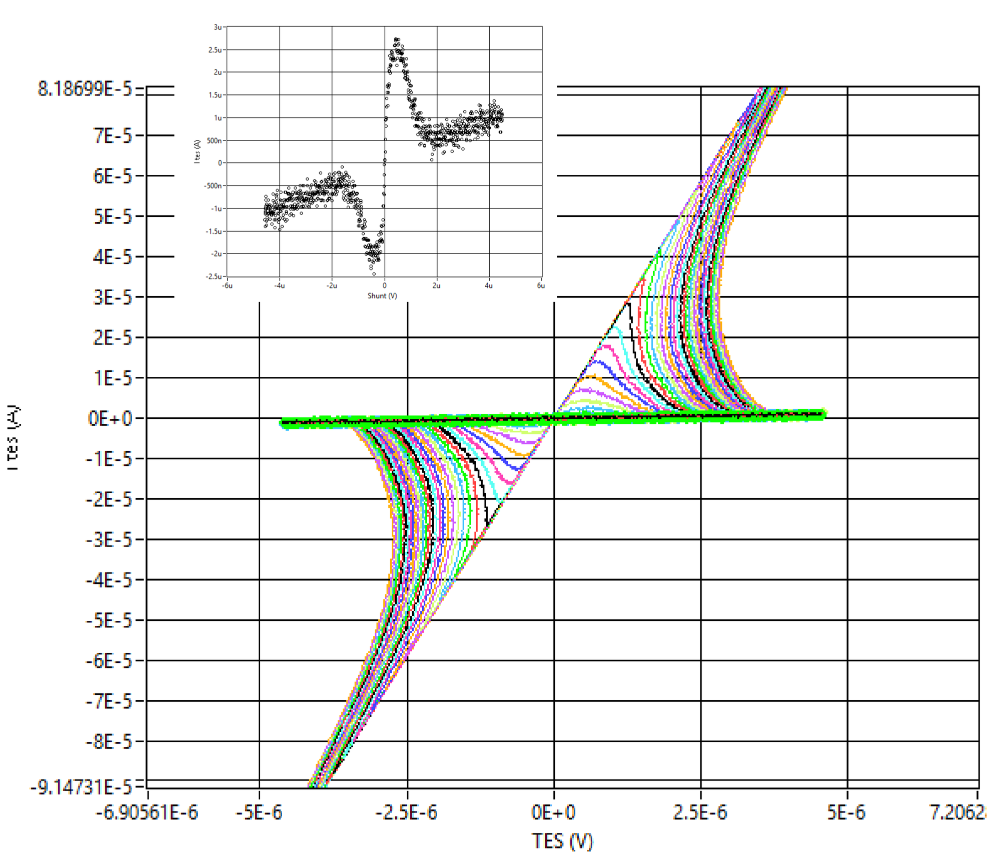




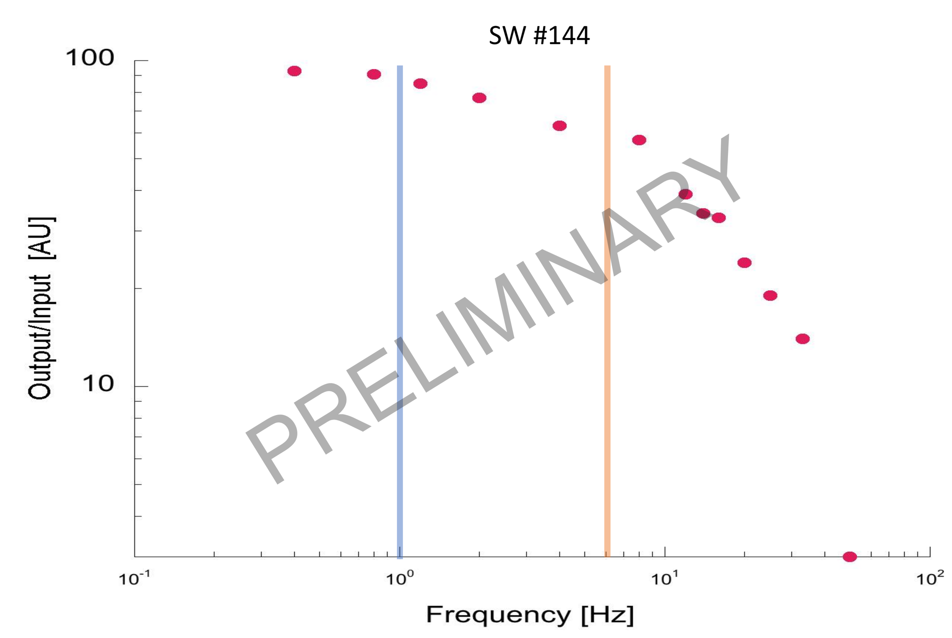


Detector caracterization

Detectors with the new improved Bi-Au absorber are currently undergiong characterization.



Preliminary frequency measurements show an impprovement in the respose time of the detector.
In blue the cut frequency of a bolometer with the gold absorber, in orange the cut frequency of a device with the new bismuth-gold absorber.



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[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).