On-chip refrigerator integrated into a photon-noise-limited detector for high-performance Cosmology missions

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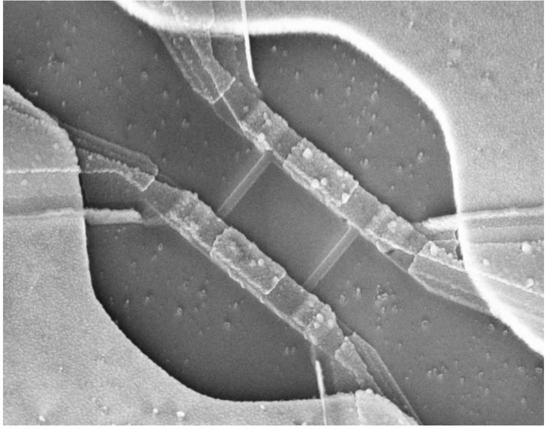
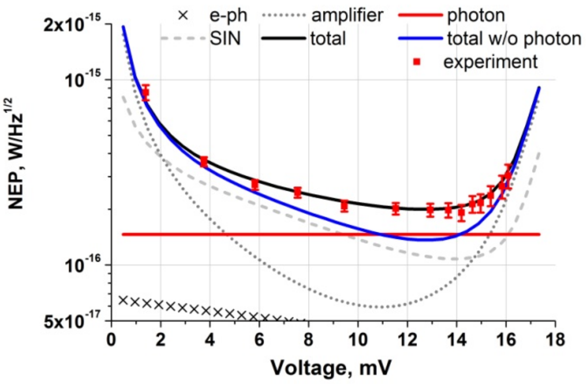
The SIN tunnel junctions are known for their ability to remove the heat from the electron system of the normal metal electrode. Two SIN junctions, connected in SINIS structure, remove the heat twice more effectively than a single junction. This property is intensively used in Cold-Electron bolometers.





We have realized cold-electron bolometers (CEB) with direct electron self-cooling of the nanoabsorber by SIN (Superconductor-Insulator-Normal metal) tunnel junctions. We have made several improvements in the bolometer design, that decreased the return power of hot quasi-particles from the vicinity of the tunnel barrier from 30% to just 1-2%.

The effective electron self-cooling acts as a strong negative electrothermal feedback, improving noise and dynamic properties. Due to this cooling the photon-noise-limited operation of CEBs was realized in array of bolometers developed for the 345 GHz channel of the OLIMPO Balloon Telescope in the power range from 10 pW to 20 pW at phonon temperature *Tph*=310 mK. The negative electrothermal feedback in CEB is analogous to TES but instead of artificial heating we use cooling of the absorber. The high efficiency of the electron self-cooling is achieved by:

- small volume of the nanoabsorber (0.02 um3) and a large area (up to 80%) of the SIN tunnel junctions,
- effective removal of hot quasiparticles by arranging double stock at both sides of the junctions and close position of the normal metal traps,
- self-protection of the 2-dimensional (2D) array of CEBs against interferences by dividing them between N series CEBs (for voltage interferences) and M parallel CEBs (for current interferences),
- suppression of Andreev reflection by a thin layer of Fe in the hybrid S/F AlFe absorber.

Due to these improvements, the internal bolometer noise (including room temperature amplifier noise) is 1.3 times smaller than the receiving signal noise (photon noise) at 20 pW power load and base temperature 310 mK.

Thus, we have developed, manufactured and tested a bolometric receiving system designed for a large received power, showing record sensitivity (the internal noise is less than the photon noise) due to the effect of electronic cooling, i.e., operating at electron temperature about 2 times less than the phonon temperature of the sample. It is shown that the NEP of a single bolometer of a given pixel at a temperature of 300 mK and the room temperature amplifiers used is 8×10^-18 W/Hz^1/2. If we replace the room temperature amplifiers with standard cooled ones, then the NEP decreases to a record 3×10^-18 W/Hz^1/2, unattainable for competitors - TES and KID bolometer for this temperature range of about 0.3 K, obtained in He3 cryostats without necessity of using dilution cryostats, which is especially important for space applications.

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