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Status of the SIMP project: Towards the Single Microwave Photon Detection

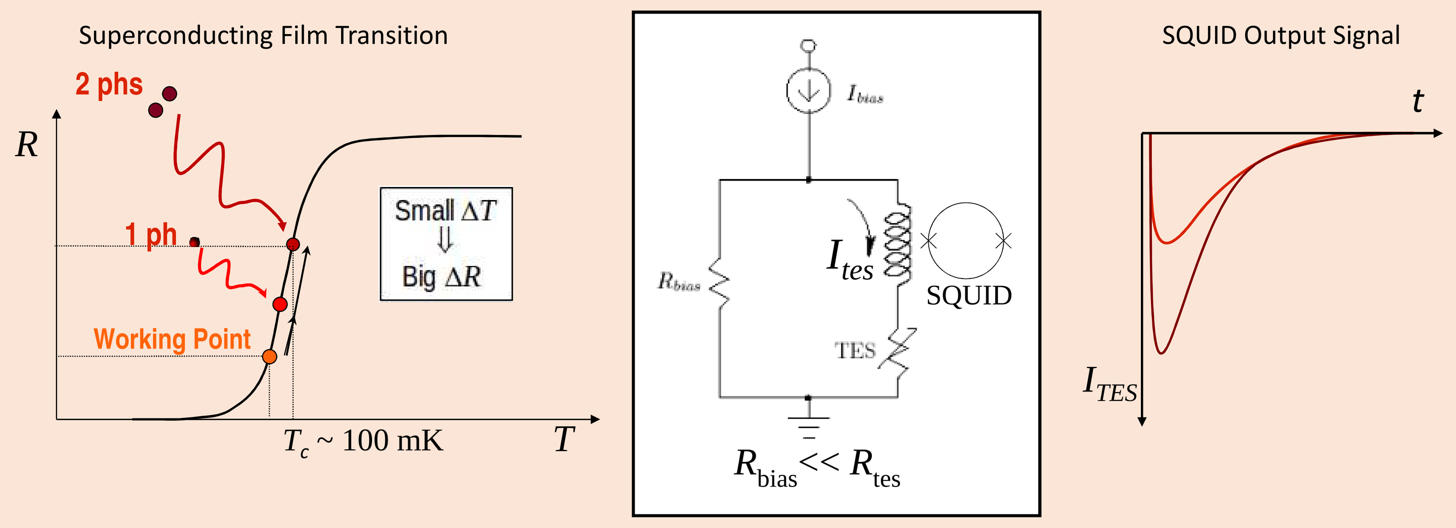
Paolo Falferi on behalf of the Simp collaboration*

The low-mass frontier of Dark Matter, the measurement of the neutrino mass, the search for new light bosons in laboratory experiments, all require detectors sensitive to excitations of meV or smaller. Faint and rare signals, such as those produced by vacuum photoemission or by an Axion in a magnetic field, could be efficiently detected only by a new class of sensors.

The Italian institute for nuclear physics (INFN) has financed the three-year SIMP project (2019-2021) in order to strengthen its skills and technologies in this field with the ultimate aim of developing a single microwave photon detector.

This goal will be pursued by improving the sensitivity and the dark count rate of two types of photodetectors: Current Biased Josephson Junction and Transition Edge Sensor

Transition Edge Sensor



Voltage-biased TES with SQUID readout

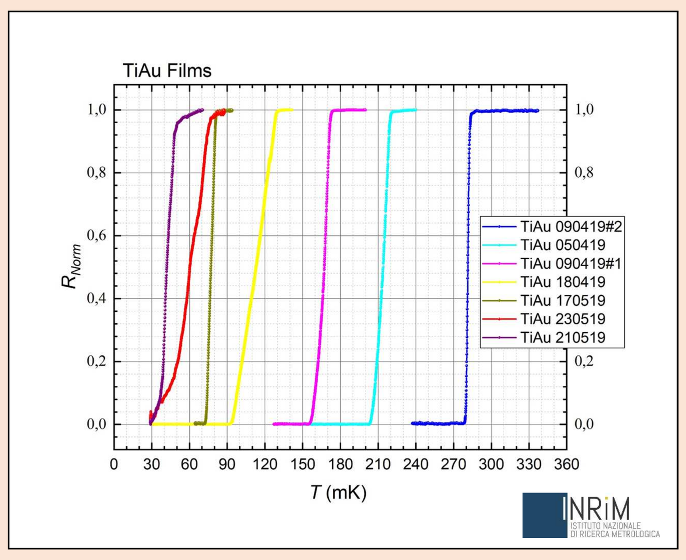
TES Energy Resolution

$$\Delta E \cong 2.35\sqrt{2k_B T^2 \frac{C}{\alpha}}$$

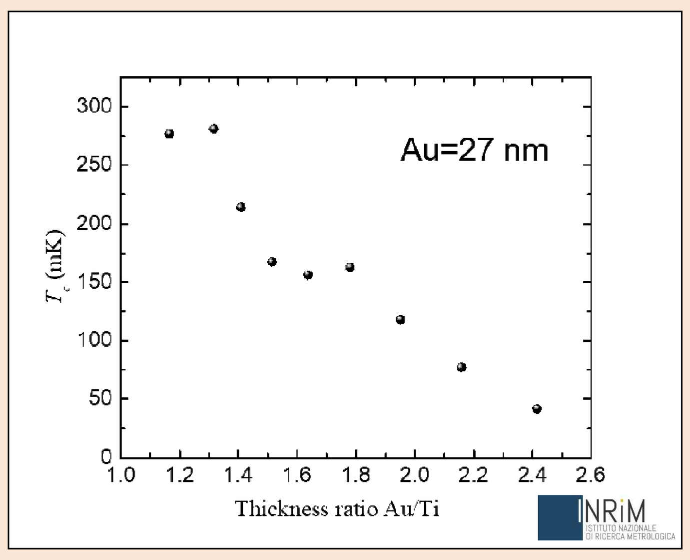
k_B - Boltzmann constant
Heat capacity: C = $\gamma V_a T$
γ - Sommerfeld coefficient
V_a - active region volume
Figure of merit α = (T/R)(dR/dT)
R - active region resistance
T - active region temperature

Expected Resolving Power $h\nu/\sigma_E$ ~ 6÷20 for 30÷100 GHz photons
$V_a \approx 10^6$ $T_c \approx 40$ mK

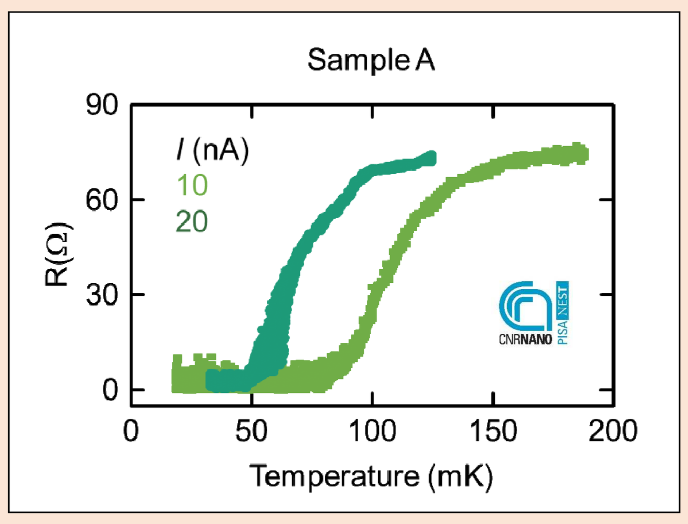
Improving α



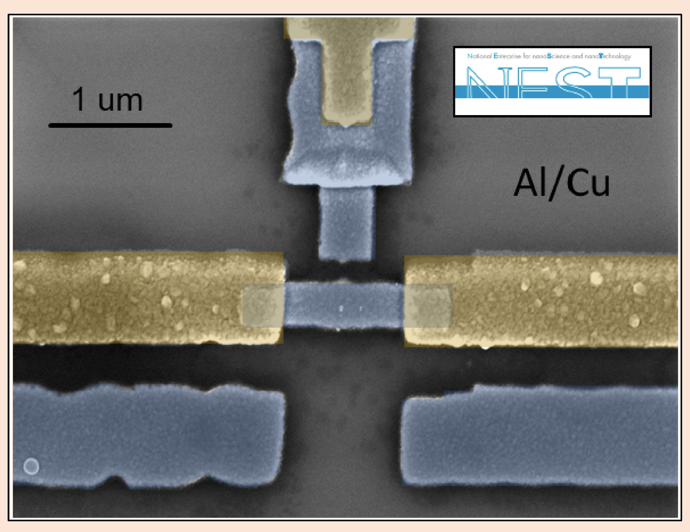
Reducing T_c by Proximity Effect



Reducing T_c by Current Injection

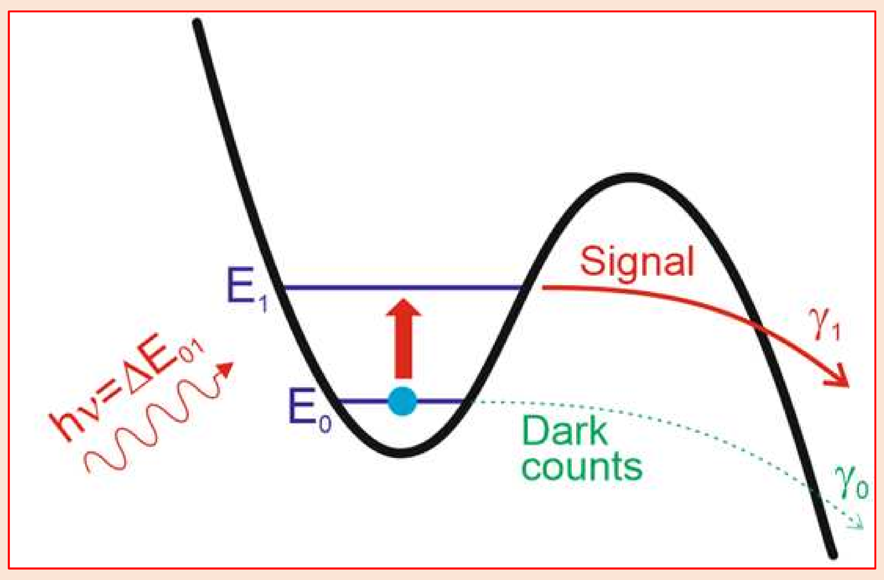


Reducing the Heat capacity

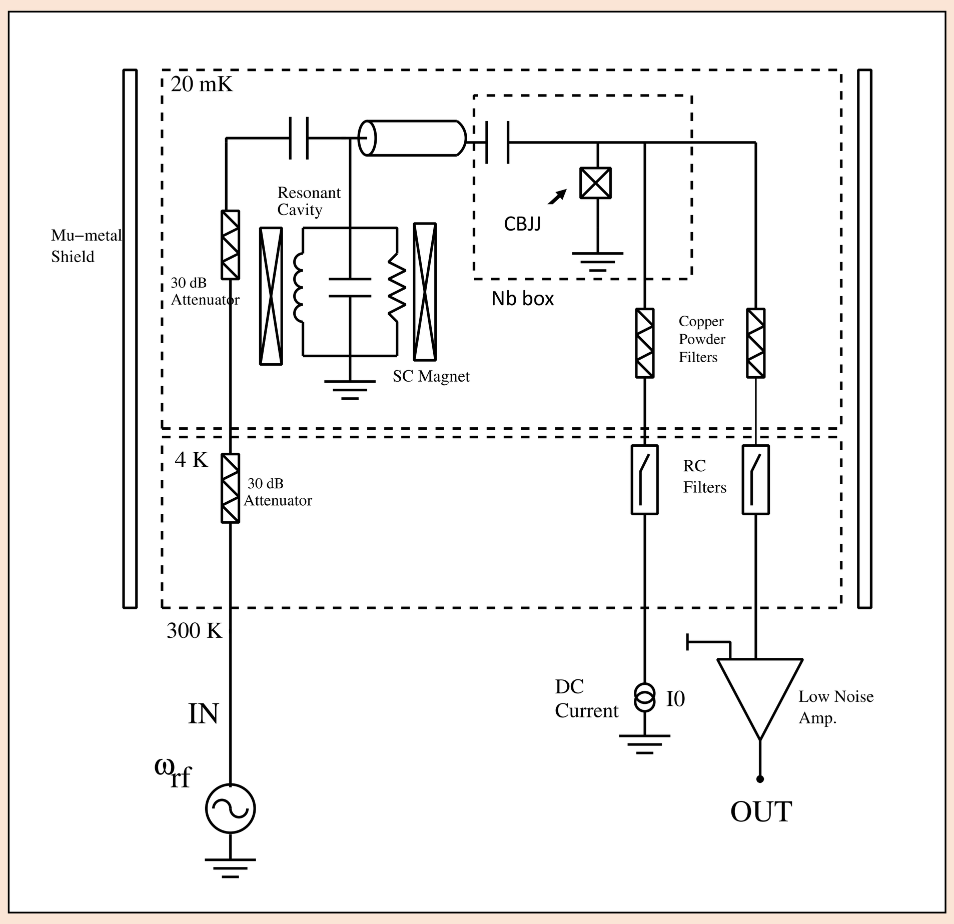


Current Biased Josephson Junction

Two voltage states:
A zero-voltage state when the state is trapped inside a minimum of the potential
A resistive state with a voltage drop when the state is free of running down

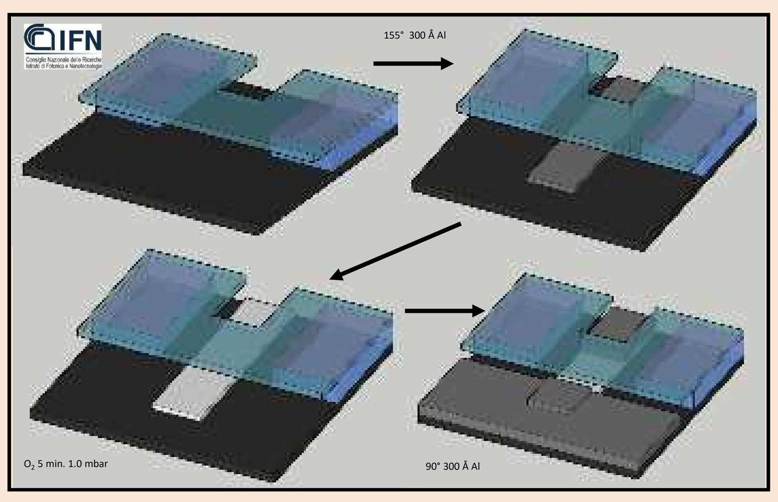


The absorption of a photon causes the transition from the ground state to an excited state with a higher tunneling rate => detectable voltage drop

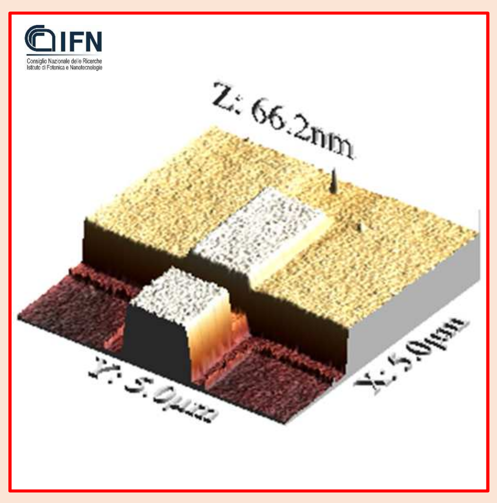


A sketch of the CBJJ calibration experimental setup
It also reproduces the operating condition of the detector in an axion experiment

Fabrication of an Al/AlOx/Al Josephson Junction (Shadow Evaporation Technique)



Atomic Force Microscopy scan of an Al/AlOx/Al Josephson Junction



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