Electron-phonon coupling in Ti/TiN MKIDs multilayer microresonator

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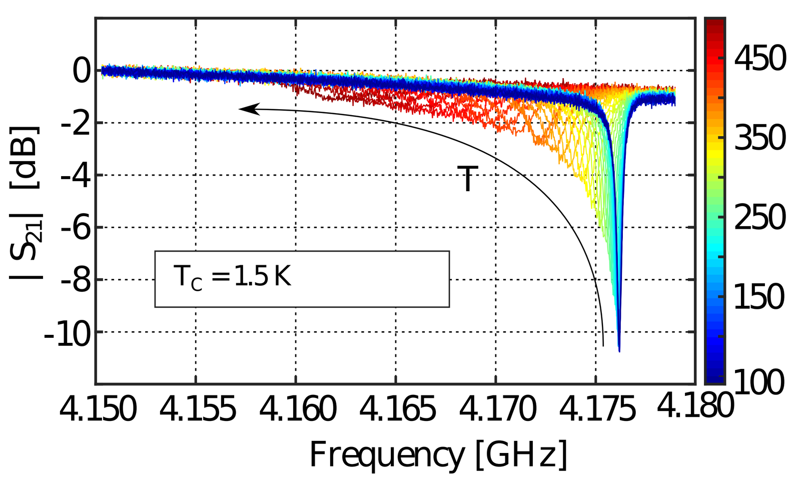
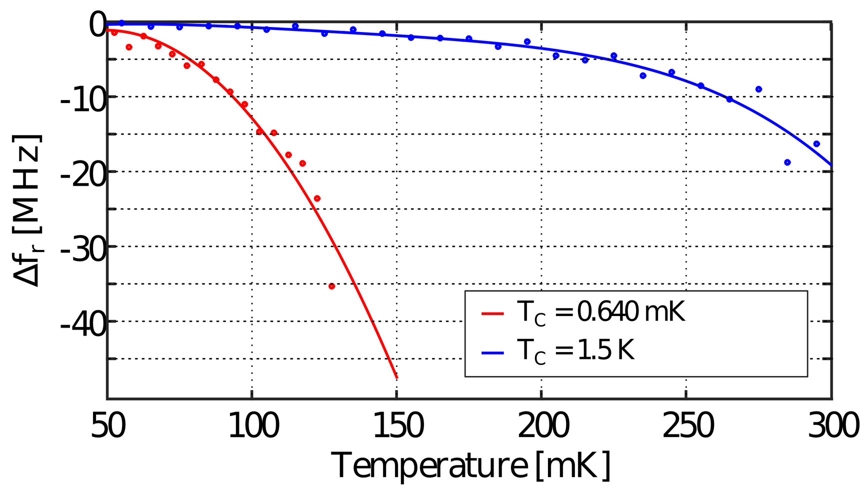
Over the last few years there has been a growing interest toward the use of superconducting microwave microresonators operated in quasi-thermal equilibrium mode, especially applied to single particle detection. Indeed, previous devices designed and tested by our group with X-ray sources in the keV range evidenced that several issues arise from the attempt of detection through athermal quasiparticles produced within direct strikes of X-rays in the superconductor material of the resonator. In order to prevent issues related to quasiparticles self-recombination and to avoid exchange of athermal phonons with the substrate, our group focused on the development of thermal superconducting microresonators. In this configuration resonators composed of multilayer films of Ti/TiN sense the temperature of an absorbing material. To maximize the thermal response, low critical temperature films are preferable. By lowering the critical temperature, though, the maximum probing power bearable by the resonators decreases abruptly because of the weakening of the electron-phonon coupling. A proper compromise has to be found in order to avoid signal to noise ratio degradation. In this contribution we report the latest measurement of the electron-phonon coupling and the latest designs of our thermal devices.

Aim: adapt the MKIDs technology to perform spectroscopy in the keV region

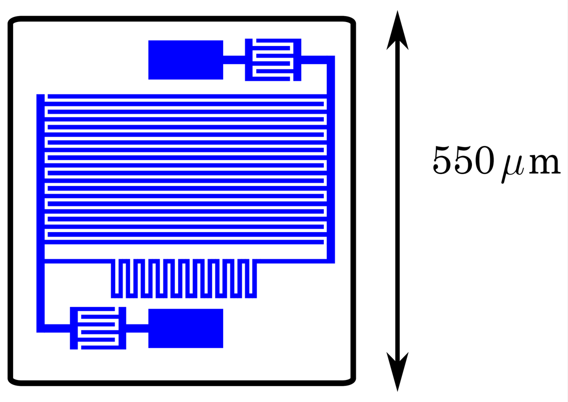
The frequency and quality factor shift can be caused either by external radiation absorbed directly in the superconductor or by an increase of temperature



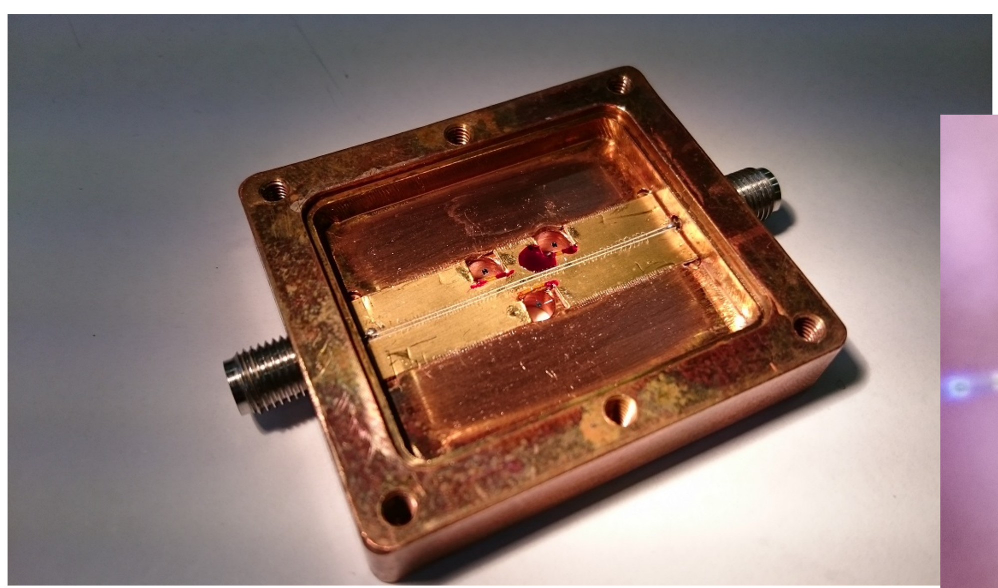


Requirements for thermal sensitivity:

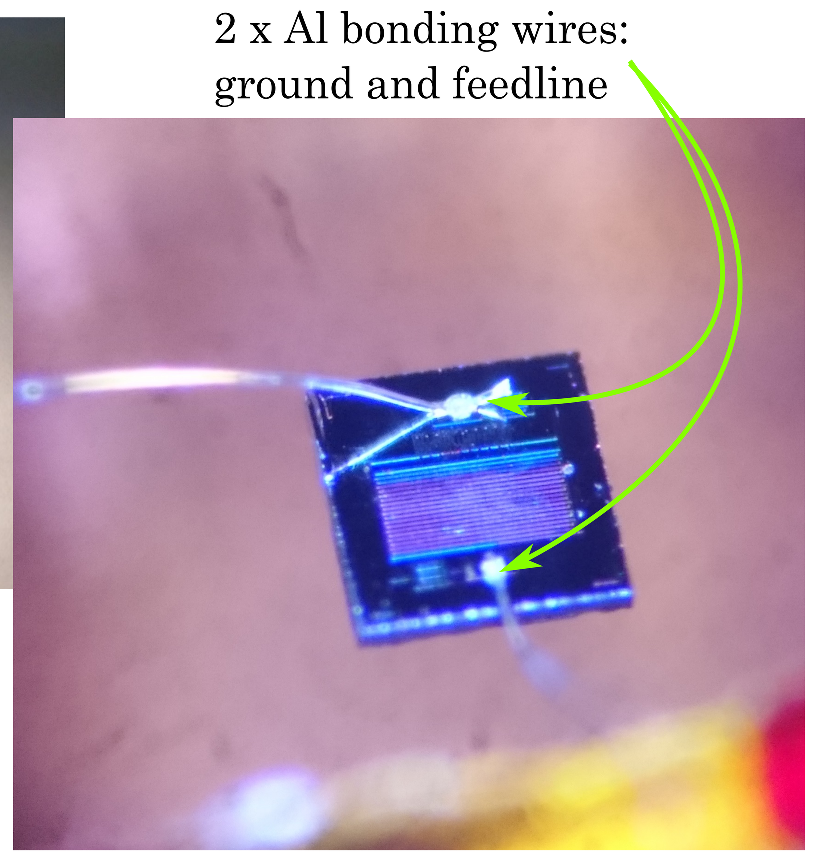
- low heat capacity
- finite thermal conductance to the bath G
- low critical temperature
- readout P power as large as possible (S/N $\propto 1/\sqrt{(P)}$)



- The devices were tested and characterized in a MX-40 by Oxford dilution refrigerator
- The thermal conductance was provided by two 17 μm aluminum bonding wires
- To reduce the heat capacity the subtrate was reduced to about 100 μm
- Low T_c: 640 mK obtained with 12 x Ti(12nm)/TiN(7 nm) multilayer film
- ^{55}Fe test source (6 keV X-rays) faced to the bottom of the substrate



2 x Al bonding wires: ground and feedline

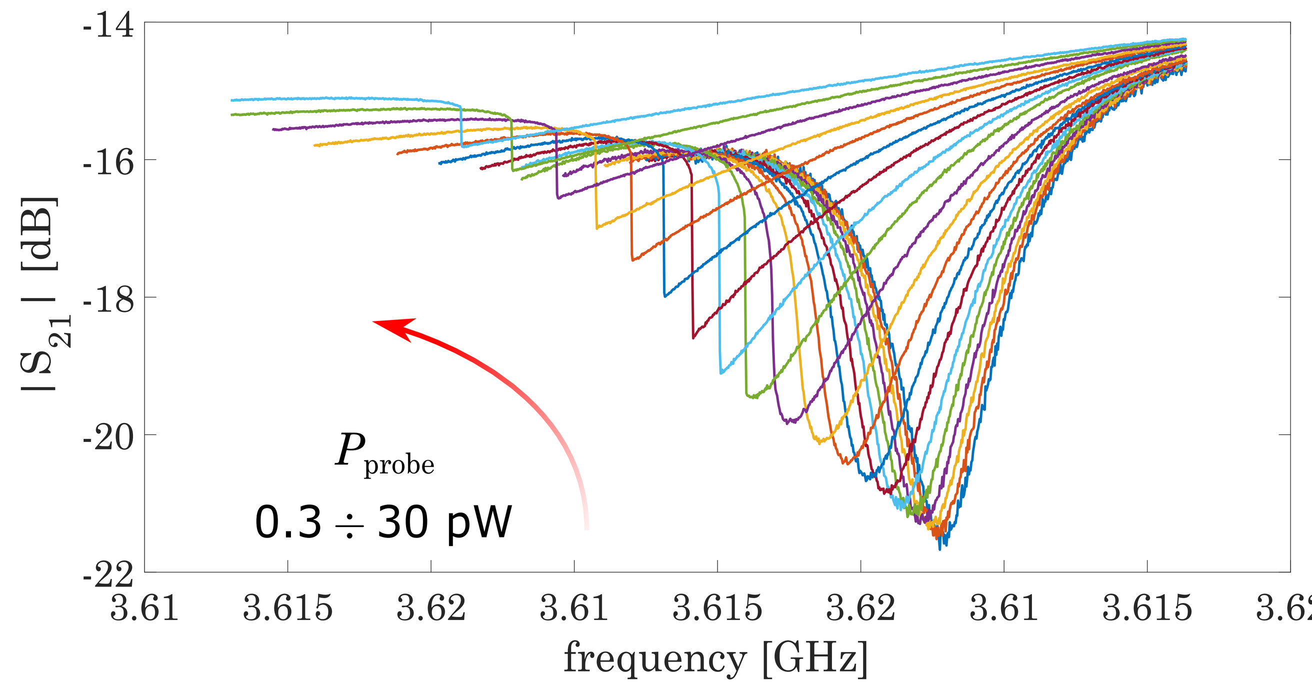


Gold CPW acting as feedline: the chips are suspended by means of Al bonding wires, which provide also a finite thermal reference to the bath

It was not possible to observe any X-ray pulse because the probe signal affects the resonance profile, heating the electrons and causing a hysteretic behaviour

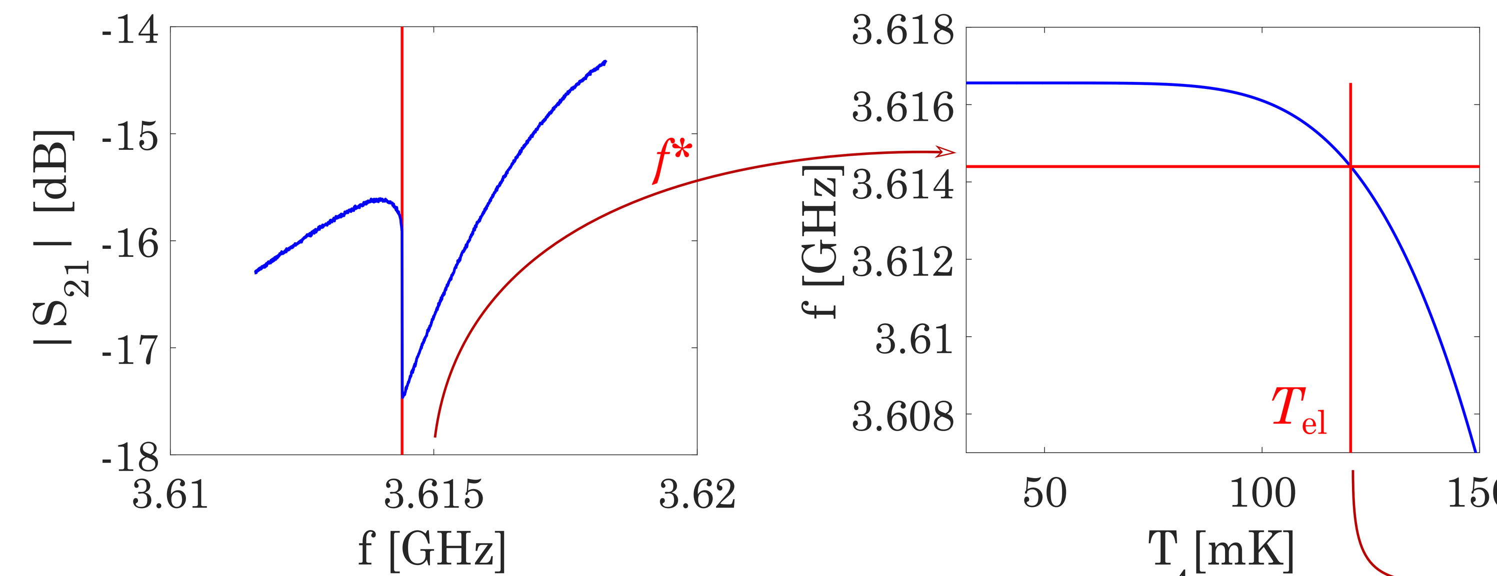
Electron-phonon coupling measurement

By lowering the T_c, the maximum power bearable by the resonator becomes very faint, such that the signal coming from the ^{55}Fe source can not overcome the amplifier noise and **the pulses remain below the threshold**

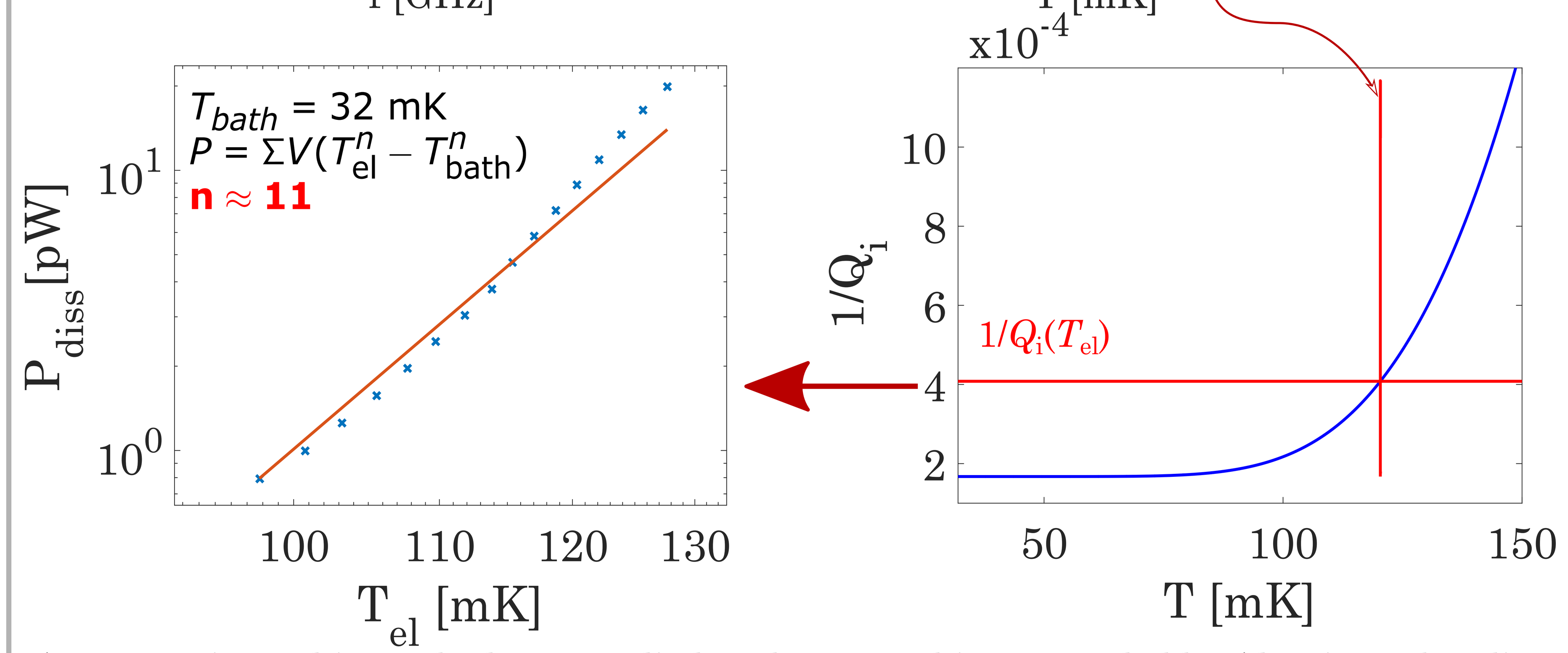


To measure the electron-phonon coupling, the chips were glued to the holder box, so that the phonon temperature is fixed to the bath temperature

Electron-phonon coupling weakens while decreasing the T_c?
To assess the coupling it is necessary to know the temperature of the electrons as a function of the dissipated power due to the readout: $P_{diss} = 4\frac{Q_r^2}{Q_c Q_i}$



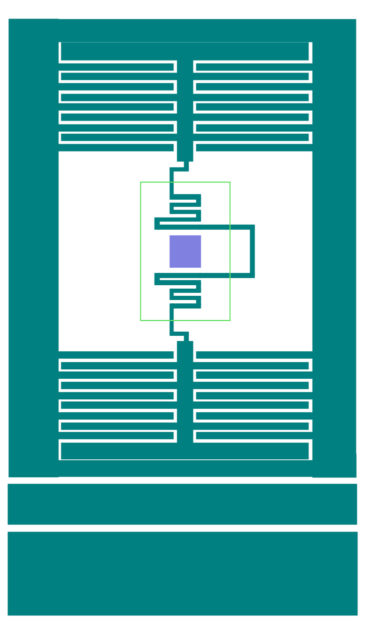
Calibration curves made with low readout power: T_{el} is the electrons' temperature



As comparison, this method was applied to the same chip suspended by Aluminum bonding wires: in this way it was measured the coupling of the Al wires, obtaining **n=6**, as expected.

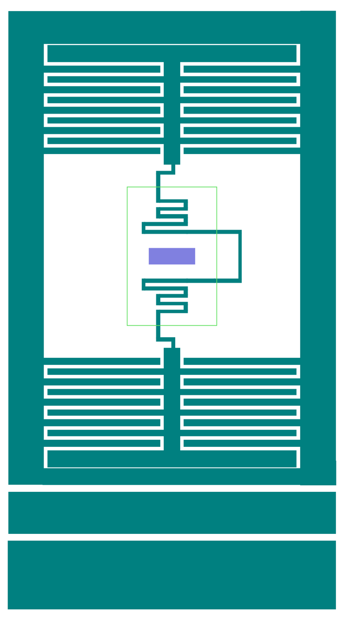
Latest designs of thermal devices (currently in production)

A



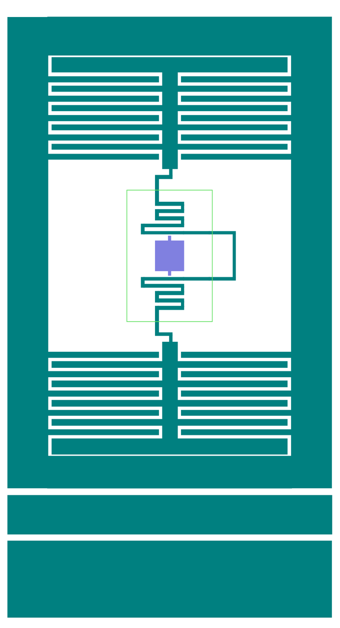
Thermal device with Si_3N_3 membrane to keep a gold absorber suspended through a finite thermal conductance. Three Ti/TiN multilayer films with three L_s: 12-20-30 pH/sq

B



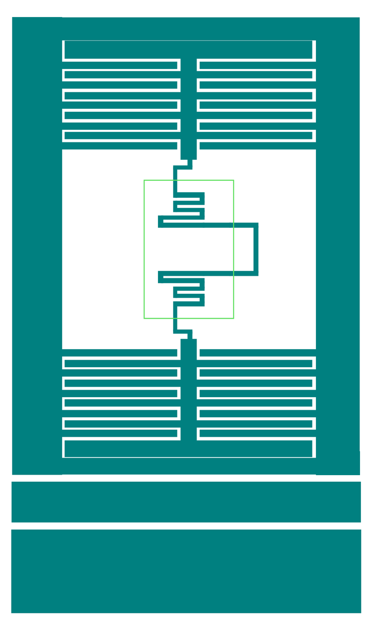
Variation of the "A" design: the absorber maintains the same perimeter, but it is kept farther from the inductor: this is intended to observe the effect of proximity of the gold to the superconductor

C



In this variation the absorber has two little "fingers" in the direction of the meander: the purpose is to increase the coupling between the absorber and the inductor maintaining the distance among the two constant

D



Same as the design "A", but without the gold absorber. This resonator will be used as a reference for the other ones in case the gold affects the behaviour of the resonator

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