Study of TES response to low energy electrons at Milano-Bicocca and more...

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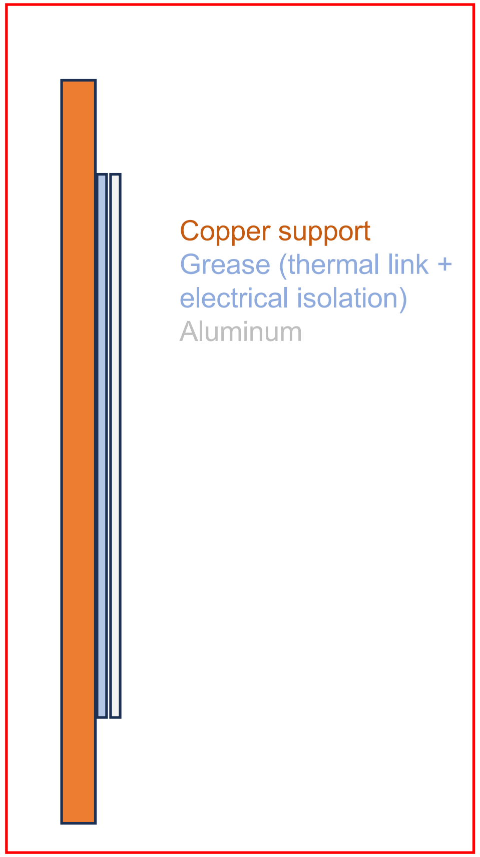
PTOLEMY meeting, Princeton 6-8 November 2023

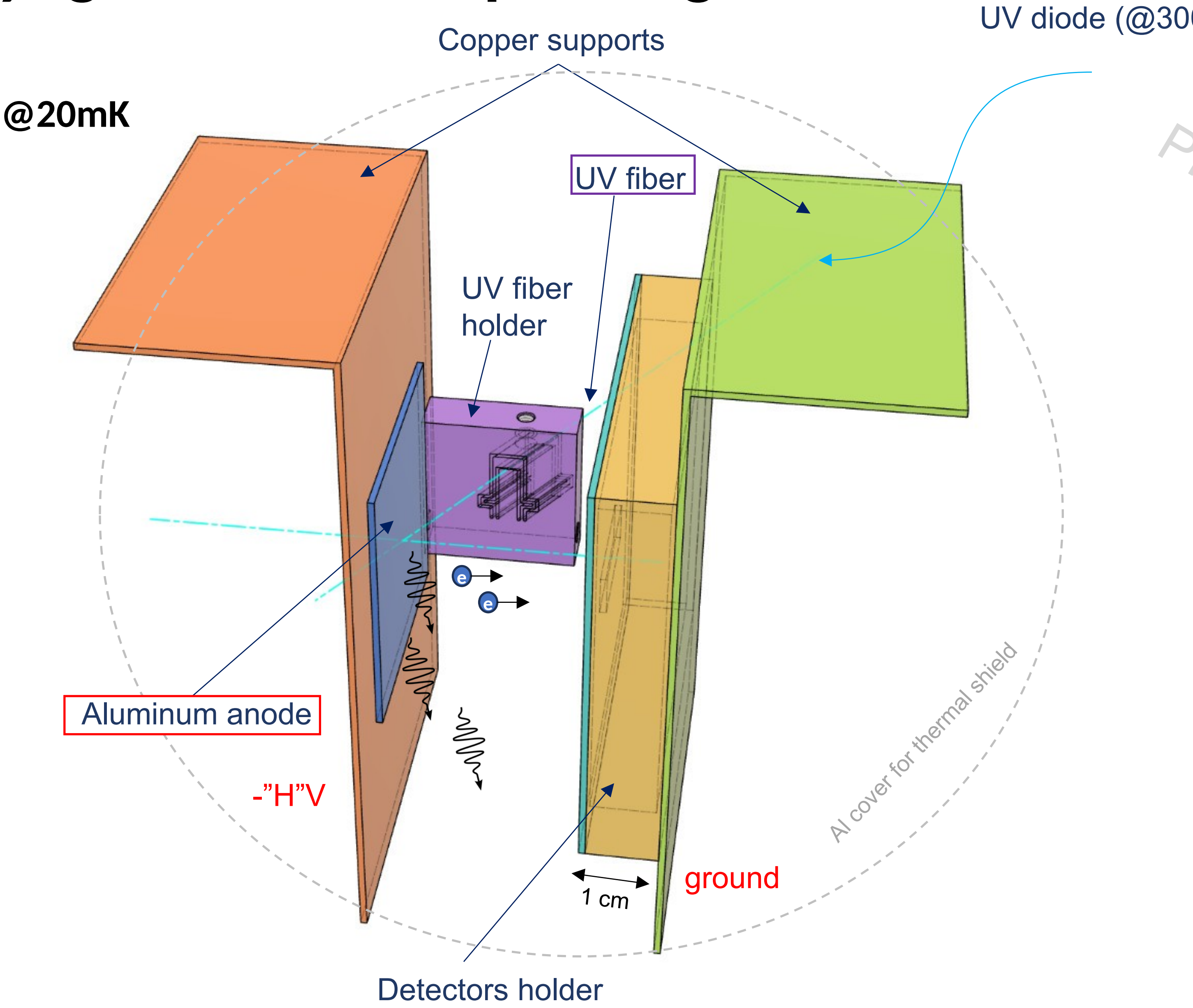
Progresses on

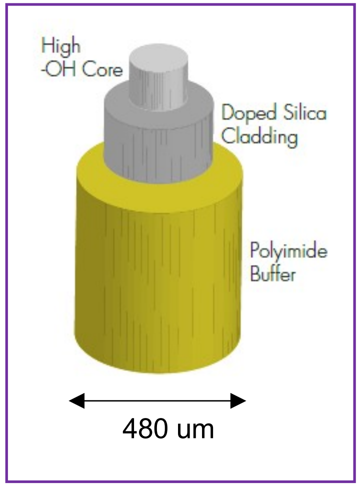
1. development of a cryogenic low energy electron source
2. TES multiplexing by Kinetic inductance current sensor (KICS)
3. Microwave Kinetic Inductance Travelling Wave Parametric Amplifiers

Slides thanks to
Matteo Borghesi (1)
Andrea Giachero (2,3)

Design for a cryogenic and compact e-gun

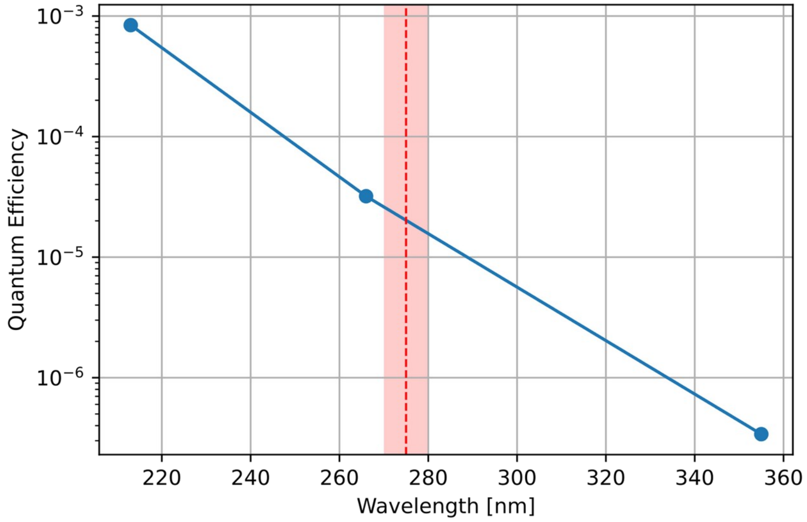






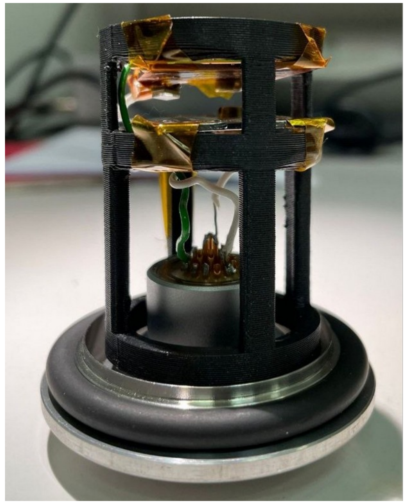
Why aluminum?

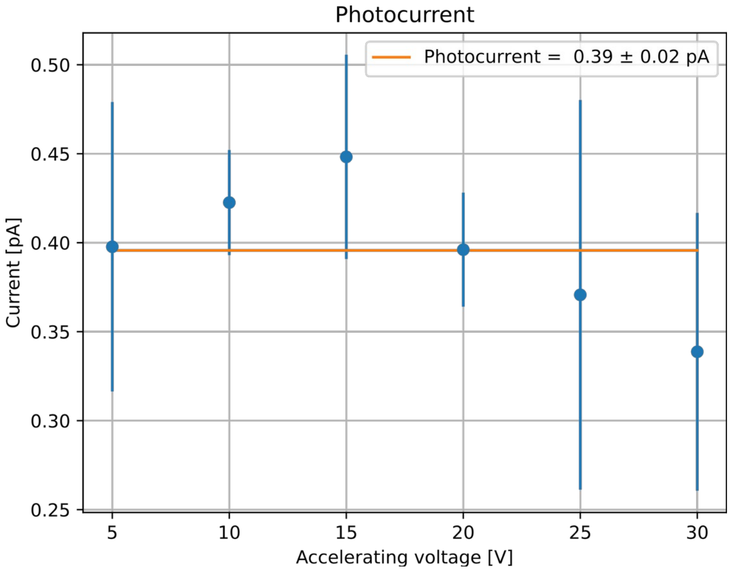
- **Low work function** (4.2 eV) (UV LED diode energy: 4.5 eV)
- Good QE of clean **aluminum (no oxide)** in high vacuum



https://doi.org/10.1016/0168-9002(94)91293-9

- Measured QE of **aluminum with oxide** in vacuum @MIB (300K): $\approx 10^{-10}$





(we can easily change the anode material)

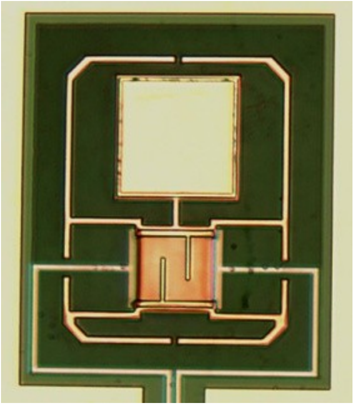
Still good for e-gun!

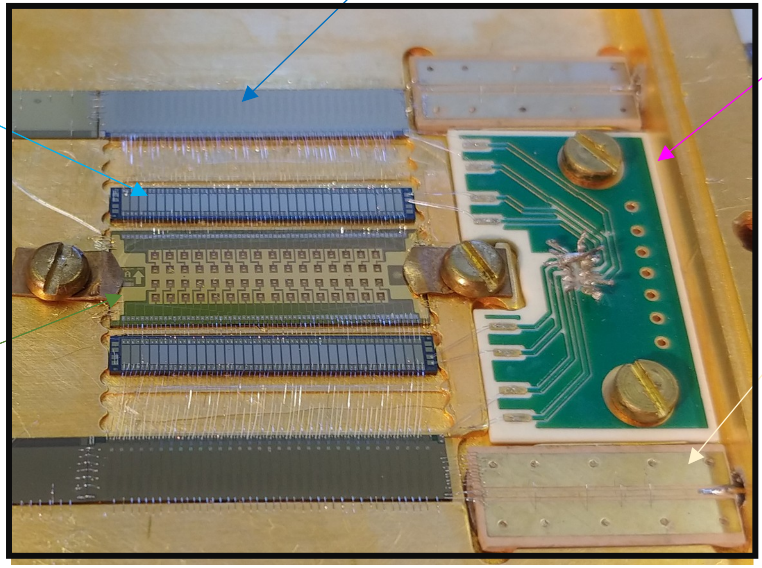
(see later)

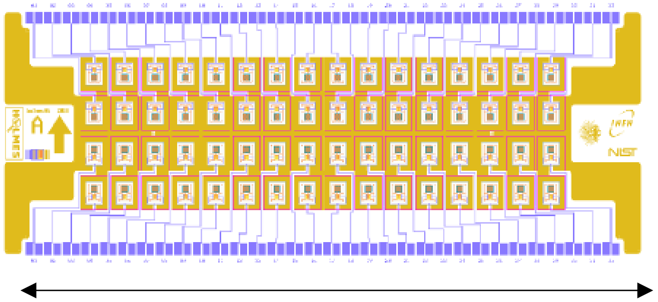
Technique now used routinely by Tristan @UNIMB to produce e-beams at 5-20keV to study SDD response

TES detectors @ UNIMIB

- **Spare TES** designed for HOLMES (array of 32x2 pixels)





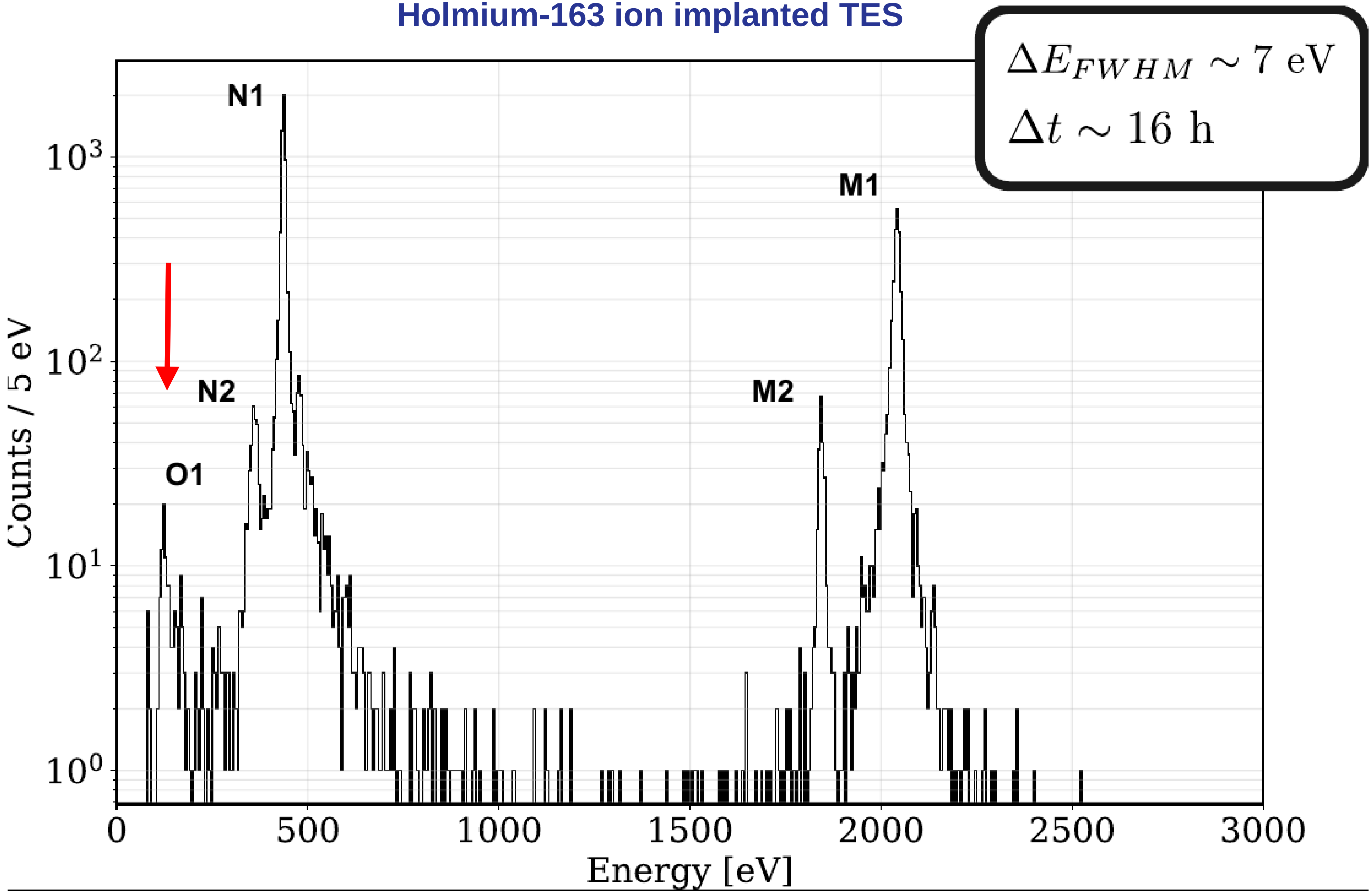


- TES designed for soft X-rays
  - E_{max} around 7 keV
  - ^{163}Ho end-point at 2.8 keV
  - $\Delta E_{FWHM} \approx 5$ eV at 1.5 keV
  - we can detect events from O1 peak in ^{163}Ho spectrum at ≈50 eV
  - Should detect **electrons** with energy as low as few tens of eV

⇨ Not good for Ptolemy… **but suitable for the preliminary test of the e-gun!**

(Readout chips already available, “large” total collecting area)

Holmium-163 ion implanted TES



Preliminary conclusion

Kassiopeia simulations

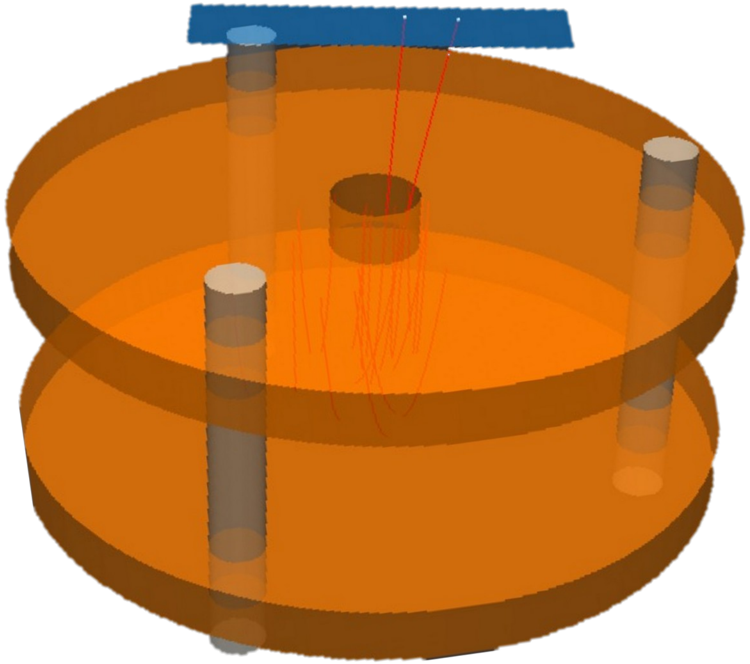
- Maximum UV diode power: 800 uW
- Cooling power @100mK : 200 uW
- Electron initial energy: 0-0.3 eV
- Voltage: 50 eV

⇨

With an UV power @100mK of 80uW, the **expected rate of electron per pixel** (from preliminary simulations with Kassiopeia) should be around **1.3 Hz**
(photon background must be checked)

TODO list:

- [x] Buy UV fibre (and diode) (arrived last month)
- [x] Estimate Al QE @300K
- [x] Setup of the detectors holder (wire bonding ongoing right now!)
- [ ] Cryogenic setup
- [ ] First measure of low energy electron with TES at the end of this year!



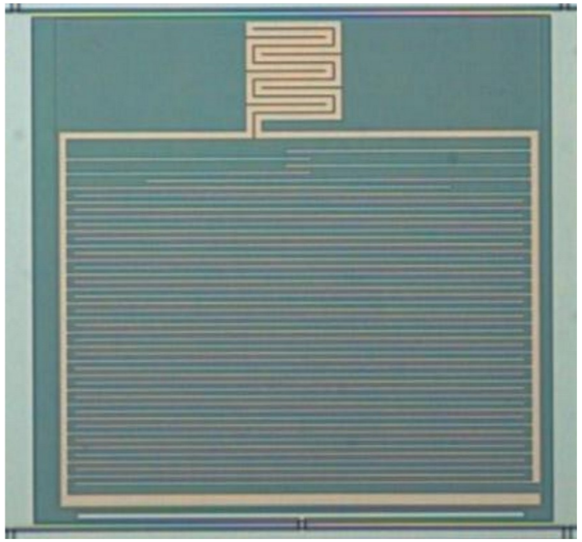
LT microcalorimeters multiplexing

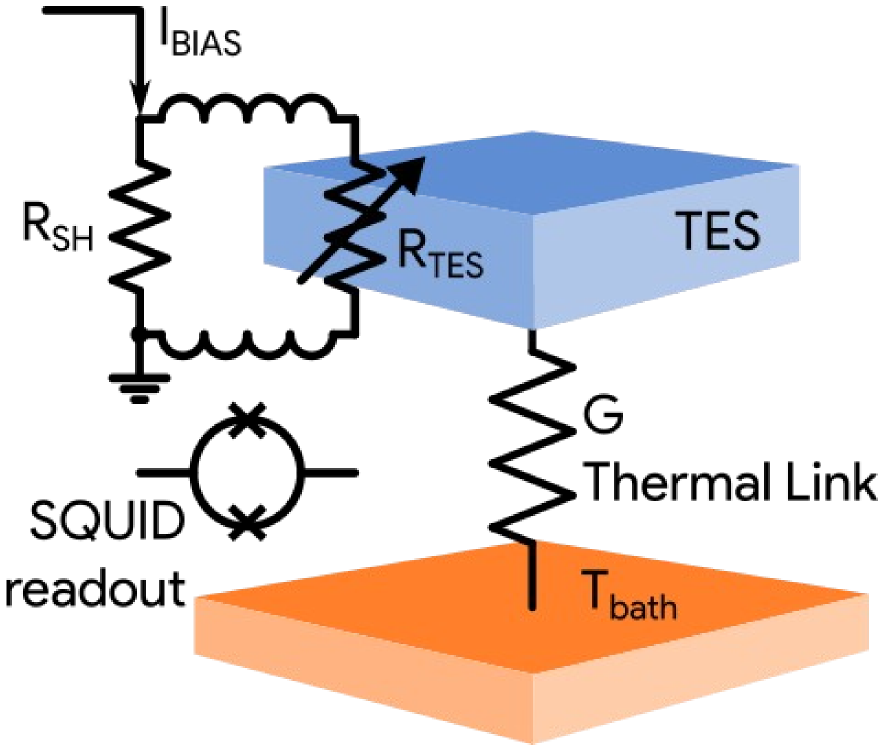
MKIDs

- MKID is essentially a superconducting LC resonator;
- Photons absorbed in the inductor increase the kinetic inductance, shifting the resonance frequency;
- The frequency shift is proportional to the energy of the photon, providing spectral resolution
- Very natural to read out using frequency division multiplexing (FDM) techniques standard in the telecommunications industry

TESs

- TESs are essentially, a superconducting slab operated in the superconducting-normal transition region
- Photon events drive the TES more resistive, creating a current pulse
- Complicated fabrication involving small junctions, difficult to fabricate integrated TES and SQUID arrays for compact detector formats
- SQUID switching times in TDM, flux ramp in µMUX, limit readout timescales to a few microseconds





A. Giachero

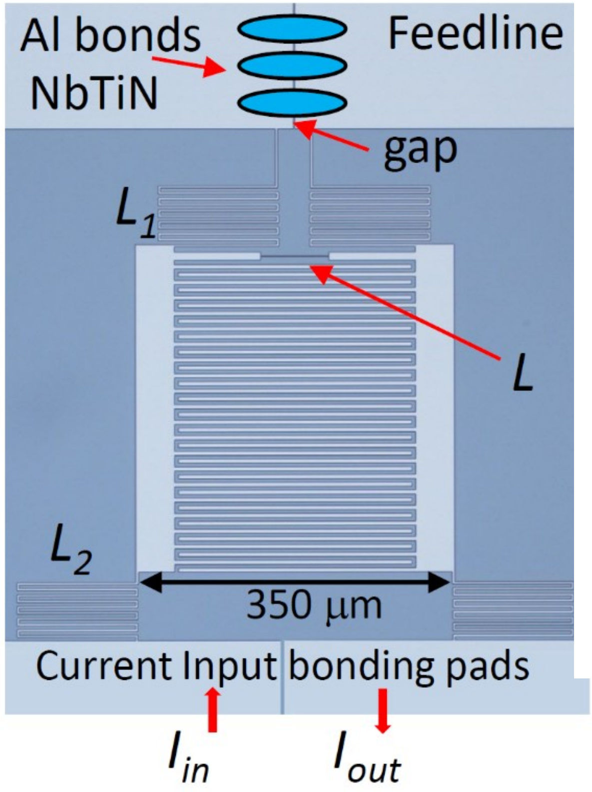
Kinetic inductance current sensor (KICS)

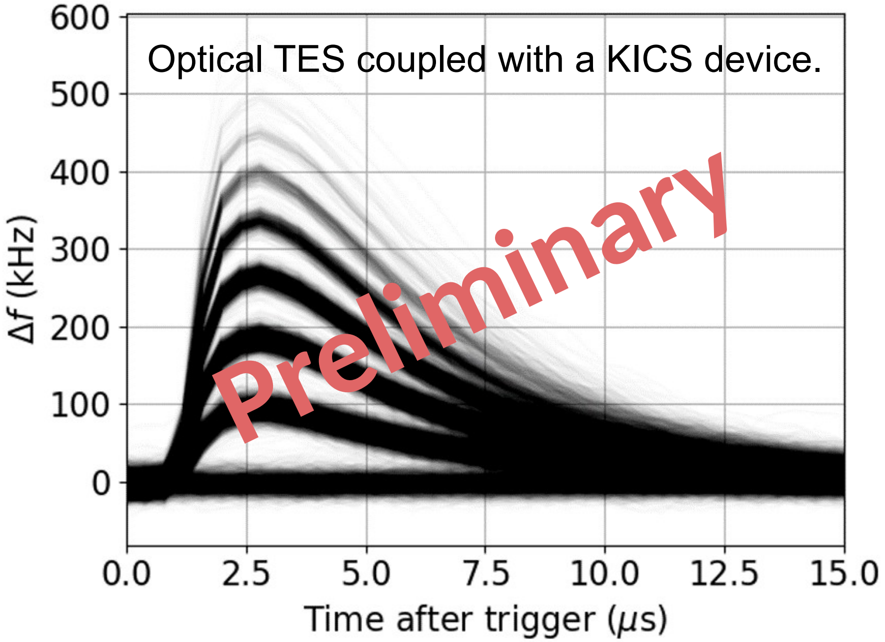
- Proposed and implemented by the Quantum Sensor Division at **NIST**
- Based on tunable resonators: Appl. Phys. Lett. 107, 062601 (2015)

- Superconducting resonator with inductor made in high nonlinear kinetic inductance material (i.e NbTiN, TiN, ect)

$$L_{KI}(I) = L_0\left(1 + \frac{I^2}{I_{*,2}^2} + \frac{I^4}{I_{*,4}^4} + \cdots\right)$$

- L depends on L_{KI} that depends on the current I that flows from I_{in} and I_{out}
- If I changes L changes and the resonant frequency of the microresonator shifts at lower frequencies





R = 5.7 at 1550 nm, already surpassing a SQUID readout of the same detector.

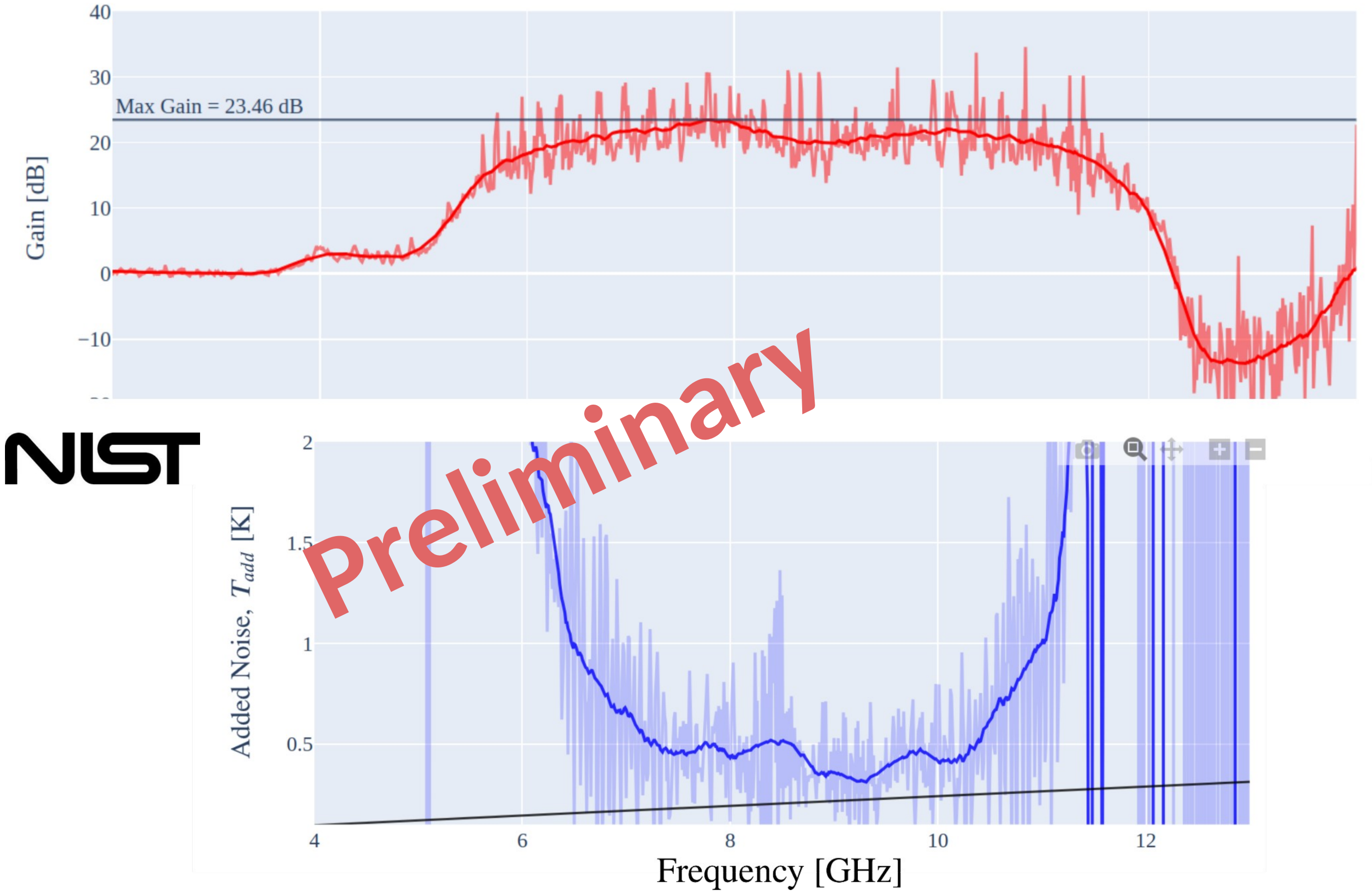
Fast multiplexing of TESs without any SQUID and complicated modulation techniques

We plan to develop and fabricate these devices with **FBK** and **INRIM**

A. Giachero

Traveling Wave Parametric Amplifier

Broadband quantum limited parametric amplifier for resonators, cavities, and antennas readout



- Long transmission line made made in nonlinear kinetic inductance material (i.e NbTiN, TiN, ect);
- High kinetic inductance material (L_{KI} > 30 pH/sq) can provide higher performances and more compact designs;
- Design tunable per different bandwidths: C, X, K and W;
- Interest in K band (30 GHz) for hot-qubit readout;

Result obtained at **NIST** with new amplifiers design with L_{KI} > 30 pH/sq (project developed at NIST in collaboration with UNIMIB)