Detecting single infrared photons with a W-TES for ALPS II

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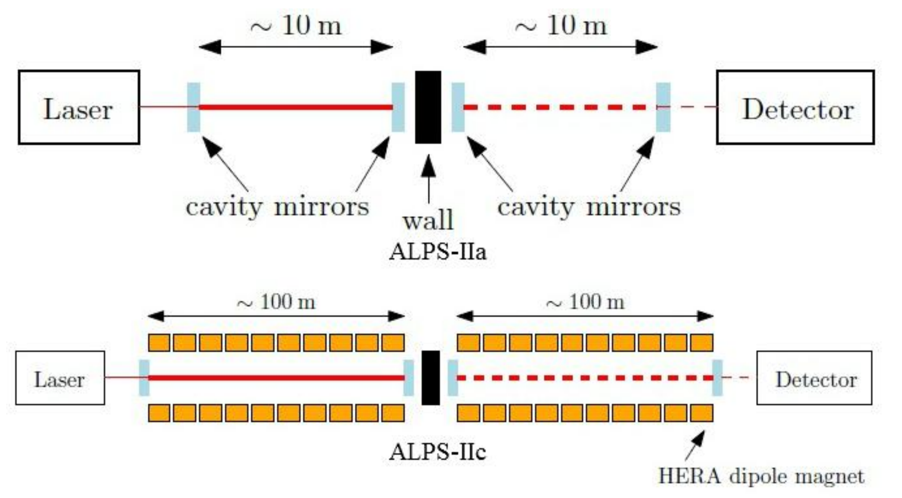
Abstract

The ALPS II experiment, Any Light Particle Search II at DESY in Hamburg, will look for sub-eV masses new fundamental bosons (e.g., axion-like particles, hidden photons and other WISPs) in the next years by the means of a light-shining-through the wall setup.
The ALPS II photosensor is a Transition Edge Sensor (TES) optimized for 1064 nm photons. This TES, operated at 80 mK, has already allowed single infrared photon detections as well as non-dispersive spectroscopy with very low background rates. The expected quantum efficiency for such TES is > 95 % (1064 nm). For 1064 nm photons, the measured dark count rate is < 10^{-2} sec^{-1}. At this wavelength, the intrinsic dark count rate is of 10^{-4} sec^{-1}. The relative energy resolution for 1064 nm signals is < 8%. In order to set accurately the device and for reading purposes, TESs are inductively coupled to a SQUID (Superconducting Quantum Interference Device). In the near future, complete characterization, calibration and optimization (e.g., background suppression, robust operation) need to be finalized.



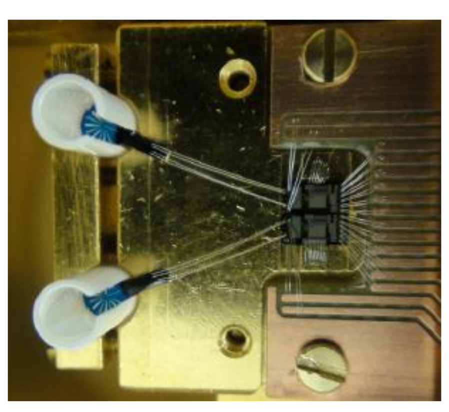
Technical Challenges

LOW ENERGY (1.17 eV)
LOW RATE (1 γ every few hours)

- ❑ **High detection efficiency**
- ❑ **Low dark count rate**
- ❑ **Long-term stability**
- ❑ **Good energy resolution**
- ❑ **Good time resolution**

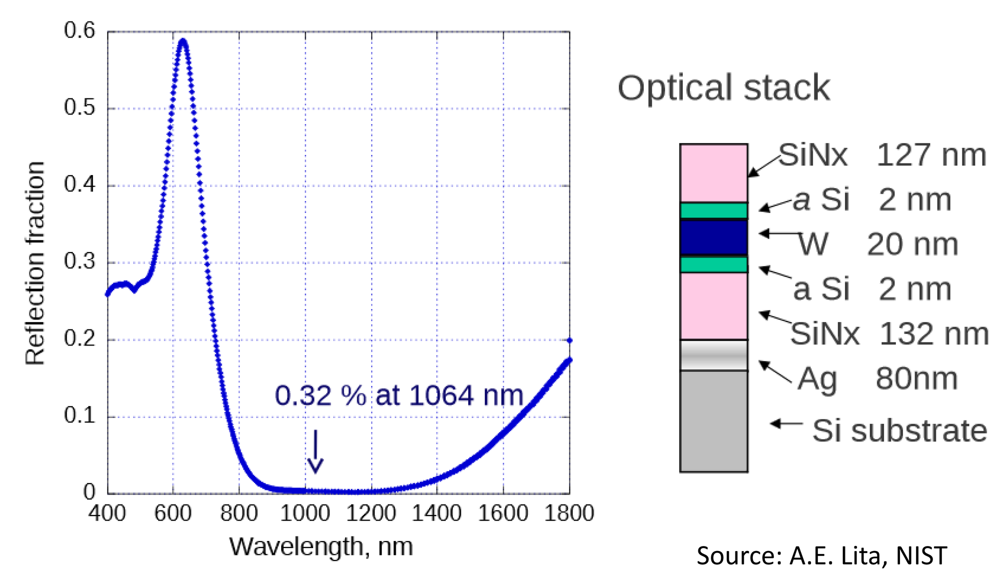
NIST W-TES	
Efficiency (1064 nm)	95 % (*)
Intrinsic dark current	10^{-4} sec^{-1}
Long term stability	☑
Good energy resolution	< 8%
Good time resolution	☑

(*) A.E. Lita, A.J. Miller, S.W. Nam, *Counting near-infrared single photons with 95 % efficiency*, Opt Expres. 2008



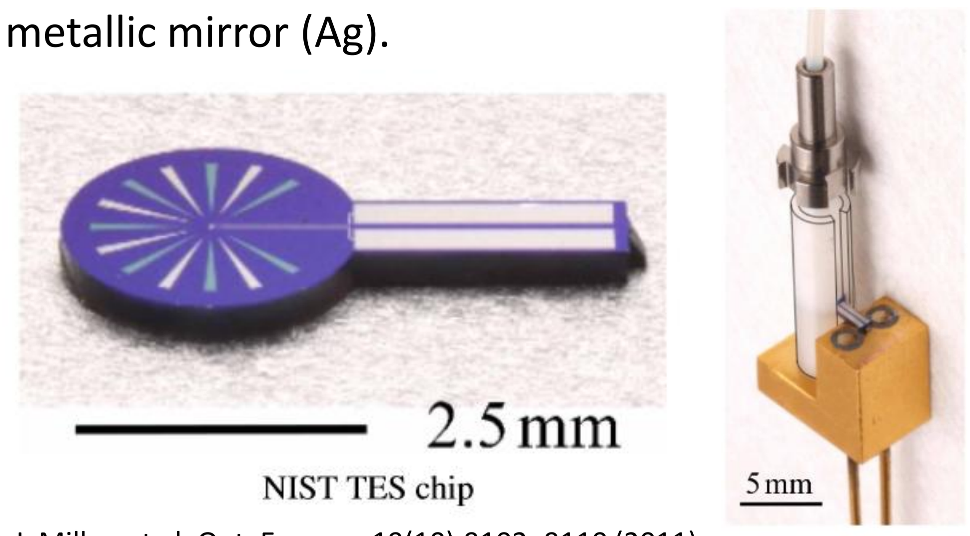
Two chanels module (3 x 3 cm²)
Tungsten chip (25 x 25 µm², 20 nm)
Tc ≈ 140 mK
Inductive coupling to a SQUID

TES structure



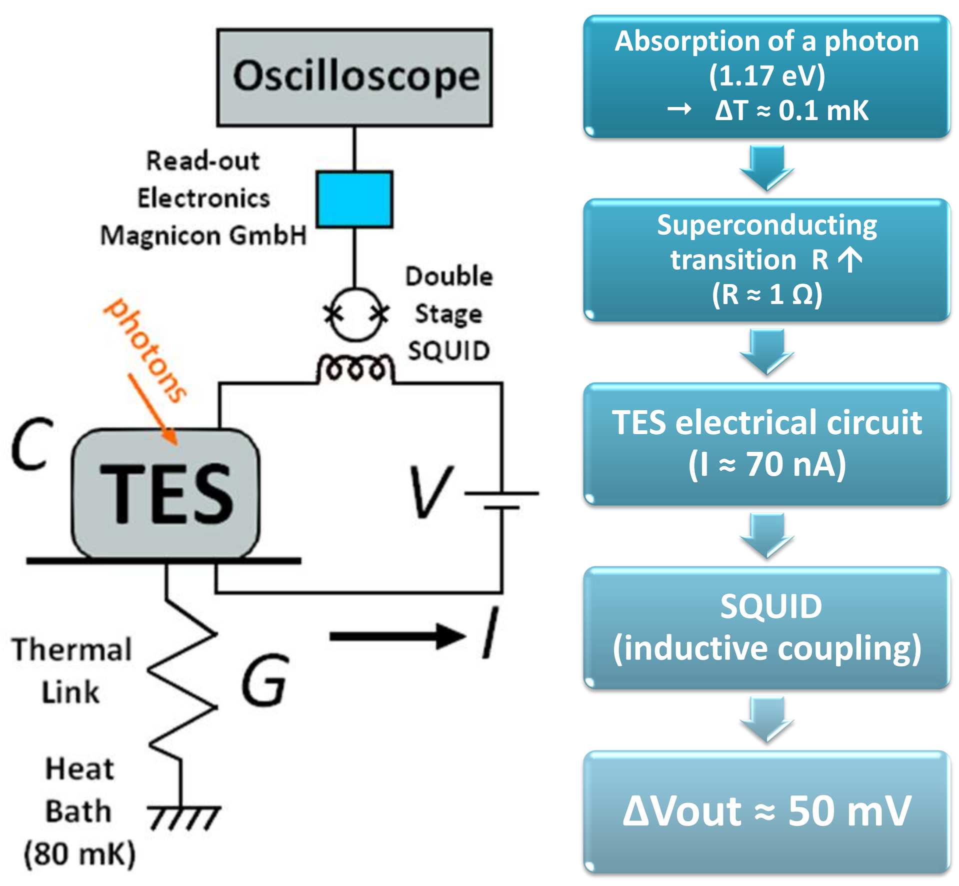
Source: A.E. Lita, NIST

The TES was produced by NIST and is optimized for 1064 nm photons. The tungsten (W) layer is surrounded by an antireflective coating (aSi, amorphous silicon, SiNx, silicon nitride) and a metallic mirror (Ag).



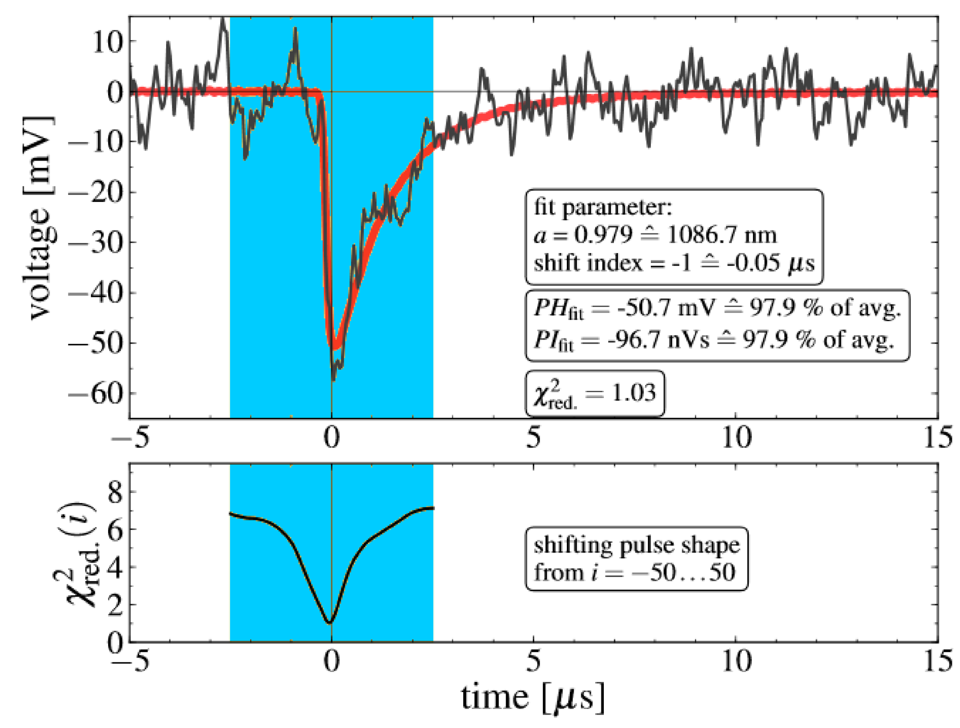
A.J. Miller, et al. Opt. Express, 19(10):9102–9110 (2011) fiber-to-chip coupling

Low noise read-out



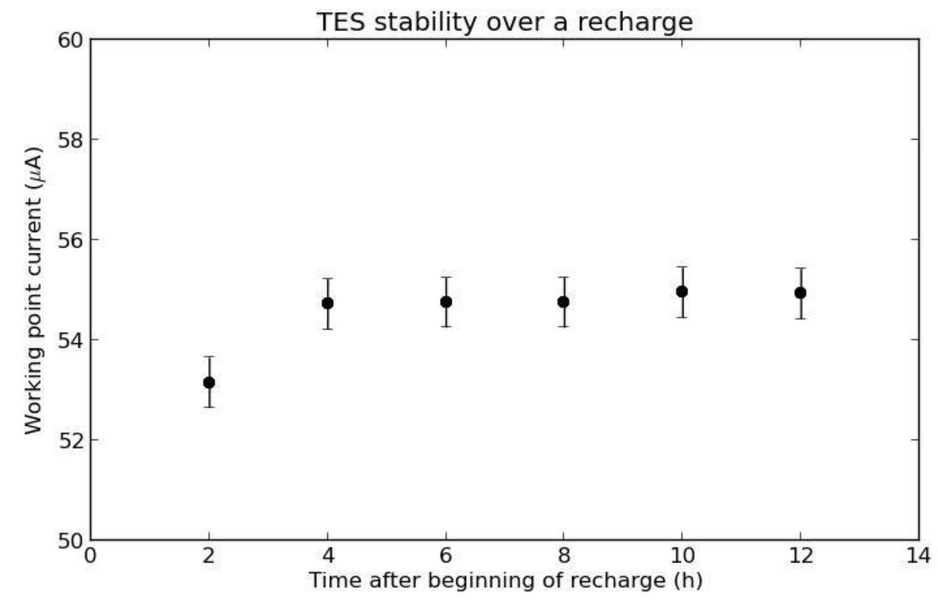
Two stage SQUID
Noise level 2 pA/√Hz
Read-out system bandwidth f_{3dB} ≈ 0.9 MHz
Signal output recorded with an oscilloscope

Single Photon Event



Stability

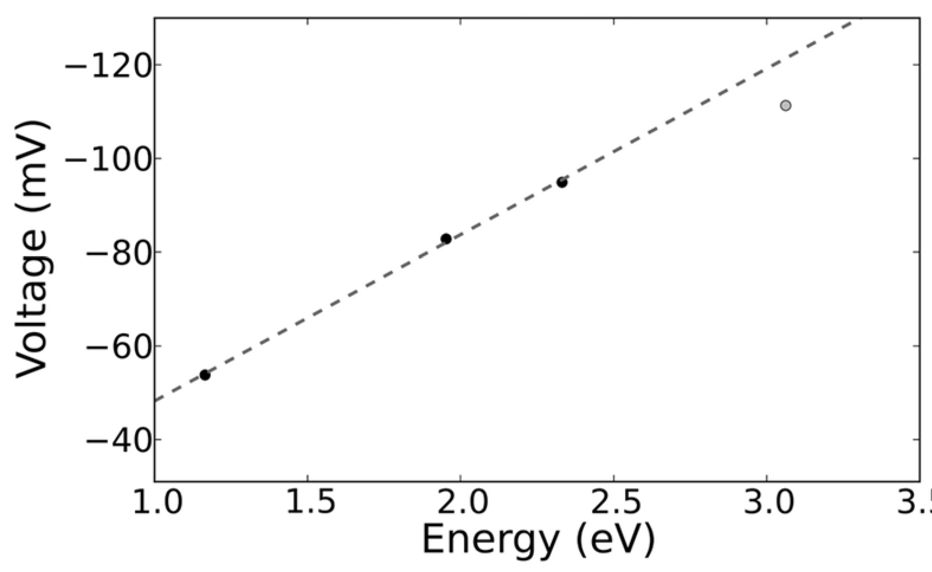
Detections with TESs are stable during a recharge, during one cool-down as well as during different cool-downs.
The results are not operator dependent (adjustment method).



The TES working point current equivalent to R0= 30 % Rnormal as a function of time after the beginning of a recharge.

Linearity

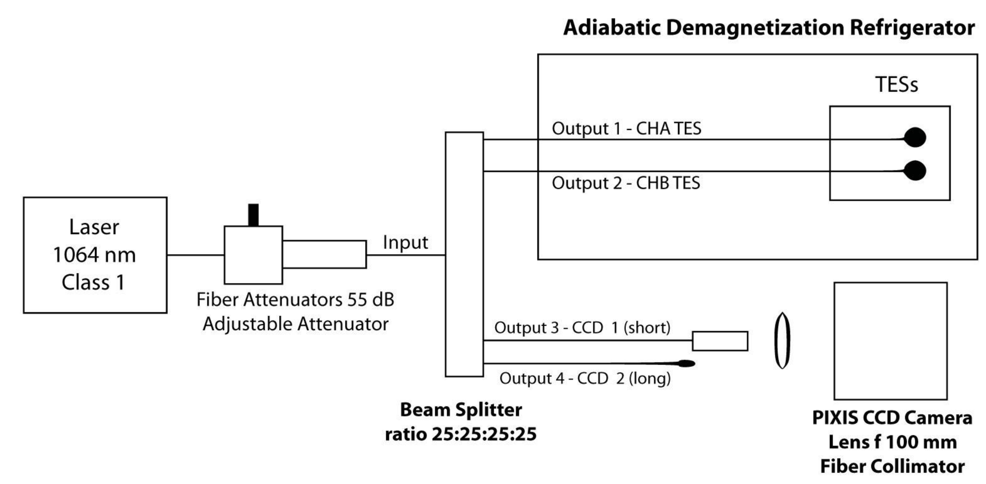
W-TESs are linear in our region of interest (1.17 eV). The non-linearity at higher energies matches expectations (saturation of the detector).



Average pulse height in units of voltage output as a function of photon energy for the TES. The dashed line is a fit to the first three points.

Quantum Efficiency

Back-to-back measurement of the TES quantum efficiency using a previously carefully calibrated PIXIS CCD camera (Von Seggern, 2014).



A first estimation of the current TES quantum efficiency gave a result of ~ 30 %.

Next steps

- ➪ **Cleanliness of the detector surface.**
- ➪ **Fiber behavior in the cold.**
- ➪ **Reflectivity of the setup.**
- ➪ **Distance between the fiber end and the detector.**
- ➪ **Fiber-TES alignment.**

References

ALPS II TDR, JINST (2013) arXiv:1302.5647
Characterization, 1064 nm photon signals and background events of a tungsten TES detector for the ALPS experiment, JMO (2015) arXiv:1502.07878v1

Acknowledgment

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