DETECTING SINGLE INFRARED PHOTONS WITH A W-TES FOR ALPS-II

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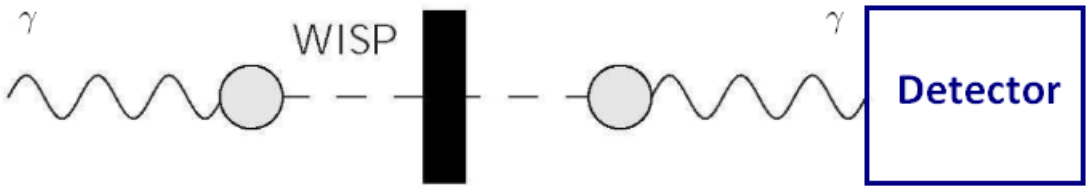
for the ALPS-II collaboration

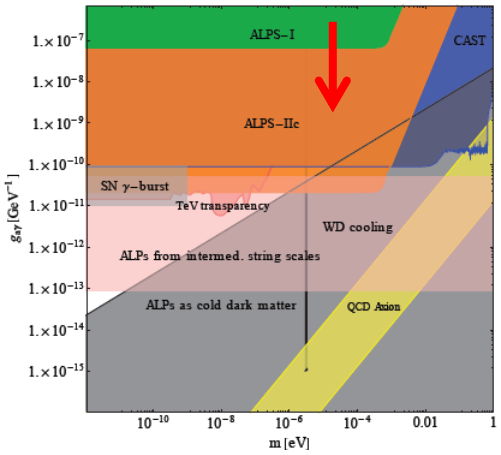
A brief reminder…



Light shining through the wall experiment:

Photon-mixing + Additional light boson

→ Re-appearance of few bosons behind a light-tight barrier



1064 nm laser → 1.17 eV photons

ALPS-I: $g_{a\gamma} \leq 7.10^{-8}\ GeV^{-1}, m_a \leq 10^{-4} eV$

ALPS-II: $g_{a\gamma} \approx 2.10^{-11}\ GeV^{-1}$

➥ **1 photon every few hours**

Technical challenges

⇨ **Low energy (1.17 eV) and low rate (1 photon every few hours).**

1) **High efficiency**

2) **Low dark count rate**

3) Long-term stability

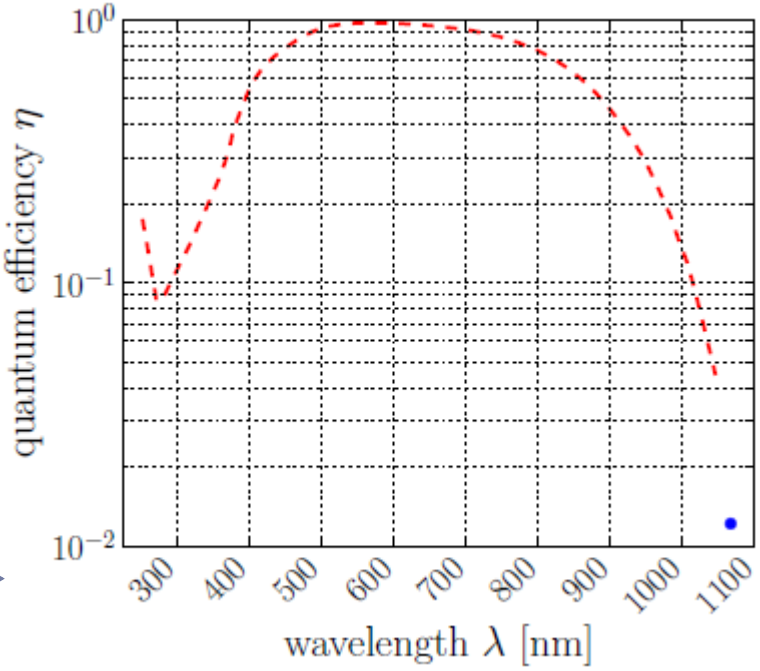
4) Good energy resolution

5) Good time resolution

CCD in ALPS-II

PIXIS 1024B CCD camera	
Dark current	10^{-3} e$^-$ / *pixel* / sec
Efficiency (1064 nm)	1.2 %
Long term stability	☑
Good energy resolution	☒
Good time resolution	☒

Low efficiency due to the proximity of the wavelength to the Si band gap energy.



Von Seggern JE, *Constraining Weakly Interacting Slim Particles with a Massive Star and in the Laboratory*, Dissertation, Univ. Hamburg, 2014

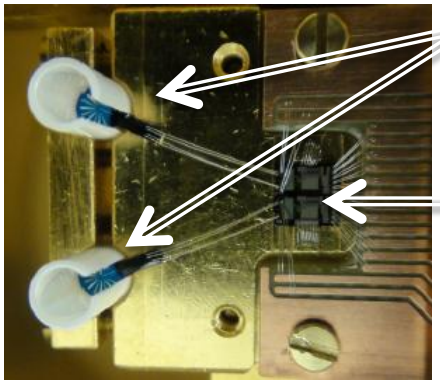
Transition Edge Sensor

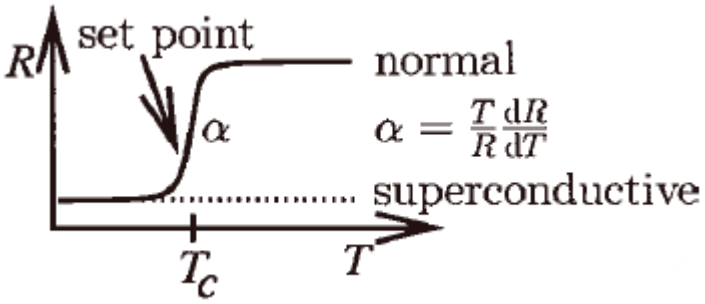
TES – Microcalorimeter measuring the temperature difference ΔT of the absorber material.

NIST

PTB

*Two channels module (3 cm * 3 cm)*





Tungsten chip (25 x 25 μm , 20 nm)
Tc ≈ 140 mK

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

NIST W-TES	
Efficiency (1064 nm)	95 %
Dark current	$<10^{-4}$ sec
Long term stability	☑
Good energy resolution	☑
Good time resolution	☑

CCD vs. Transition Edge Sensor

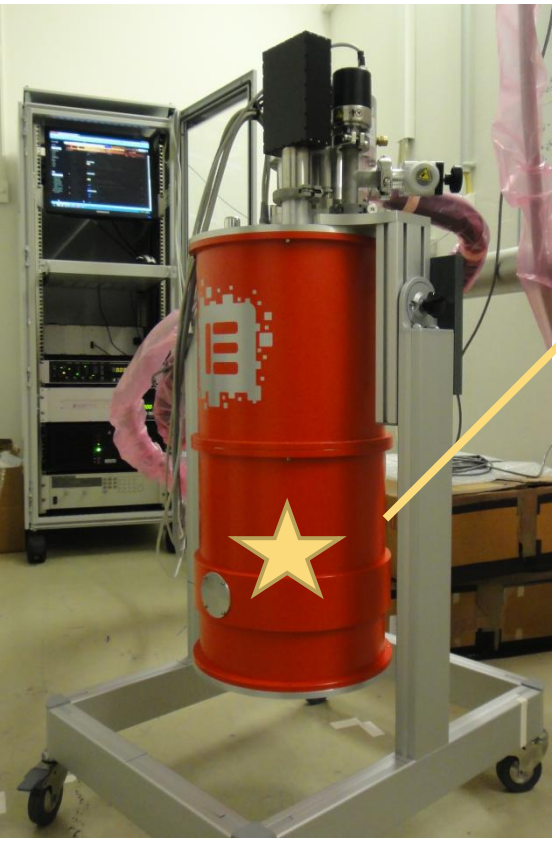
At 1064 nm

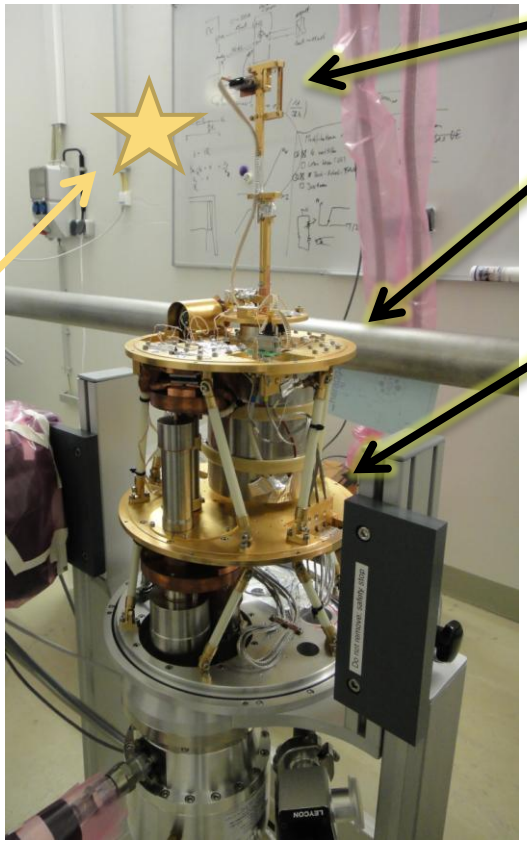
PIXIS 1024B CCD camera	
Efficiency (1064 nm)	1.2 %
Dark current	10^{-3} e$^-$ / *pixel* / sec
Long term stability	☑
Good energy resolution	☒
Good time resolution	☒
NIST W-TES	
Efficiency (1064 nm)	95 %
Dark current	$< 10^{-4}$ sec
Long term stability	☑
Good energy resolution	☑
Good time resolution	☑

TES environment in ALPS-II

CLOSED

OPENED

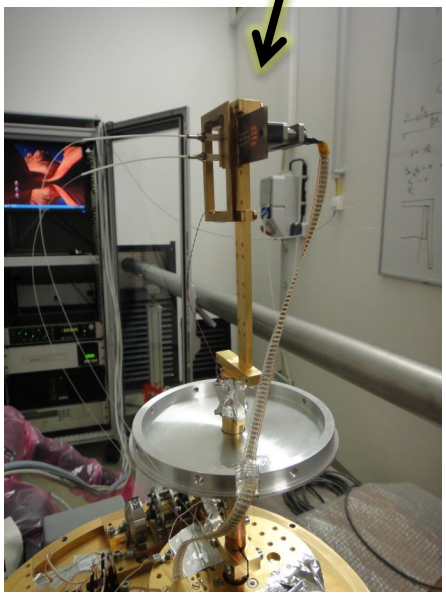




Transition Edge Sensor (80 mK)

4K - plate

77K - plate



Adiabatic Demagnetization Refrigerator (ADR)

Photon absorption to signal output

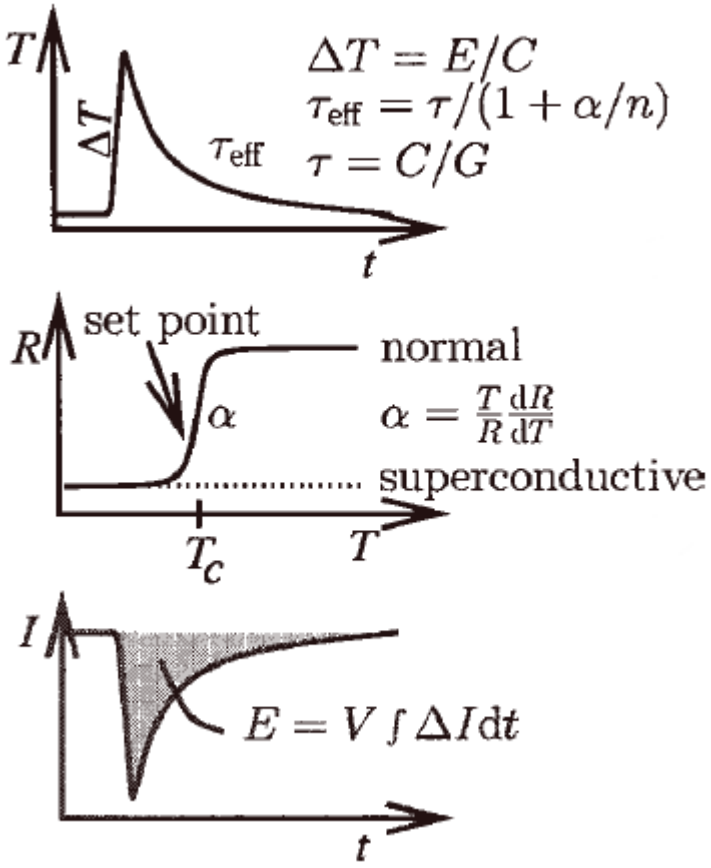
Absorption of a photon (1.17 eV)
→ ΔT ≈ 0.1 mK

Superconducting transition R ↑
(R ≈ 1 Ω)

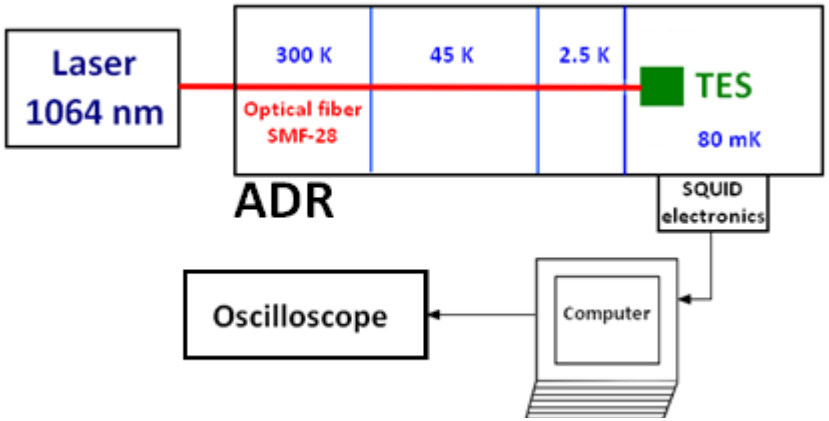
TES electrical circuit
(I ≈ 70 nA)

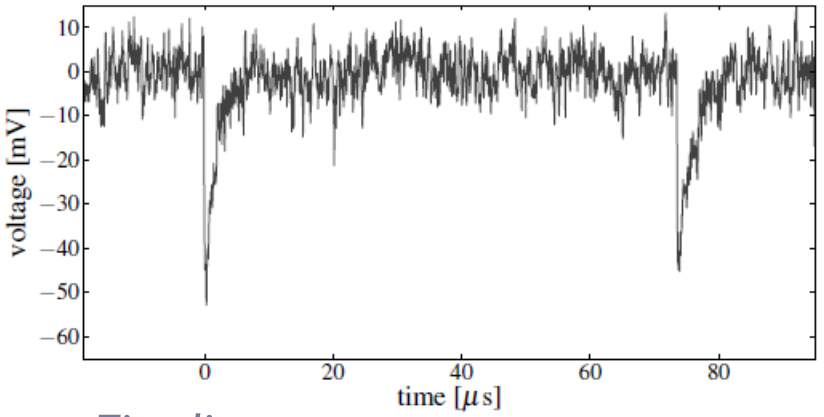
SQUID (inductive coupling)

ΔVout ≈ 50 mV



Single photon events



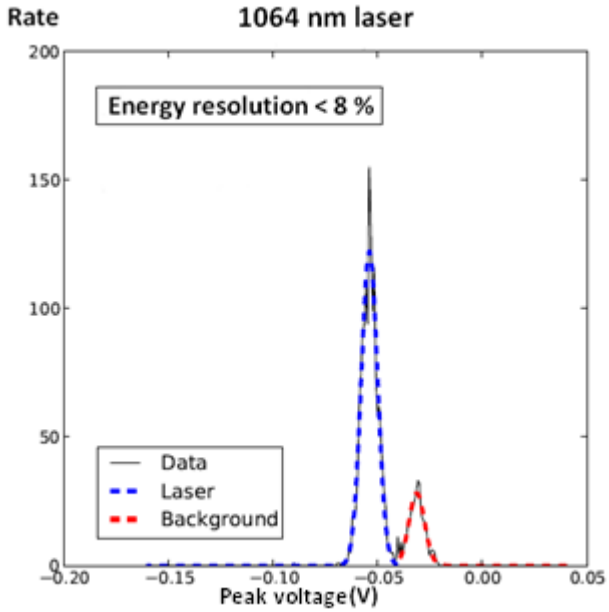


Timelines

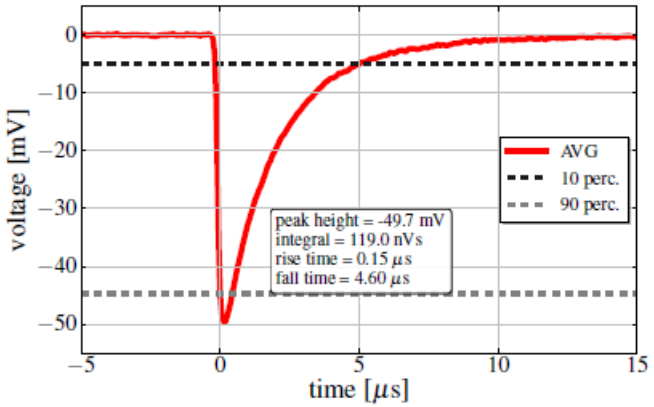
(source: J. Dreyling)

Average pulse

(source: J. Dreyling)



Histogram of peak voltages



N. Bastidon for ALPS-II

Summary

• ALPS-II experiment (DESY, Hamburg) follows the light-shining through the wall concept.

• A tungsten Transition Edge Sensor operated below 100 mK has been successfully used to detect single-photons in the near-infrared.

• The low rate and energy represent lots of challenges. Our TES will rise up to them.

ALPS-II TDR: arXiv1302.5647

Outlook

→ Finalizing characterization (quantum efficiency, linearity,…).

→ Pulse shape analysis.

→ Trying to reduce the background even further than what was already obtained (blackbody photons, …).

→ First ALPS-II data taking and physics results in 2014.