Setup of a TES detector
detecting single photons for ALPS

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Any Light Particle Search (ALPS) is a Light-shining-through-a-wall experiment

- green laser, production cavity, one HERA magnet
- Si-CCD (96% QE @ 532 nm) with 1h data/dark frames
  - dark current dominates over read-out noise
  - limited by background

> exemplary result:

\[ \gamma_{\text{in}} \sim 10^{21} \text{ 1/s} \]

\[ \gamma_{\text{meas.}} = (2 \pm 13) \times 10^{-3} \text{ 1/s} \]

Living map of WISP (Weakly Interactive Slim/SubeV Part.) e.g. ALPs (Axion-Like-Particles)
How can we lower the limit?

> Increase sensitivity of experiment: ALPS-II in three steps

- laser power resp. photon flux (1064 nm)
- regeneration cavity
- length of experiment (up to 200 m)

> Improve sensitivity of detector

- **Challenge**: detection of low rates of single infrared photons (< 1/h)
- **Requirements**: High efficiency and low (dark) noise and background

→ cryogenic microcalorimeter
Working principle of a TES (Transition-Edge Sensor) detector

\[ \Delta T = \frac{E}{C} \]
\[ \tau_{\text{eff}} = \frac{\tau}{1 + \alpha/n} \]
\[ \tau = \frac{C}{G} \]

\[ \alpha = \frac{T}{R} \frac{dR}{dT} \]

\[ E = V \int \Delta I \, dt \]

Some technical realizations and applications

- Direct Dark Matter Search (e.g. CRESST II)
- X-ray & gamma spectroscopy
- Bolometer in mm/sub-mm wave in astronomy
- single photon counter (near-infrared) for quantum-information (1310/1550 nm)

- Time / energy res.: ~ 1 μs / ~ 0.1 eV
- Detection efficiency up to 99%
- No dark noise intrinsic, but background....

Working principle of a TES (Transition-Edge Sensor) detector

Realizations for ALPS

> Sensor module:
  - Fiber-coupled high-efficient optical/infrared TES (NIST, USA or AIST, Japan)
  - SQUID as current sensor (PTB, Berlin)

> Read-out:
  - SQUID read-out electronic (Magnicon GmbH, Hamburg)

> cryogenics:
  - compact ADR cryostat (Entropy GmbH, Munich)

Adiabatic Demagnetization Refrigerator (ADR)

ADR is a dry, compact cryostat:

- Only water, high current needed
- Pulse-tube cooler: in ~20 h to ~2.5 K
- Salt pill unit
- 6 T magnet for demagnetization cooling
Going to mK: a recharge cycle and holding mK

> Recharge time: 
  ~ 2 h

> Lowest temperature 
  ~ 30 mK

> Regulation by adjusting magnetic field

~60h @ 100 mK (rms ~15 μK)
(wo experiment)
First operation with loaned NIST module (Sept. 2012, PTB)

**NIST TES:**

- doped W with Tc = 170 mK
- 25μm x 25μm x 20nm
- optical resonator and metallic mirrors
- 98% QE for 1064 nm

Stray light and laser photons

Summary and Outlook

Summary:
- ALPS-II is on the road
- TES detector as low-noise single infrared photon detector is on the road
- Proof of principle: “High efficient optical TES with 2-stage-SQUID read-out is working in an ADR cryostat.”

Outlook:
- March: Optimization of ADR
- From April: Characterization of AIST (Japan) TES chip
- Long term background/noise measurements (for low, low photon rates)
- Optical efficient coupling to the experiment
- First ALPS-II run in end of 2013
Backup
ALPS-II: Go bigger step by step

- **ALPS-IIc**: Hidden photon search and proving the regeneration cavity *(end of 2013)*
  - New laser lab in HERA-West, 50, room 607: 2 x 10 meter

- **ALPS-IIb**: 2 x 100 meter *(in 2014)*

- **ALPS-IIc**: 10 + 10 straightened HERA dipoles *(in 2017)*
TES-SQUID modules

NIST chips (W, Tc = 170 mK) with optical resonator and metallic mirrors reaching 98% quantum efficiency for 1064 nm

AIST chips (Ti/Au, Tc = 300 mK) with optical resonator and dielectric mirrors reaching 98% quantum efficiency for 850 nm
