Cold filtering of photons for a TES detector in the ALPS II experiment

Christina Schwemmbauer

DESY Summer Student Talks, September 5th, 2019

HELMHOLTZ SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

ALPS

DESY.

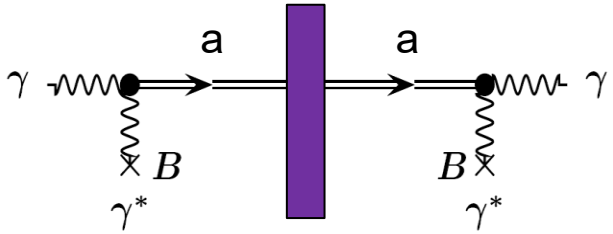
ALPs

- Could solve strong CP problem in QCD
- Axion-Like-Particle (ALP)
- Weakly Interacting Slim Particles (WISPs)
- Viable dark matter candidates
- Could explain multiple astrophysical phenomena
- Possible detection through Primakoff-like Sikivie Effect

Adapted from: A. Lindner, ALPS Summer Student Lecture 2019

ALPS II – Any Light Particle Search

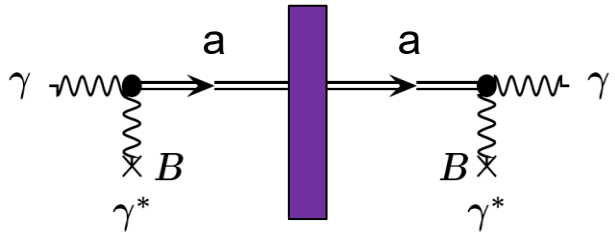
Adapted from: A. Lindner, ALPS Summer Student Lecture 2019

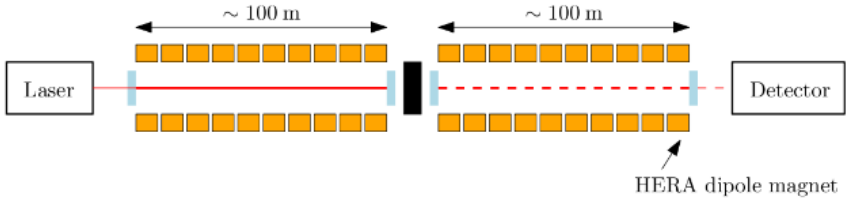


- **LSW** (**L**ight-**S**hining-through-a-**W**all) Experiment (less dependent on theor. models)
- Using the Sikivie Effect
- ALPs generated through photon-ALPs-oscillations
- ALPs can pass through light-tight walls

ALPS II – Any Light Particle Search

Adapted from: A. Lindner, ALPS Summer Student Lecture 2019

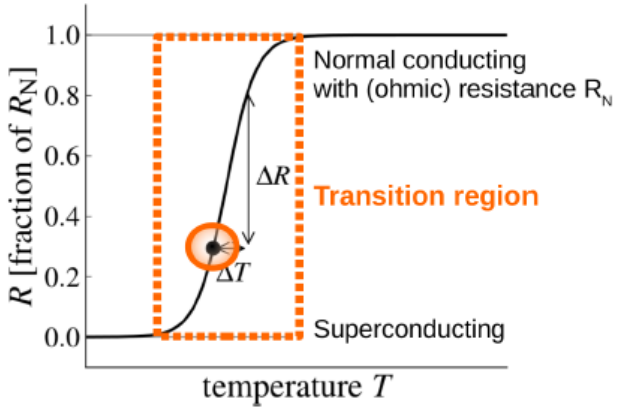




J. Dreyling-Eschweiler, A superconducting Microcalorimeter for Low-Flux Detection of Near-Infrared Single Photons

- **LSW** (**L**ight-**S**hining-through-a-**W**all) Experiment (less dependent on theor. models)
- Using the Sikivie Effect
- ALPs generated through photon-ALPs-oscillations
- ALPs can pass through light-tight walls
- **24** HERA magnets
- Regeneration of photons in second cavity
- Photons sent to **TES** (**T**ransition-**E**dge-**S**ensor)

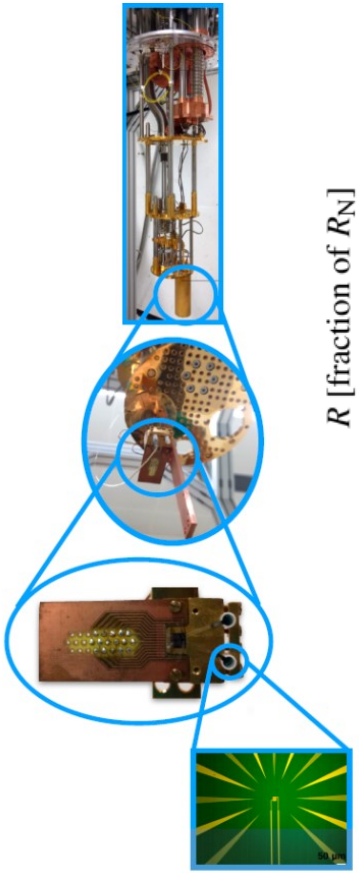
TES and black body radiation

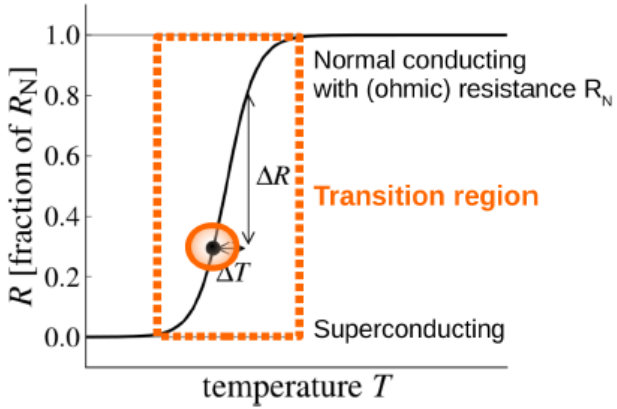


Adapted from J. Dreyling-Eschweiler, A superconducting Microcalorimeter for Low-Flux Detection of Near-Infrared Single Photons

- TES detects reconverted photons
- Tungsten sensor operated at ~80mK
- Working point within superconducting transition region

TES and black body radiation



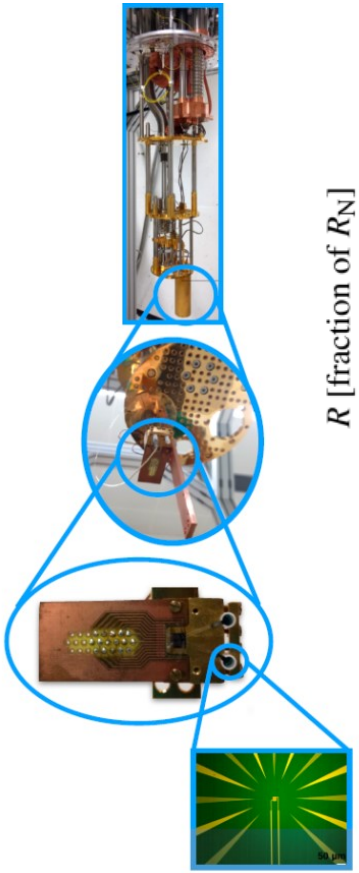


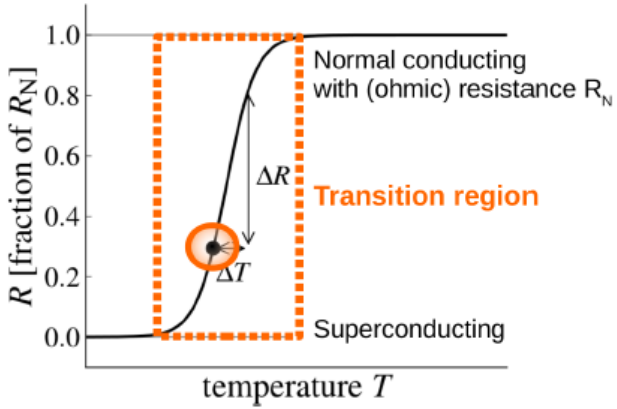
Adapted from J. Dreyling-Eschweiler, A superconducting Microcalorimeter for Low-Flux Detection of Near-Infrared Single Photons

- TES detects reconverted photons
- Tungsten sensor operated at 80mK
- Working point within superconducting transition region
- Readout via SQUIDs
- Needed: extremely **low background**

Manuel Meyer, Internal Communication, 2019.

TES and black body radiation



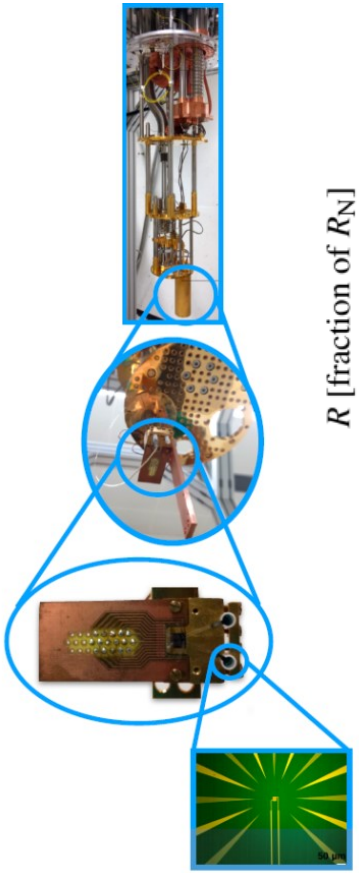


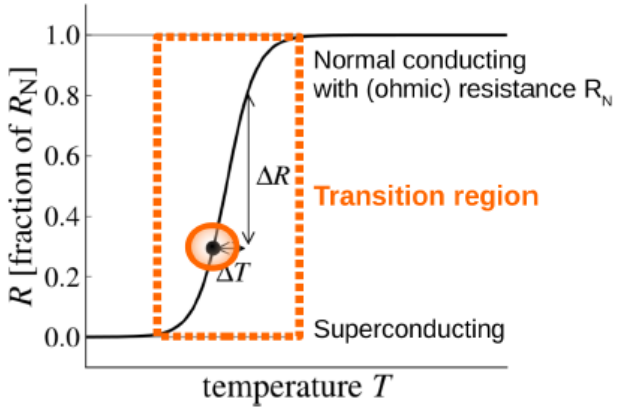
Adapted from J. Dreyling-Eschweiler, A superconducting Microcalorimeter for Low-Flux Detection of Near-Infrared Single Photons

- TES detects reconverted photons
- Tungsten sensor operated at 80mK
- Working point within superconducting transition region
- Readout via SQUIDs
- Needed: extremely **low background**
- Problem: background dominated by photons from black body radiation
- Assumption: Pile-up

Manuel Meyer, Internal Communication, 2019.

TES and black body radiation





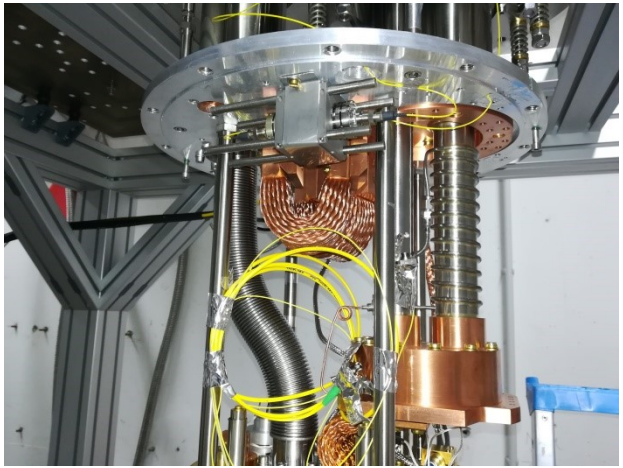
Adapted from J. Dreyling-Eschweiler, A superconducting Microcalorimeter for Low-Flux Detection of Near-Infrared Single Photons

- TES detects reconverted photons
- Tungsten sensor operated at 80mK
- Working point within superconducting transition region
- Readout via SQUIDs
- Needed: extremely **low background**
- Problem: background dominated by photons from black body radiation
- Assumption: Pile-up

Motivation:
Reduce background!

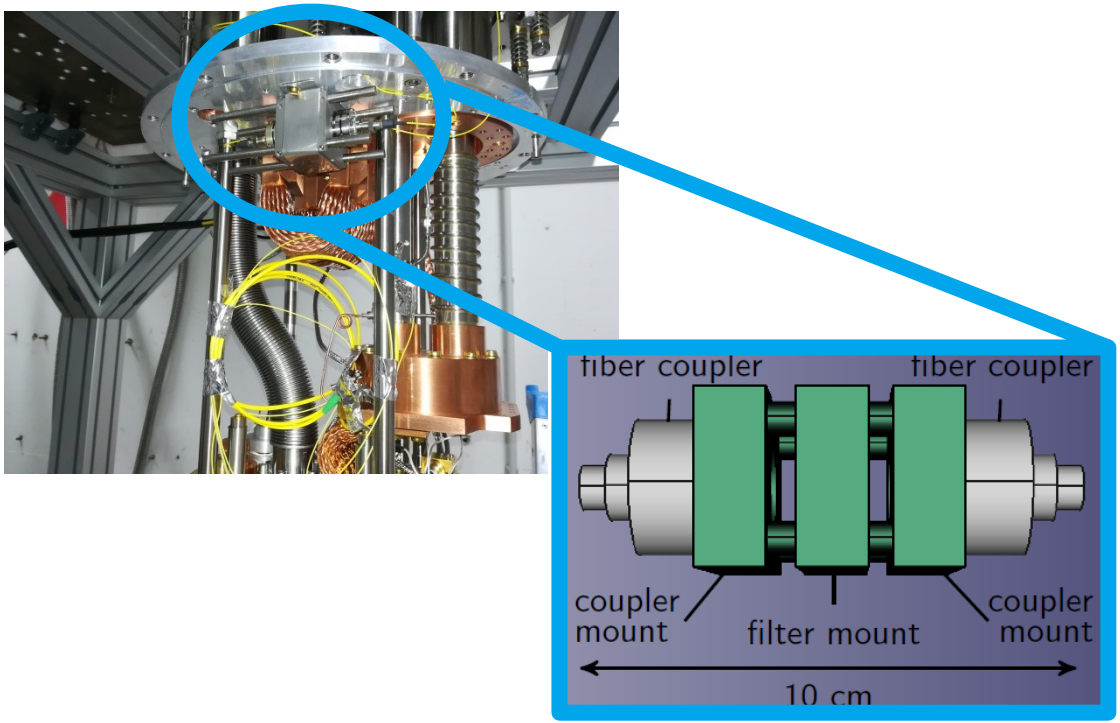
Manuel Meyer, Internal Communication, 2019.

Filtering principle



- Filter bench with broadband bandpass filter
- Central wavelength: 1050nm
- Supposed to reduce low-energy photon pileup

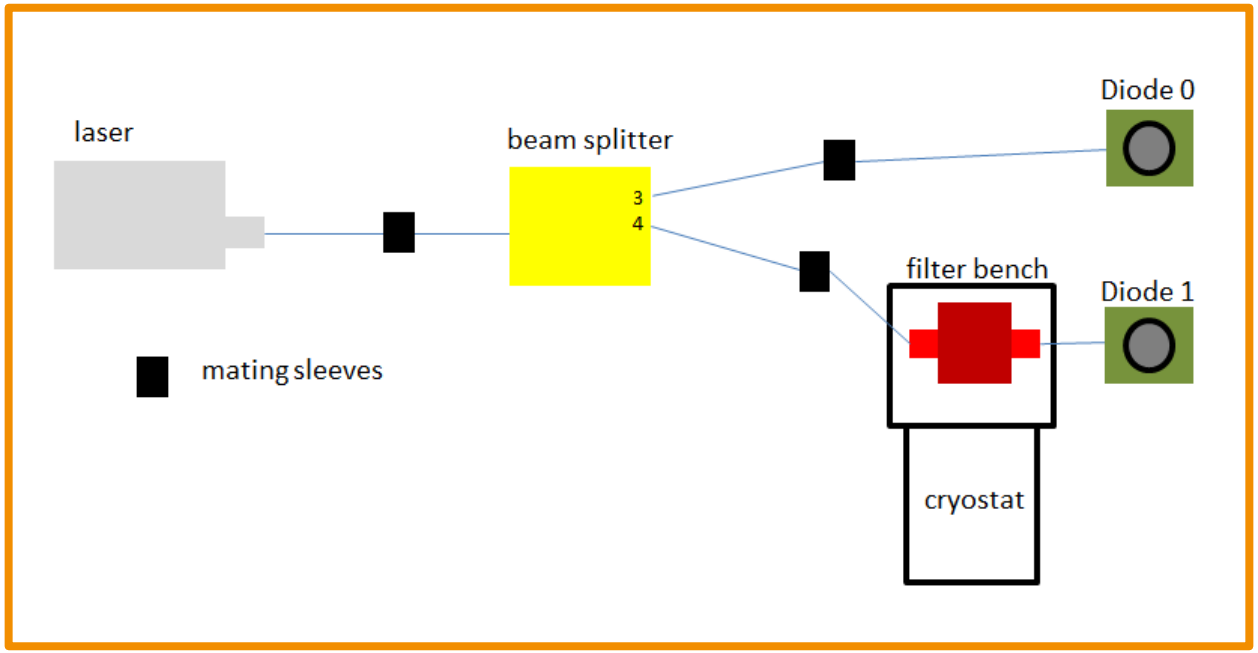
Filtering principle



- Filter bench with broadband bandpass filter
- Central wavelength: 1050nm
- Supposed to reduce low-energy photon pileup
- Calibration of fiber couplers very **sensitive**
- Originally: 2 titanium couplers
- Here: 1 titanium, 1 nickel-silver

K. Zenker, Construction of a filter bench for ALPS. Internal communication. (2017)

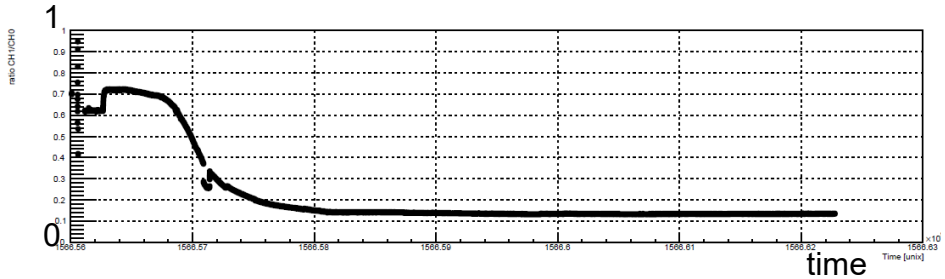
Diode measurement setup

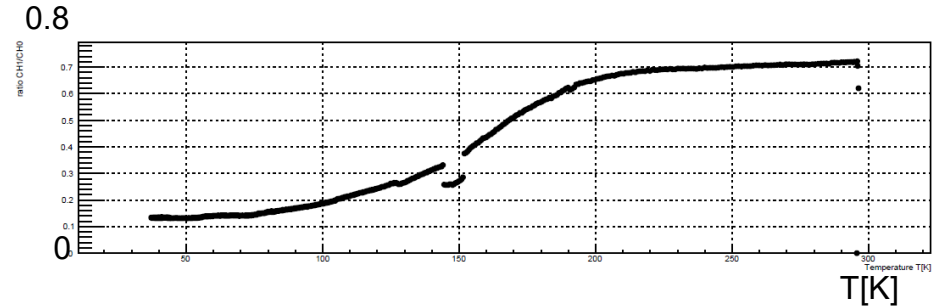


Setup for screening the laser behavior during cool-down and warm-up cycle

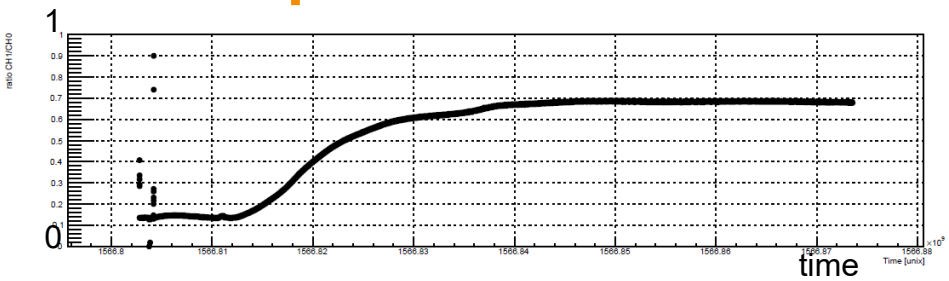
Ratio Comparison CH0/CH1

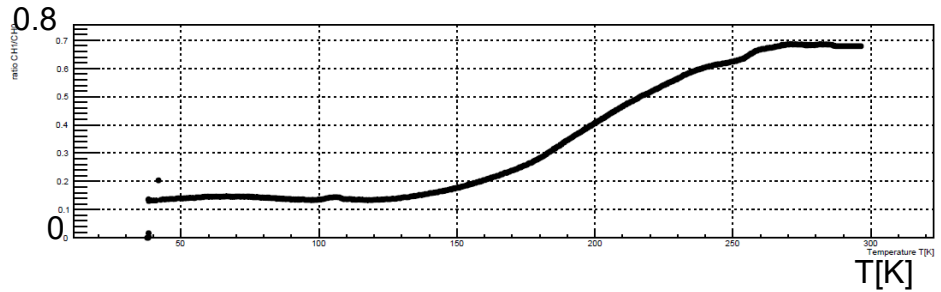
Cool-down





Warm-up



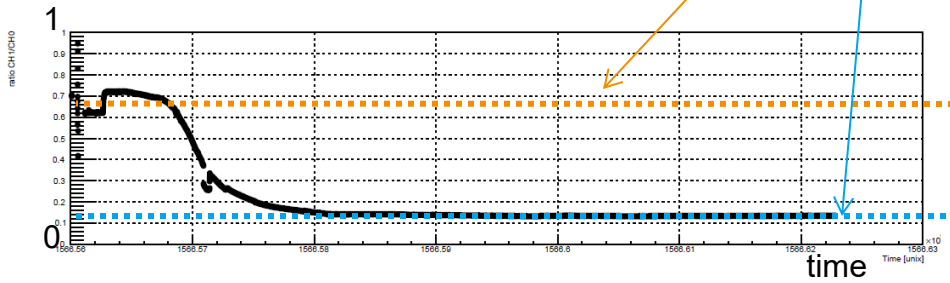


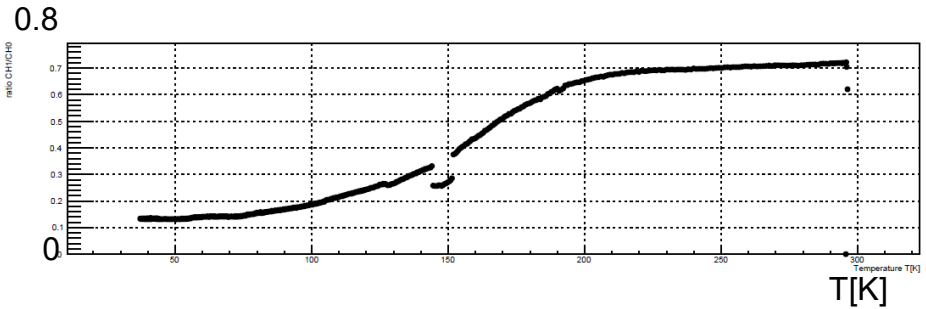
Ratio Comparison CH0/CH1

Cool-down

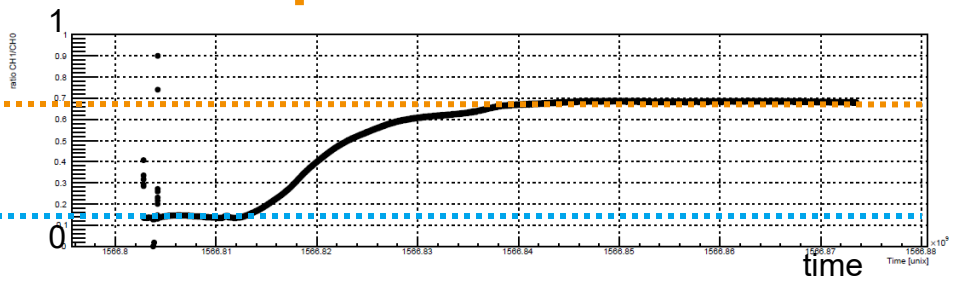
66%

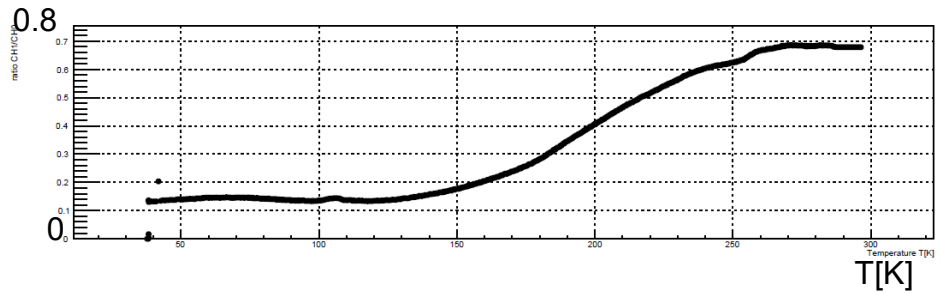
14%





Warm-up



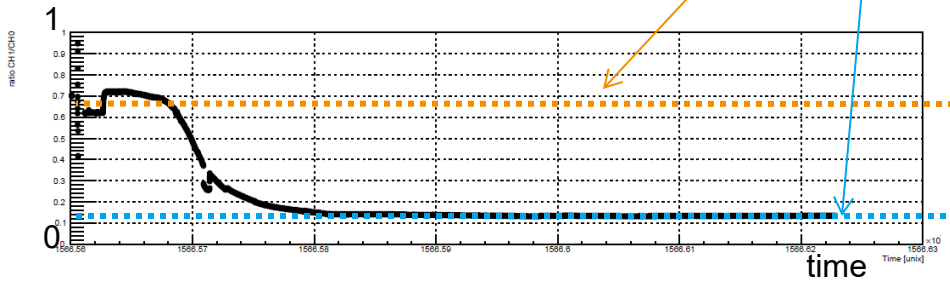


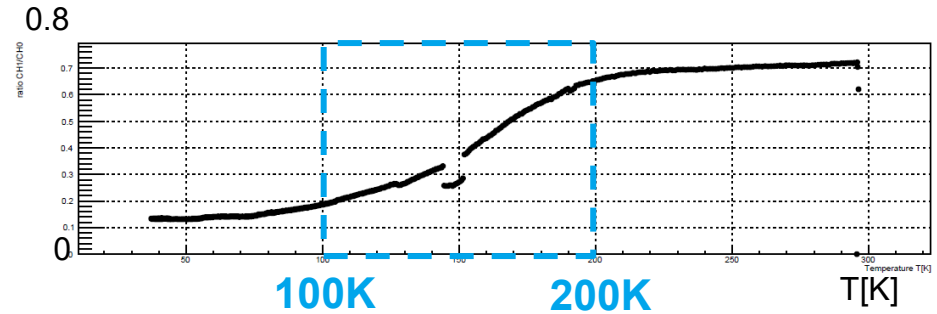
Ratio Comparison CH0/CH1

Cool-down

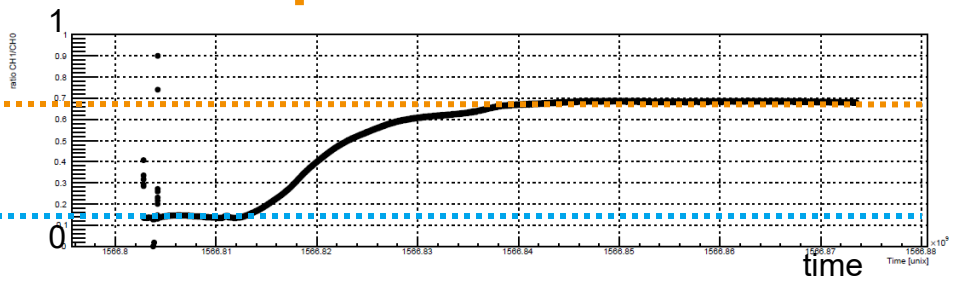
66%

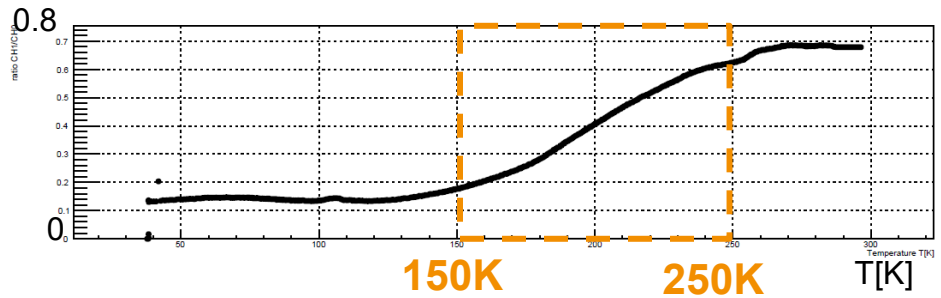
14%





Warm-up





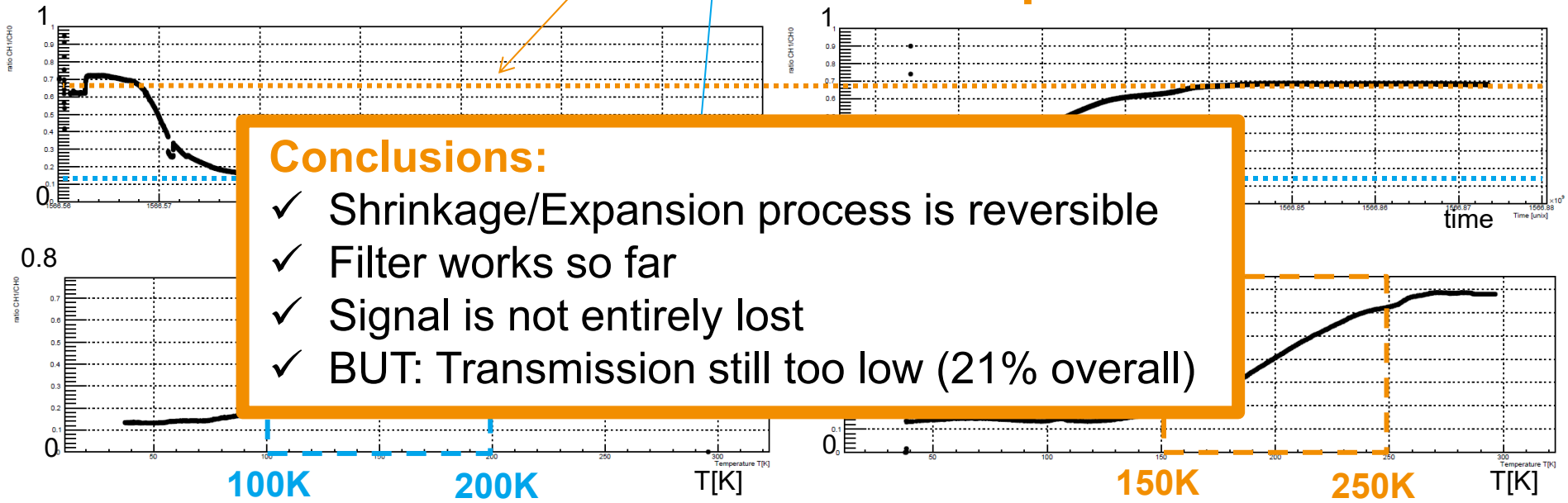
Ratio Comparison CH0/CH1

Cool-down

66%

14%

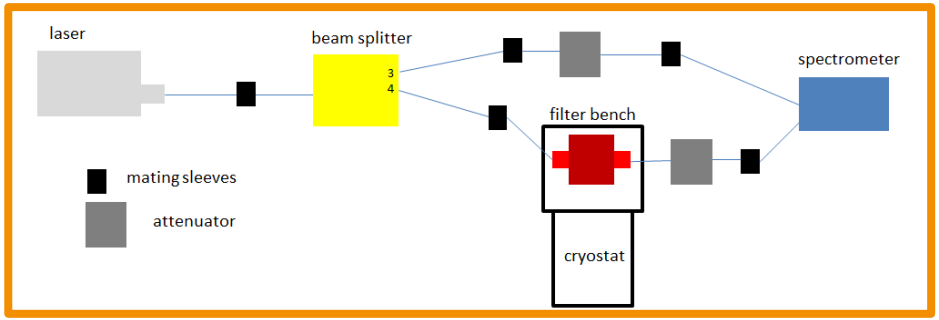
Warm-up

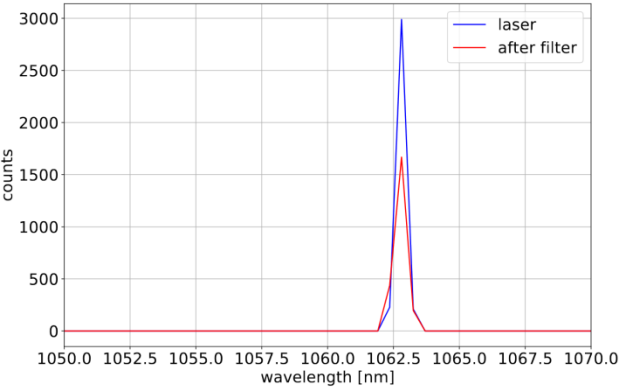


Conclusions:

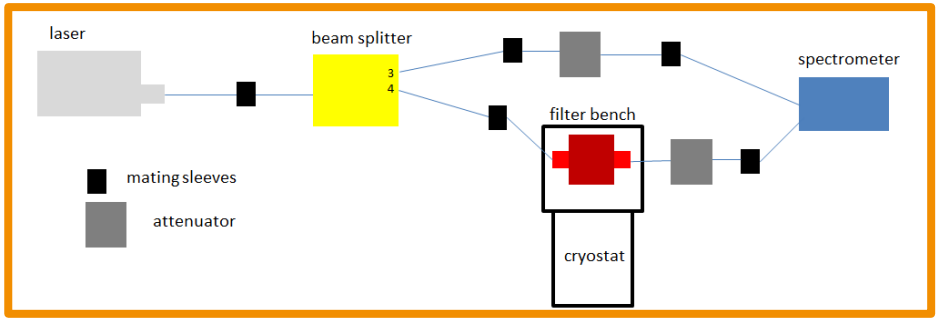
- ✓ Shrinkage/Expansion process is reversible
- ✓ Filter works so far
- ✓ Signal is not entirely lost
- ✓ BUT: Transmission still too low (21% overall)

Laser spectrum

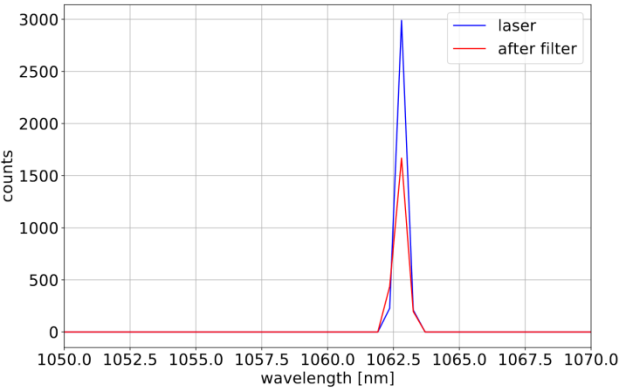


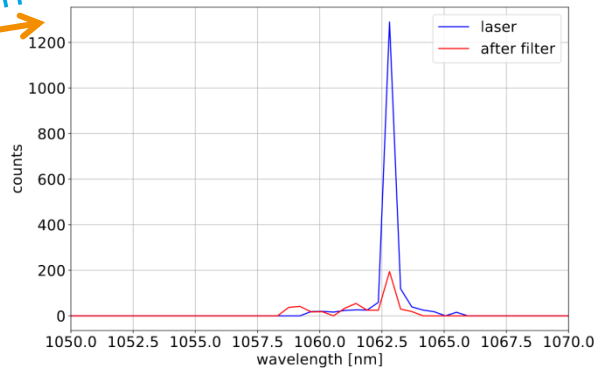


Laser spectrum with filter in cryostat



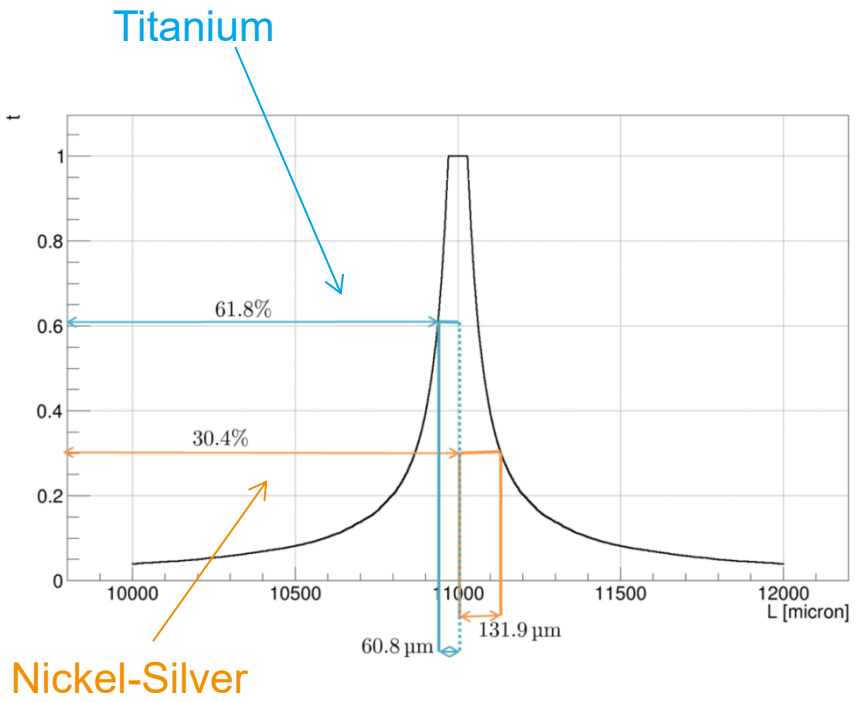
cool-down





- Main peak remains
- Filter spectrum behaves as expected
- Transmission losses in accordance with diode measurements

Expectation from expansion coefficient

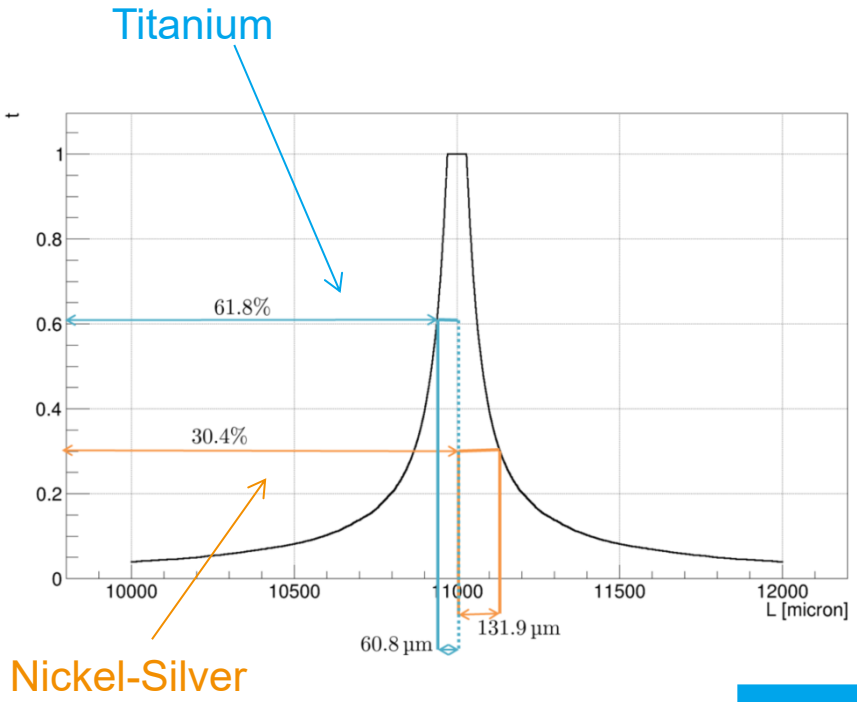


Adapted from E. Mazzeo. Summer Student 2018

- Simulation of material shrinkage dependent on ΔT
- Simulation: 19% transmission
- Measured: 21% transmission

Expectation from expansion coefficient

Adapted from E. Mazzeo. Summer Student 2018



- Simulation of material shrinkage dependent on ΔT
- Simulation: 19% transmission
- Measured: 21% transmission

Comparison:

$$\alpha_{\mathrm{Nickel-Silver}} = 18.4 \cdot 10^{-6}\,\mathrm{K}^{-1}$$
$$\alpha_{\mathrm{Titanium}} = 8.5 \cdot 10^{-6}\,\mathrm{K}^{-1}$$

Large transmission loss mainly due to material shrinkage

Conclusions and Outlook

- Filter works as expected
- Shrinking process during cooldown is reversible
- Further influences in transmission losses than just thermal shrinkage?

Conclusions and Outlook

- Filter works as expected
- Shrinking process during cooldown is reversible
- Further influences in transmission losses than just thermal shrinkage?

- Thermal shrinkage needs to be reduced and characterized further
  - ➡ new coupler
- Characterize influence of beam splitter/attenuator/mating sleeves
- Conduct background measurements with TES
- Measure background reduction through filter