Development of a triple-type thermometer

EMPIR EURAMET
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MetFerTC

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Concept

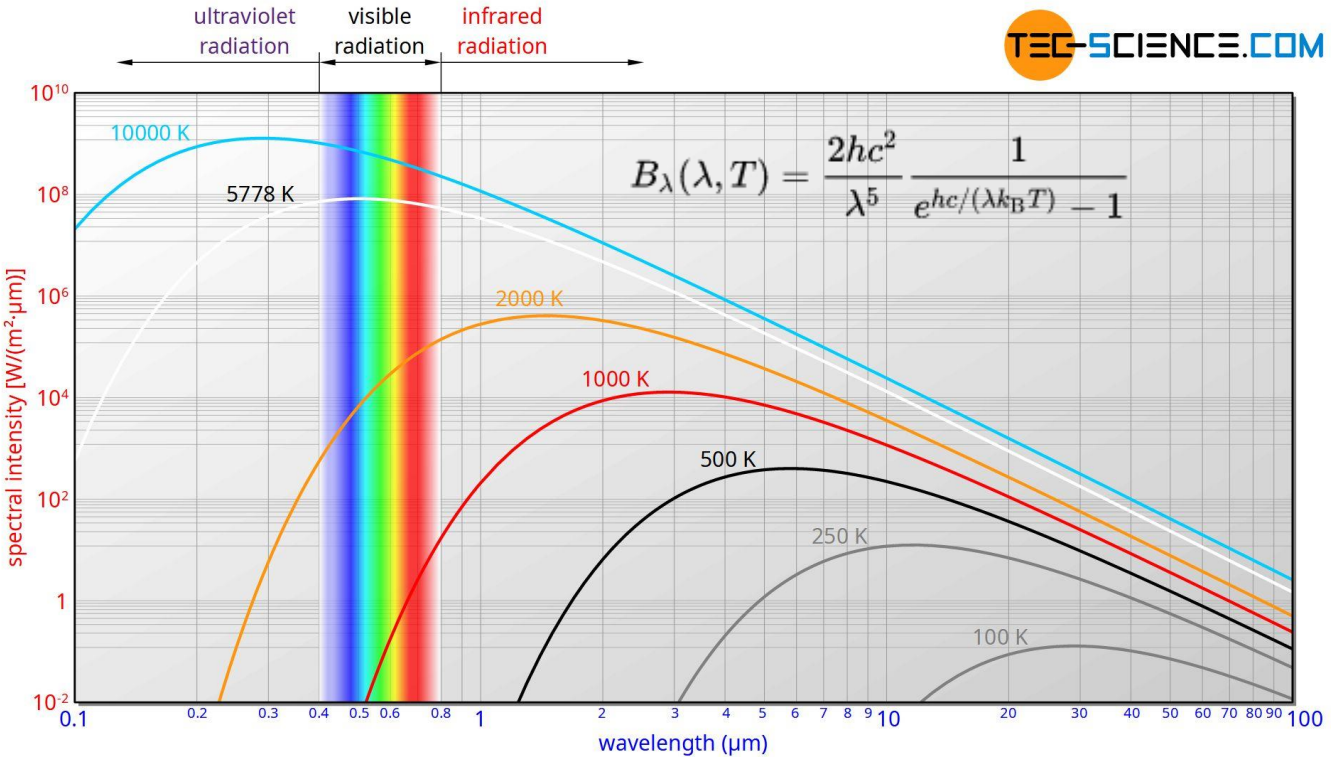
Triple type thermometer:

- Type N thermocouple
- Type S thermocouple
- Fibre-optical setup

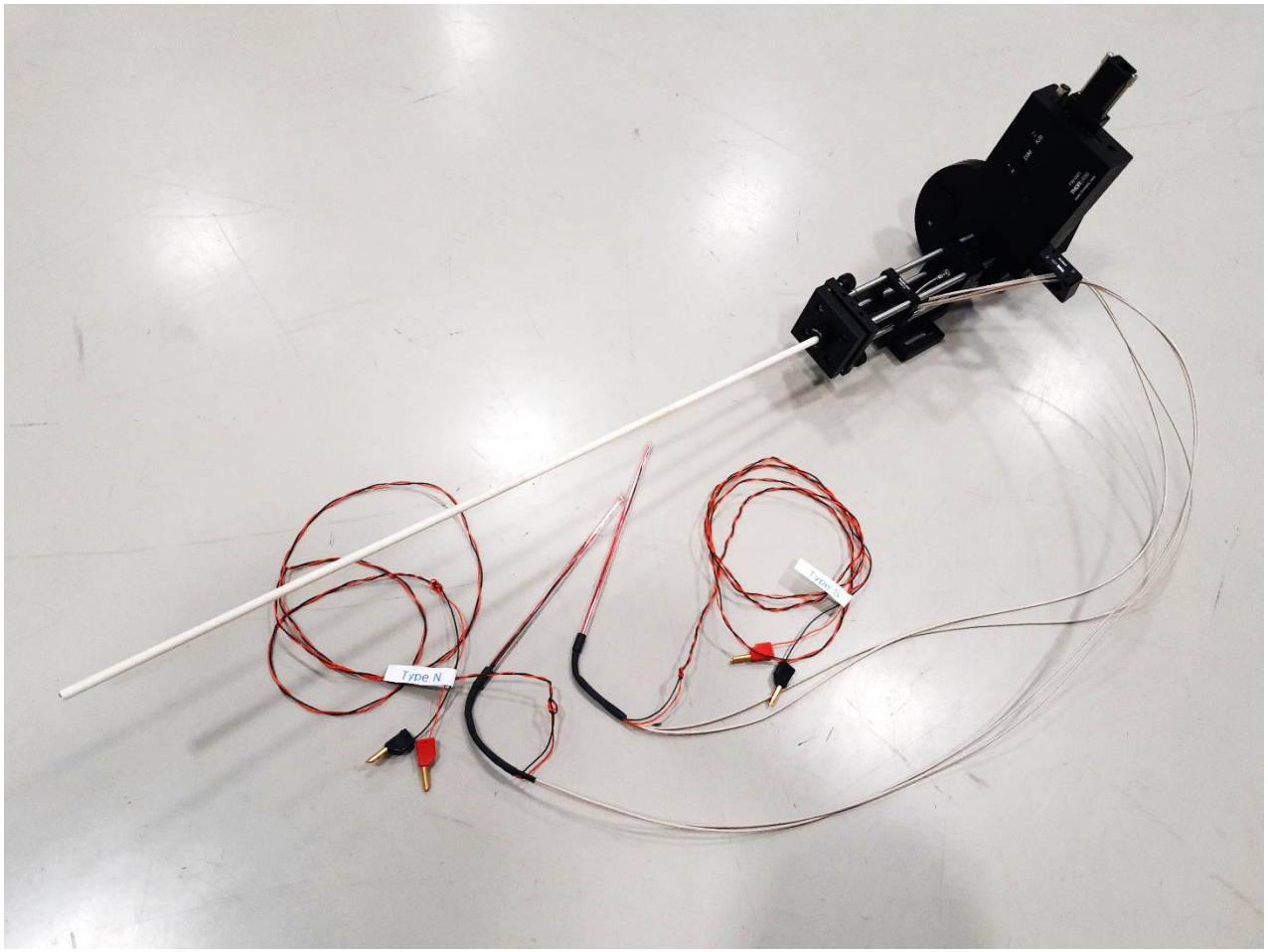
Comparison of these sensors against each other.

Planck blackbody radiation

- Every object with T > 0 K emits radiation
- Intensity dependent on wavelength and temperature
- Lower temperature → maximum of intensity at higher wavelength



Setup of optical fibre, type N and type S thermocouple



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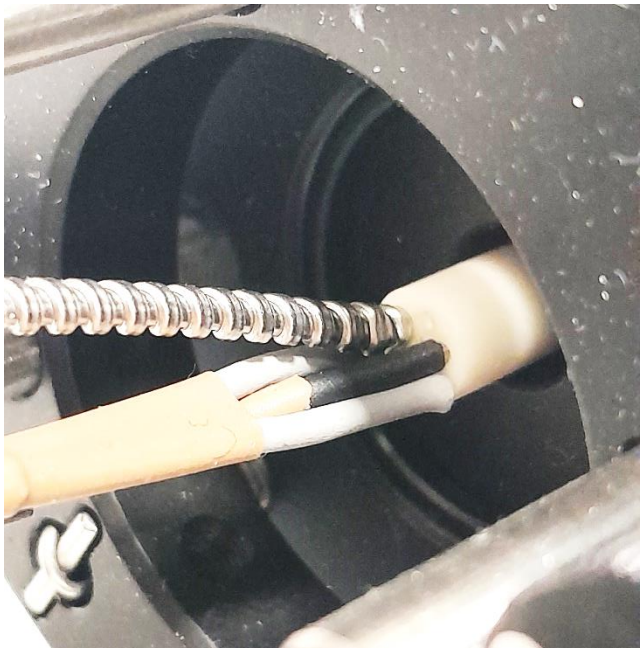
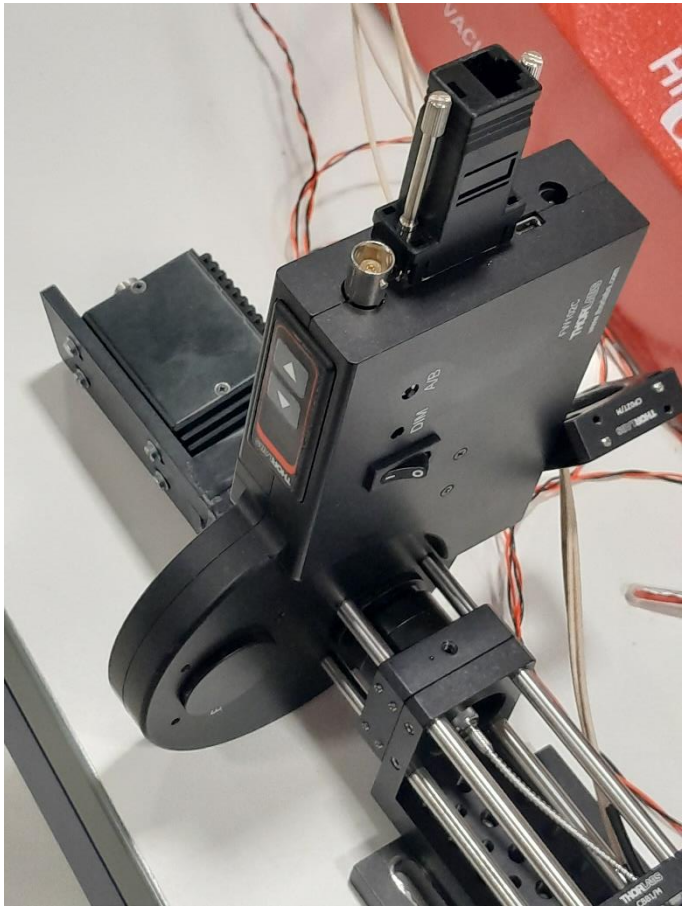
Initial setup: 6-bore insulator with sensors

- Silica fibre, transmission 400-2400 nm, diameter 0.2 mm
- Type N thermocouple, 0.5 mm
- Type S thermocouple, 0.5 mm

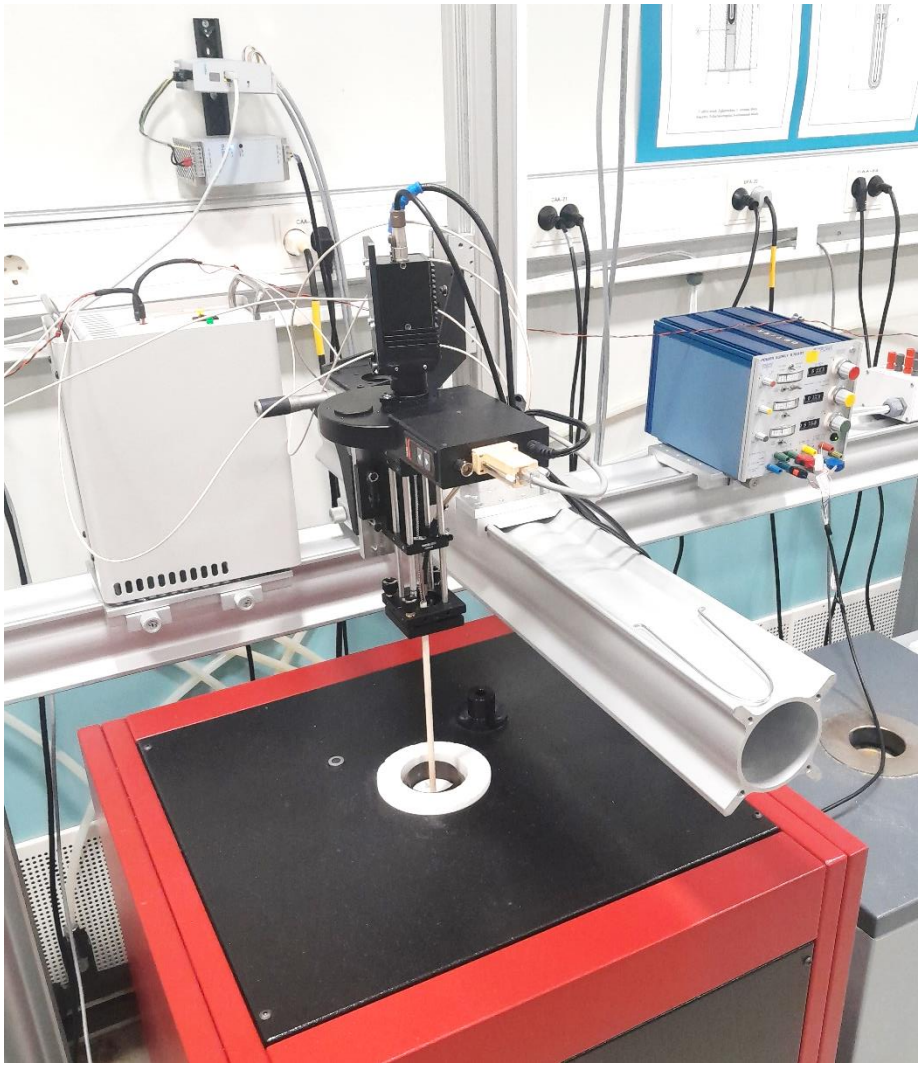


Filtering and detection

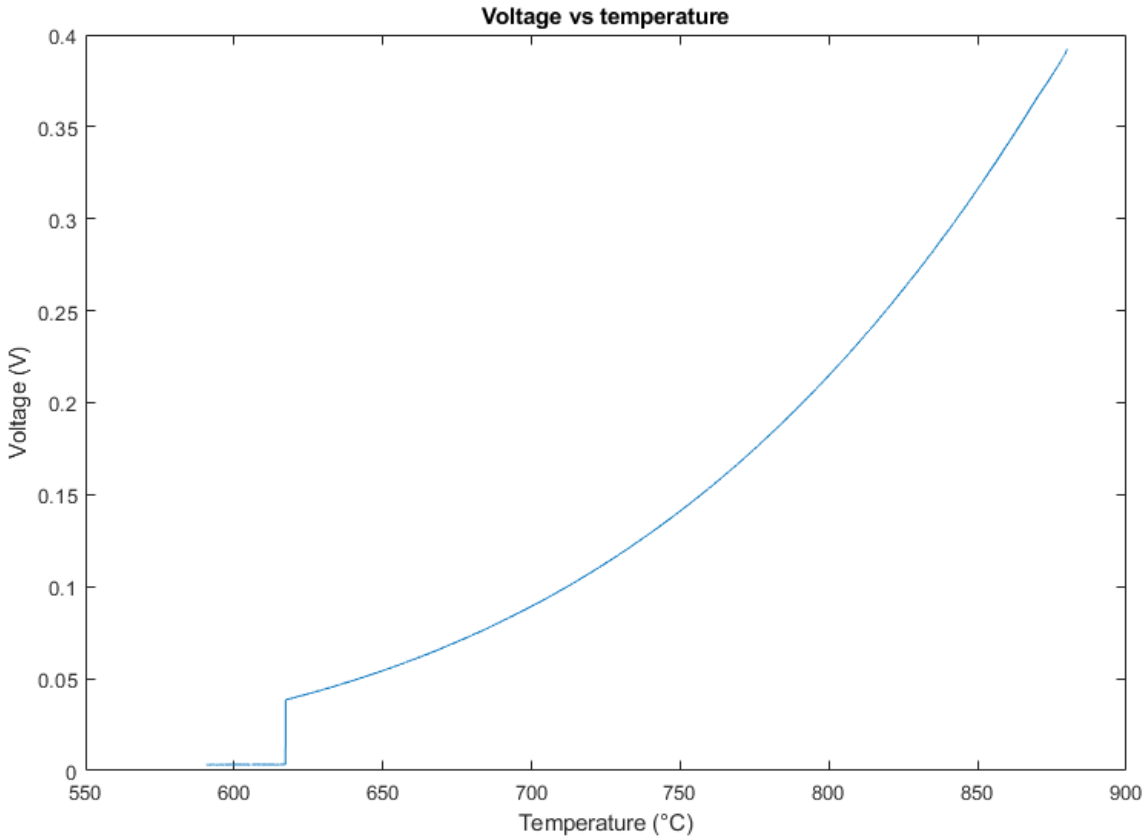
- Automated filter wheel with six filters: 1100/1200/1310/1400/1510 /1600 nm
- InGaAs detector (Peltier-cooled, integrated pre-amp, ca. 1000-1600 nm)
- Output signal in the range of a few mV to 2 V



Setup used in fixed-point cell



First test in heatpipe furnace

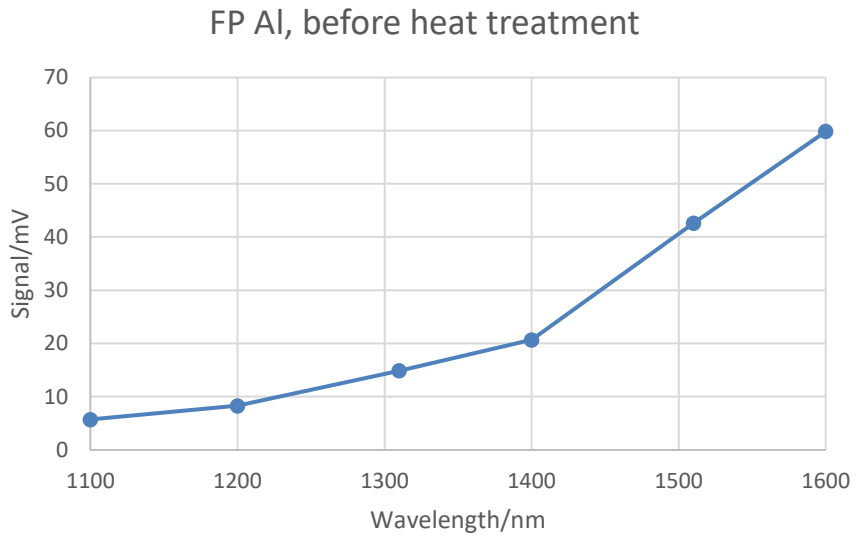


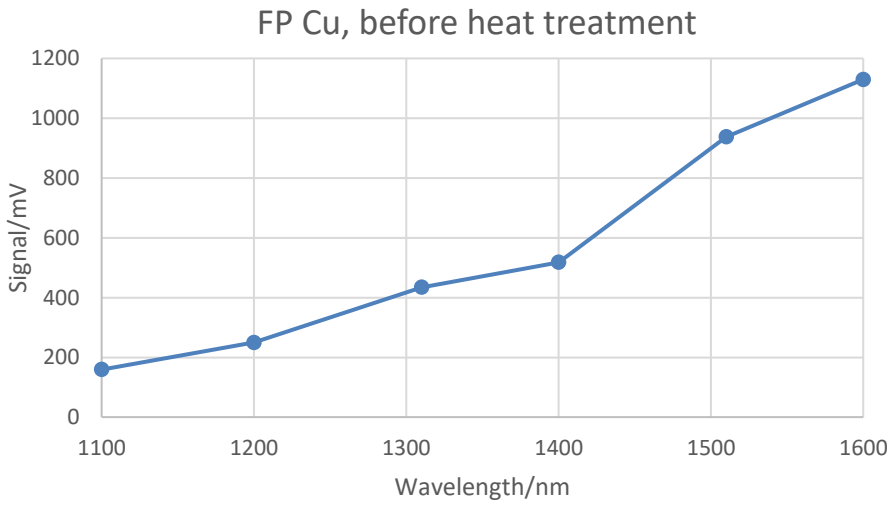
- Only with optical fibre, without thermocouple
- Fixed filter 1510 nm
- Shutter opened slightly too late, therefore signal from 620 °C
- Expect signal from about 550 °C with this setup

Thermal cycling

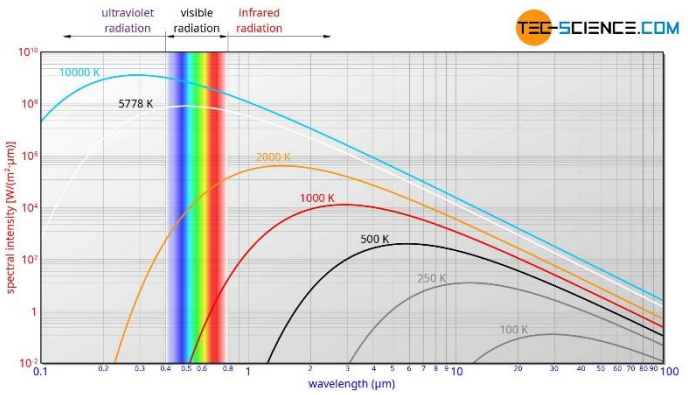
- Calibration of fibre optics and thermocouples at freezing points (FP) of Al and Cu
- Heat treatment in heatpipe furnace at 950 °C for 100 h
- Recalibration of all three sensors at FP Al and FP Cu
- In total, three cycles of heat treatment/recalibration

Fibre optics before heat treatment





- Different order of magnitude in signal between FP Al and FP Cu
- Signal increasing with filtered wavelength as we are below intensity maximum according to Planck's law

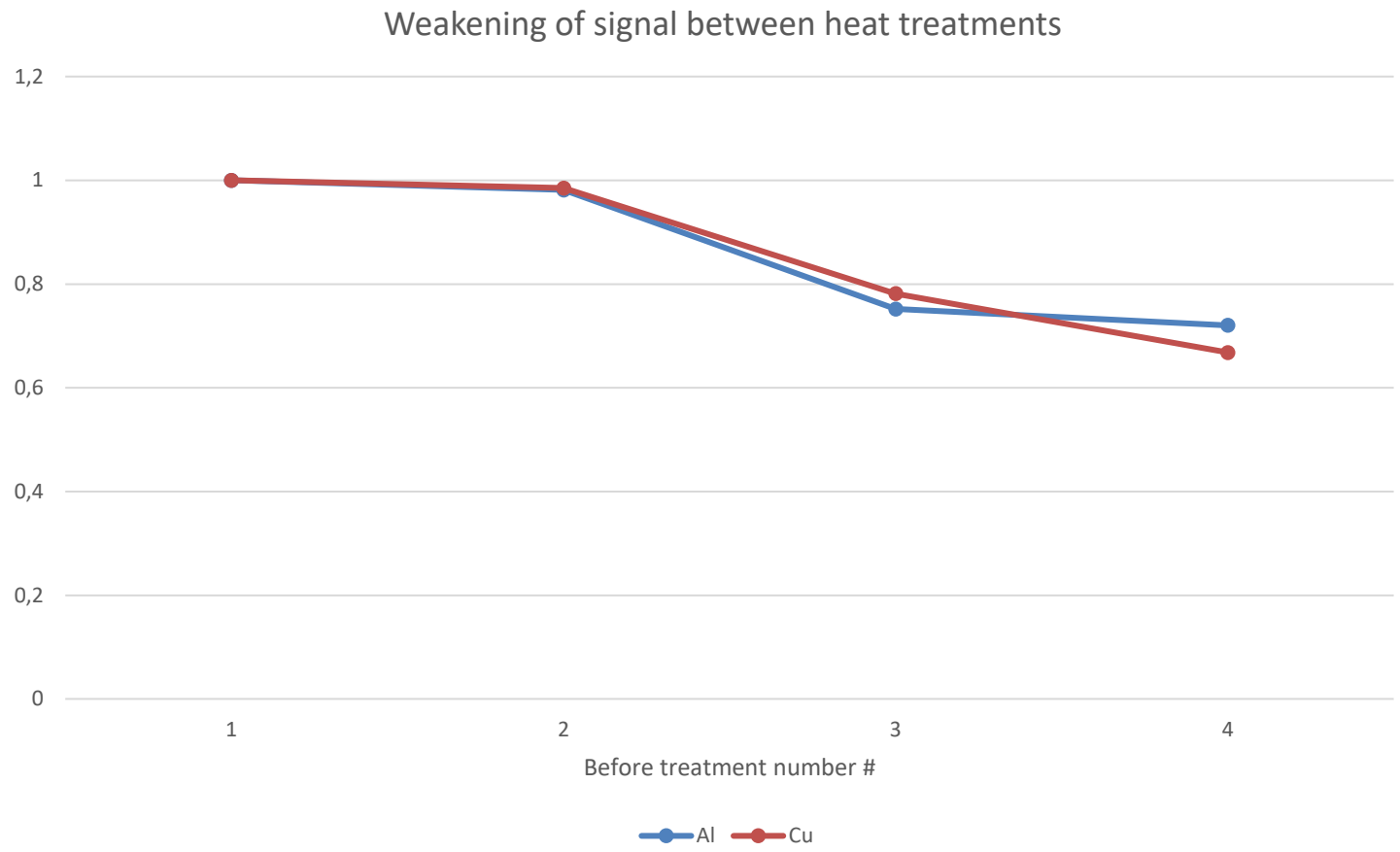


Sensor drift

- Type N: about 0.4 °C at FP Al, 1.1 °C at FP Cu
- Type S: below 0.1 °C at both FP Al and FP Cu
- As expected, type S is better.

What about the fibre optics?

Intensity drift of fibre optics at 1600 nm

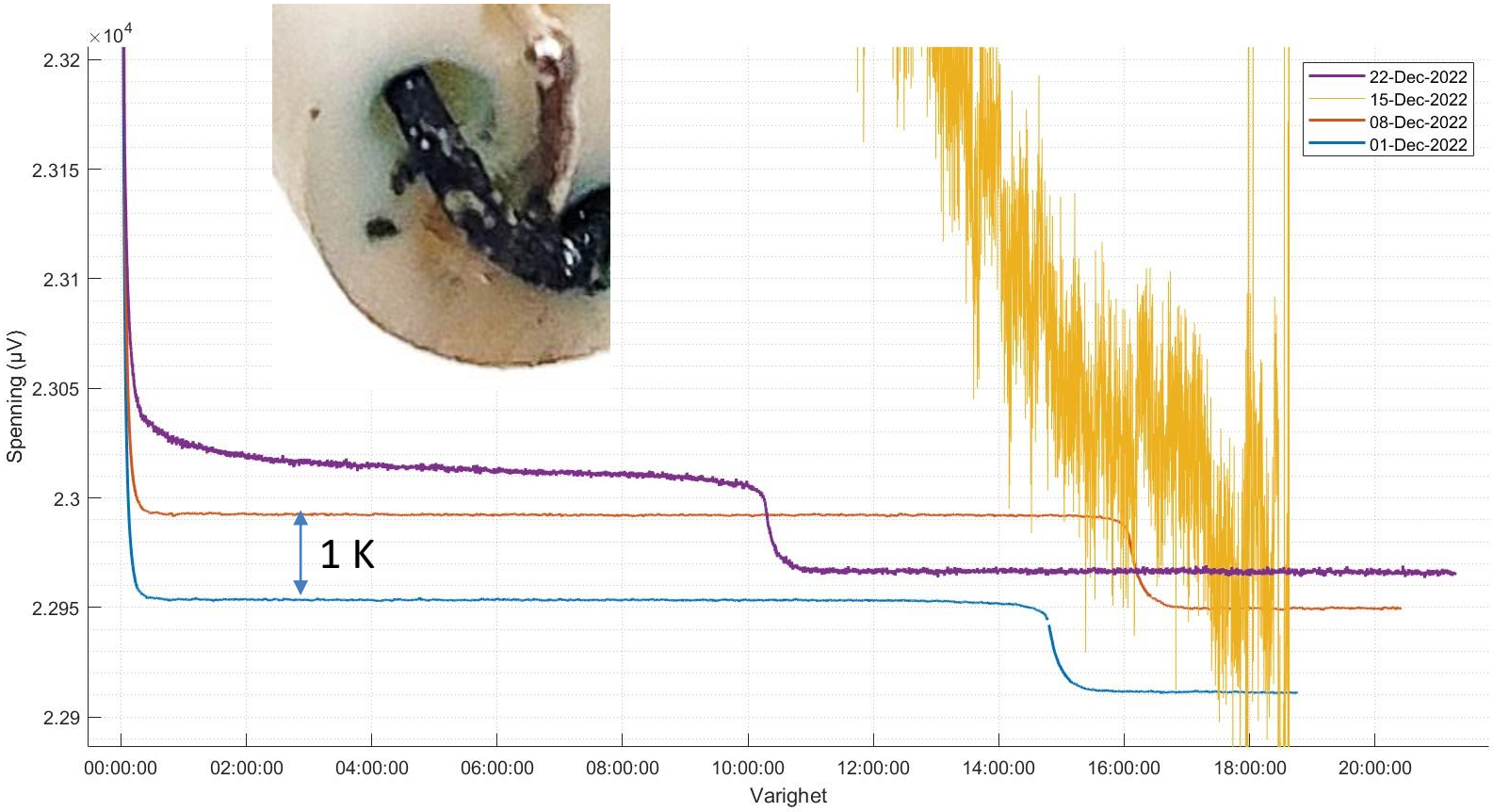


Intensity drifts far too much to be usable.

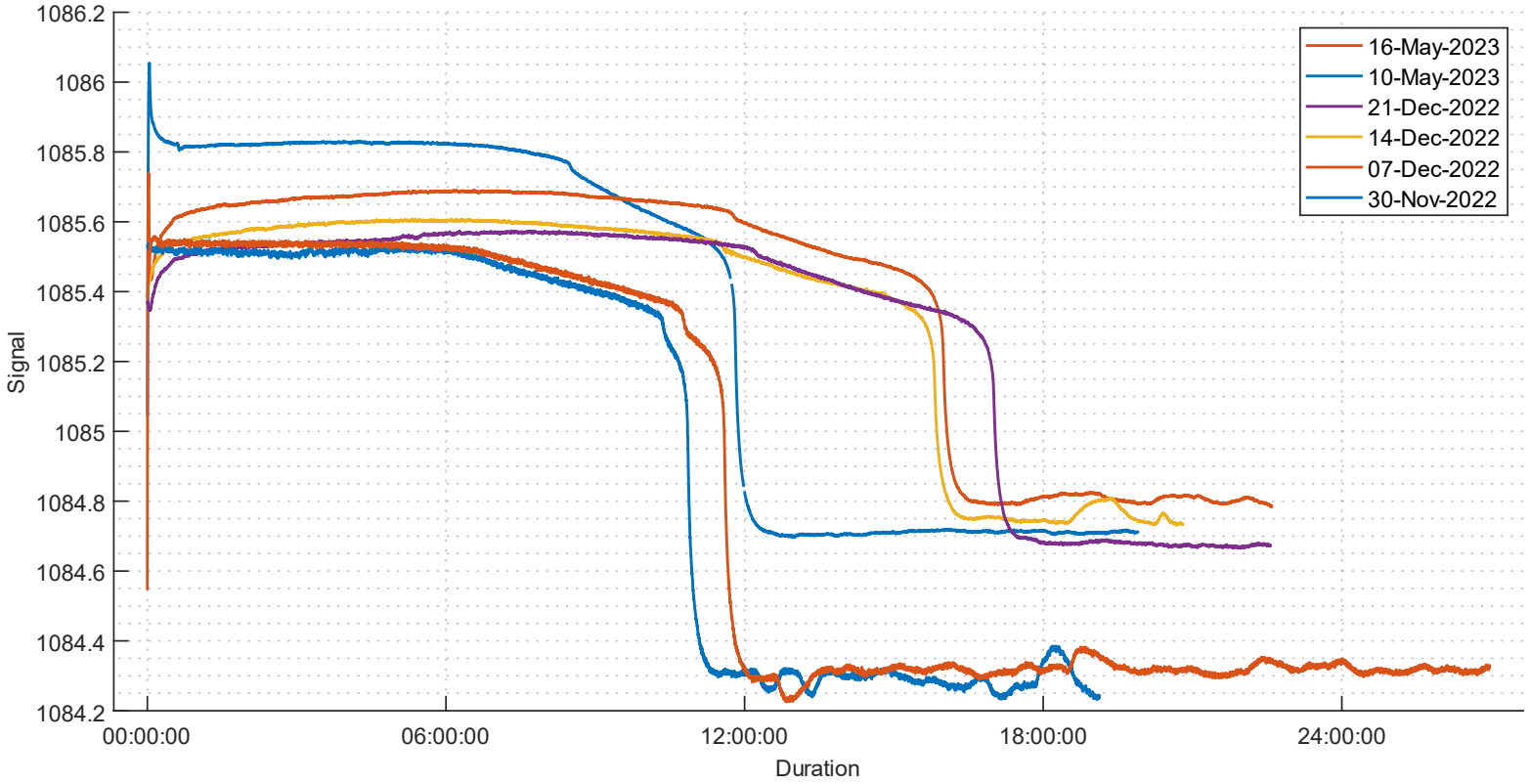
Stepwise modified setup

- Silica fibre was replaced by sapphire fibre.
- Replacement of some filters:
  - Remove filters transmitting low wavelength radiation due to very low intensity at FP Al.
  - Initially used filters at 1500-1600 nm wavelengths partly transmit radiation of higher wavelengths. Replaced by filters with better specifications.
- 6 calibrations and 4 annealings with modified setup

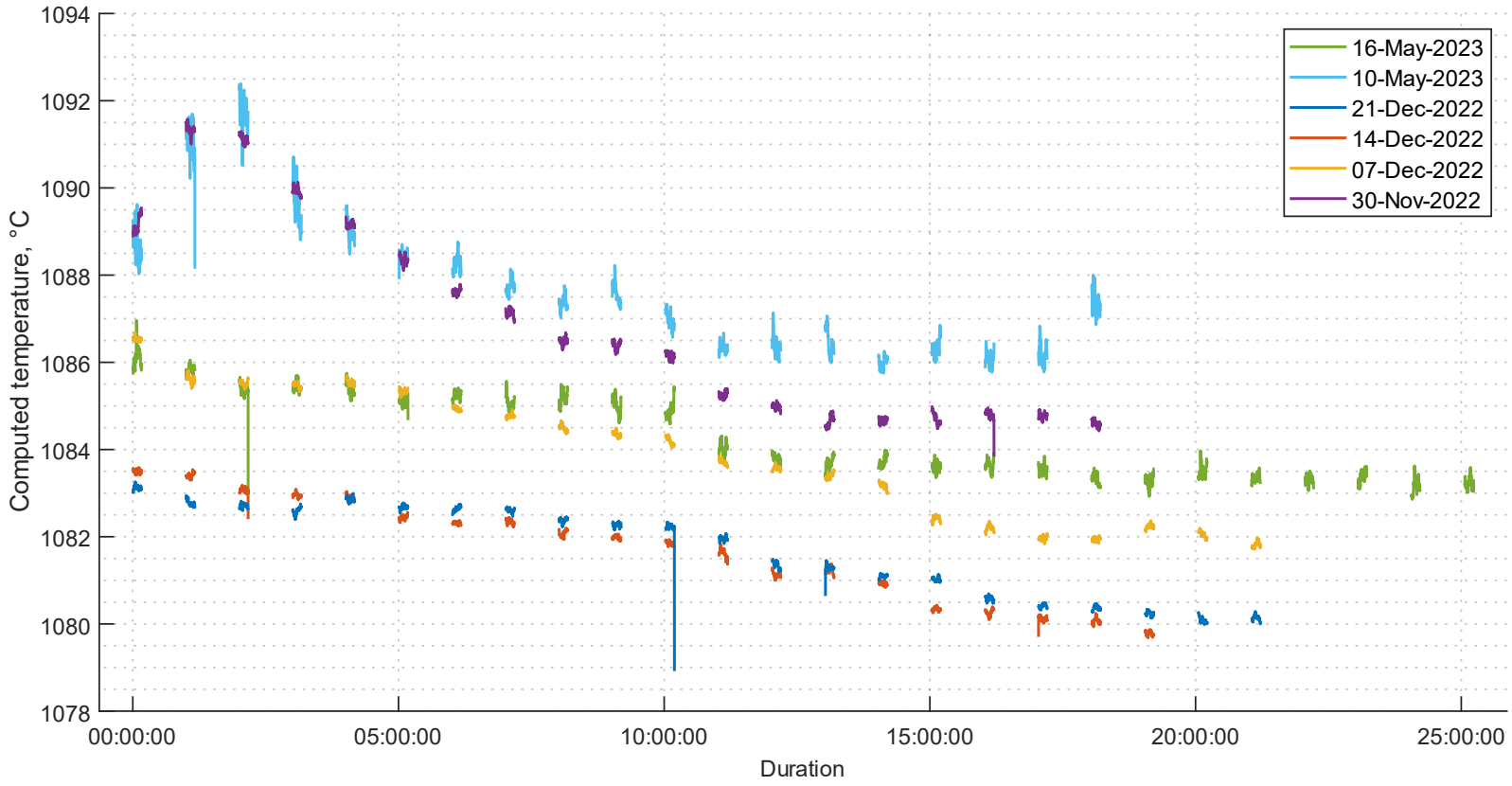
Realizations of FP Al, type N



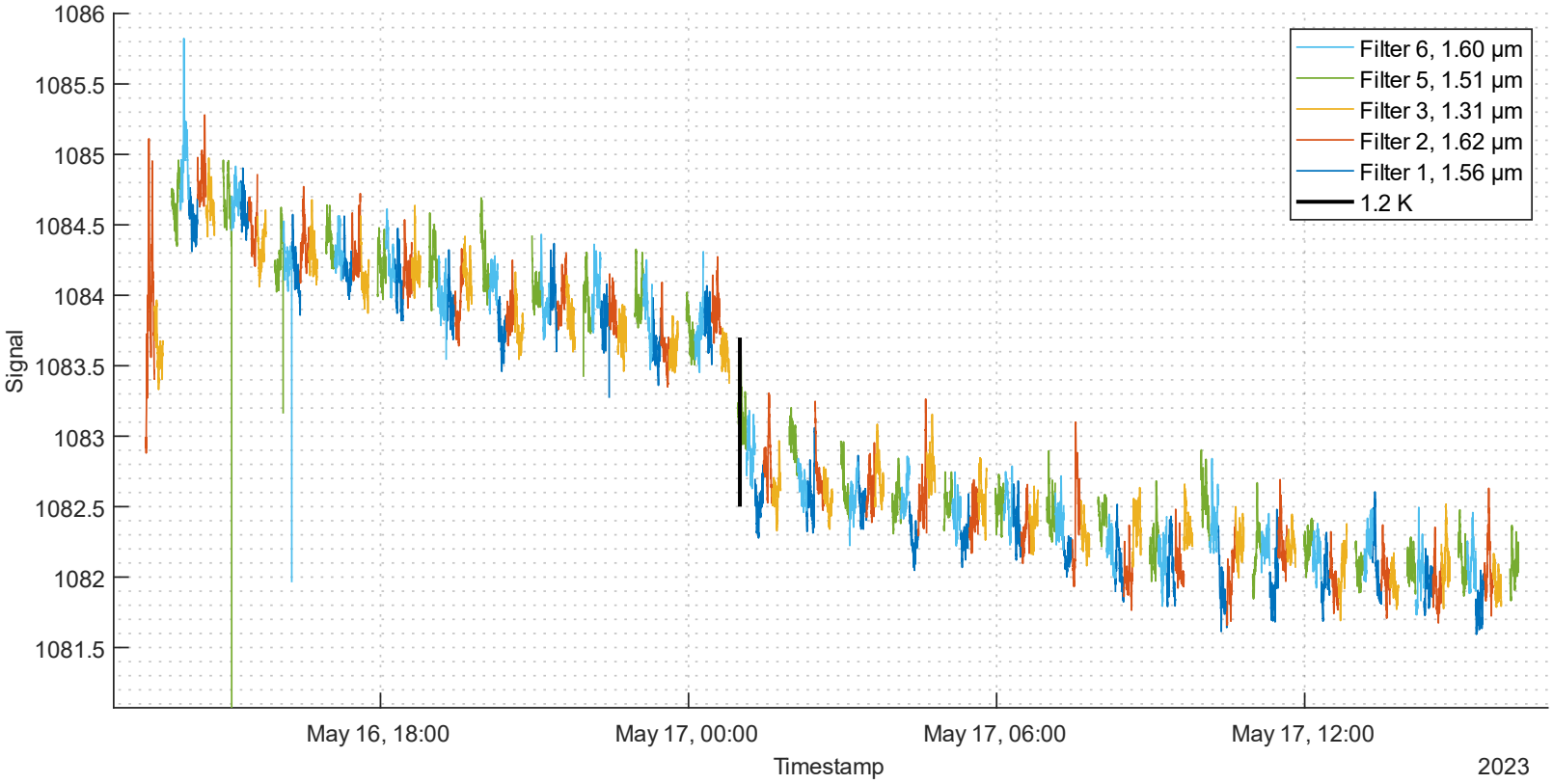
Realizations of FP Cu, type S



Realizations of FP Cu, filter 6



Final realization of FP Cu



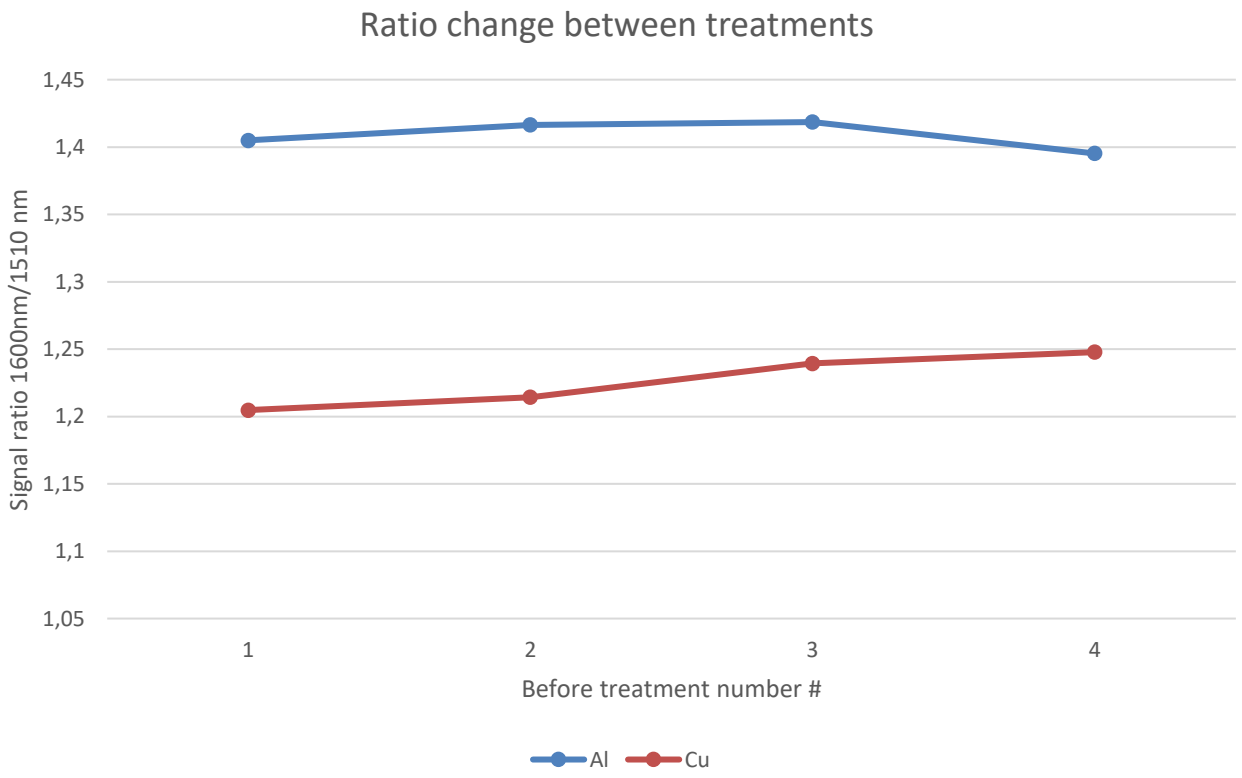
Conclusions

- Sapphire is more stable over time than silica, approx. within 2 °C.
- Sapphire needs a few cycles to stabilize.
- Problems with temperature stabilization of detector.

Thank you for your attention!

Questions?

Ratio (1600 nm/1510 nm) drift



More robust than absolute intensity but still not good enough.