Status of Material Load Experiments at MAMI in Mainz

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Outline

- Motivation for material tests
- Beam parameters of the Mainz Microtron and irradiated targets
- Target temperatures (measured, maximal average, temperature rise per pulse)
- Estimations of thermal stress
- Summary

Motivation

Motivation:

To check the target and exit window materials under expected thermal load conditions at the ILC undulator-based positron source.

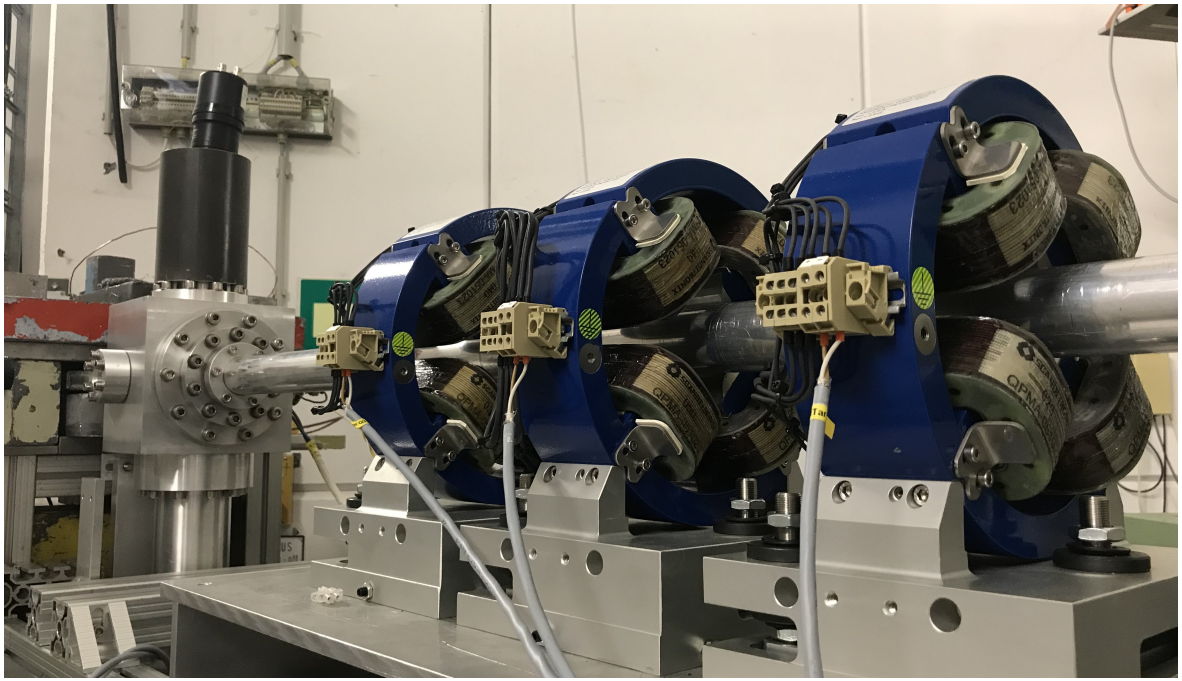
For instance, 7 mm thickness Ti6Al4V target cooled by radiation at 250 GeV center-of-mass energy has ≈470 °C average temperature and ≈510 °C peak temperature (see S. Riemann talk).

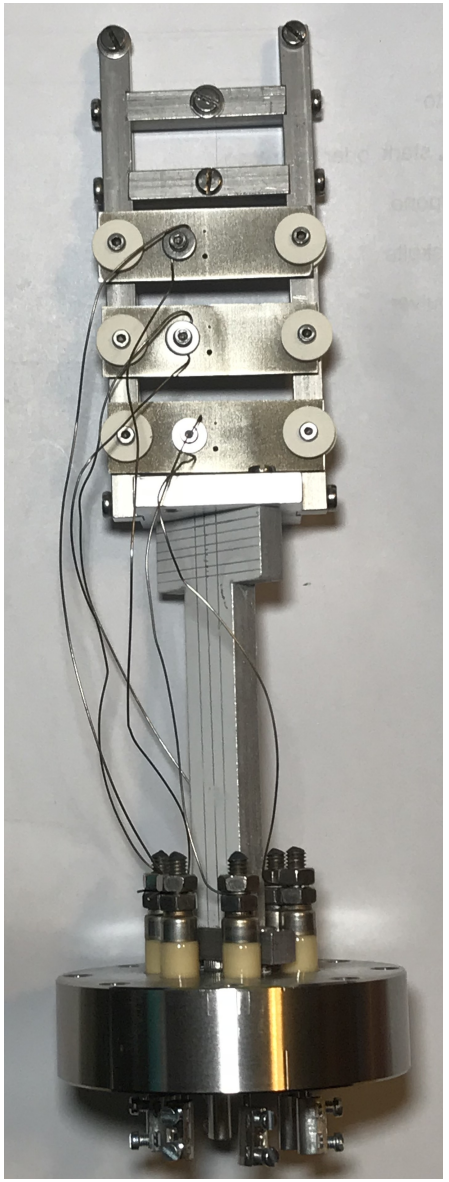
Pulsed 14 MeV e^- beam of the **Ma**inz **Mi**crotron MAMI (50 μA, 2 ms pulses, 100 Hz) was used to heat the 1 mm and 2 mm thick Ti6Al4V samples to $\langle T_{1\text{mm}} \rangle \sim 600$ °C and $\langle T_{2\text{mm}} \rangle \sim 700$ °C with $\Delta T \sim 70$ °C that has resulted in swelling (see IPAC'17 proceedings TUPAB002).

Improved beam focusing system allows systematical studies of Ti-alloy (Grade 5) up to 450°C average T and significantly higher temperature rise per pulse (up to 350°C).

New wire scanner was used for the high accuracy beam size measurements.

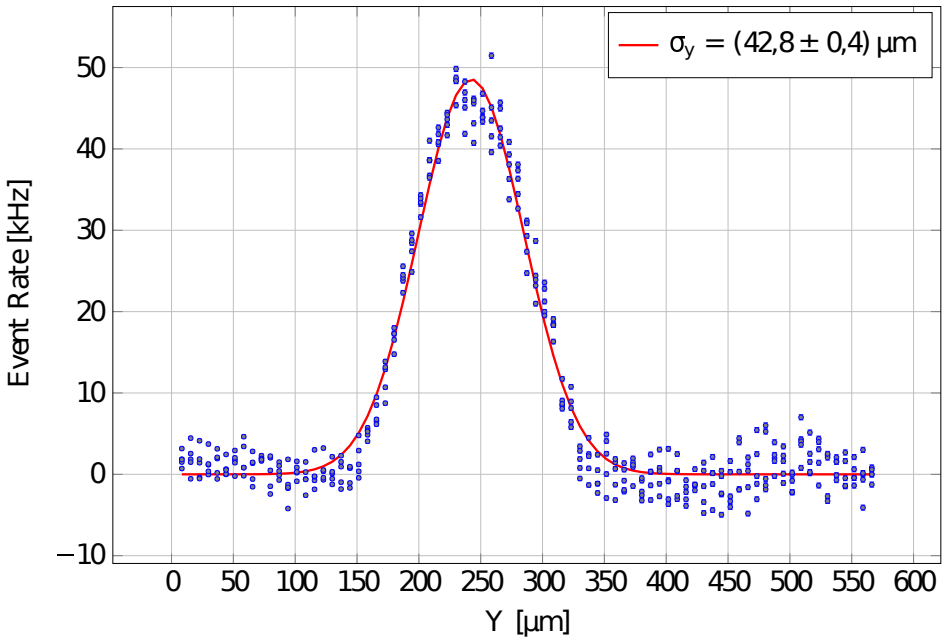
Beam Focusing System and Target Holder

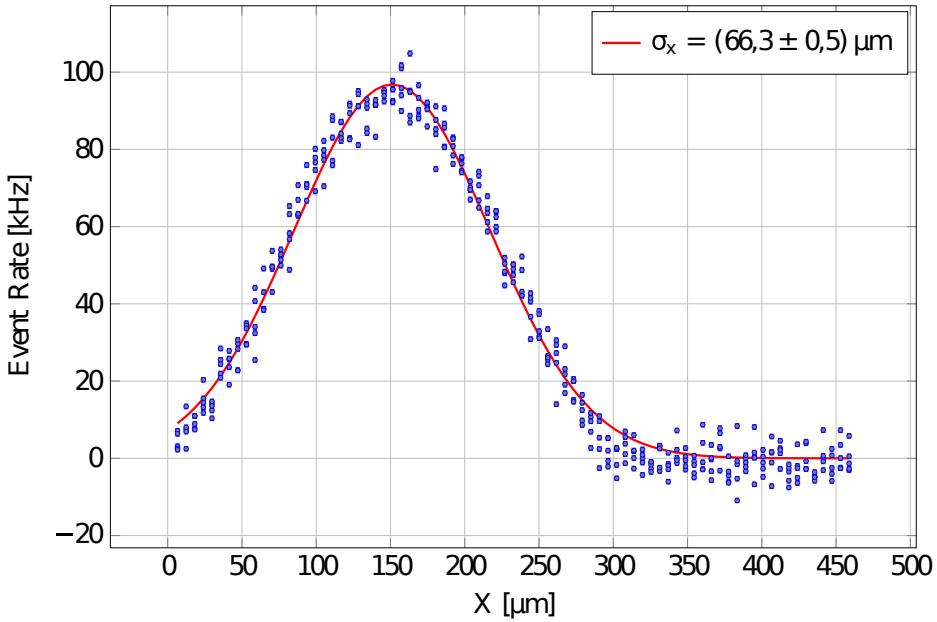




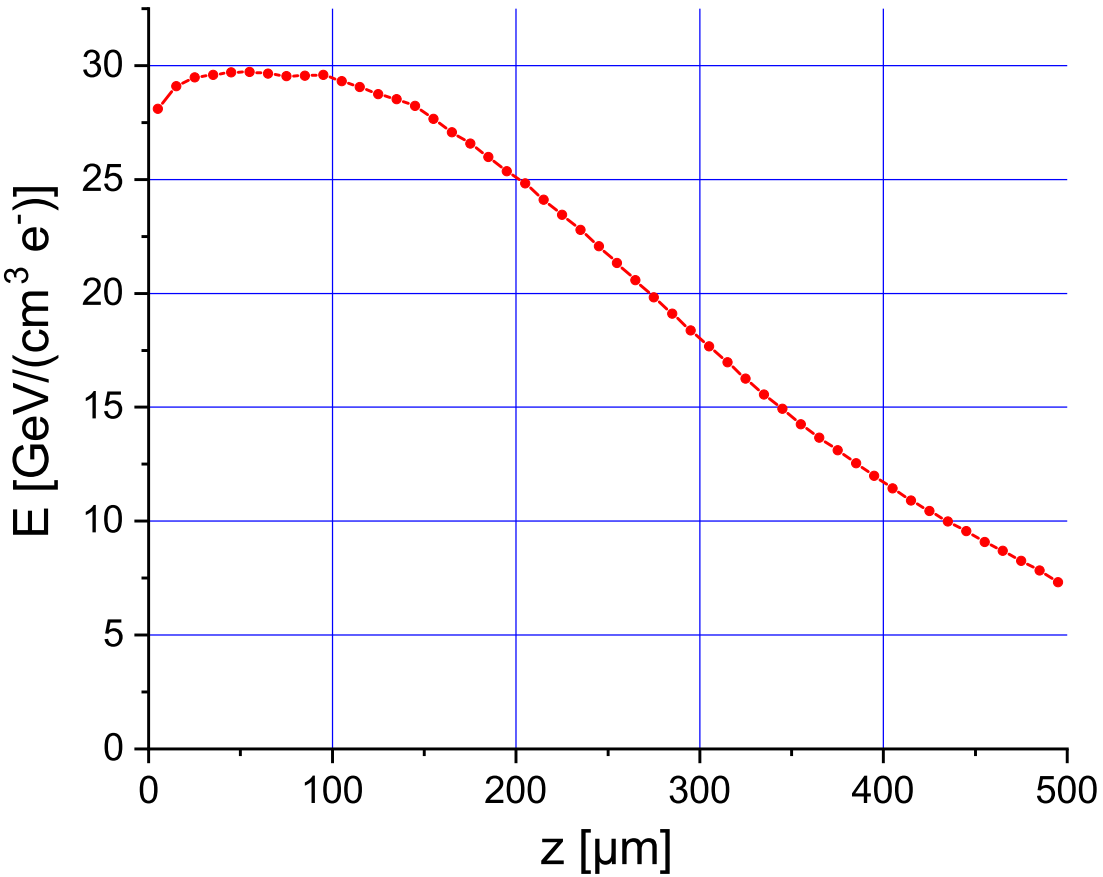
Beam Spot Size on Target

Beam size was measured at full (50 μA) current and very low repetition rate:
$\sigma_y = 42.8\mu$m, $\sigma_x = 66.3\mu$m





Energy Deposition Profiles on Beam Axis



Three target thicknesses were used: 200 μm, 250 μm, 500 μm: thicker targets have higher average temperatures.

1-2 Oct. 2018: Logbook

50 μA during pulse, 2.48 GHz ($4.08 \cdot 10^{-10}$ s bunch spacing)

200 μm target thickness

1. 1.5 ms, 10 Hz, 90 min., middle
2. 1.5 ms, 20 Hz, 40 min., top
3. 1.0 ms, 100 Hz, 40 min., bottom

250 μm target thickness

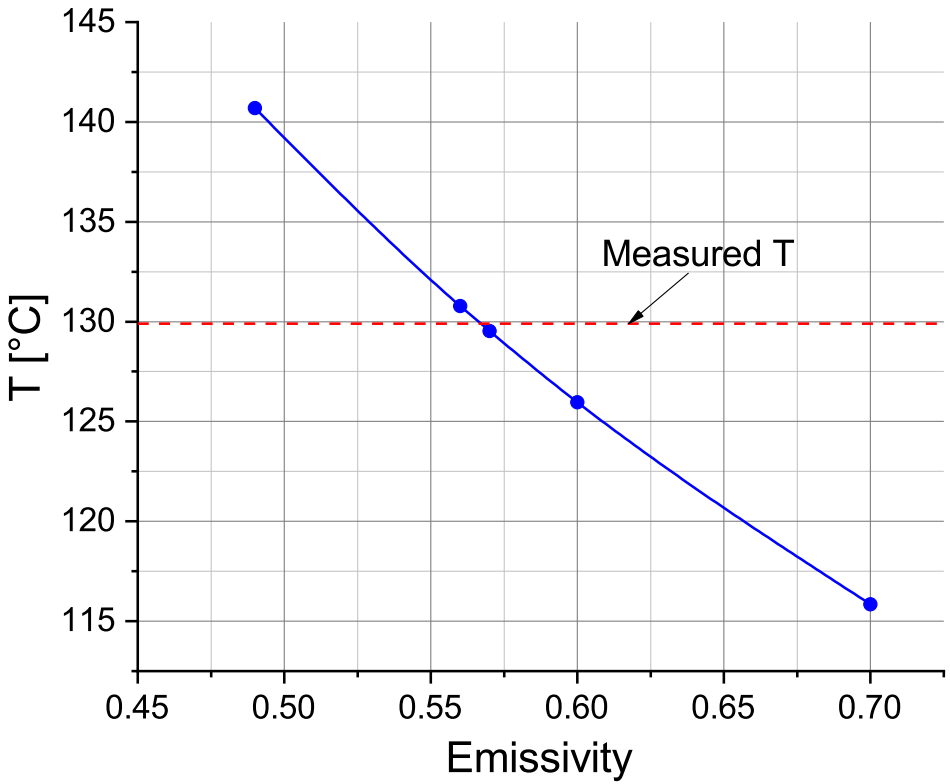
5. 1.0 ms, 120 Hz, 45 min., middle (radiation level is too high at $f > 120$ Hz)
6. 0.5 ms, 140 Hz, 40 min., bottom

500 μm target thickness

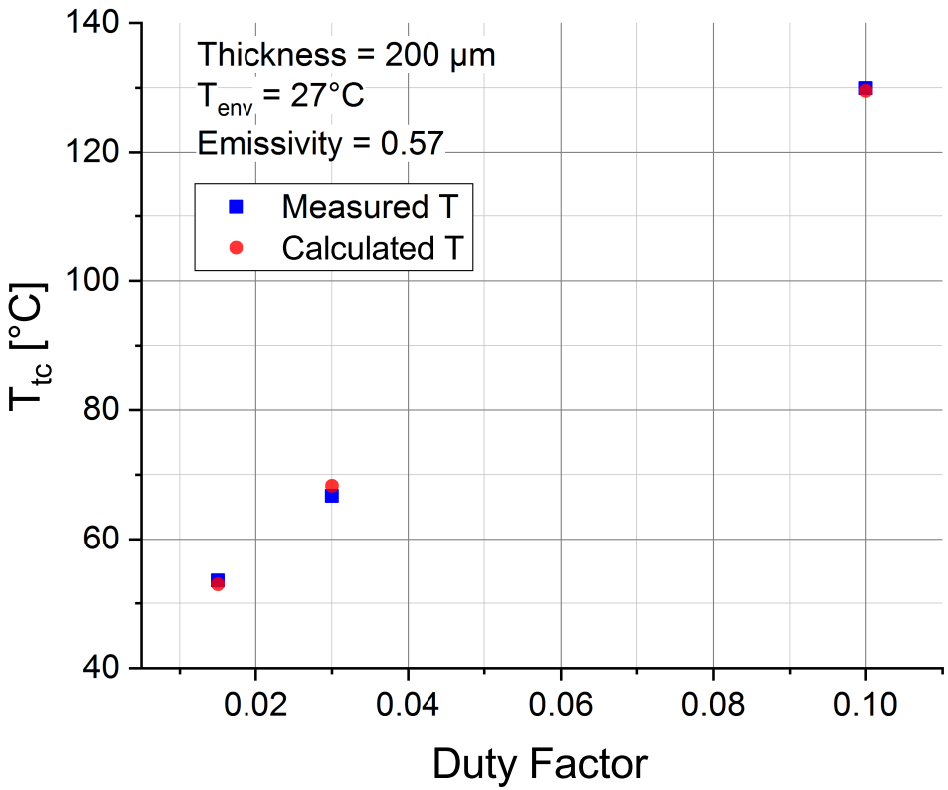
7. 1.0 ms, 100 Hz, 40 min., middle (radiation level is too high at $t_{\text{pulse}} > 1$ ms)
8. 0.5 ms, 100 Hz, 40 min., top
9. 0.5 ms, 140 Hz, 40 min., bottom

Estimation of Emissivity

Calculated T vs Emissivity (200 μm, 1 ms, 100 Hz)

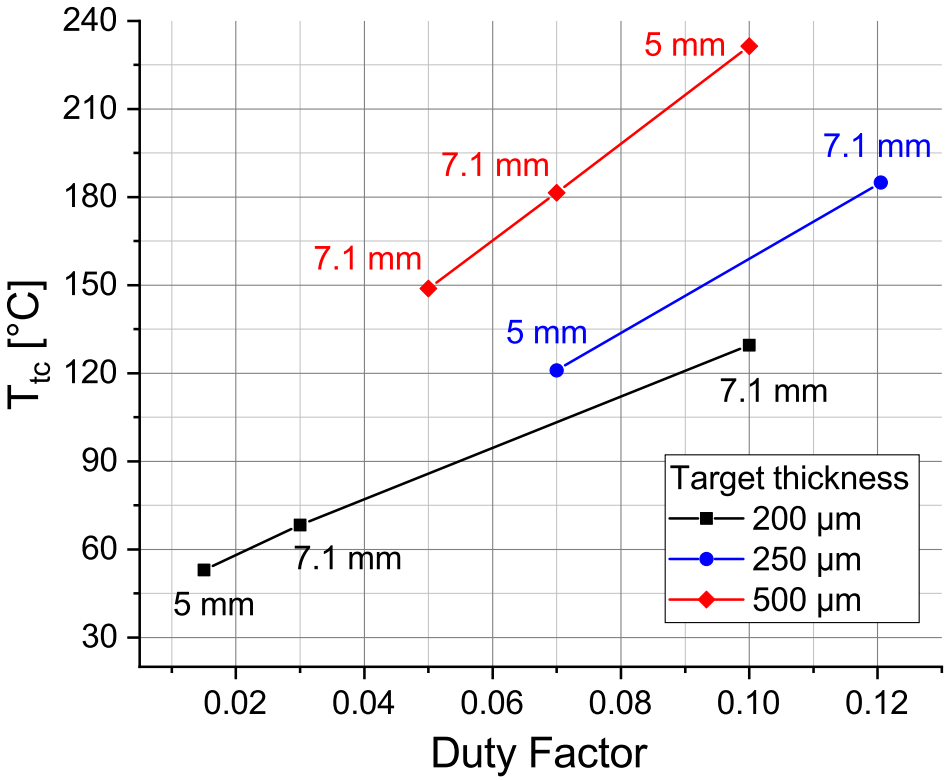


Measured and Calculated T vs Duty Factor (200 μm Target)

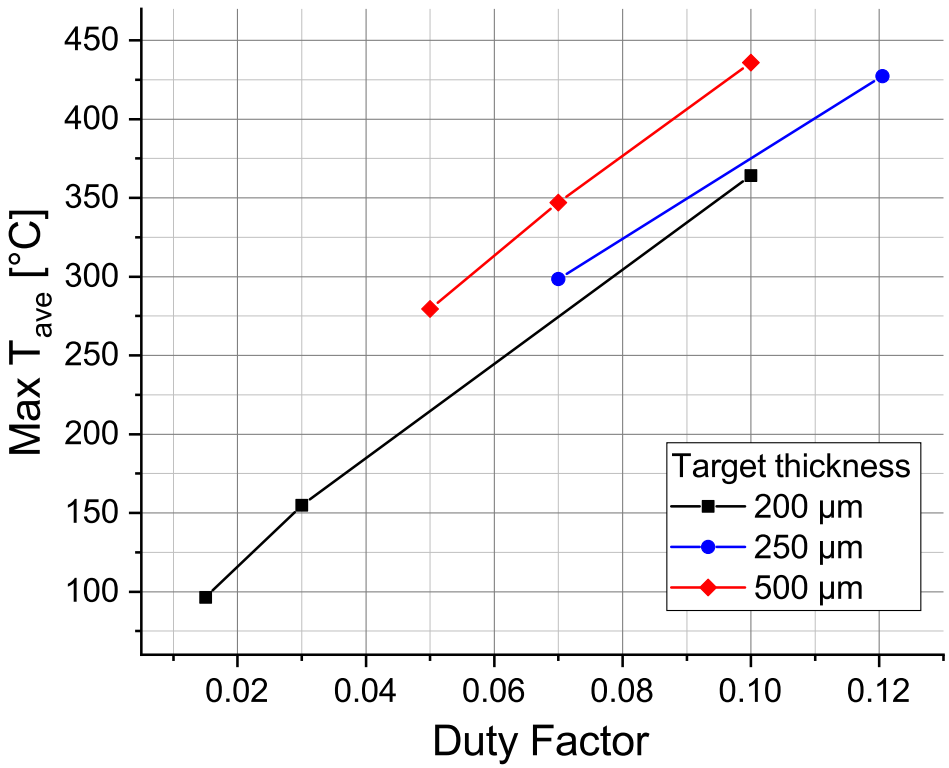


Average Temperature at Location of Thermocouples and in the Middle of Beam

Temperature at Location of Thermocouples

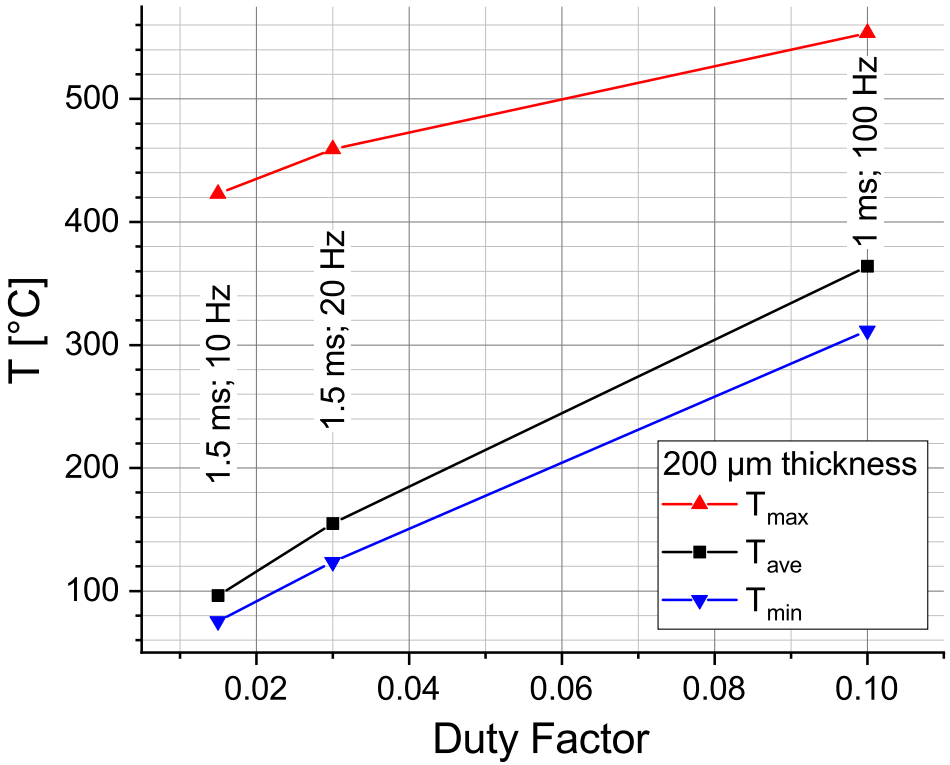


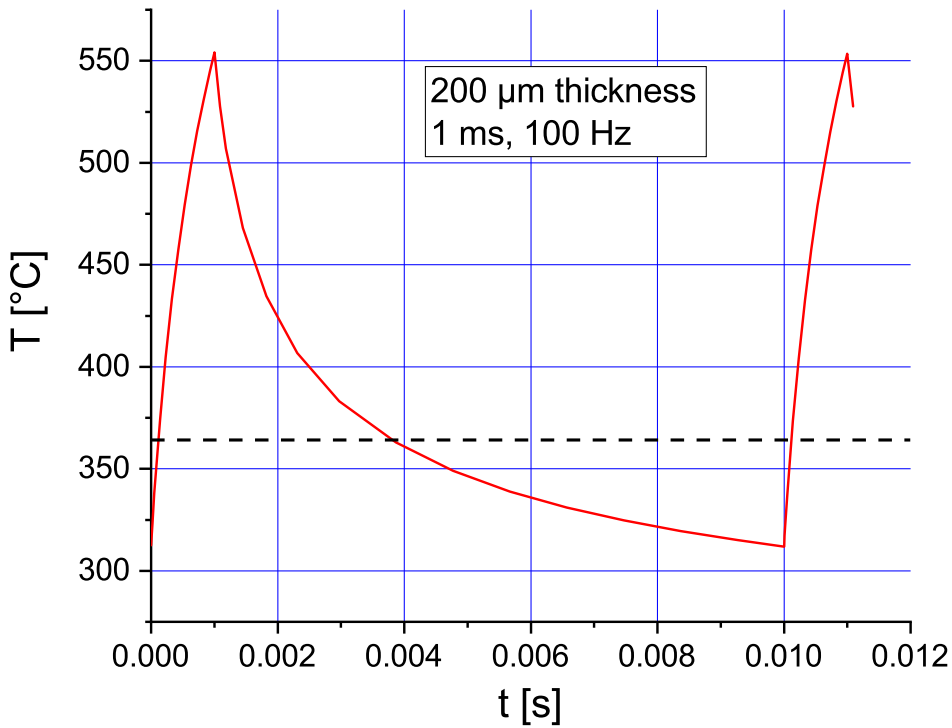
Average Temperature in Middle of Beam



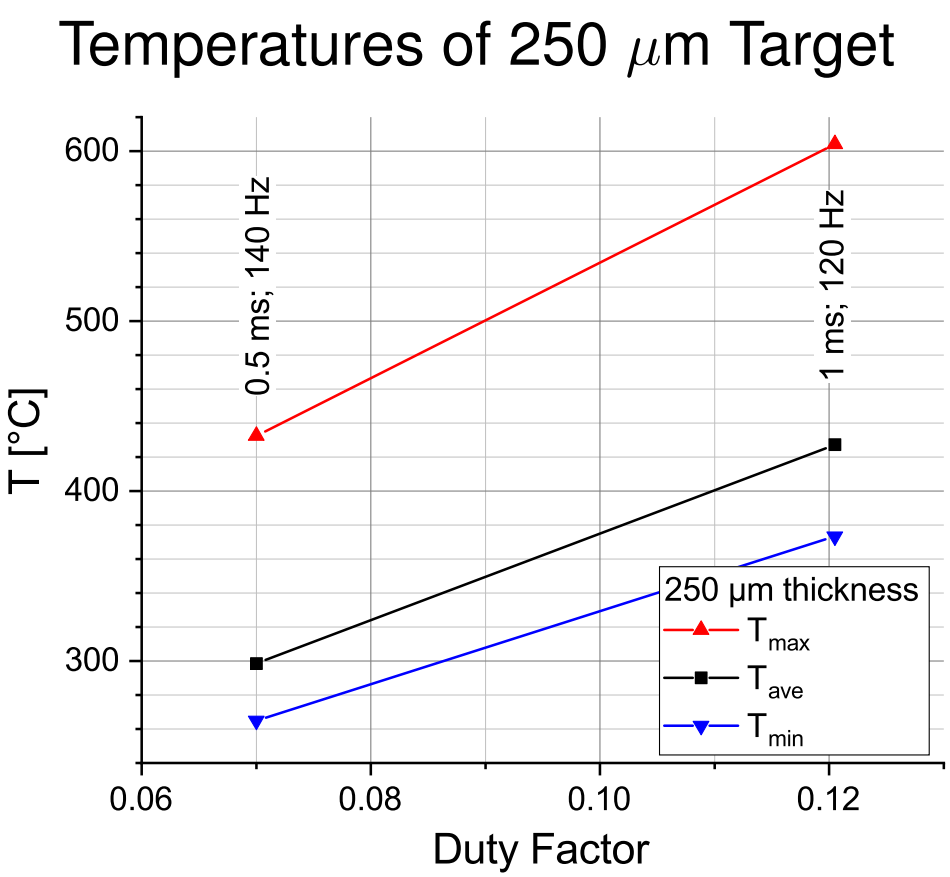
5 mm and 7.1 mm indicate the distance from middle of beam to thermocouples

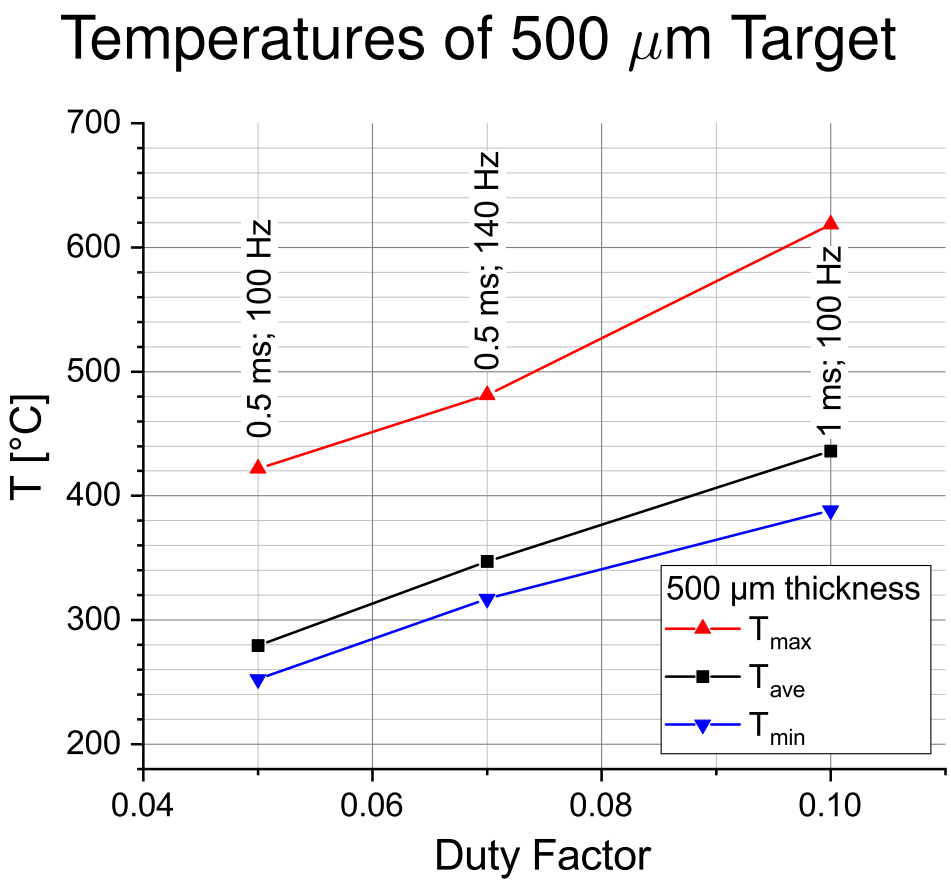
200 μm Target: Thermal Cycles



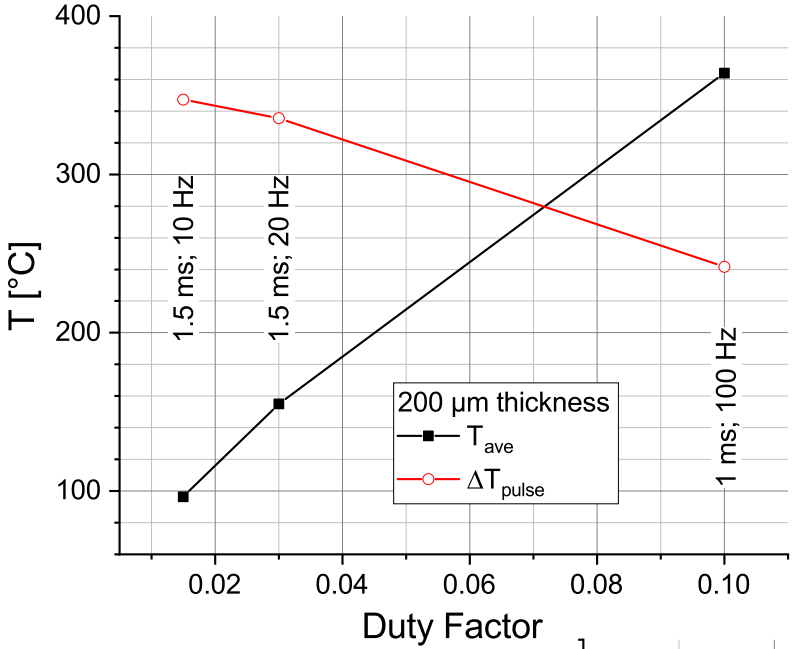


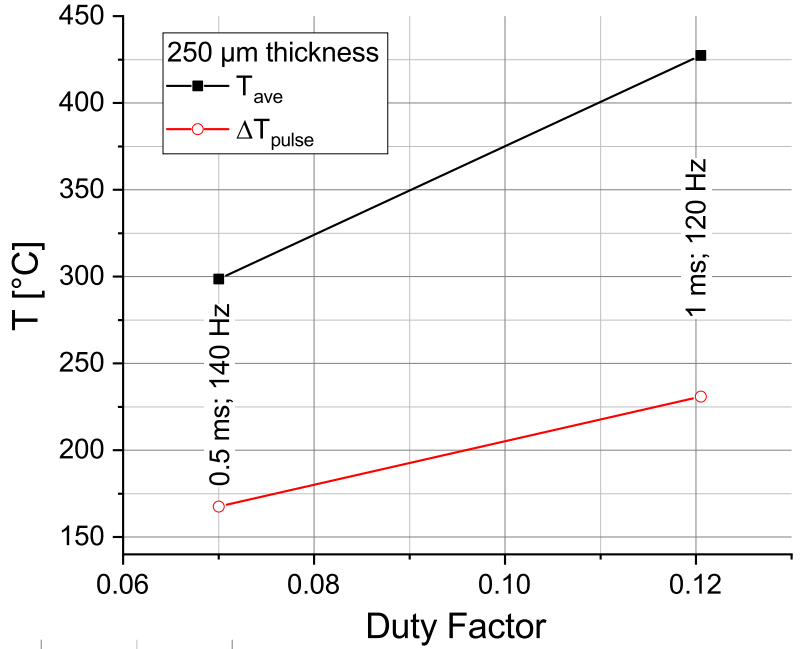
Min, Ave and Max Temperature of 250 μm and 500 μm Thick Targets

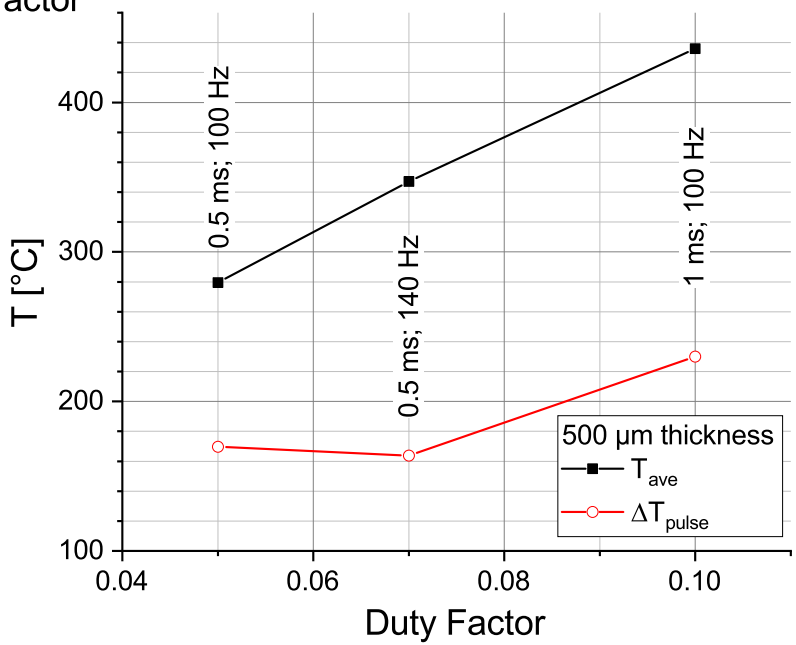




Temperature Rise per Pulse

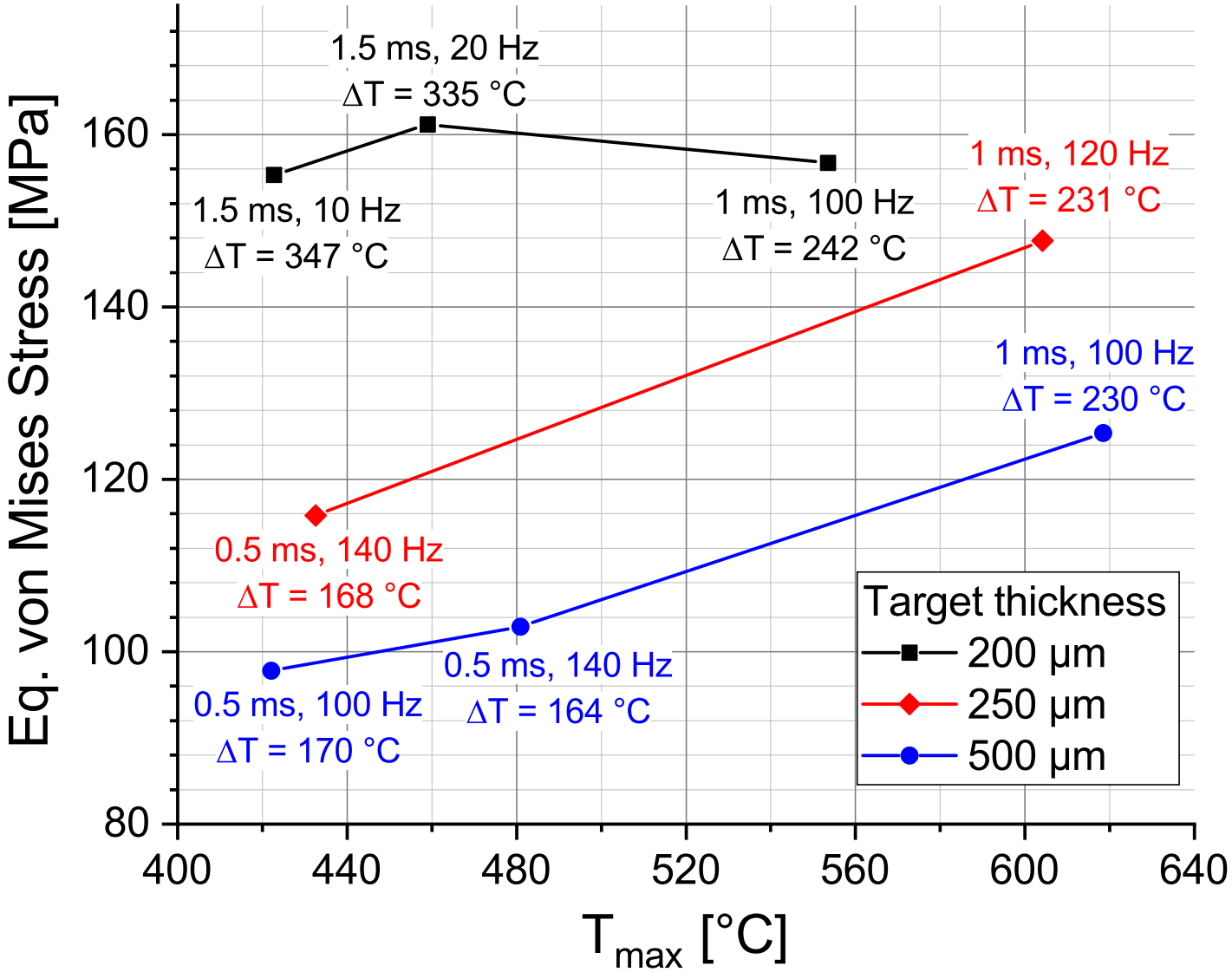






Equivalent von Mises Stress vs Peak Temperature

at the end of pulse

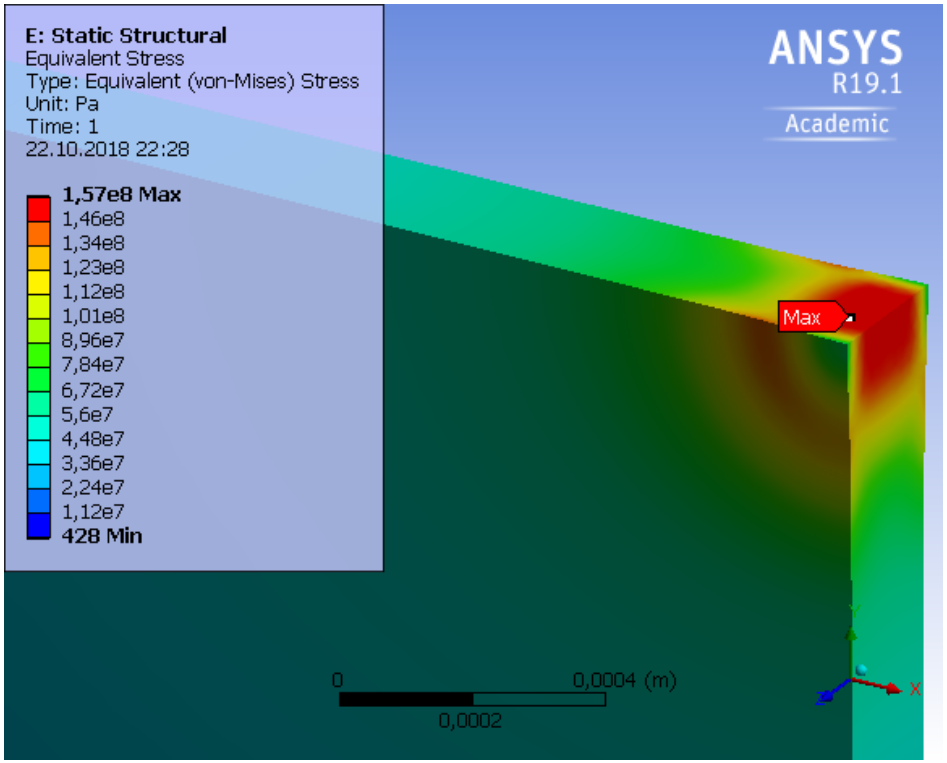


Distribution of Eq. Stress for 1 ms Pulses and 100 Hz

at the end of pulse

200 μm Target

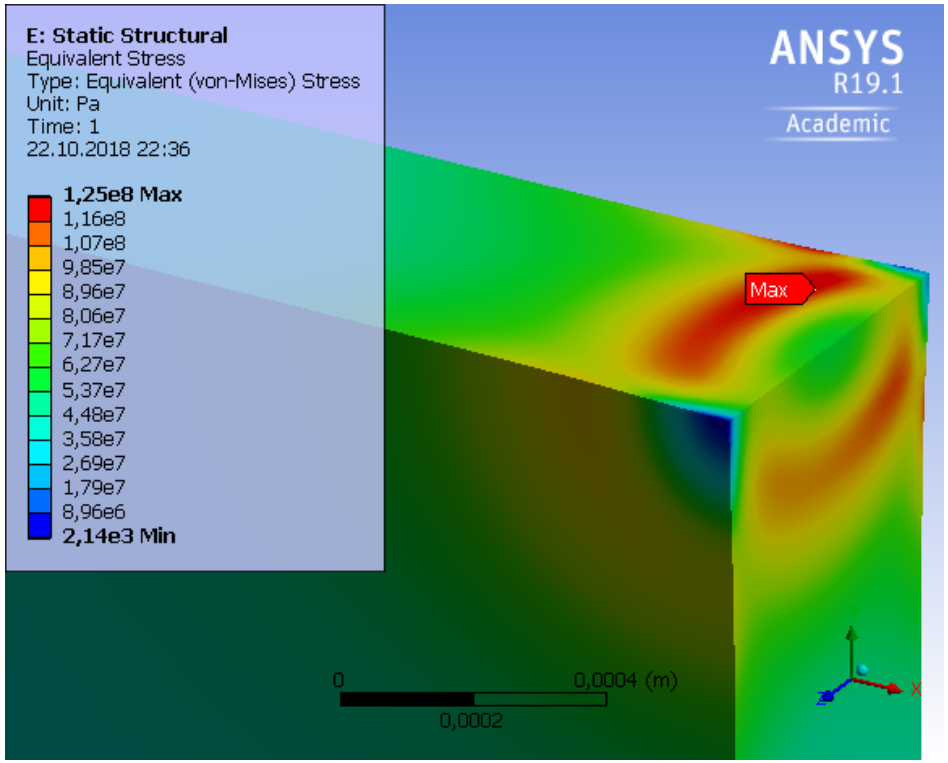
$\Delta T = 242\ ^\circ\mathrm{C}$, $T_{\max} = 554\ ^\circ\mathrm{C}$



Max $\sigma_{\mathrm{vM}} = 157$ MPa

500 μm Target

$\Delta T = 230\ ^\circ\mathrm{C}$, $T_{\max} = 618\ ^\circ\mathrm{C}$



Max $\sigma_{\mathrm{vM}} = 125$ MPa

Yield Strength σ_{Y} [Ushakov et al. POSIPOL2018 talk]:

$\sigma_{\mathrm{Y}}(T = 400^\circ\mathrm{C}) \simeq 550$ MPa,

$\sigma_{\mathrm{Y}}(T = 600^\circ\mathrm{C}) \simeq 450$ MPa

Summary

- Ti-alloy (Grade 5) targets were irradiated by 3.5 MeV pulsed electron beam at Mainz Microtron on 1-2 October 2018.
- Estimated peak temperatures of irradiated samples were in the range between 400 °C and 600 °C as it is expected for the target of ILC positron source.
- Beam focusing system has allowed to obtain the relatively high temperature rise per pulse (160°C ÷ 350°C).
- Analysis of irradiated targets by laser scanning microscope will be done during the next few days (after we will obtain them from University of Mainz).
- "Material Tests" project supported by German Federal Ministry of Education and Research (BMBF) is close to the end (December 2018).