Material Tests for the ILC Positron Source

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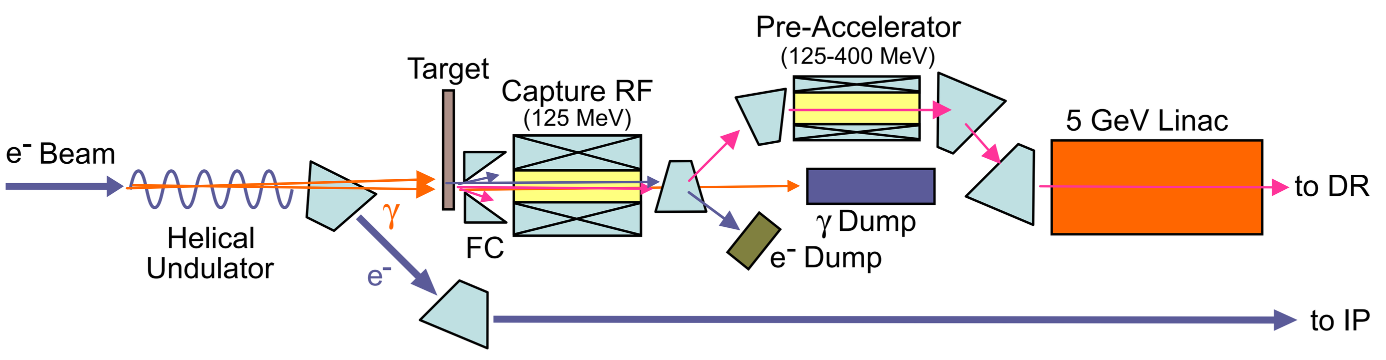
Abstract

The positron source is a vital system of the ILC. The conversion target that yields 10^{14} positrons per second will undergo high peak and cyclic load during ILC operation. In order to ensure stable long term operation of the positron source the candidate material for the conversion target has to be tested. The intense electron beam at the Mainz Microtron (MAMI) provides a good opportunity for such tests. The first results for Ti6Al4V are presented which is the candidate material for the positron conversion target as well as for the exit window to the photon beam absorber.

Scheme of ILC Positron Source



Source Parameters

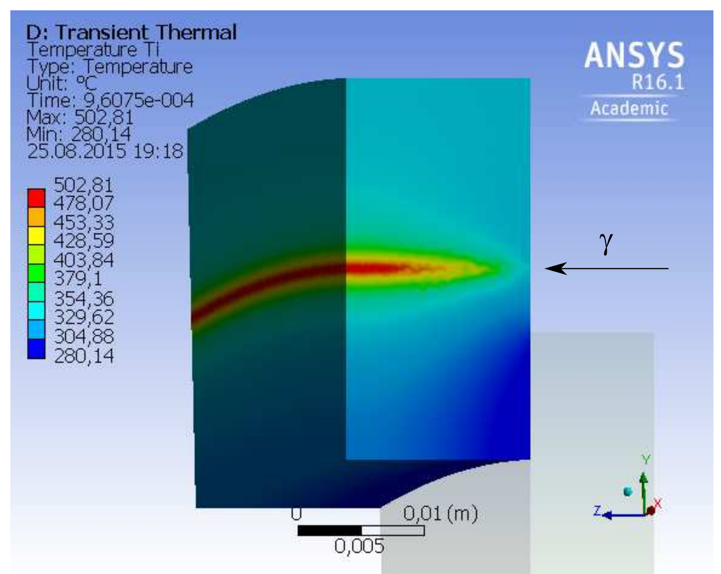
e⁻ Beam
125 - 250 GeV, $2 \cdot 10^{10}$ e⁻/bunch
nominal: 1312 bunches/pulse, 554 ns bunch spacing
high-luminosity: 2625 bunches/pulse, 366 ns bunch spacing

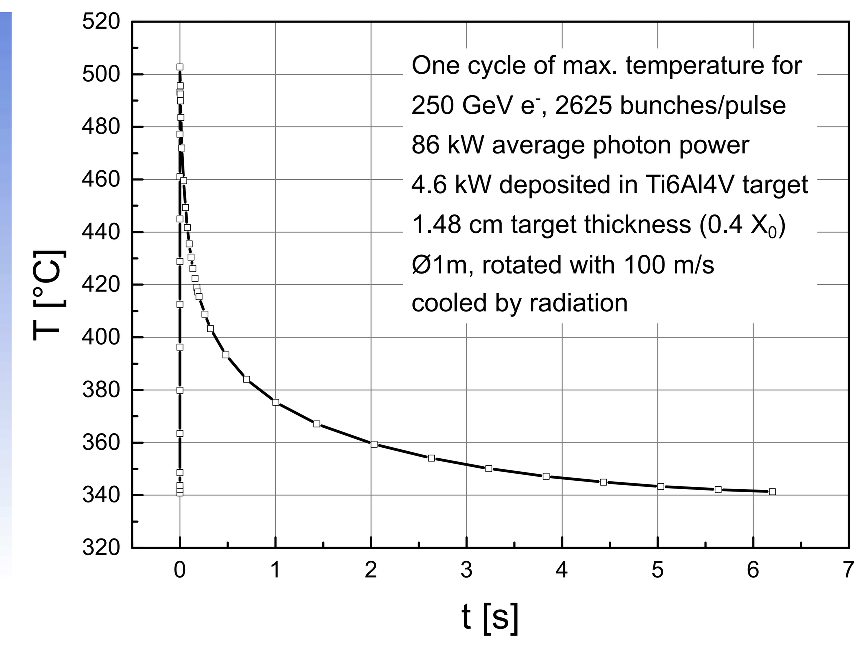
Helical Undulator
231 m magnet length, K = 0.92, 11.5 mm period

Photons
Average energy: 27 MeV (250 GeV e⁻)
Average power: 43 kW (250 GeV e⁻, nominal)

Peak Energy Deposition Density (PEDD)
nominal:
0.4 X0 thick target rotated with 100 m/s: ≈45 J/(g pulse)
0.2 mm thick Ti vacuum exit window: ≈55 J/(g pulse)

Temperature in Positron Target

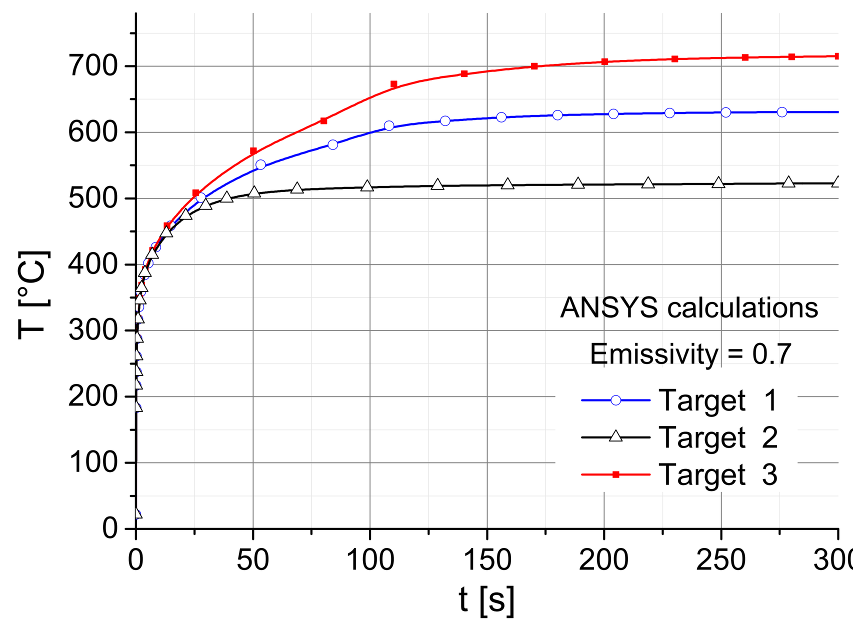




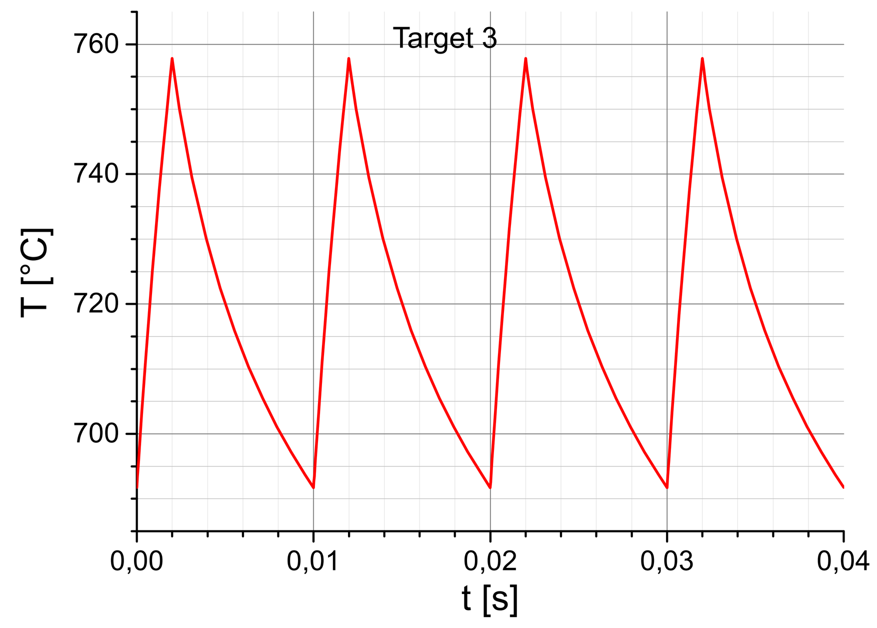
Aim of Material Tests

- Test target materials at thermal conditions similar to that expected at the ILC positron source.
- Photon beam with required intensity and energy is not available.
- Load at ILC e⁺ target:
  - peak energy deposition desity (PEDD) ≈ 65 J/g;
  - average temperature above 500 °C;
  - few 10^6 load cycles.
- Use e⁻ beam of Mainz Microtron (MAMI) injector: 50 μA @ 14 MeV, 2 ms pulses, 100 Hz rep. rate, rms size on target σ = 180 μm.

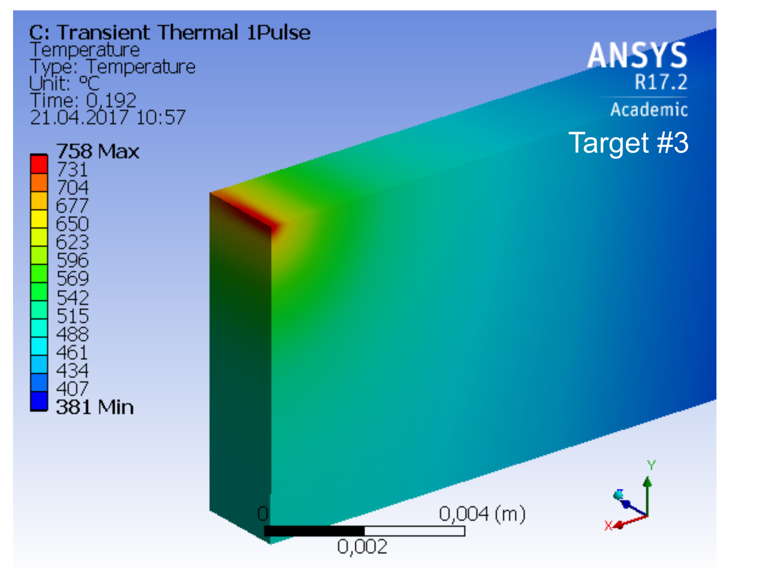
Average Peak T vs Time



Thermal Cycles



Temperature at Pulse End



Irradiated Targets and Beam

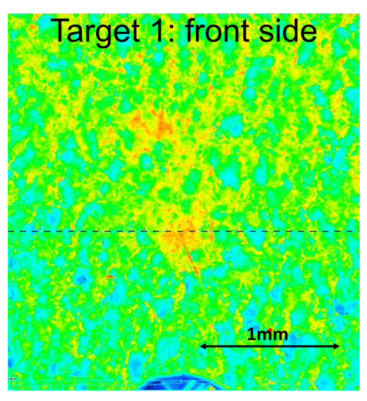
All targets: 50 μA during pulse

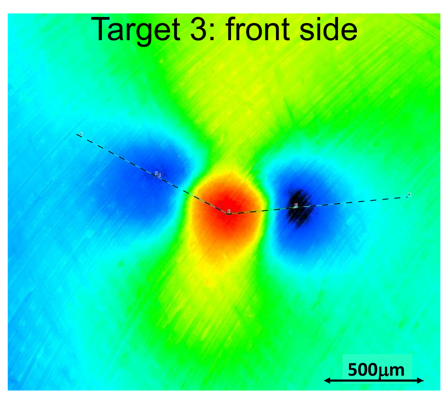
#1: 1 mm thickness, wo thermal contact to holder — 2 ms, 100 Hz, ~18.5h of irradiation

#2: 1 mm thickness, with thermal contact to holder — 3 ms, 67 Hz, ~4h of irradiation

#3: 2 mm thickness, wo thermal contact to holder — 2 ms, 100 Hz, ~14.5h of irradiation

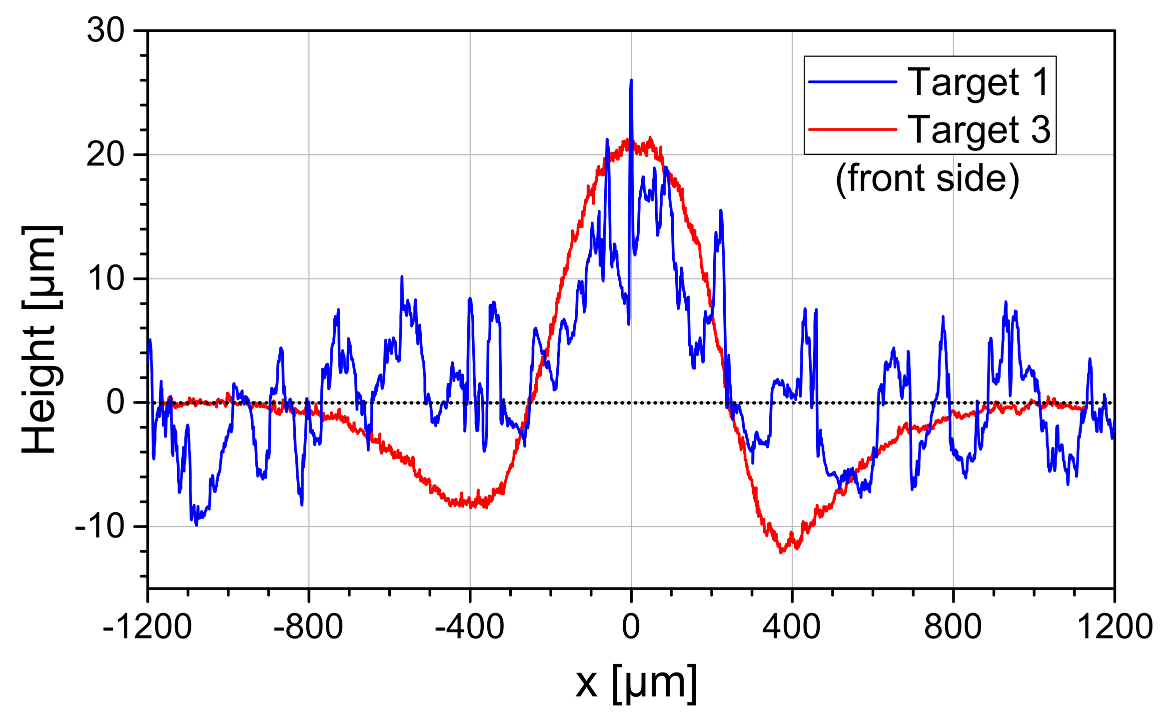
#4: not used





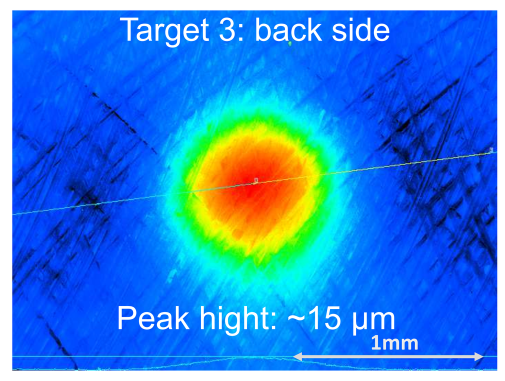
Deformation of Targets after Irradiation

Surface analysis with 3D laser scanning microscope

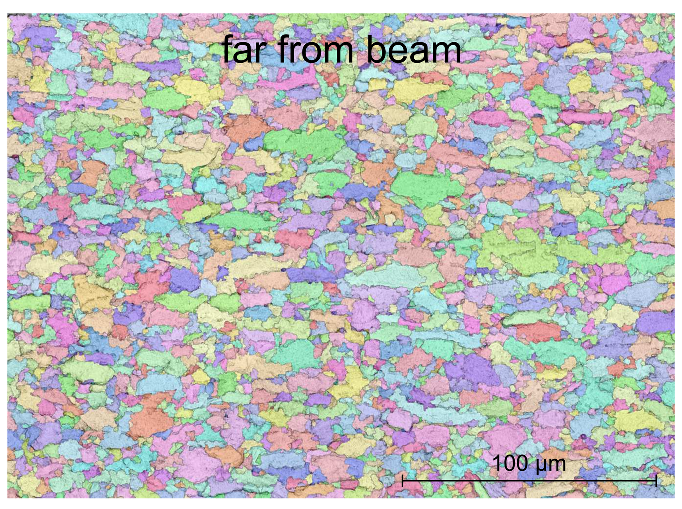


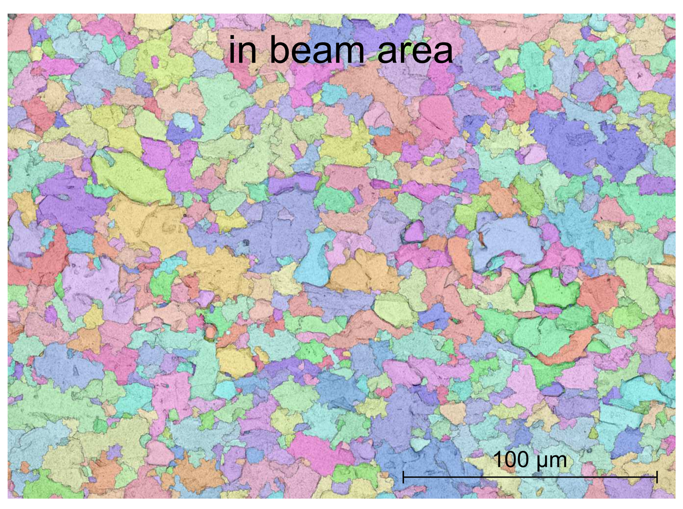
No visible deformation on back side of target 1

No visible deformation on both sides of target 2



Grain Stucture of Target 3





far from beam		in beam area
19.1	Mean grain area [μm²]	50.0
291	Max grain area [μm²]	982

Summary and Outlook

	Target 1	Target 3
Target thickness [mm]	1	2
Peak current [μA]	50	
Pulse length [ms]	2	
Rep. rate [Hz]	100	
Irradiation time [min]	1108	862
Number of cycles [10^6]	6.648	5.172
T_{max}^{ave} [°C]	629	713
T_{peak} [°C]	690	772
ΔT/pulse [K]	61	59
$\Delta\sigma_{normal}^{max}$ per cycle [MPa]	230	210
ε_{max} (front side) [μm]	≤ 15	≤ 28
ε_{max} (exit side) [μm]	∼ 0	≤ 15

- The test at MAMI demonstrated that Ti6Al4V stands a long-term irradiation with high cyclic load as expected at the ILC positron production target.
- At temperatures above 700°C dimensional changes and substantial grain growth in the region around the beam path are obtained.
- The design of the ILC e⁺ target made of Ti6Al4V must ensure that the temperature remains below 700°C.
- Further studies:
  - Clearify whether dimensional changes influence the creep properties and other parameters important for the construction of the spinning target wheel.
  - Test performance against high cyclic stress of thin Ti and Ti-alloy foils under irradiation conditions as expected for exit windows at ILC.

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