Setup for Beam Profile Measurements Using Optical Transition Radiation*

WEPC04

J. Pforr#, M. Arnold, T. Bahlo, L. Jürgensen, N. Pietralla, A. Rost, TU Darmstadt, Darmstadt, Germany
F. Hug, Johannes Gutenberg-Universität Mainz, Mainz, Germany

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Abstract

The S-DALINAC is a thrice-recirculating, superconducting linear electron accelerator at TU Darmstadt. It can provide beams of electrons with energies of up to 130 MeV and currents of up to 20 μA. The accelerator performance was improved by an extension of the beam diagnostics, as this increases the reproducibility of the machine settings. In addition, the installation of several beam profile measurement stations is planned, which should be operational down to a beam current of 100 nA, as this current is used for beam tuning. Combining these devices with a quadrupole scan also allows for emittance measurements. The beam profile measurements shall be done based on optical transition radiation (OTR), resulting from the penetration of relativistic electrons from vacuum into a metal target. The radiation can be detected using standard cameras that provide information on the two-dimensional particle distribution. This contribution will address the layout of the measurement stations and a first test measurement will be presented.

Diagnostic Stations

- Based on optical transition radiation (OTR) targets and standard (CMOS) cameras
- Existing quadrupoles allow for emittance measurements

Target:

- Two options: pure aluminium or aluminium coated on kapton foil
- Aluminium due to high plasma frequency, thus high OTR intensity
- Kapton can be stretched before aluminium coating to achieve flat surface

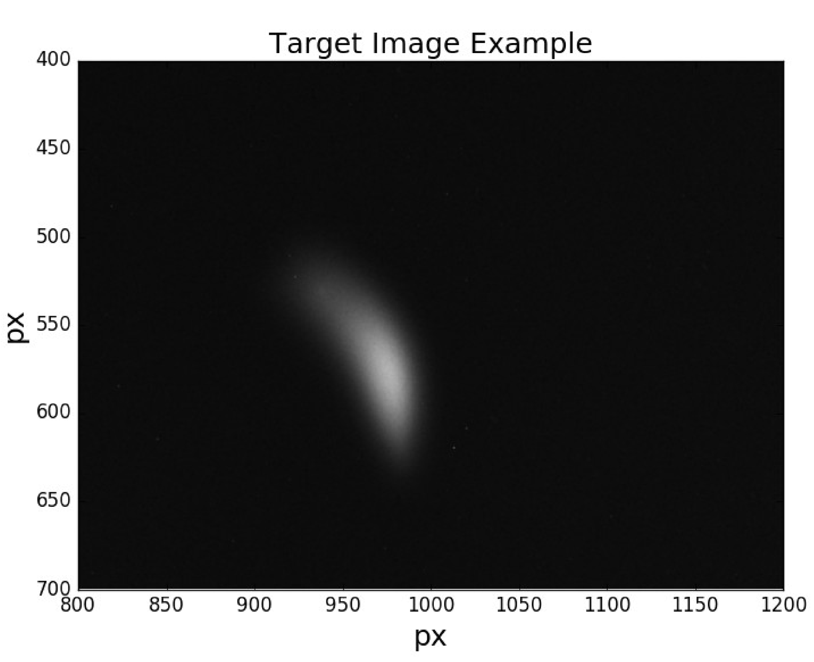
Optics:

- Camera: FLIR BFLY-PGE-31S4M-C
  - Flexible (adjustable gain, exposure time etc.)
  - Resolution 2048x1536 px, 35 frames per second
- Shielding needed: observe target via mirror

[1] FLIR Blackfly manual

Demonstration Measurement (Dec. '17)

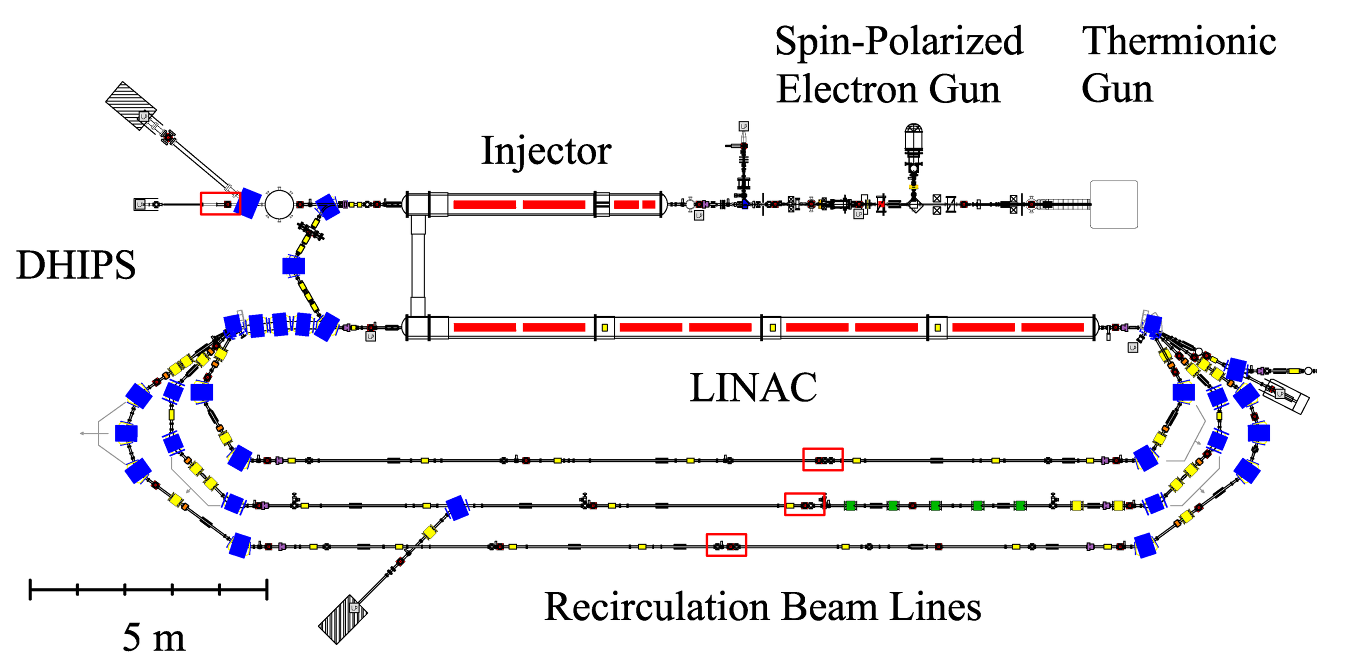
- Beam parameters: 100 nA current, 5.2 MeV energy
- Sufficient image brightness at low current, no saturation
- No 2D-Gaussian profile
- After projection, calibration and background subtraction beam size determination by Gaussian fit possible
- Emittances measured [3]



- Successful demonstration of OTR targets, camera and adjustment

[3] F. Hug et al., Proc. IPAC 2018, pp. 4219-4222

S-DALINAC



Beam current:	up to 20 μA	Frequency:	2.997 GHz
Duty cycle:	cw	Max. energy:	130 MeV

Red boxes: planned new diagnostic stations after each acceleration

Thermal Considerations

Target temperature changes by:

- Beam heating (red)
- Thermal conduction (blue)
- Radiation (green)

$$\frac{\Delta T(r,t)}{\Delta t} = \frac{1}{c_p \rho} \left[\frac{dE}{dx} \rho \exp\left(-\frac{r^2}{2\sigma^2}\right) N(t) - k \nabla^2 T(r,t) - \frac{2\epsilon\sigma_s}{\delta} \left(T(r,t)^4 - T_0^4 \right) \right]$$ [2]

	Aluminium	Kapton
Density ρ [g/cm³]	2.7	1.4
Conductivity k [W/Km]	250	0.2
Emissivity ε	0.04	0.24

Immediate conclusion:

- Small target thickness (δ) beneficial
- More power deposited in aluminium due to higher density

Simulations:

- Approx. 10^{-3} W deposited in 10^{-2} mm³ for δ=10 μm
- High conductivity of aluminium distributes heat load over large volume, thus target is hardly warmed up
- Kapton needs limitation of beam current to ~1 μA, as higher power density would destroy the target

[2] E. Bravin et al., Proc. PAC 2003, pp. 2464-2466.

Conclusion

Successful demonstration of emittance measurement with OTR targets.
Production of kapton-based OTR targets for low beam currents started.
Pure aluminium targets for max. current possible, but flatness needed.
Design of optics setup and shielding ongoing.
Emittance measurement later this year planned.