Status of Plasma Diagnostics On The Prototype Plasma Lens For Optical Matching At The ILC e+ Source.

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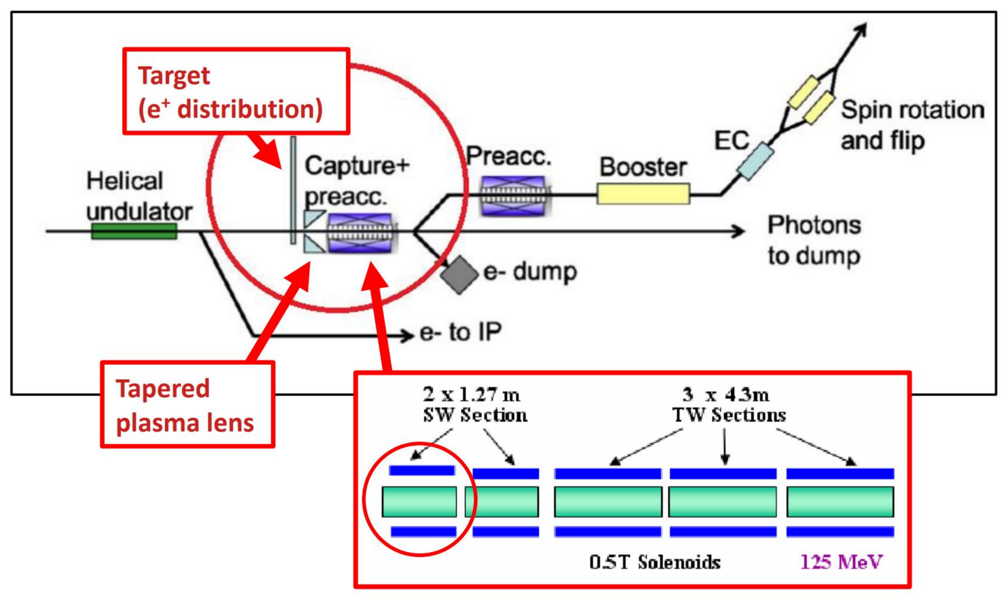
Abstract

In recent years, high-gradient, symmetric focusing with active plasma lenses has regained significant interest due to its potential advantages in compactness and beam dynamics compared to conventional focusing elements. A promising application could be optical matching of highly divergent positrons from the undulator-based ILC positron source into the downstream accelerating structures to increase the positron yield. In a collaboration between University Hamburg and DESY Hamburg a downscaled prototype for this application has been developed and constructed. Here, we present the current status of the prototype development.

ILC injection scheme

- Undulator-based positron source
- Only first SWT included in simulations
- Common positron distribution for ILC e+ source (priv. comm. M. Fukuda)
- Bunch spacing: 554 ns
- Average e+ energy: 6.1 MeV
- Energy spread: 4.8 MeV
- Divergence: 63.28 – 75.24 mrad

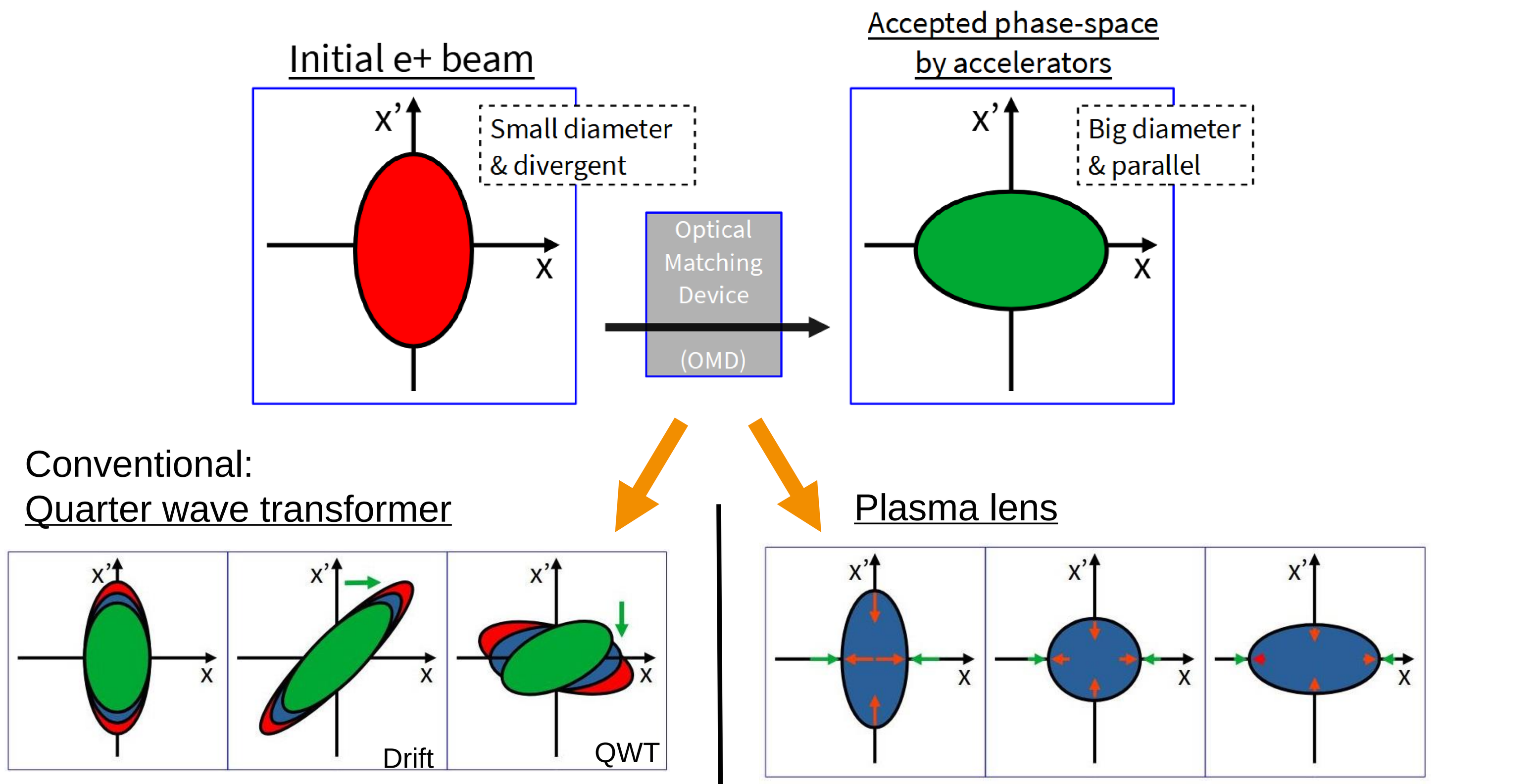


Positron Energy	5 GeV
Dynamic Aperture	<0.07 mrad
Energy Acceptance	0.75 %
Longitudinal Acceptances	3.4 x 37.5 cm-MeV
Longitudinal Emittance	0.75 x 33 % x mm

- Damping ring acceptance
- Energy acceptance
  - Longitudinal cut of 14 mm

J.W. Wang. POSITRON INJECTOR ACCELERATOR AND RF SYSTEM FOR THE ILC*. 2007
F Dietrich. Status of the undulator-based ILC positron source. 2019
M; Barish B; Buesser K Adolphsen, c; Barone. Technical Design Report | Volume 3.i: Accelerator RD. 2013

Advantages of plasma lenses



Conventional: Quarter wave transformer

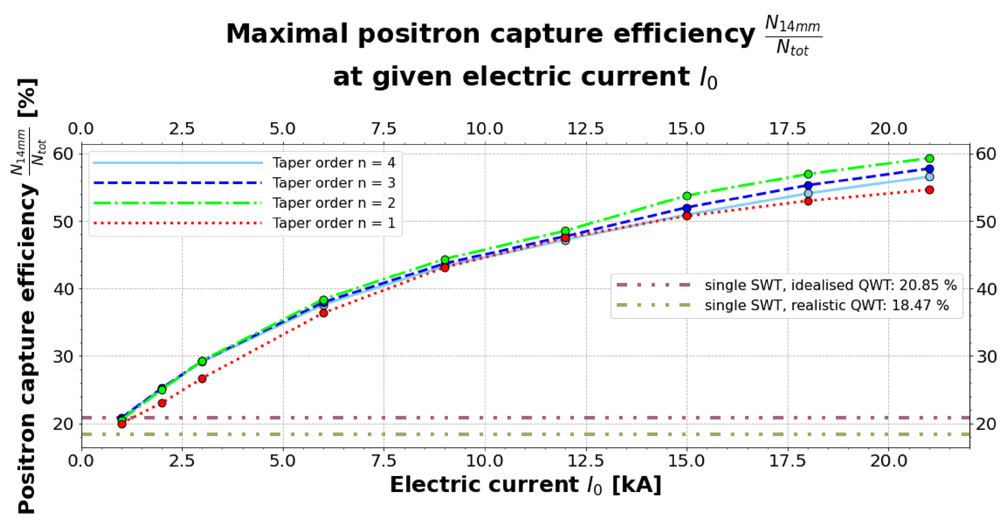
- Energy dependent phase space skewing
  - high chromaticity
- Radial and longitudinal field
  - Helical trajectory → large dephasing
- Mitigated field by mirrored twin coil
  - Manageable eddy currents in rotating target

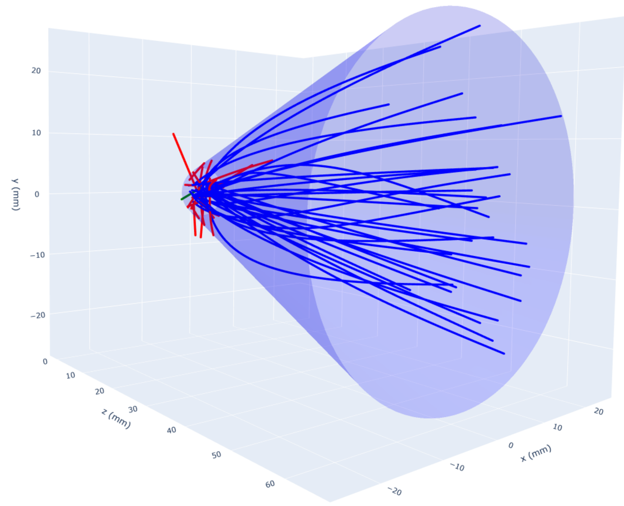
Plasma lens

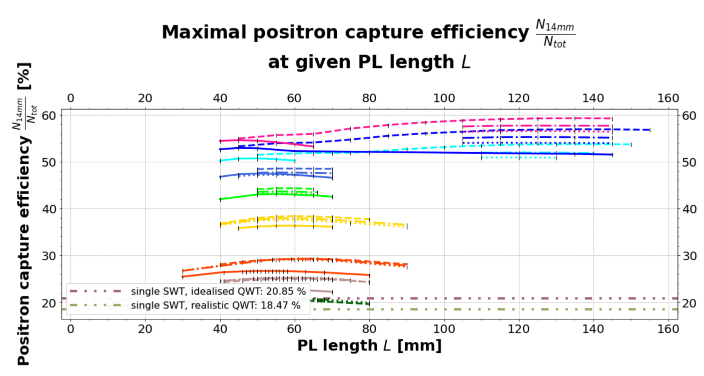
- Energy independent phase space squeezing
  - low chromaticity
- Azimuthal field
  - focusing in both transverse planes
  - Sinusoidal trajectory → low dephasing
- Field confined in cavity
  - Vanishing eddy currents in rotating target

Simulation process

- Particle tracking done with ASTRA by K. Flöttmann
  - No space charge
  - Homogeneous and static PL current density; no edge fields
  - Idealised acceleration structures
- Optimization of tapered PL design with respect to captured e+ yield (particles within 14 mm longitudinal cut which fit into the damping ring)



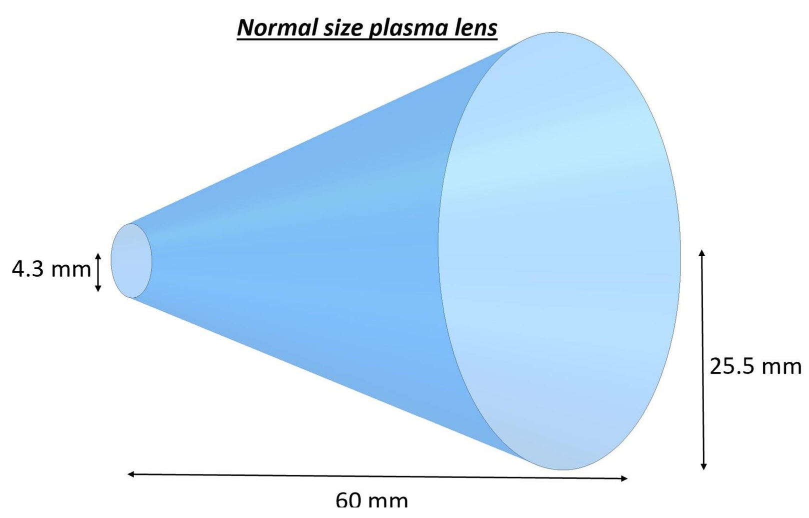




Plasma lens parameters

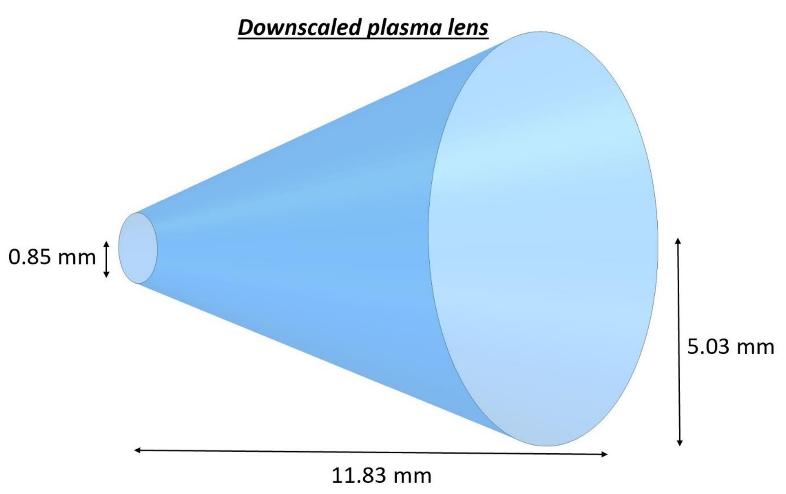
Normal size

- Starting radius: 4.3 mm
- Exit radius: 25.5 mm
- Taper strength: 0.082 mm^{-1}
- Length: 60 mm
- Taper order: 2
- Total current: 9000 A
- Phase of SWT: 225 deg



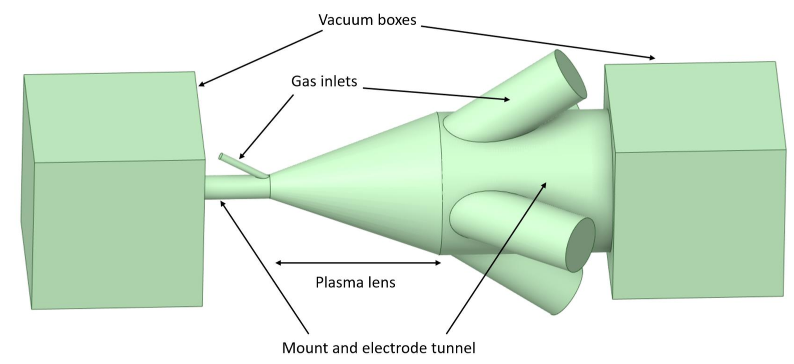
Downscaled

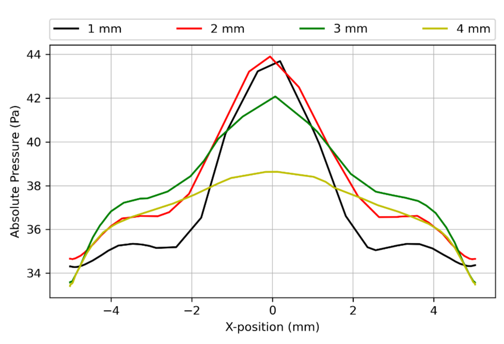
- Starting radius: 0.85 mm
- Exit radius: 5.03 mm
- Taper strength: 0.416 mm^{-1}
- Length: 11.83 mm
- Total current: 350 A



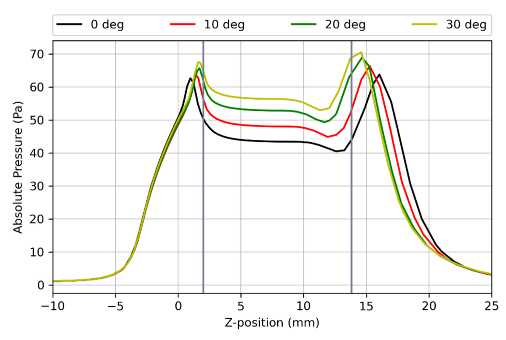
Gasflow simulations with ANSYS Fluent

- Influence of gas inlet geometry on gas distribution within plasma lens
- Larger angles correspond to higher pressure in the plasma lens
- Larger diameters lead to lower pressure in the plasma lens
- Larger diameters distribute the gas more evenly
- Final design:
  - 2 inlets at 70 degrees
  - Diameter at 3 mm
  - Overall pressure at 100 Pa





Pressure profile along the Z-axis

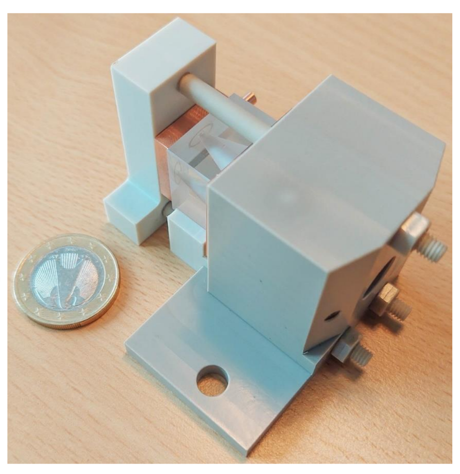


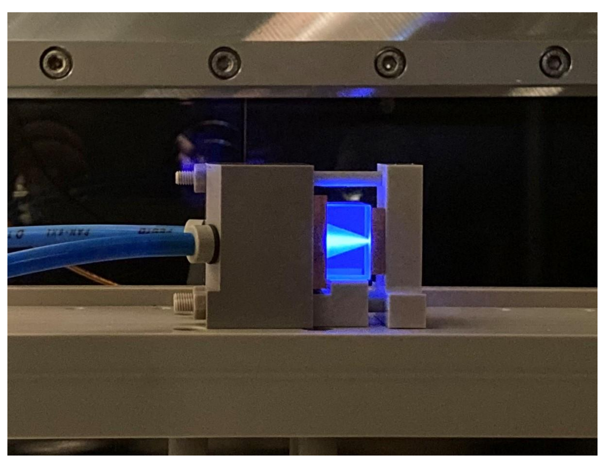
Pressure profile along the X-axis at the exit

Prototype design

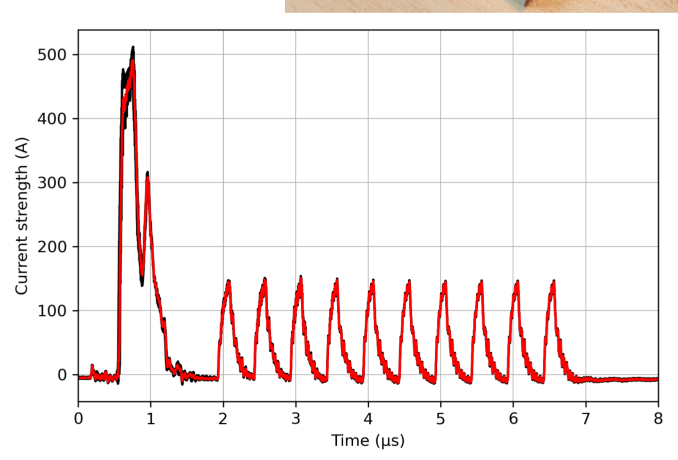
- Principle: lens is pressed in between mounts with threaded rods and sealed with O-rings
- Mounts made out of PEEK
- Electrodes made out of copper
- Plasma lens made out of sapphire block

Finished Prototype





Produced plasma



Ingoing current measured

Outlook

- Prototype finished and first implementation at DESY successful
  - Plasma seems to be strongly instable
- Next step: Measurements of plasma stability and observation of pinching effects at ADVANCE LAB at DESY
- Main goal: Measurement of magnetic field distribution
- Comparing simulations by M. Formela with experiments of prototype

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