Application of Plasma Lenses as Optical Matching Device for Positron Sources at linear colliders

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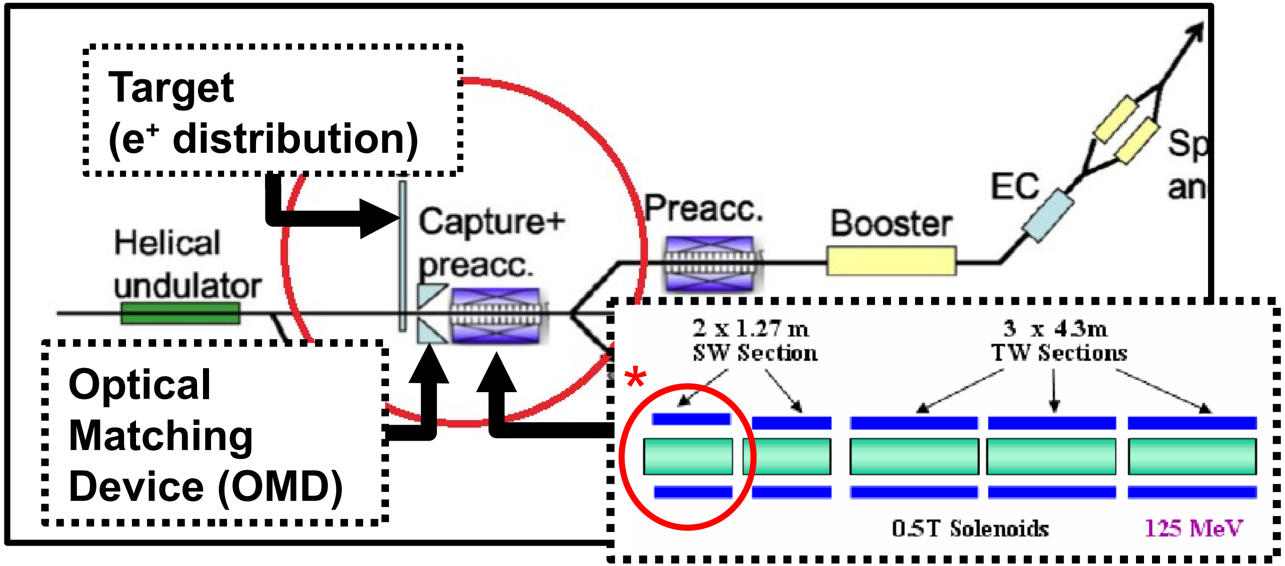
Motivation - Plasma Lens for Optical Matching

Motivation:
To achieve a twothousandfold increase in luminosity from the SLC (3e30 $cm^{-2}s^{-1}$) to the proposed ILC (7500e30 $cm^{-2}s^{-1}$), it is necessary to push all technological boundaries. One area of improvement in particular is the particle number, which is primarily determined by the capture section and specifically by its optical matching device.
This is where the application of a plasma lens could potentially open up new possibilities



*Plasma Lens optimizations
Only with 1st SWT

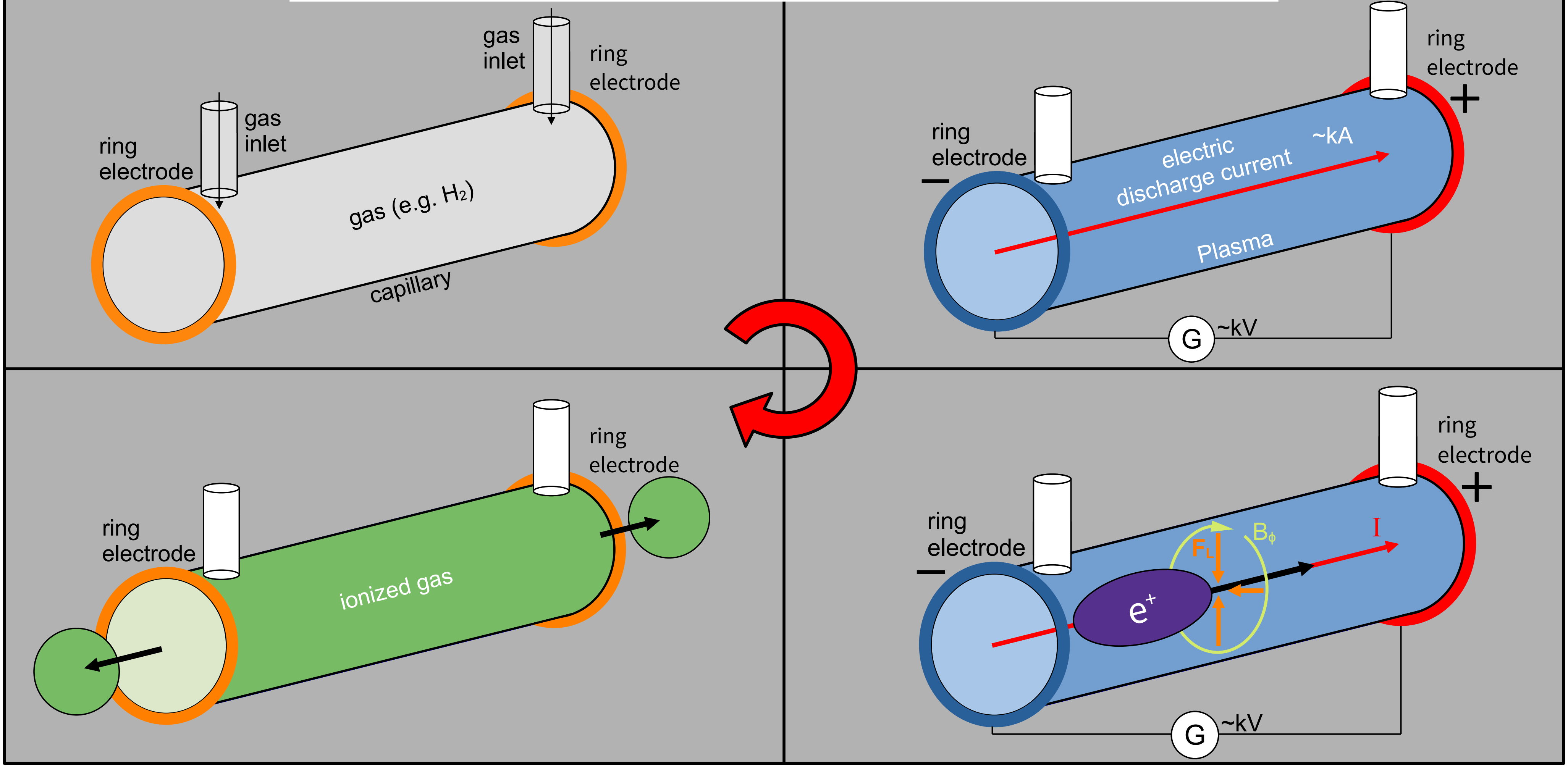
Sources: 1) J.W. Wang. POSITRON INJECTOR ACCELERATOR AND RF SYSTEM FOR THE ILC*. 2007.
2) F Dietrich. Status of the undulator-based ILC positron source. 2019.

Advantages of Plasma Lenses over conventional OMDs

	Current ILC Options		
	Quarter Wave Transformer (QWT)	Flux Concentrator (FC)	Plasma Lens (PL)
Dephasing	- helical	- helical	+ sinusoidal
Chromaticity	- high	+ low	+ low
Eddy current in rotating target	+ manageable	- problematic for fast rotation	++ spatially confined field

QWT proposed for ILC

Principle of an Active Plasma Lens



Optimization Results of Tapered Active Plasma Lens as OMD

Simulations with ASTRA

41.7% captured e^+ within DR energy acceptance of .75% (14 mm long. Cut)
→ ~50% improvement over ILC's current proposed OMD (QWT) design

Optimized Parameters at I_0 = 3000 A

	Symbol	Optimal Value
PL Length	z_{max}	6 cm
Opening Radius	R_0	3.8 mm
Tapering Order	n	1
Tapering Strength	g	136 m^{-1}
PL-SWT distance	d	1 cm
SWT Phase	φ_0	220°

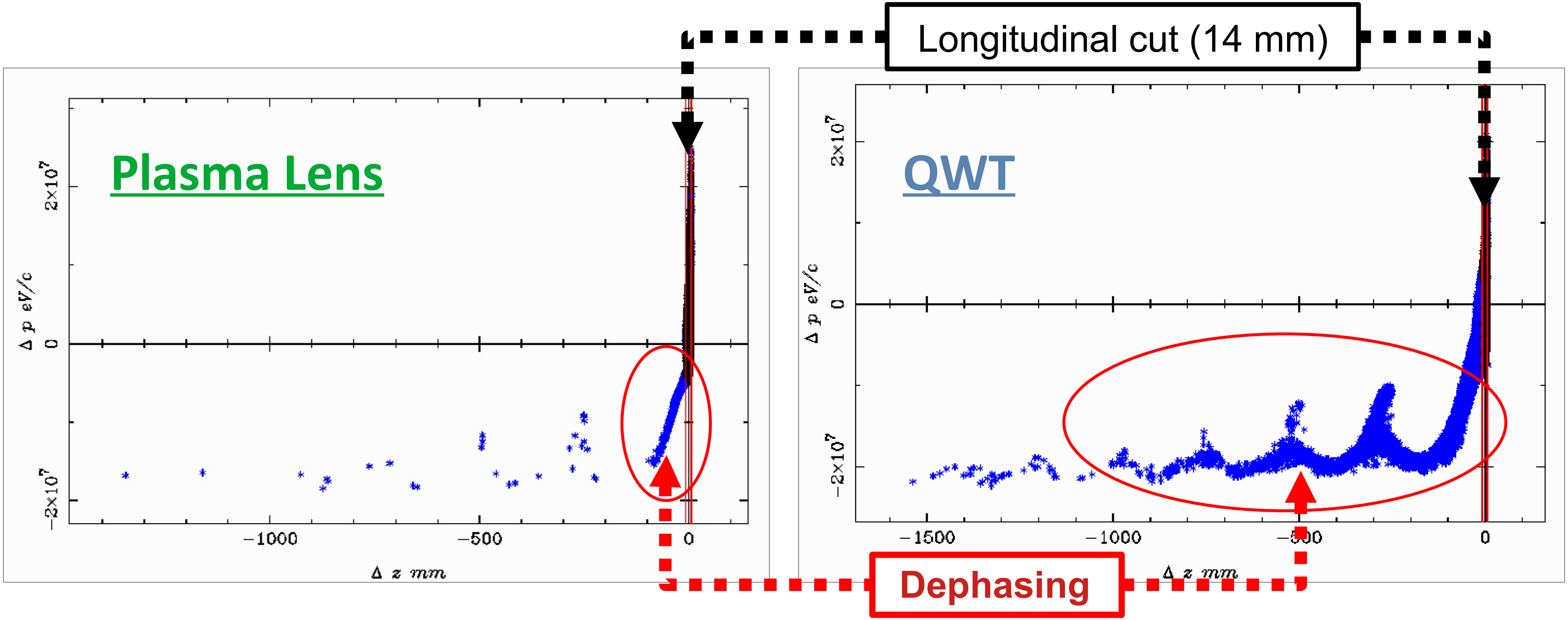
Tapered PL cavity profile: $R(z) = R_0(1 + gz)^n$

Captured Yield Stability of the Opimum

		Captured Yield Deviation for deviations in optimized parameter by	
Parameter	Symbol	-10% offset	+10% offset
PL Length	z_{max}	-0.3% yield	-0.2% yield
Opening Radius	R_0	-0.1% yield	-1.1% yield
Tapering Strength	g	-0.2% yield	-0.3% yield
Current strength	I_0	-1.5% yield	+1.2% yield
PL-SWT distance	d	+0.2% yield	-0.2% yield
SWT Phase	φ_0	-0.5% yield	-0.4% yield

Dephasing Advantage of the Plasma Lens

The azimuthal magnetic field of the plasma lens leads to a sinusoidal trajectory (helical for QWT), which results in an effectively shorter path and therefore smaller longitudinal spread, the so called dephasing.



Summary

- Theoretical advantages of PLs over conventional OMDs in Dephasing, Chromaticity & Target eddy currents
- PL with ~50% more e^+ yield over ILC's currently proposed OMD
- Stability of e^+ yield within ±2% for single parameter deviations of ±10%

Outlook

- Simulation with entire pre-accelerator structure
- Current ILC plan: 4y prelab phase (starting April 2022)
- Exploring technical details by prototyping a Plasma Lens as OMD
  - could have impact on final ILC design