Simulation of laser propagation in plasma chamber including nonlinearities by utilization of VirtualLab 5 software (trial version)

Final Report DESY SSP 2012

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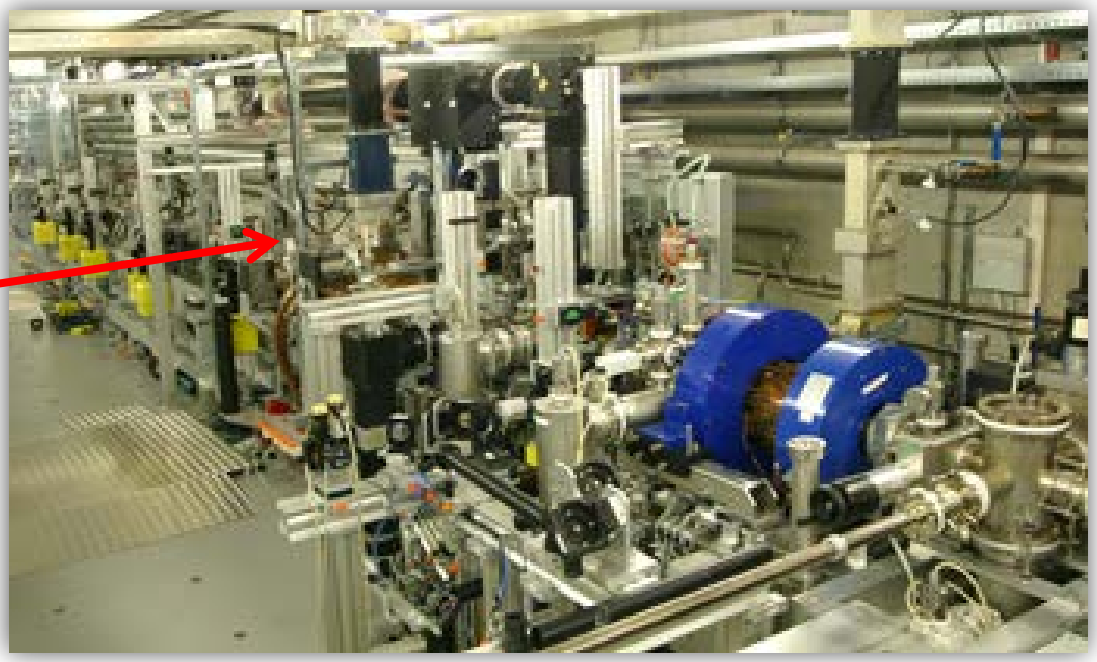
HELMHOLTZ ASSOCIATION

DESY

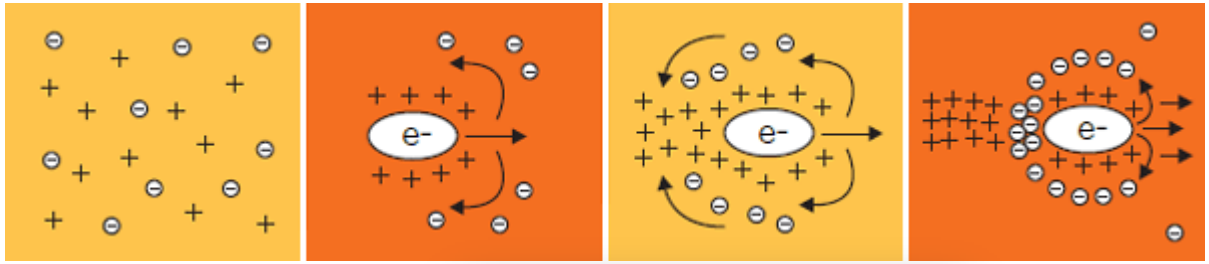
PDPWA at PITZ

> PITZ

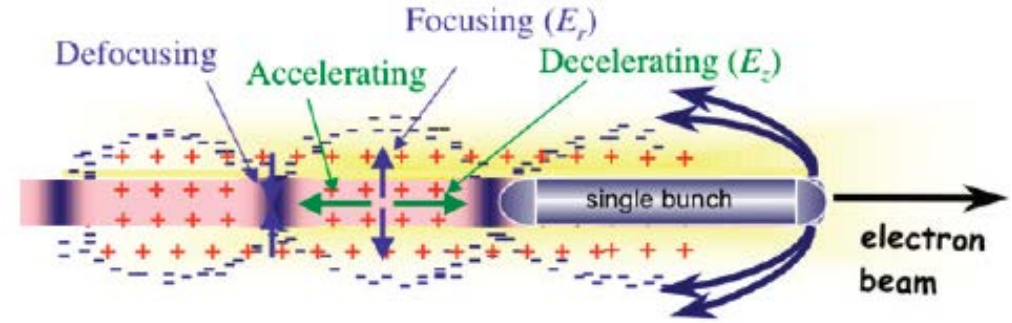
- **P**hoto **I**njector **T**est Facility at DESY, **Z**euthen Site
- To test and to optimize a photo injector to produce high brightness electron beams for free electron lasers (FELs)
- Future direction: study **P**article **D**riven **P**lasma **W**akefield **A**cceleration (PDPWA)

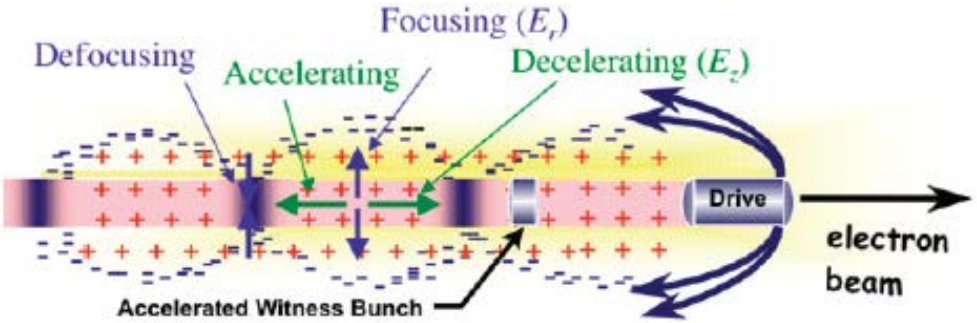


Particle Driven Plasma Wakefield Acceleration (PDPWA)



http://www.symmetrymagazine.org/cms/?pid=1000091, 2012

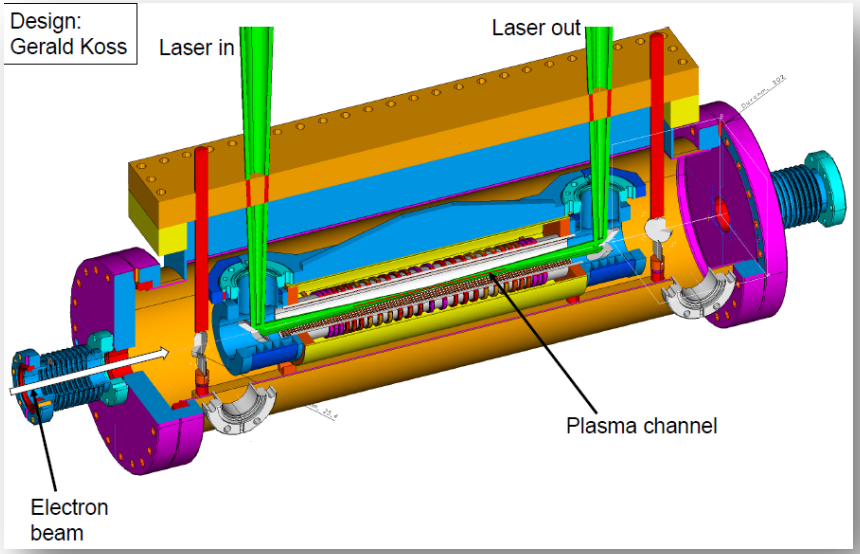


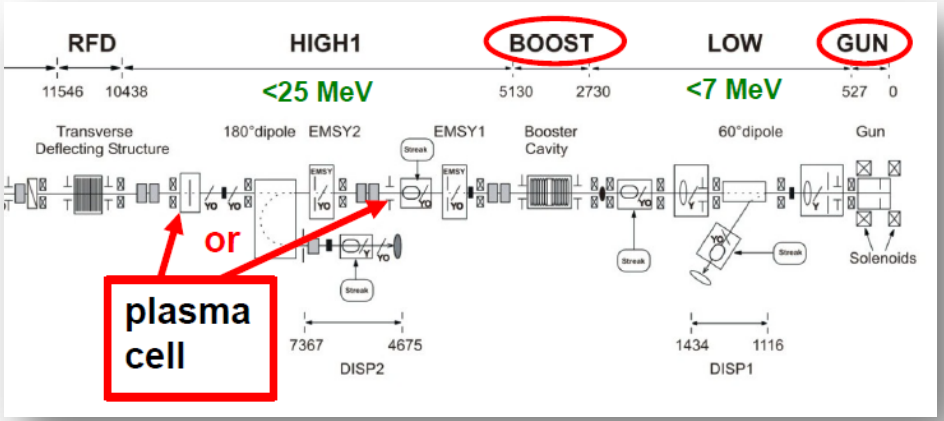


Hogan M J *et al* 2010 Plasma wakefield acceleration experiments at FACET, Nature Physics.

Objectives

- Learning basics of plasma acceleration, laser beam propagation and ionization
- Study **laser ionization** to create plasma channel
  - Laser intensity has to be above a threshold for full ionization
  - Generate simple setup to simulate laser profile in plasma chamber

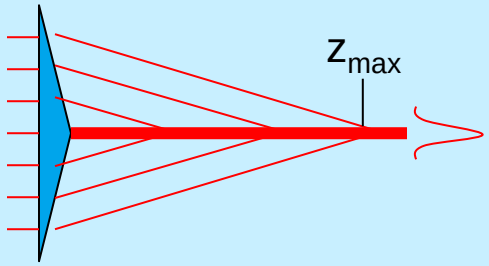




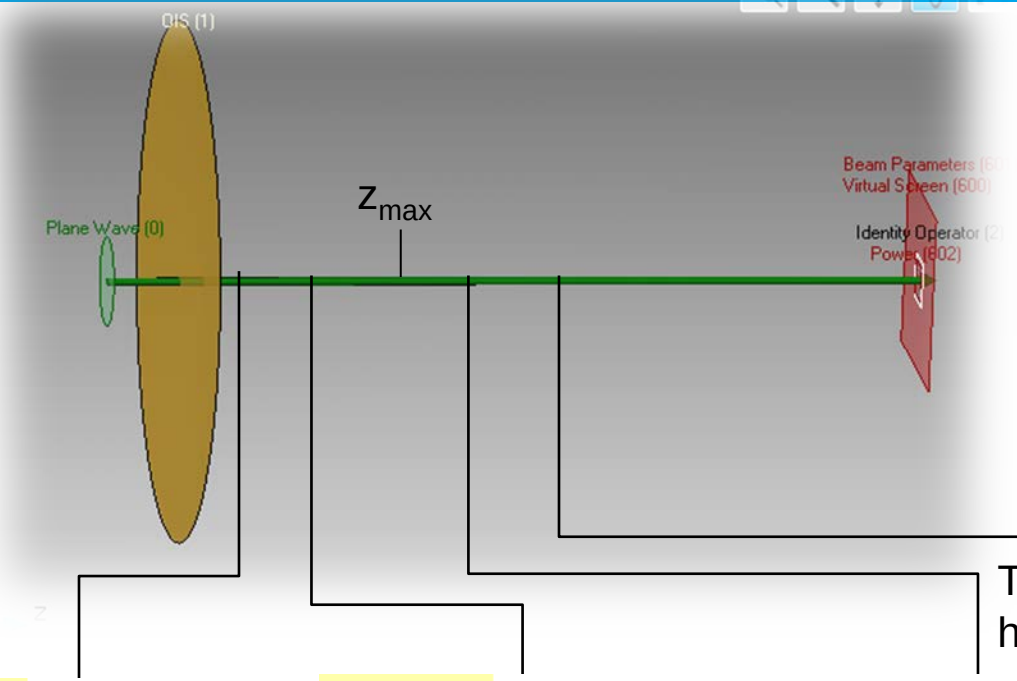
Work Program

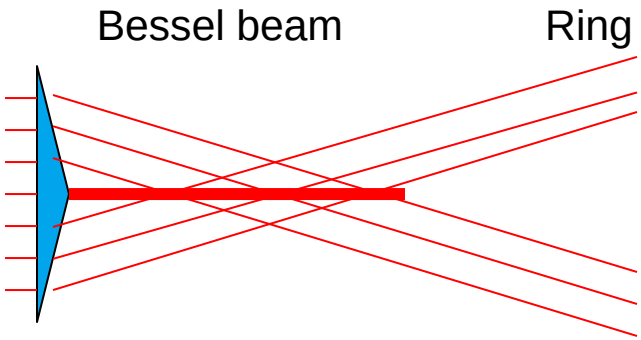
- Use VirtualLab 5 software → **Field tracing**: harmonic fields are traced through an optical system
  - Fully vectorial (Full field information is kept)
  - enables the simulation of optical systems including diffraction, interference, partial coherence, aberrations, polarization and vectorial effects
- Light sources → light → propagate through system → ideal and real components, detectors
- Simulate series of cases:
- Case1: Axicon
  - Bessel beam
- Case2: Gaussian beam
  - Circular obscuration

Axicon: Cone shaped optical device used to create quasi-Bessel beams (diffraction free high intensity region)

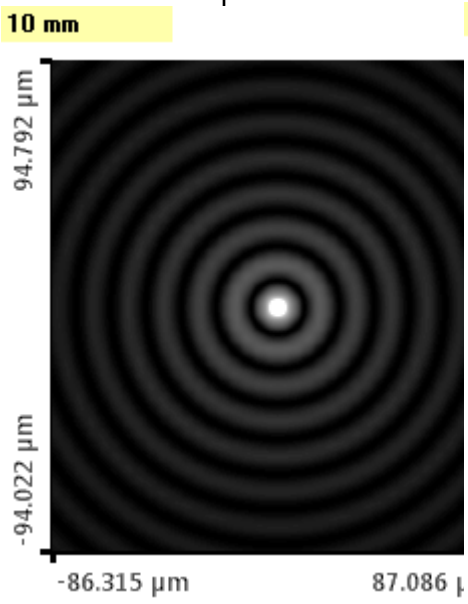


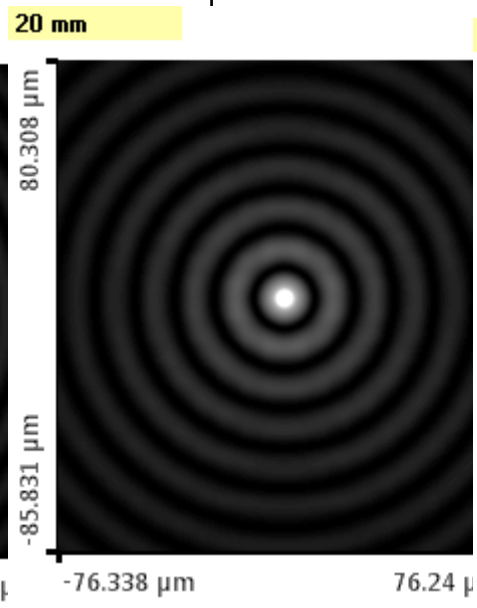
Case 1 : plane wave propagating through an axicon

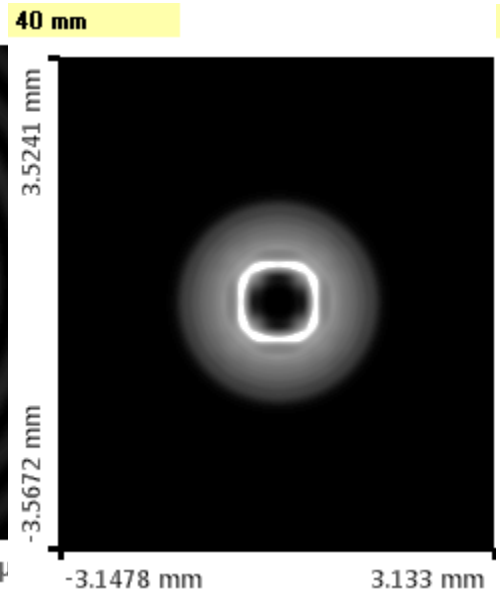


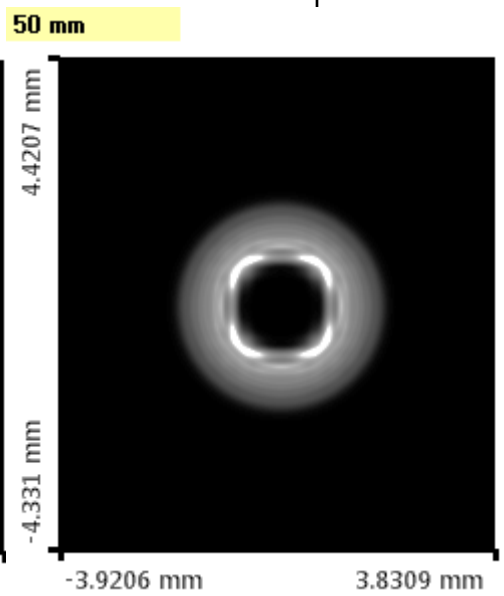


The full version is expected to have a better performance.



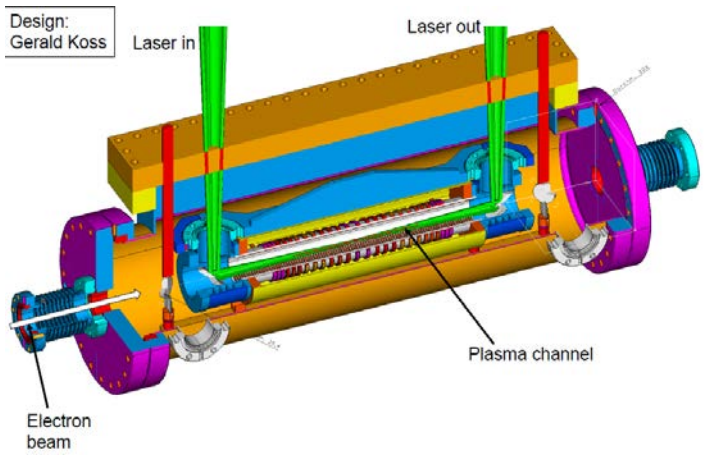


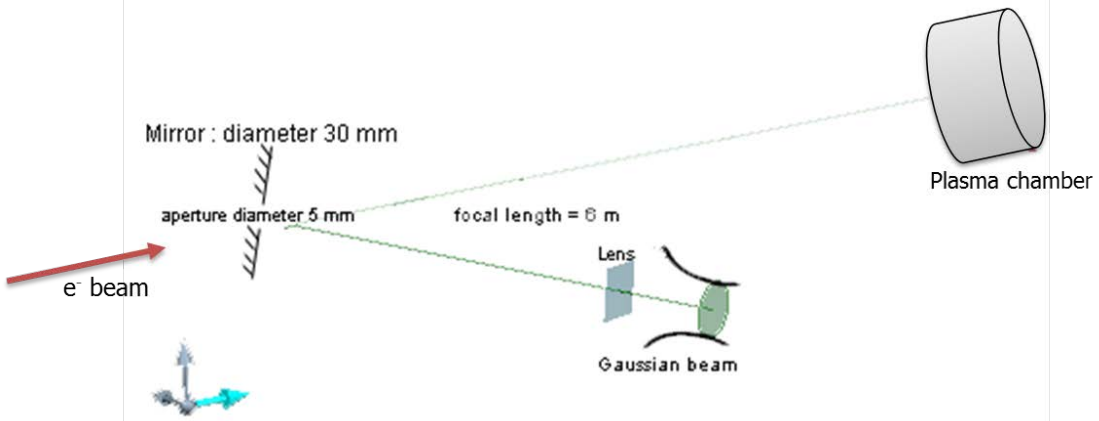


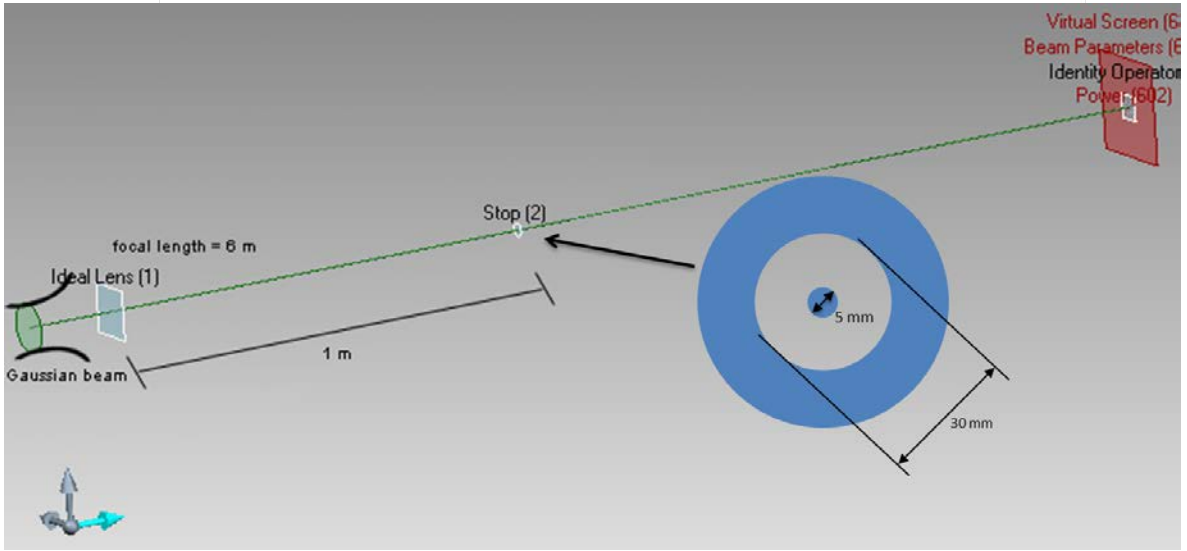


Case 2 is a Gaussian beam propagating through a focusing lens and an aperture.

> The beam waist of the Gaussian beam is placed on the lens front surface).



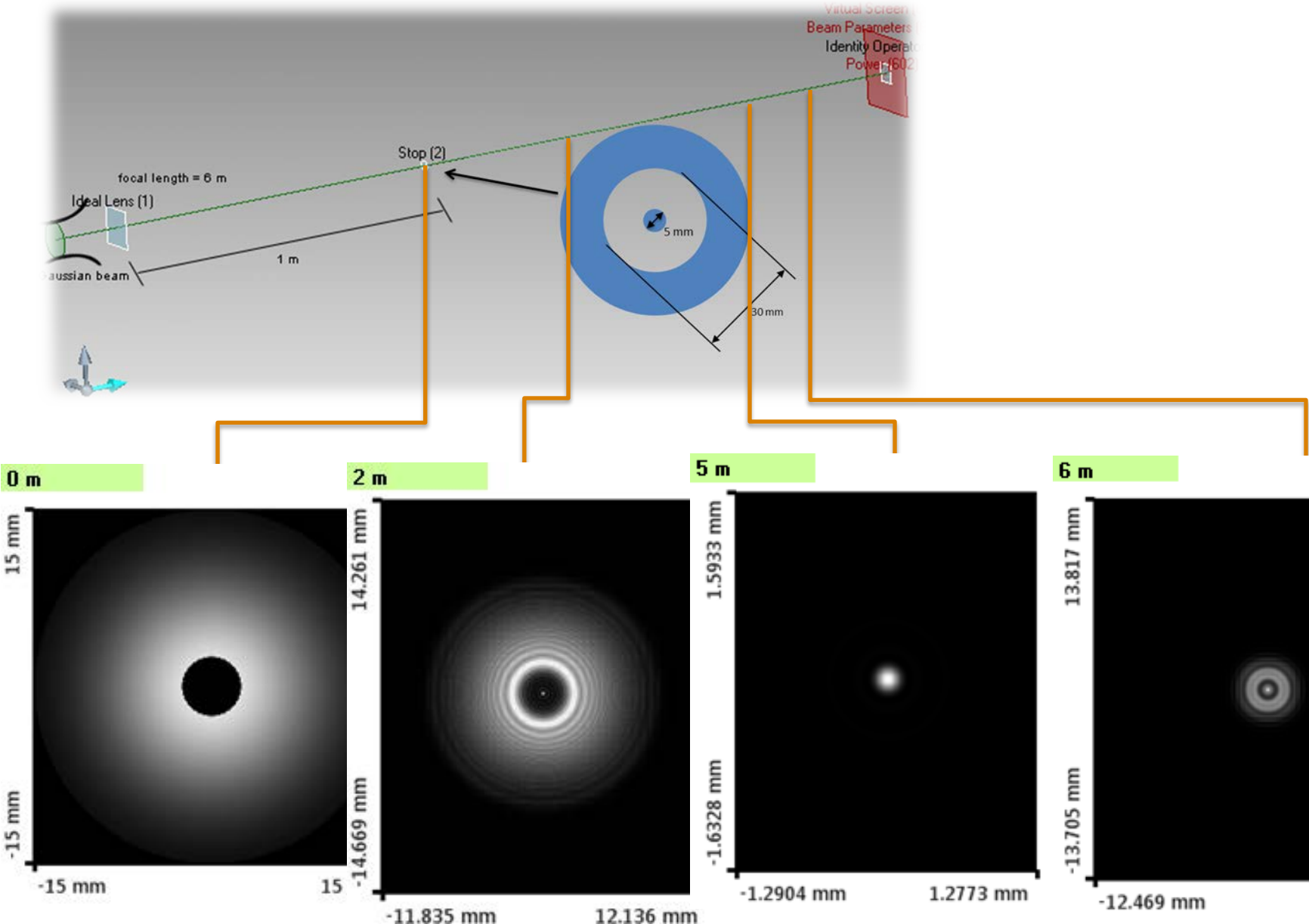




> The two setups are optically equivalent

> Simplified setup is easier to simulate

Case2 : simulation results.



Conclusions

- The basics of plasma acceleration and laser ionization were studied.
- How to use VirtualLab5 software was also studied.
- Case1: Bessel beam region and Ring region correctly simulated (numerical inaccuracies).
  - A better performance of the full version is expected.
- Case2: to understand more about laser propagating through the plasma chamber in the experiment.
  - blocking some part of the beam is equivalent to the setup of the experiment;
  - When it propagates far away of the focal point, there exists no beam propagating at the center of the Virtual Screen.
  - plasma chamber should be set around the focal point.

References

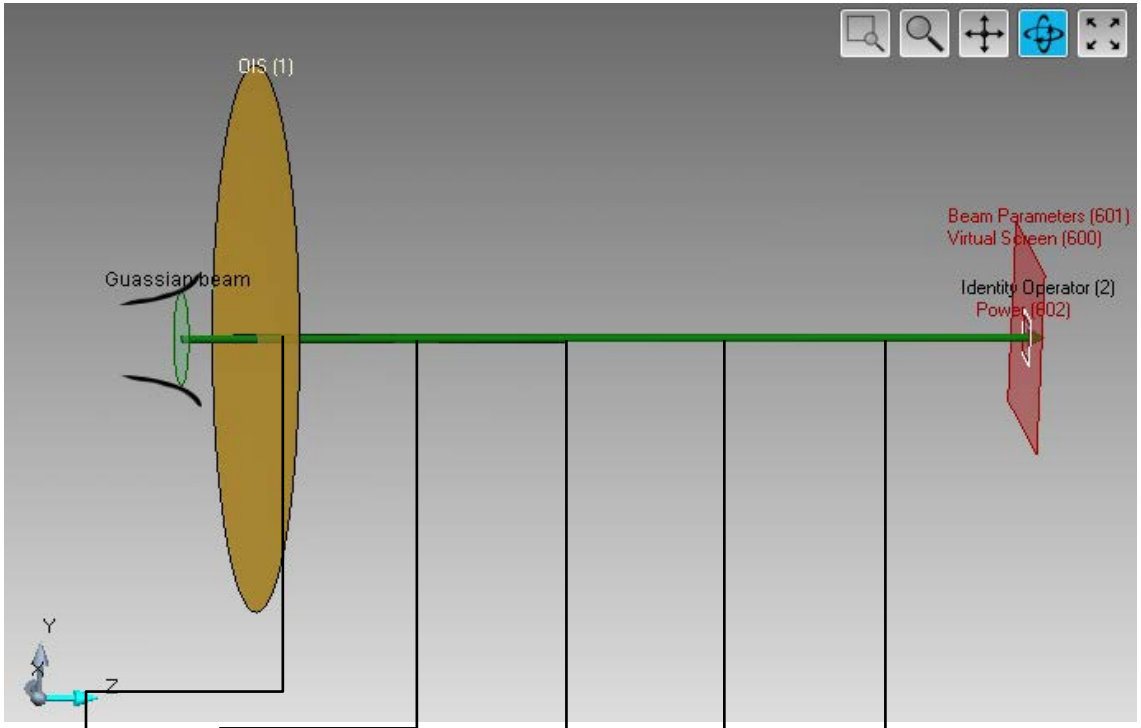
- [1] Web-site of PITZ http://pitz.desy.de/
- [2] M. J. Hogan, et al, Plasma wakefield acceleration experiments at FACET, New Journal of Physics 12, 2010.
- [3] W. Leemans, Laser-driven plasma-wave electron accelerators, Physics Today, March 2009.
- [4] M. E. Wright, Riding the Plasma Wave of the Future, symmetry, April 2005.
- [5] O. Brzobohaty, et al, High quality quasi-Bessel beam generated by round-tip axicon, OPTICS EXPRESS, August 2008.
- [6] Web-site of Lighttrans Company http://www.lighttrans.com/home.html

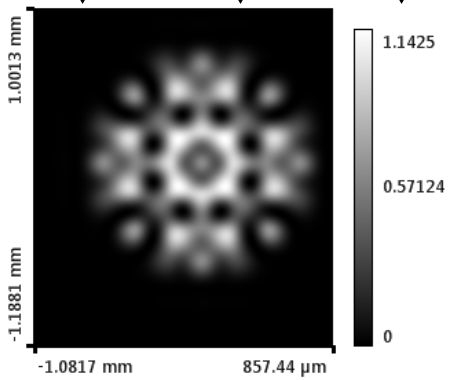
End

> Thank you for your attention.

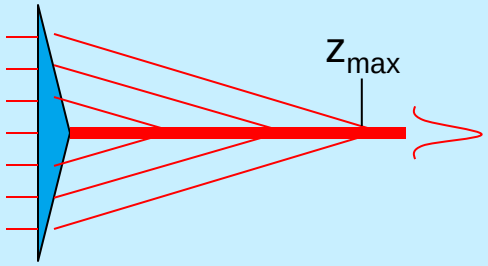
> Backup

Case 0 : a Gaussian beam propagating through an axicon (z_{max} = 54.228 mm)





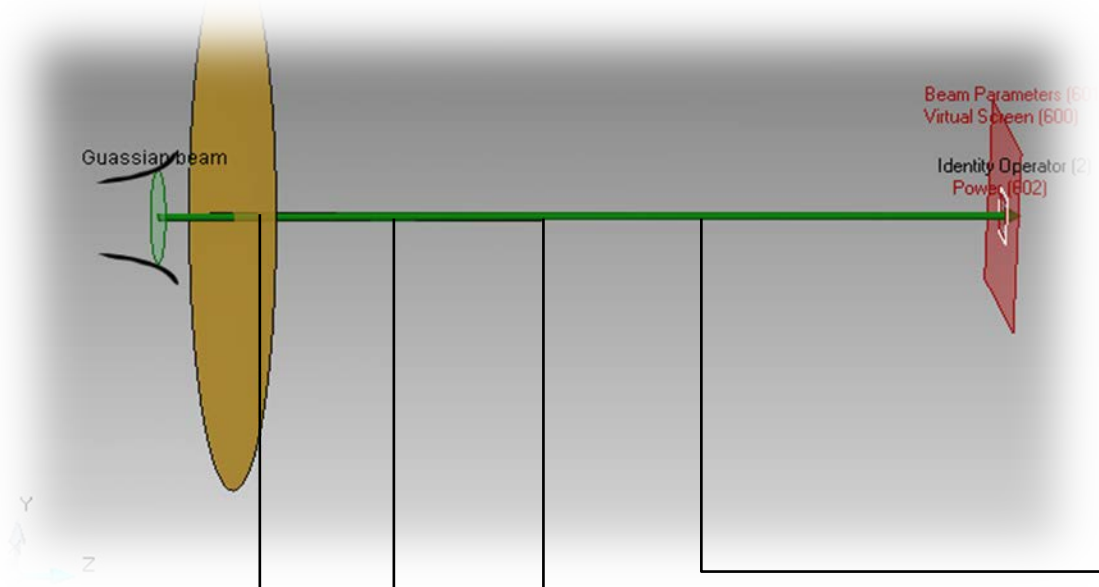
Axicon: Cone shaped optical device used to create quasi-Bessel beams (diffraction free high intensity region)



non-circular symmetric structures on Virtual screens (Squared amplitude plot)

→ increase the numerical accuracy factor of the axicon

Case 0 : Gaussian beam propagating through an axicon (z_{max} = 54.228 mm)



the Bessel beam region as the squared amplitude on Virtual Screens before z_{max}

the trial version is limiting the memory to calculate, for a complicated object like case 1

→ → simpler setup