Non Neutral Plasma Physics Group

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NNP Non Neutral Plasma Physics Group

IAP

HIC for FAIR Helmholtz International Center

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Investigation of Diagnostic Techniques on a Nonneutral Plasma

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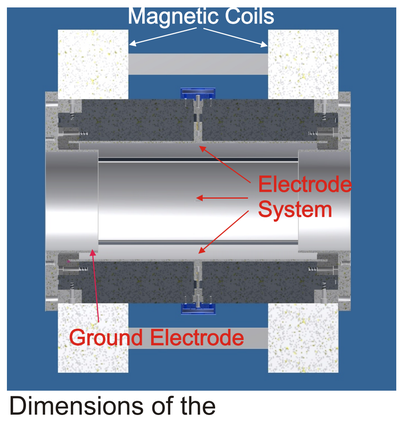
Abstract

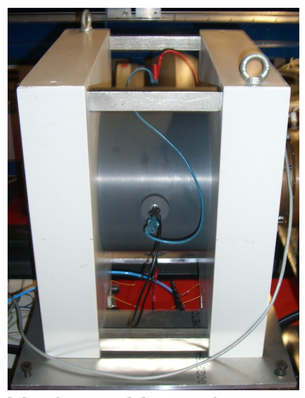
Space charge lenses use a confined electron cloud for the focusing of ion beams. The focusing strength is given by the electron density whereas the density distribution influences the mapping quality of the space charge lens and is related to the confinement.
The plasma parameters, loss as well as production mechanisms have a strong impact on plasma beam interactions. A scaled up space charge lens was constructed to investigate the properties of a nonneutral plasma in detail.
New non-interceptive diagnostic has been developed to characterize the collective behaviour of the confined nonneutral plasma in terms of an optimized lens design and parameters.
Experimental results will be presented in comparison with numerical simulations.

Space Charge Lens



Dimensions of the Space Charge Lens:

r_{anode} :	85 mm
r_{ground} :	75 mm
l_{anode} :	340 mm
L_{total} :	436 mm

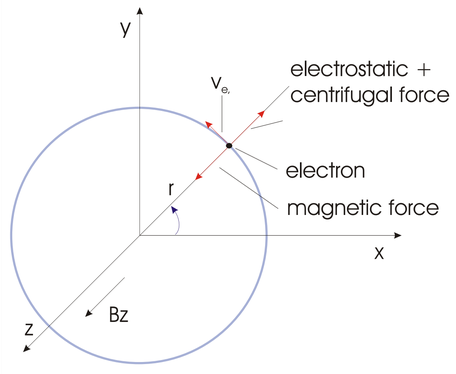


Maximum Magnetic Field and Potential:

$B_{z,max}$:	160 mT
$_{A,max}$:	50 kV

Confinement Principle of the Space Charge Lens

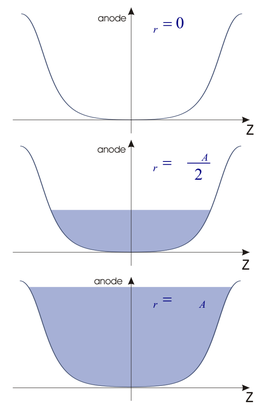
Radial



$$n_e = \frac{{}_0 B_z^2}{2m_e}$$

radial force balance for an axicentred, circular electron orbit

Longitudinal



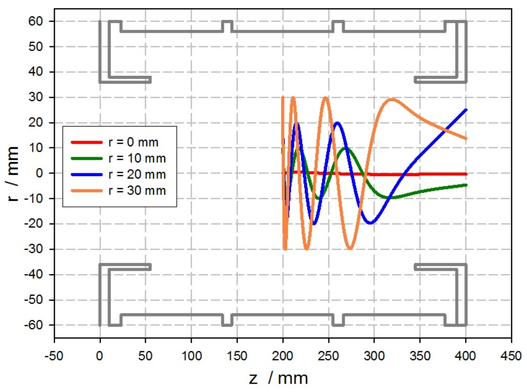
$$n_e = \frac{4 \ {}_0}{er^2}$$

potential depression by filling with electrons

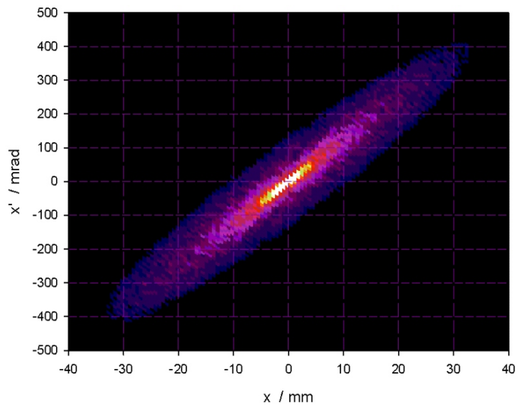
Diagnostics and Experiments

Electron Density Measurement

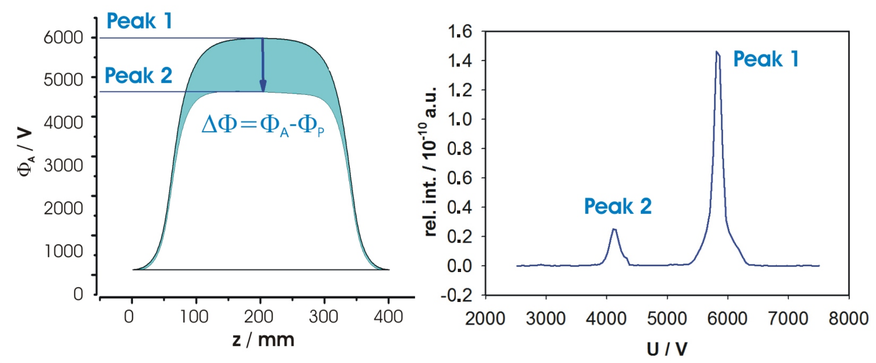
Calculated Trajectories of Emitted Residual Gas Ions

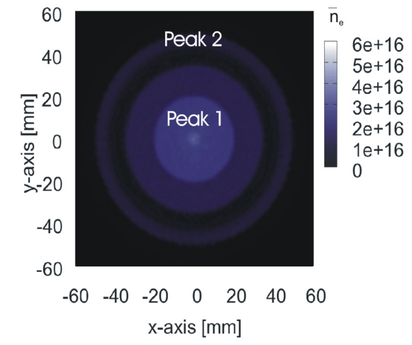


Calculated Phase Space Distribution of Residual Gas Ions

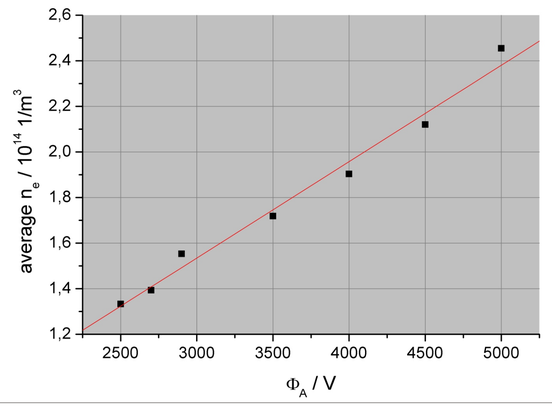


Principle of Electron Density Measurement due to Detected Ion Current

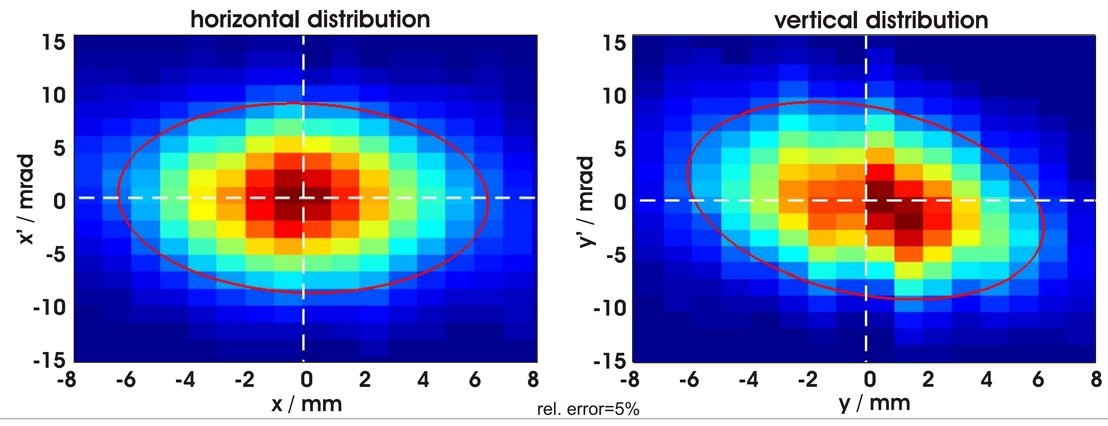




Measured Average Electron Density



Pepperpot Emittance Measurement of Residual Gas Ions



rel. error=5%

lens parameters:
B_z=8.3 mT
$_A$=2000 V
p=6.0e-5 hPa (He)

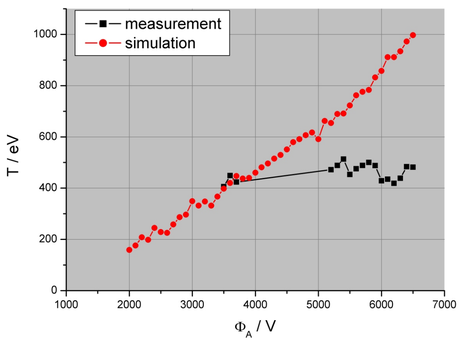
$_{x, 90\%}$ = 56.5 mm mrad
=0.05
=0.74 mm/mrad
=1.36 mrad/mm

$_{y, 90\%}$ = 54.6 mm mrad
=0.29
=0.70 mm/mrad
=1.56 mrad/mm

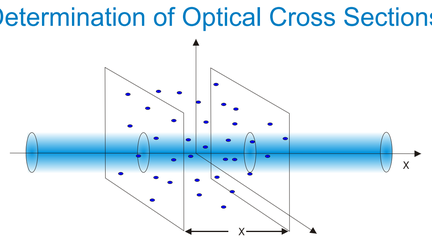
Electron Temperature Measurement

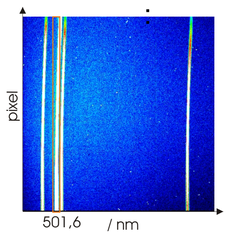
Because of low electron densities (10^{14} m^{-3}) and by absence of important recombination processes like three body recombination and radiative recombination the nonneutral plasma cannot be assumed in thermodynamic equilibrium. Therefore, the requirements for a typical temperature measurement are not fulfilled. Currently it is under investigation to determine the electron temperature by measuring the ratio of two optical cross sections of excited states in the helium.

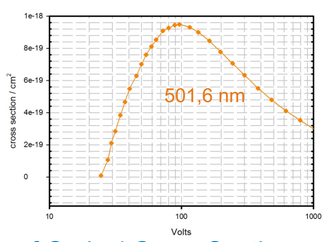
Measured Temperature Compared to Numerical Simulation



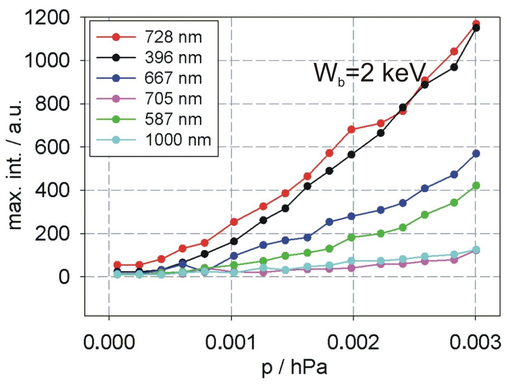
Determination of Optical Cross Sections



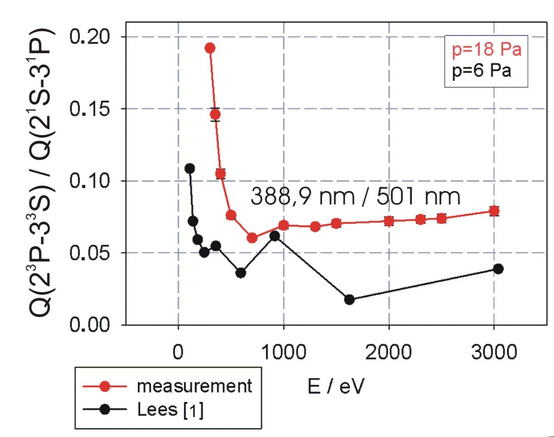




Pressure Dependency of Intensity

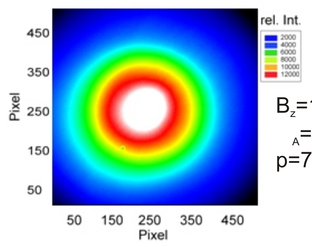


Ratio of Optical Cross Sections

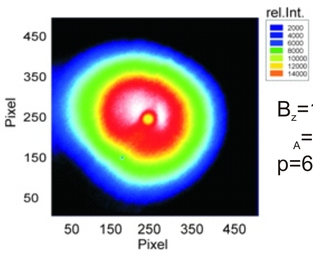


Time-resolved Diagnostics

Pressure Dependency

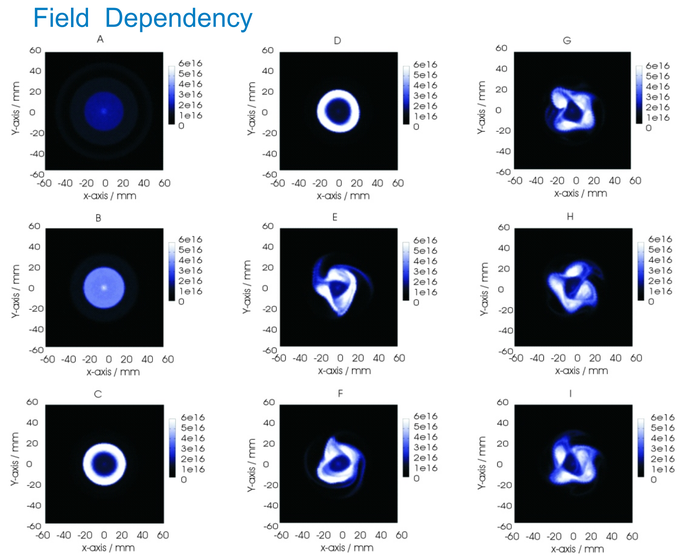


B_z=12.1 mT
$_A$=6500 V
p=7.8e-5 hPa (He)

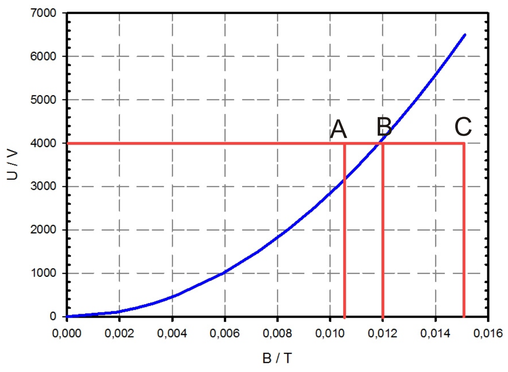


B_z=12.1 mT
$_A$=6000 V
p=6.0e-4 hPa (He)

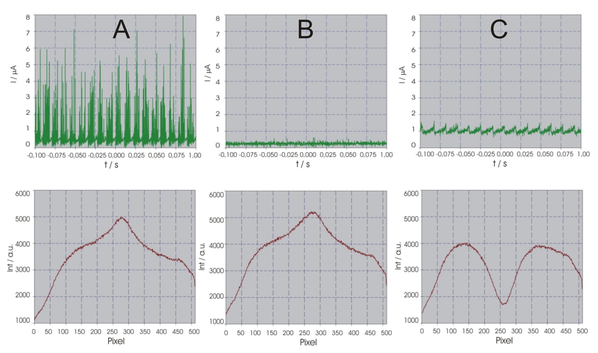
Field Dependency



Work Function of Space Charge Lens



State of Space Charge Cloud due to the Enclosing Fields



B=10,6 mT B=11,8 mT B=15,2 mT

lens parameters:
$_A$=4000 V
p=6.0e-4 hPa (He)

[1] J.H. Lees “The Excitation Function of Helium”, H. H. Wills Physical Laboratory, University of Bristol, 1932, p. 173-186.