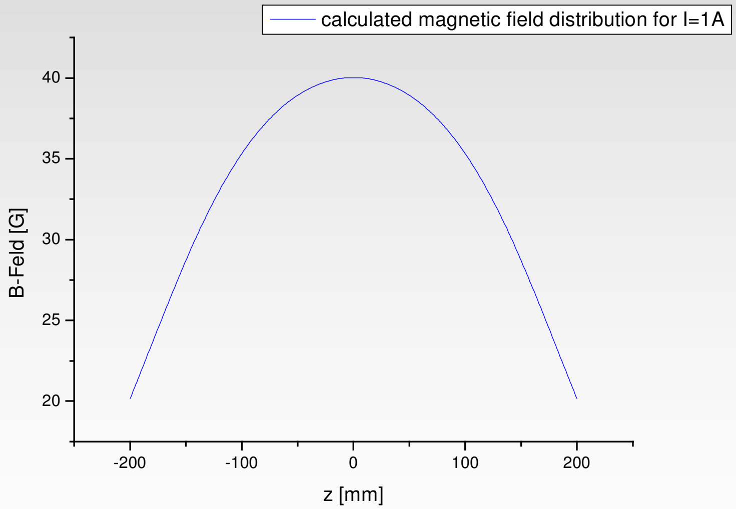
Plasma Diagnostics on a Confined Nonneutral Plasma Column

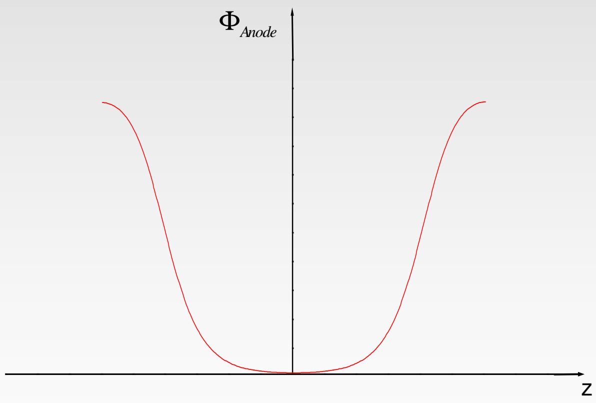
Content

I.1. Concept of the Gabor Lens

- **Radial Confinement:**
  axial magnetic field produced by Helmholtz coils

- **Longitudinal Confinement:**
  electrode system of the Gabor lens excites a potential in longitudinal direction



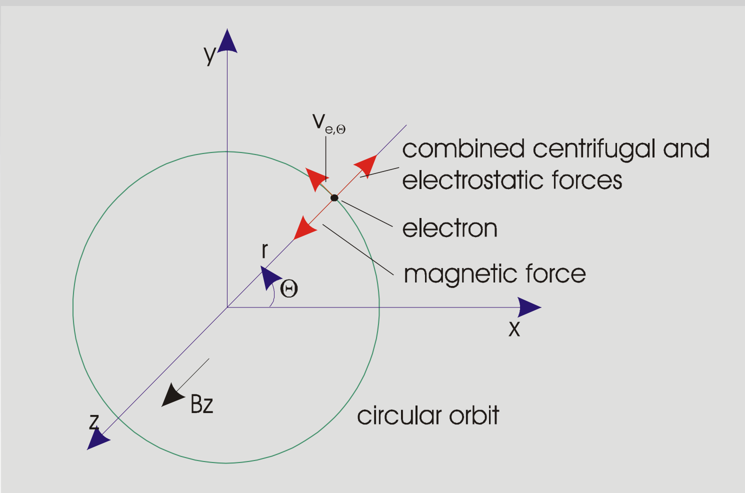


I.2. Concept of the Gabor Lens

Radial Confinement

Force Balance equation of a trapped cold nonneutral plasma in the transversal section:

$$\frac{-m_e v_{e,\Theta}^2}{r} = -eE_r - ev_{e,\Theta}B_z$$



$$\omega_e = \frac{v_{e,\Theta}}{r}$$ **angular velocity**

$$\omega_e = \omega^{\pm} = \frac{\Omega_e}{2}\left[1 \pm \left(1 - \frac{2\omega_{pe}^2}{\Omega_e^2}\right)^{\frac{1}{2}}\right]$$

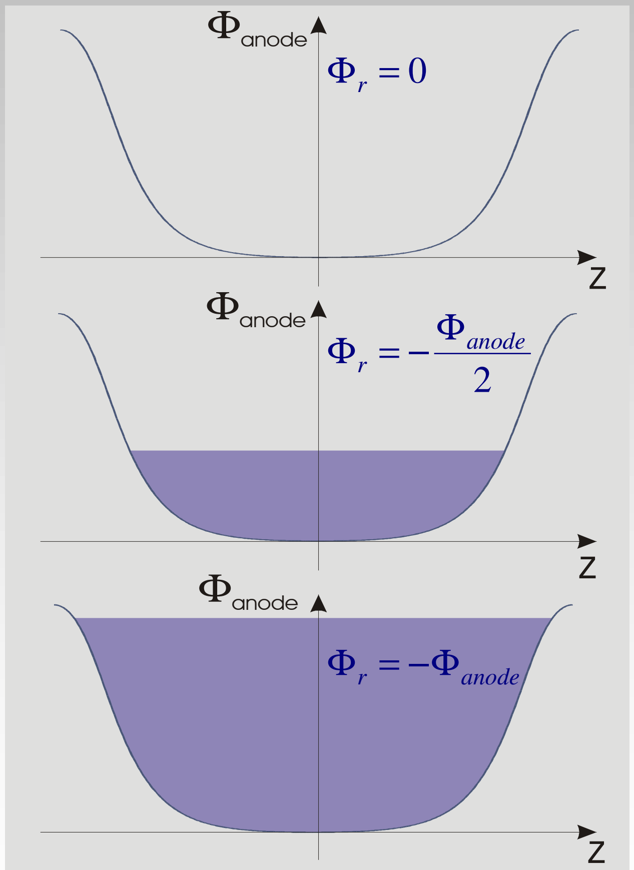
$$\omega_{pe}^2 = \frac{e^2 n_e}{\varepsilon_0 m_e}$$ **plasma frequency**

$$\Omega_e = \frac{eB_z}{m_e}$$ **cyclotron frequency**

maximum density by a trapping efficiency of $\kappa_r = \frac{2\omega_{pe}^2}{\Omega_e^2} = 1$

I.3. Concept of the Gabor Lens

Longitudinal Confinement



Φ_r is determined from Poisson's equation:

$$-\frac{1}{r}\frac{\partial \Phi_r}{\partial r} - \frac{\partial^2 \Phi_r}{\partial r^2} = \frac{e n_e(r)}{\varepsilon_0}$$

integrated for $0 < r < R_p$

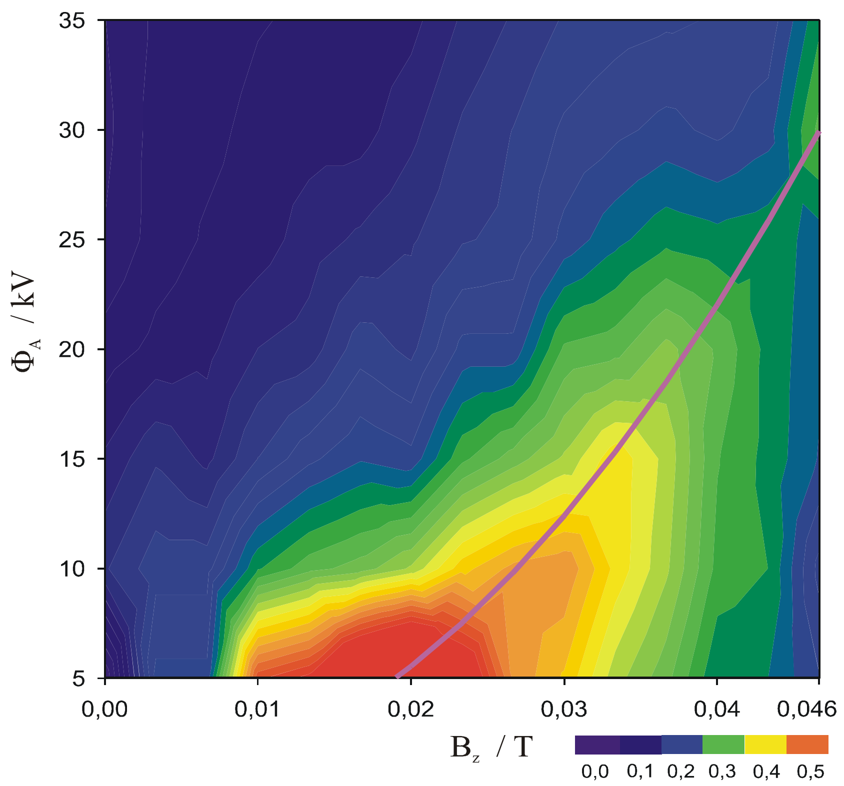
$$\Phi_r = -\frac{e n_e r^2}{4\varepsilon_0}$$

trapping efficiency: $\kappa_l = \frac{\Phi_r}{\Phi_{anode}}$

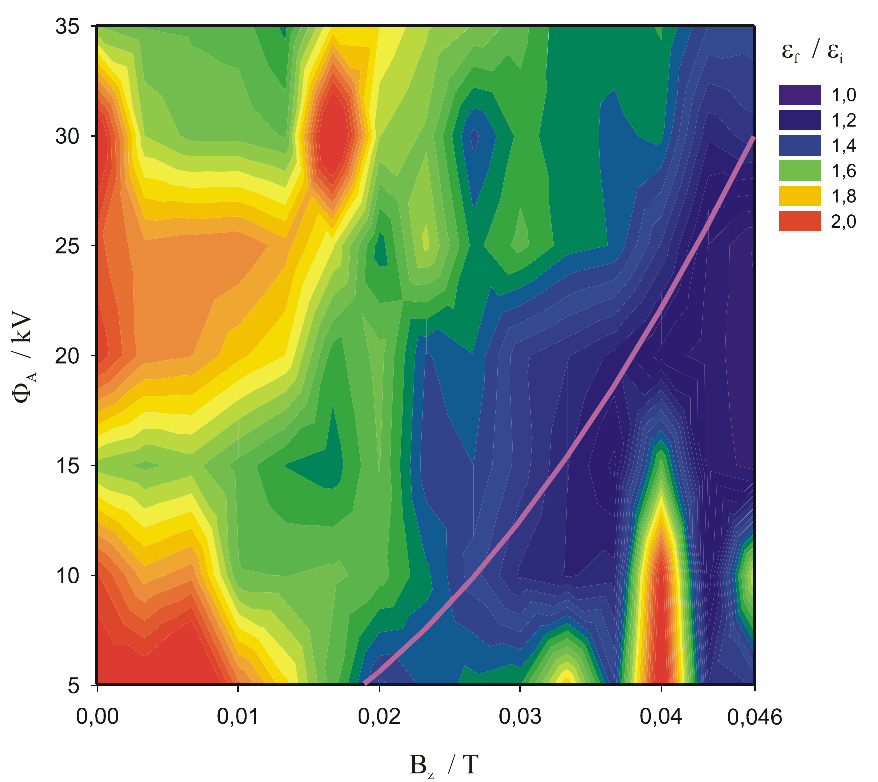
$\Rightarrow$ maximum density at $\Phi_{anode} = -\Phi_r$

II. Motivation of the Diploma Thesis

Results of the beam transport experiments

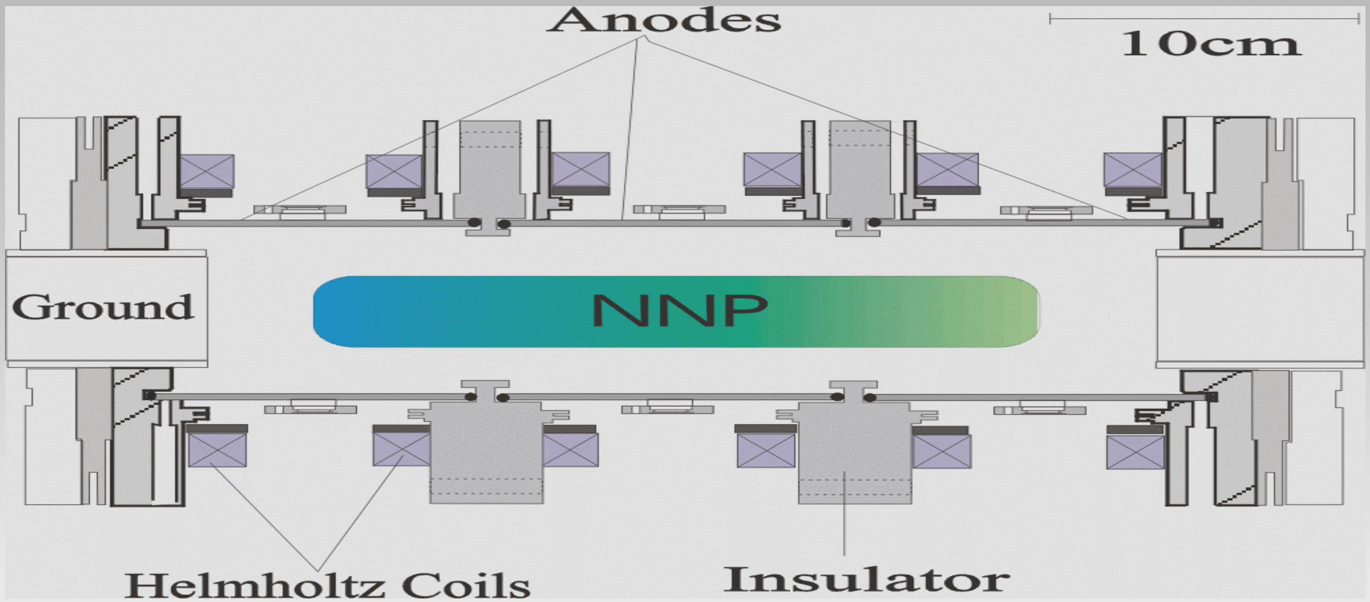


experimental appraised filling degree of the Gabor lens as a function of the lens parameters



Measured emittance growth as a function of the external fields using a high field Gabor lens and a 440 keV He^+ beam

III.1. Design of the Gabor Lens



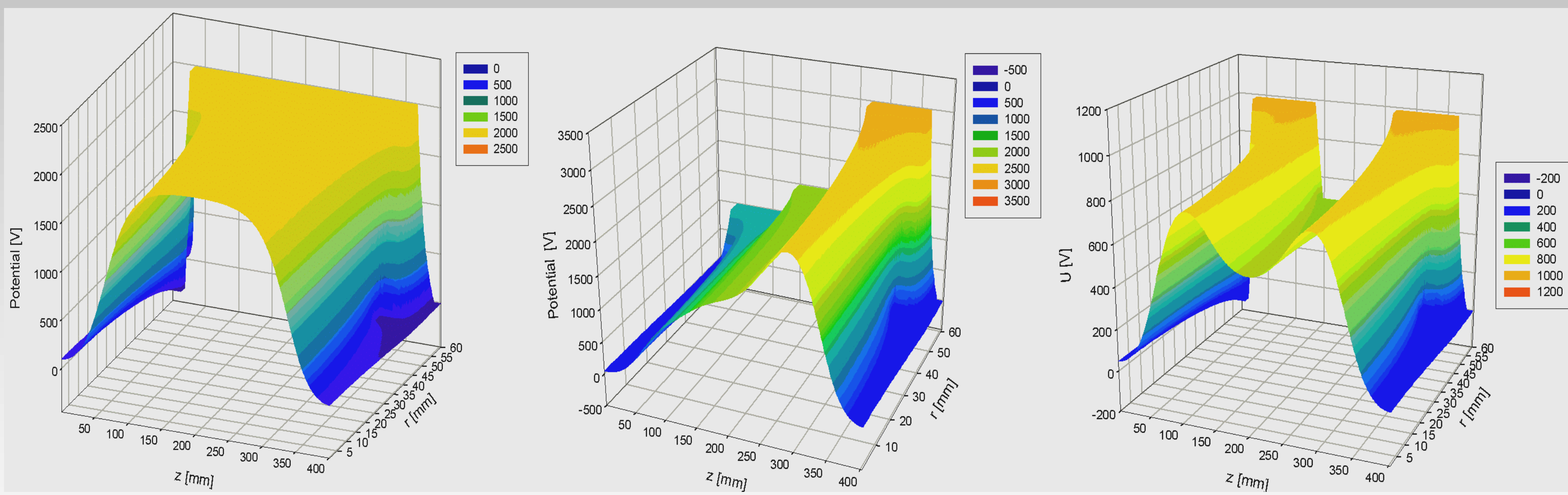
- **3 electrodes** and
- **3 Helmholtzs coils**

  for generation of field gradients/temperature gradients
- **sight glass**

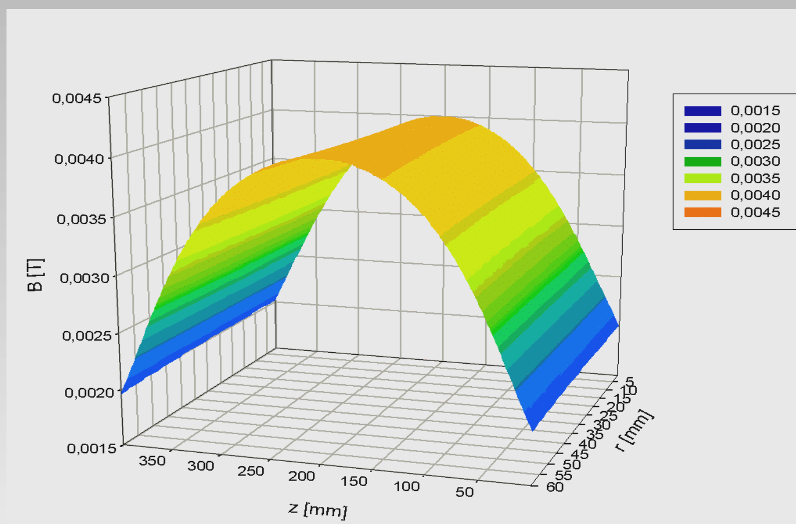
  for insight in the longitudinal section

III.2. Design of the Gabor lens

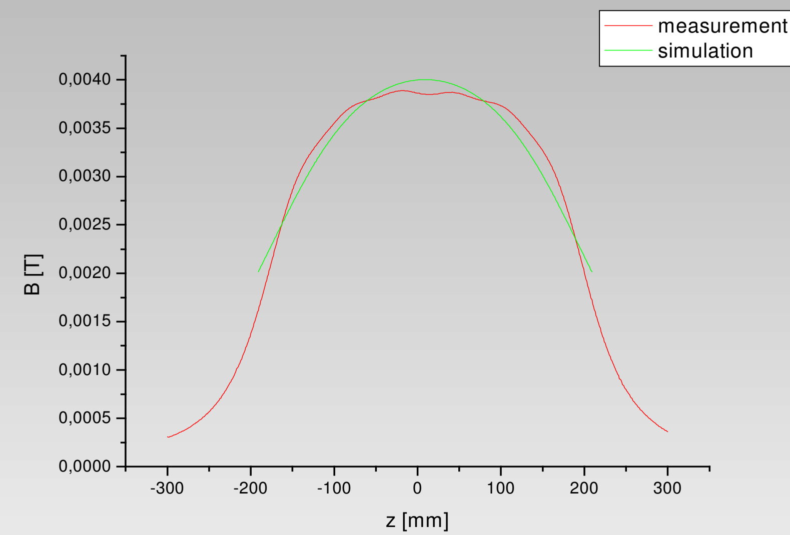
calculated potential at different anode voltages:



III.3. Design of the Gabor Lens

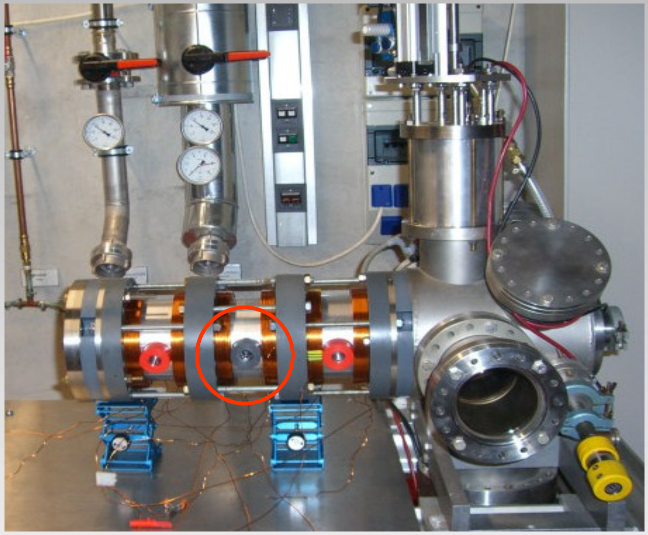


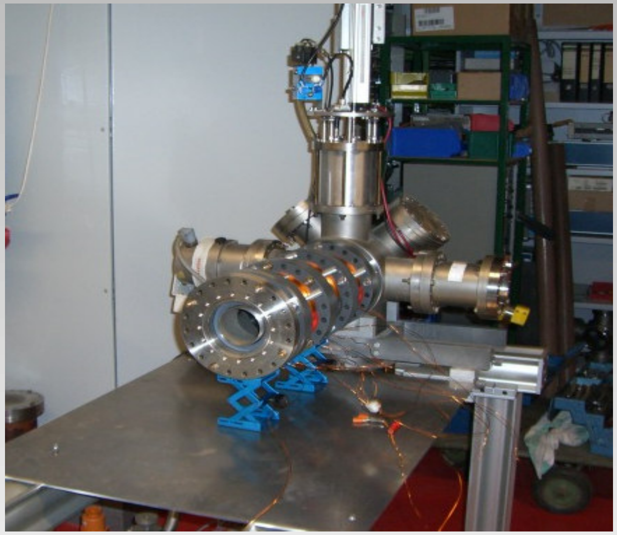
calculated magnetic field by GaborM



measured and calculated magnetic field

III.4. Design of the Gabor Lens





•maximum potential: $\Phi_A = 6000V$

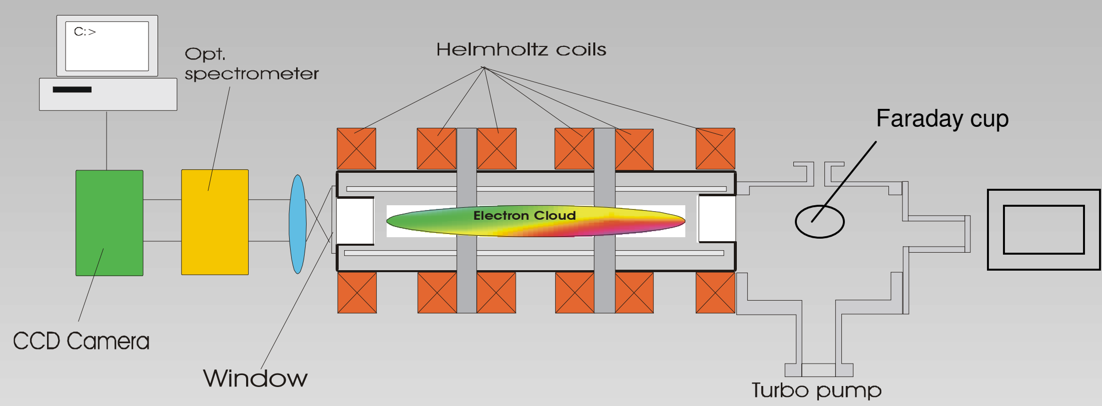
•maximum magnetic field: $B_z = 0{,}012T$

IV. Production mechanism

1. several residual gas atoms are ionised by natural radioactivity or cosmos radiation in the lens volume: $\gamma + \text{RGA} \rightarrow \text{RGI} + \text{e} + \gamma'$
2. in the electric field the produced residual gas ions are accelerated out of the Gabor lens and on their way they are able to ionise other residual gas atoms: $\text{e} + \text{RGA} \rightarrow \text{RGI} + 2\text{e}$
3. additionally electrons are produced at interaction of high energy gamma-quanta with the surface of the electrode:

   $\text{RGI} + \text{RGA} \rightarrow 2\text{RGI} + \text{e}$

V.1. Diagnostic Investigation

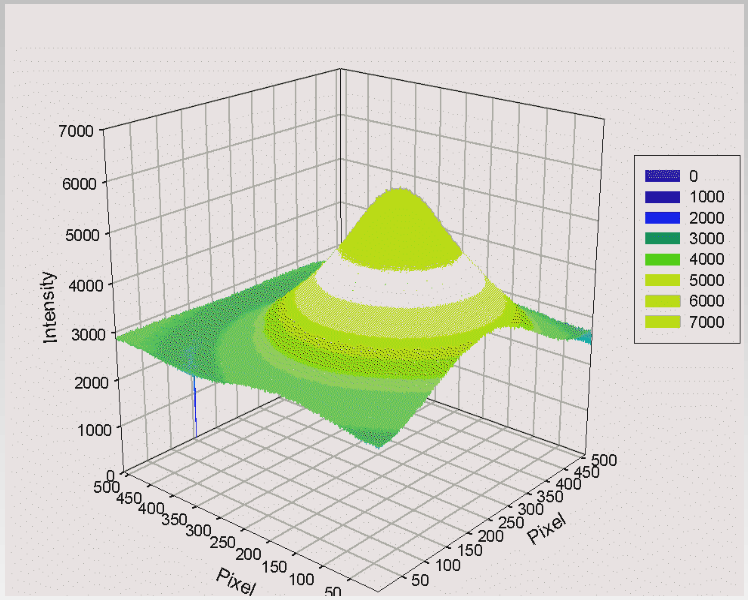


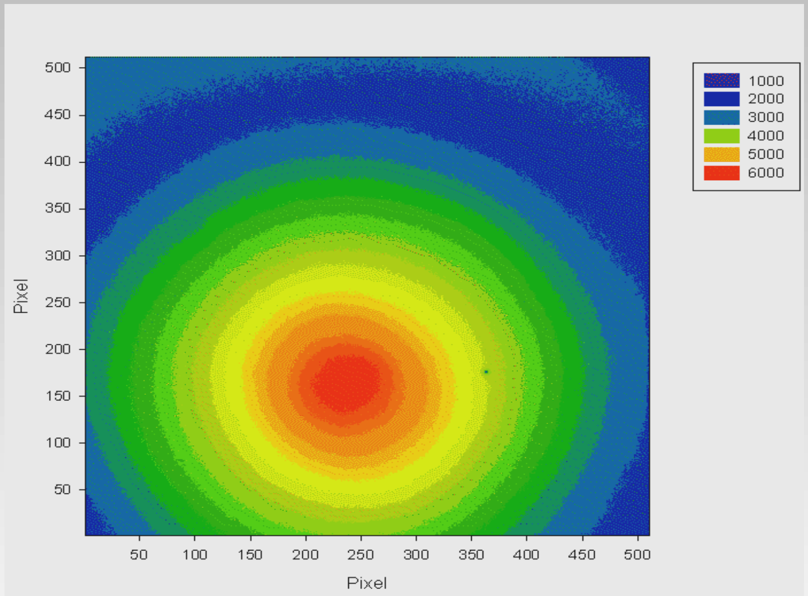
Determination of the plasma parameters dependance on external fields:

- optical methodes e.g. CCD and monochromator exposure of the light emitted by residual gas
- momentum spectroscopy of the loss electrons and the residual gas ions

V.2. Diagnostic Investigation

Luminance distribution





U = 4000 V

B = 0,01 T

p = 5 10^{-5} hPa

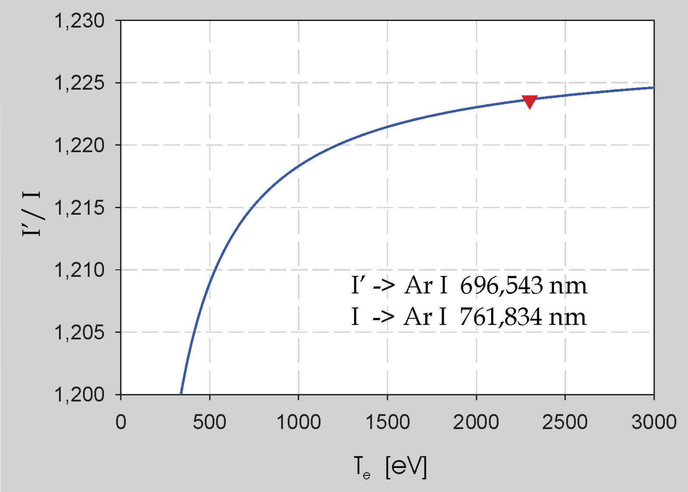
V.3. Diagnostic Investigation

- Investigation of the temperature:
  Relative intensities of lines from the same element and ionization stage

$$k_b T_e = \frac{E' - E}{\ln\left(\frac{I\lambda^3 g'f'}{I'\lambda'^3 gf}\right)}$$

Griem, Plasma Spectroscopy,1964

I total intensity
g statistical weight of the lower state of the line
f absorption oscillator strength



intensity ratio as a function of the temperature

VI. Outlook

1. determination of plasma temperature
2. investigation of plasma density dependance on external field
3. numerical calculated density
4. estimating the degree of thermalisation stage