Research of Diagnostic Techniques on a Nonneutral Plasma

Content

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II. Motivation

Thermodynamic Equilibrium (TE)

TE -when every process is in equilibrium with its converse

a+e ⟷ a*+e

a+e ⟷ i+e+e

a+hv ⟷ a*

a+hv ⟷ i+e

- Sahaequation
- Boltzmannequation

Nonneutral Plasma

- electron density ~ 10^{14} 1/m^3

  minimum density (He,T=100eV):

$$n_e \geq 9 \cdot 10^{23} \left(\frac{E_2}{E_H} \right)^3 \sqrt{\frac{kT}{E_H}} \frac{1}{m^3}$$

$$n_e \geq 9{,}78 \cdot 10^{23} \frac{1}{m^3} \text{ (Griem)}$$

- ion loss, no 3-body recombination
- ion loss, no radiative recombination

→ **Corona- /Collisional Radiative-Model**

→ **Thermalisation**

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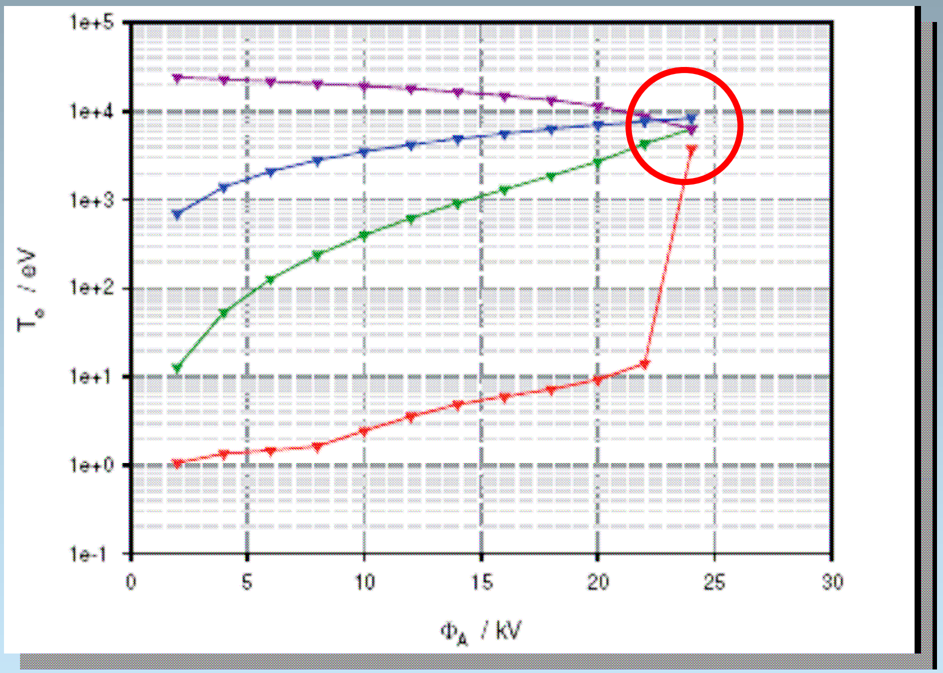
Thermalisation

- homogeneous electron density distribution
- equality of longitudinal and radial average kinetic energy



average kinetic energy of electrons by optical diagnosis

calculated average kinetic energy of electrons

cyclotron frequency

ExB rotation

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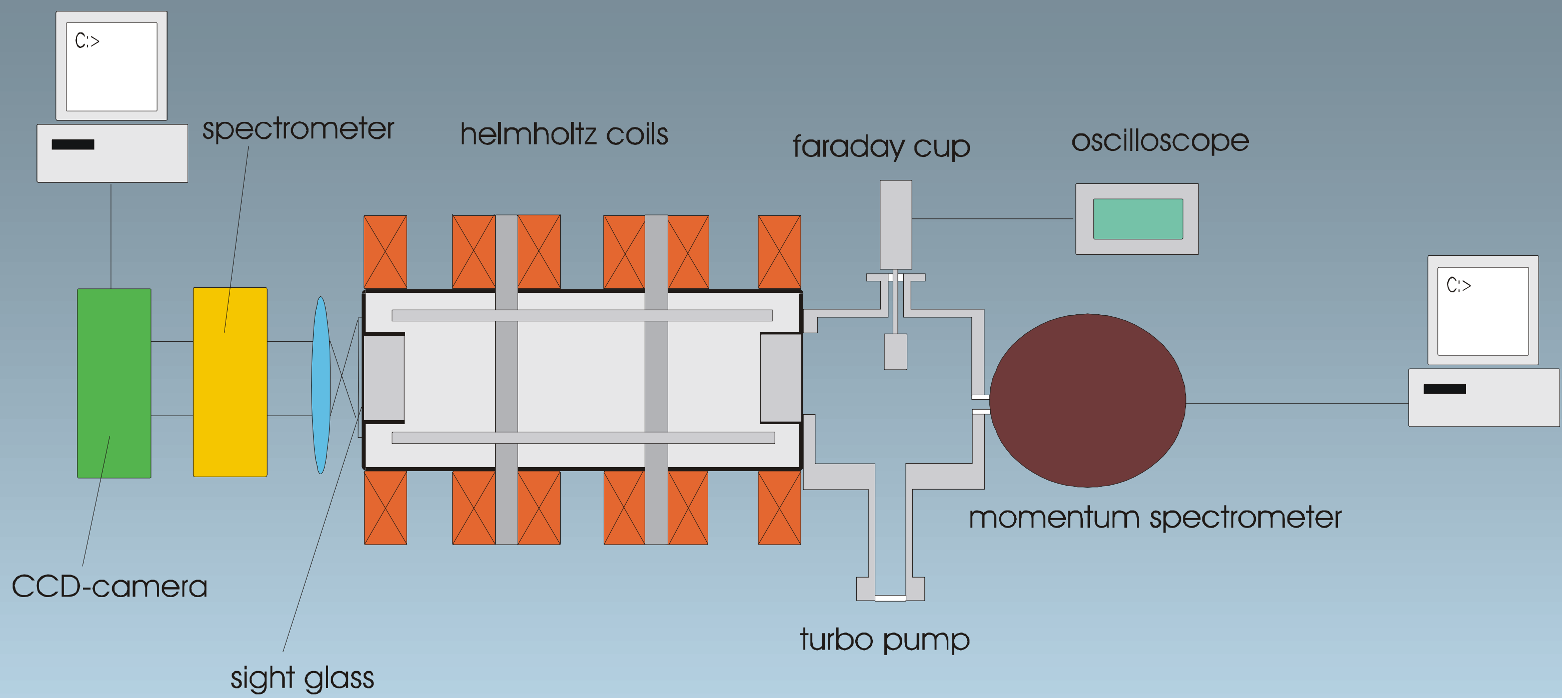
I. Experimental Setup



Determination of the plasma parameters dependence on external fields:

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

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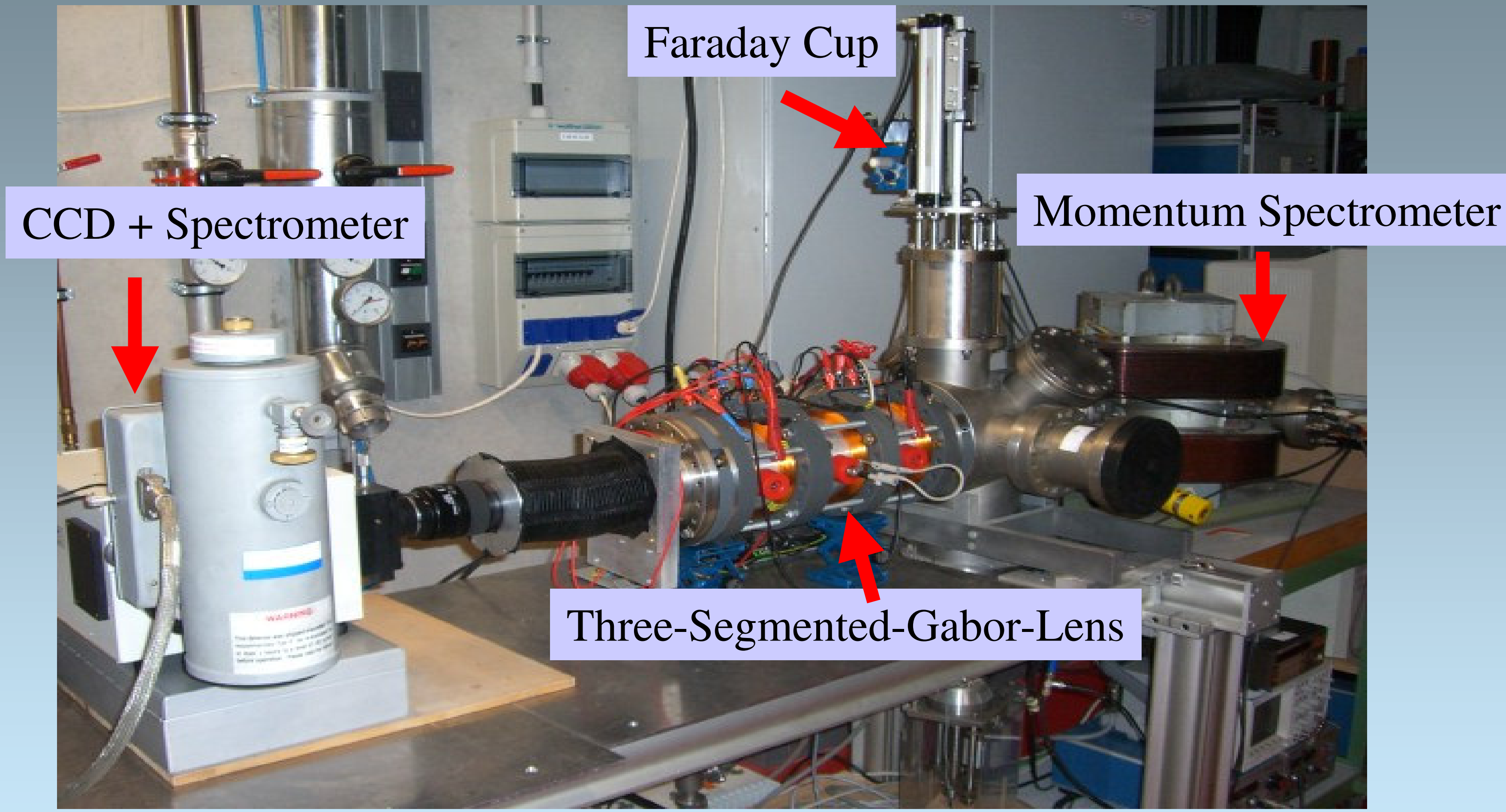
I. Experimental Setup



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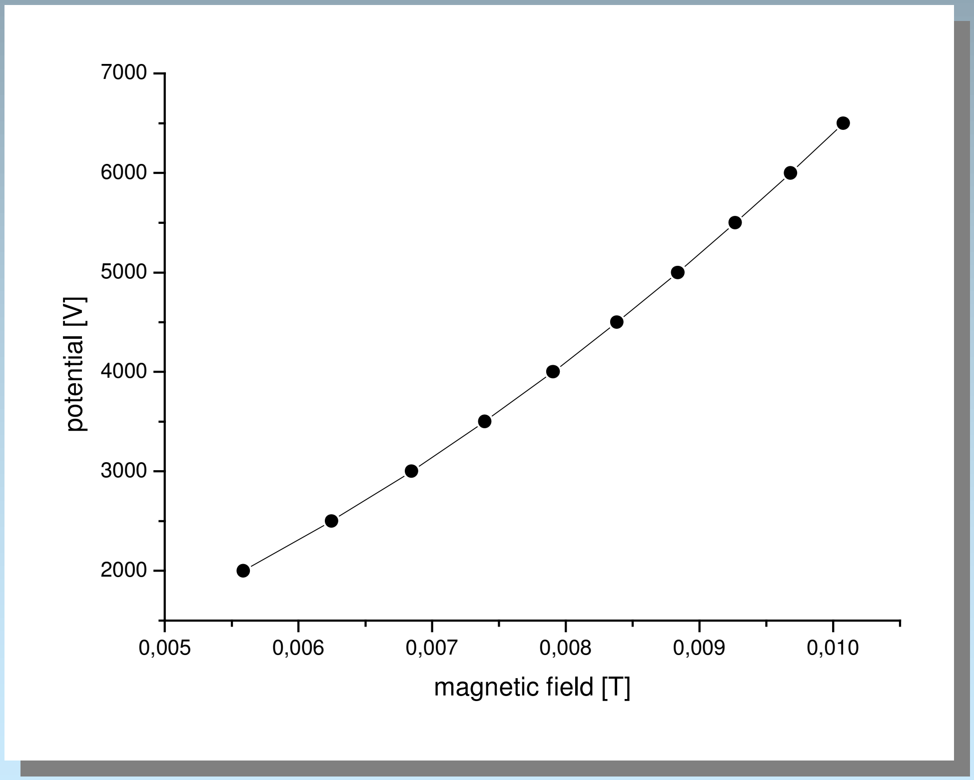
Confinement

The NNP is assumed to be thermalized with similar strengths in longiutudinal & radial confinment.

Confinement Condition: $\Phi_A = \dfrac{e r_{anode}^2 B_z^2}{8 m_e}$ ← corrected by



1. radius
2. residual gas pressure

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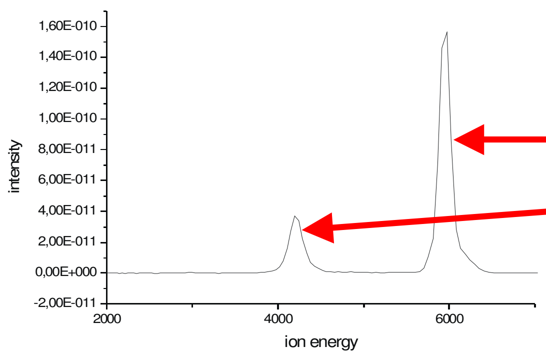
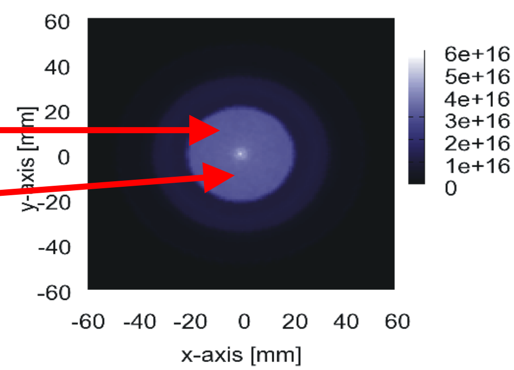
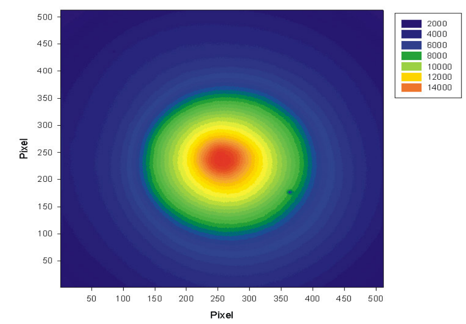
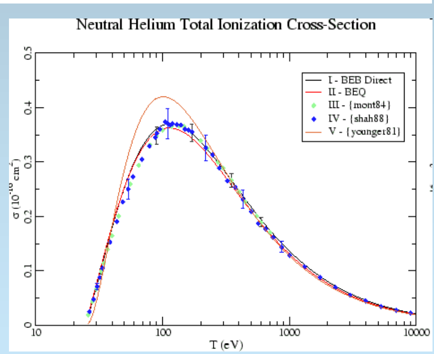
Residual Gas Pressure







The residual gas pressure affects the rate ion production R_c.



$$R_c = n_e v_{iz} = n_e n_n \left(\frac{2}{m_e}\right)^{\frac{1}{2}} \int_0^{\infty} \left(\frac{2E}{\pi^{\frac{1}{2}} (T_e)^{\frac{3}{2}}}\right) \sigma_{iz} e^{-\frac{E}{T_e}} dE$$

CNT-Experiment

It depends on the neutral number density as well as electron temperature.

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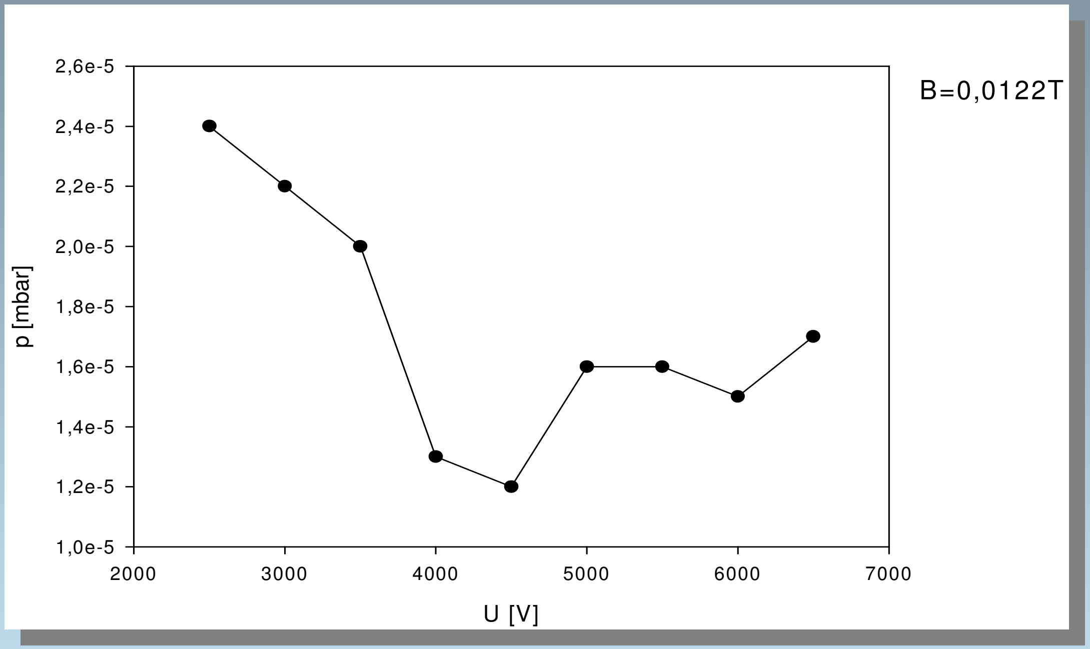
Pressure Ranges

Better confinement at low pressure ranges:



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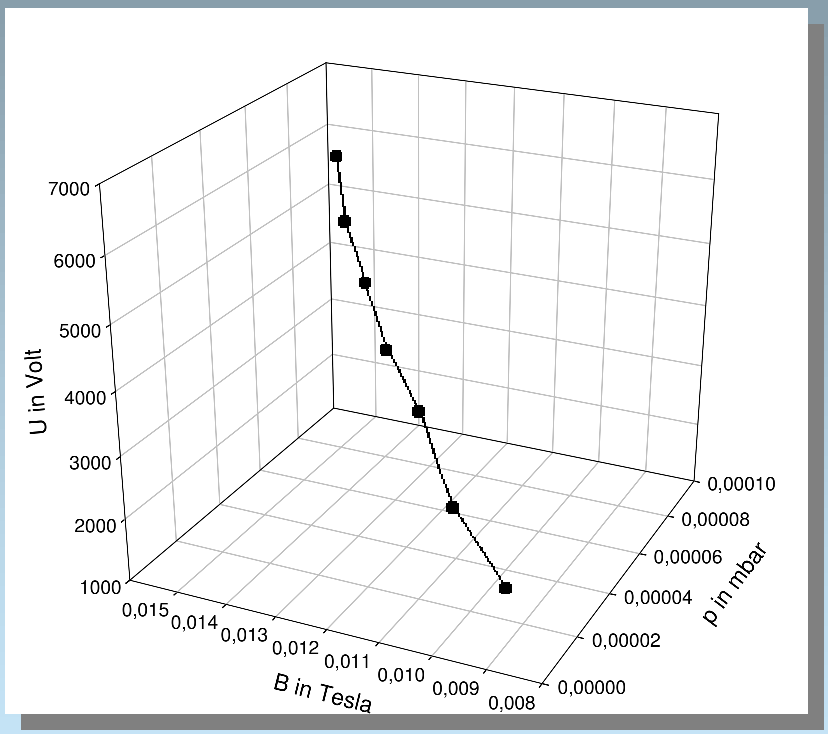
Confinement 1.0

The work function of the Gabor lens changes with external parameters:



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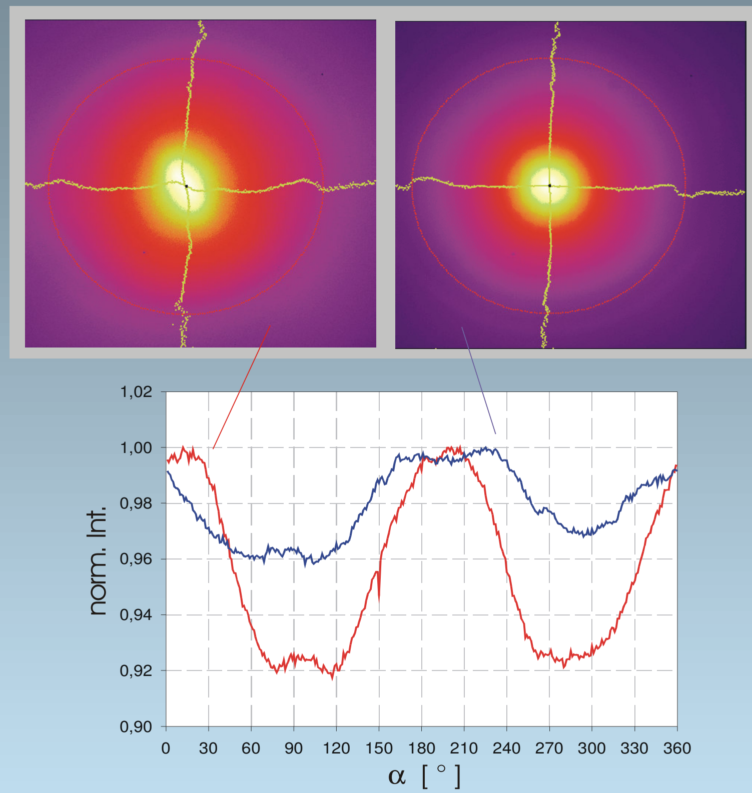
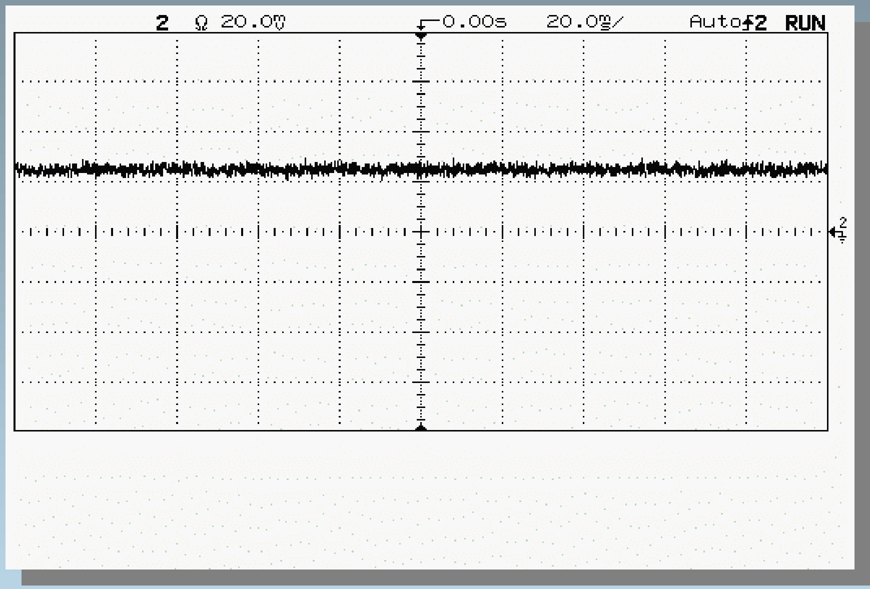
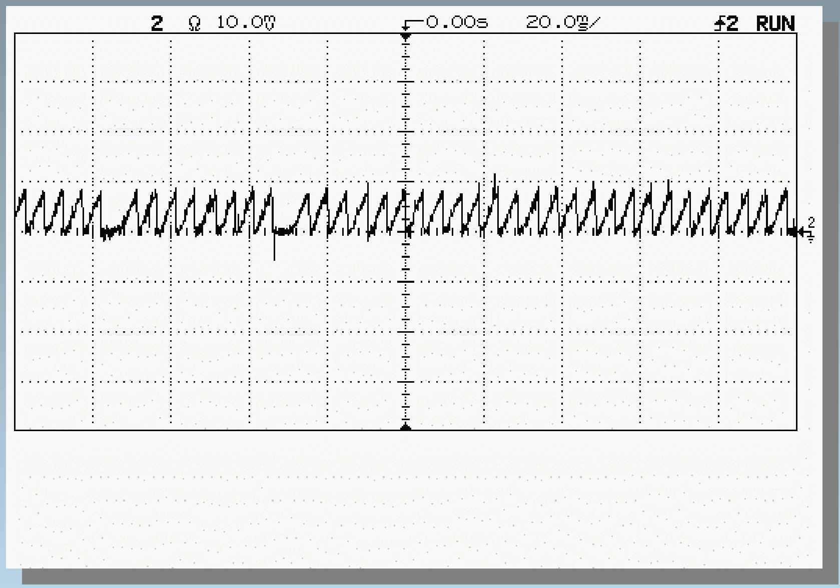
Symmetry of Plasma Column



Symmetry as evidence of thermalisation of the plasma column.

Ion Current with Minimum Fluctuation





The continous ion current indicates that the sojourn time of electrons within the Gabor lens is long enough for thermalisation.

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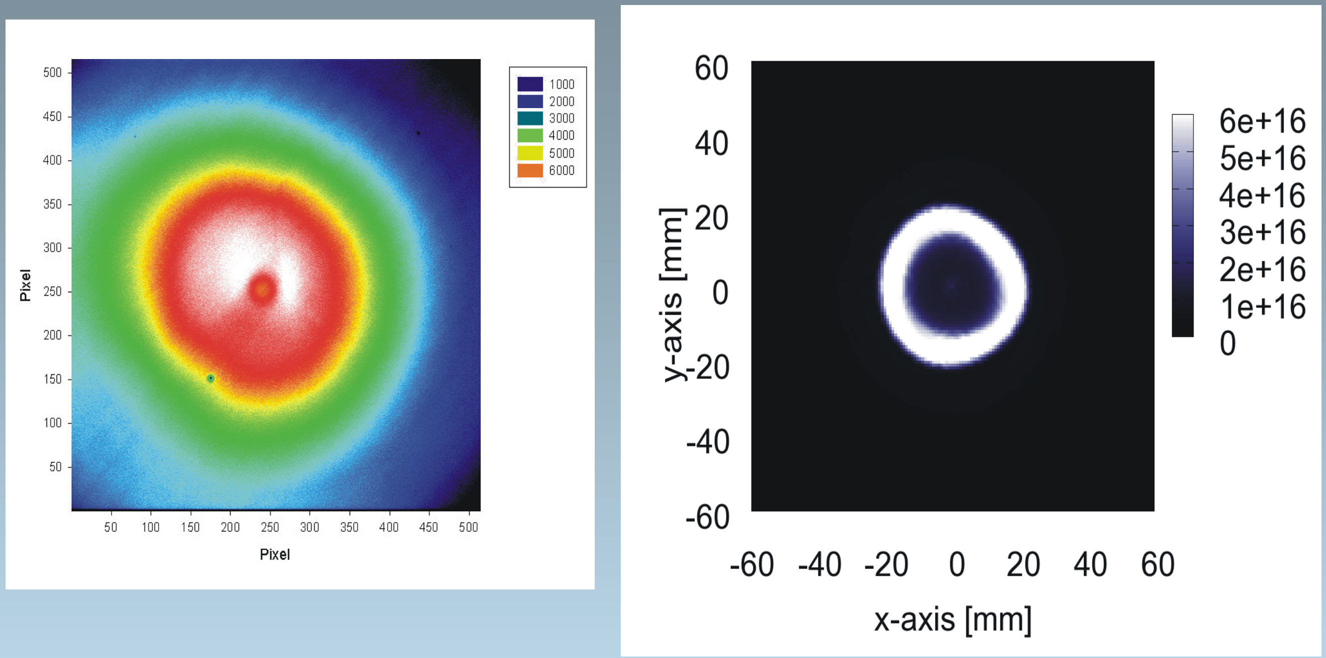
Instabilty



Far from the optimum parameter range a variety of plasma instabilities can be observed

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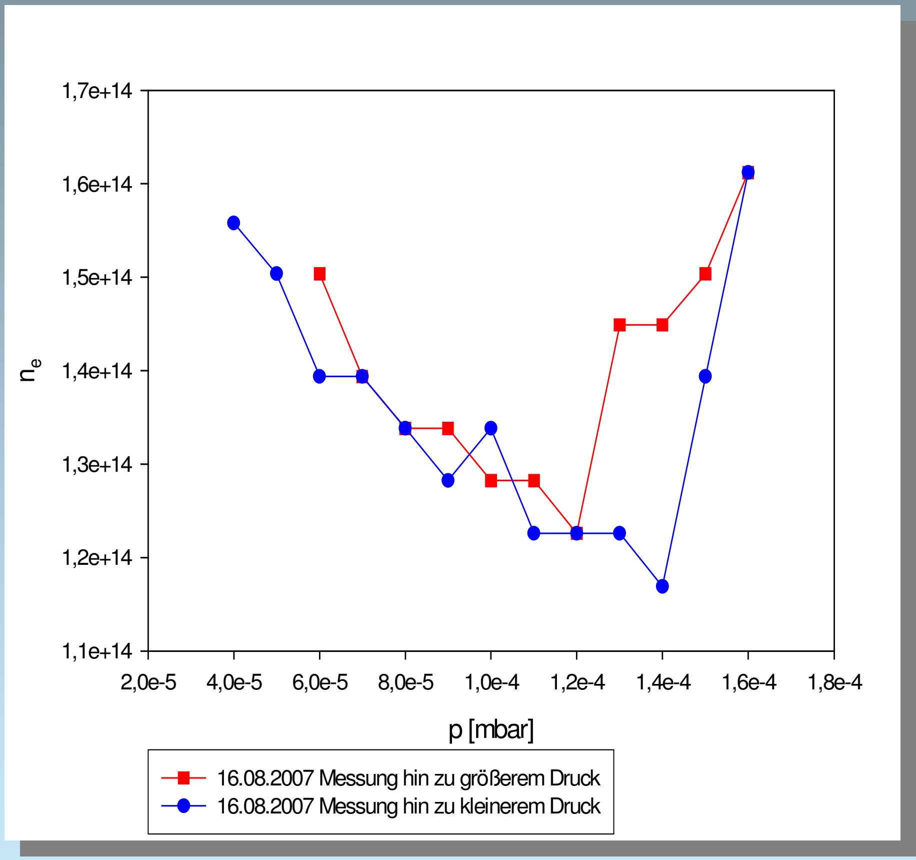
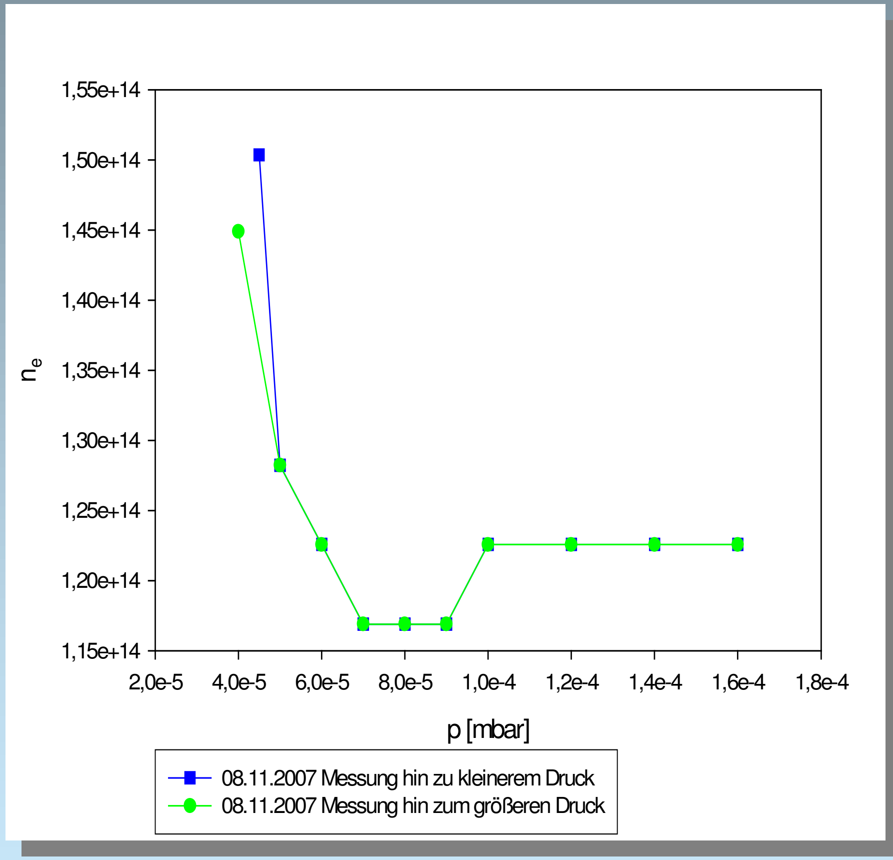
Conditioning of the Three-Segmented-Gabor-Lens

non reproducible measured data:



reproducible measured data:



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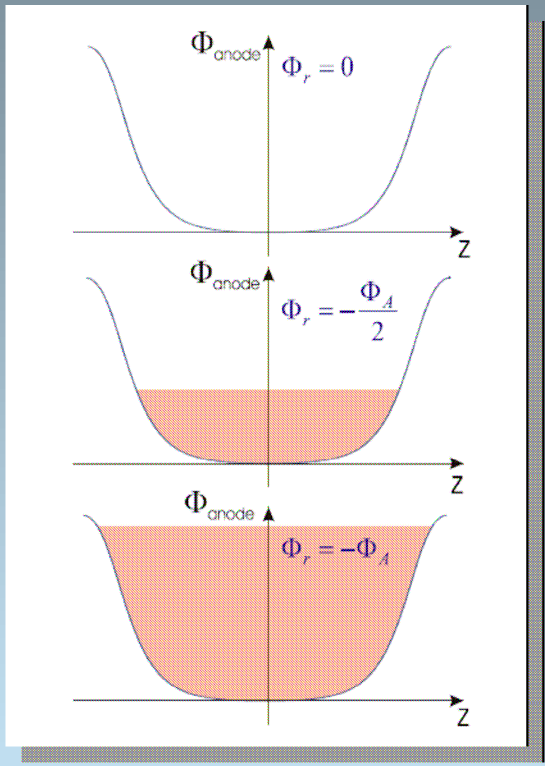
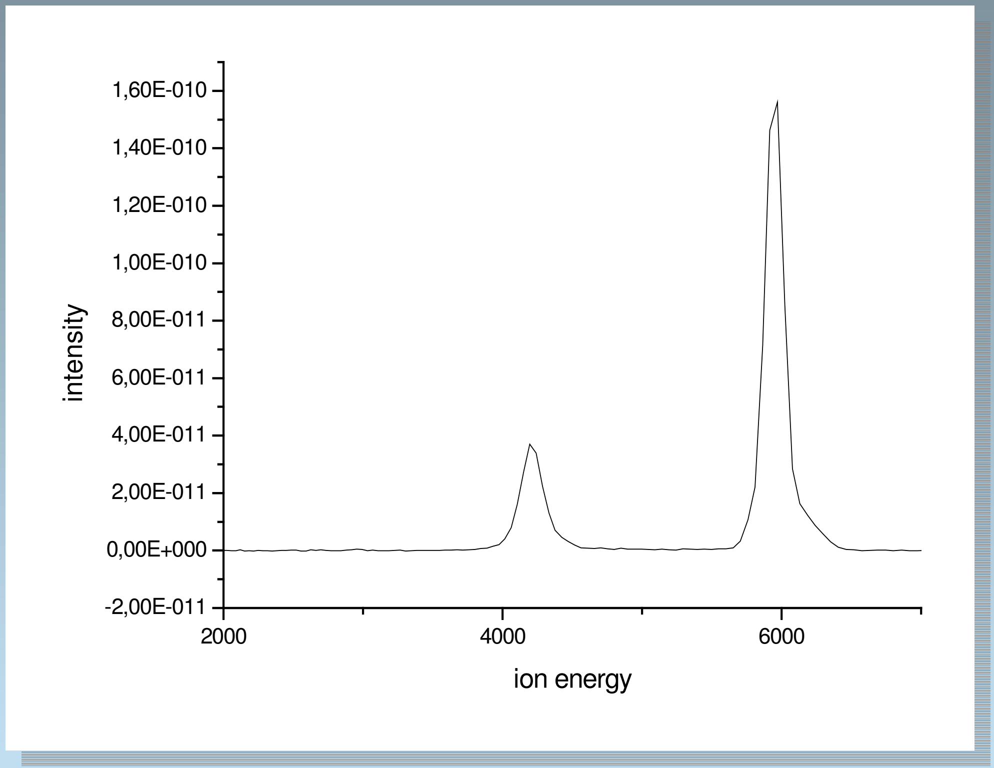
Density Measurement





Elektronendichte: $n_e \approx 1 \cdot 10^{14} \frac{1}{m^3}$

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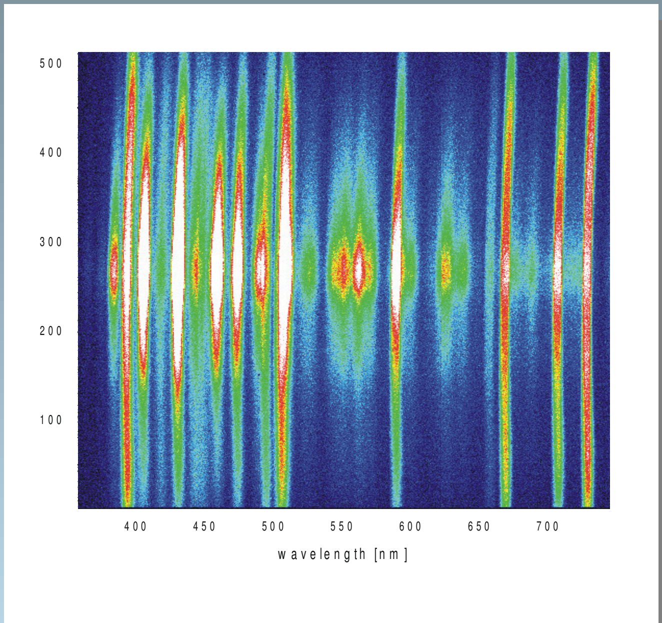
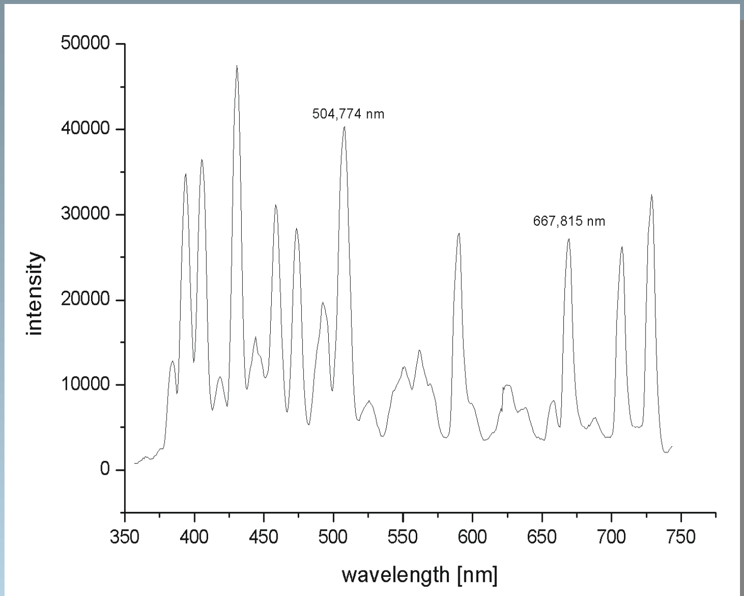
Temperature Measurement





Für LTE Plasma:

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

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Broadening Mechanisms

- Stark Broadening

broadening of spectral lines due to the interaction of electric field near the radiator.

This mechanism doesn't occure in the NNP with densities about ~10^{14} 1/m^3

Estimation by semi impirical formula: $n_e = 1{,}03 \cdot 10^{16} (\Delta\lambda)^{\frac{3}{2}} \frac{1}{cm^3}$, $\Delta\lambda$ in nm

- Doppler Broadening

broadening of spectral lines due to the Doppler effect in which the thermal movement of atoms or molecules shifts the apparent frequency of each emitter:

$$\Delta\lambda_{1/2} = \left(\frac{2kT \ln 2}{Mc^2}\right)^{1/2} \lambda_0 nm$$

A spectral resolution of 1,24 pm would be needed to observe the doppler broadening for a residual gas with temperature about 300K.

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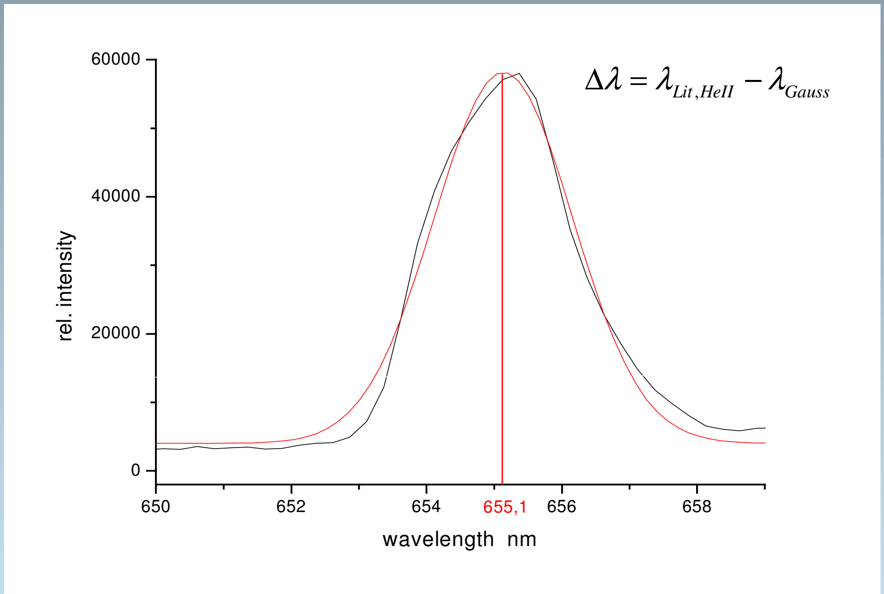
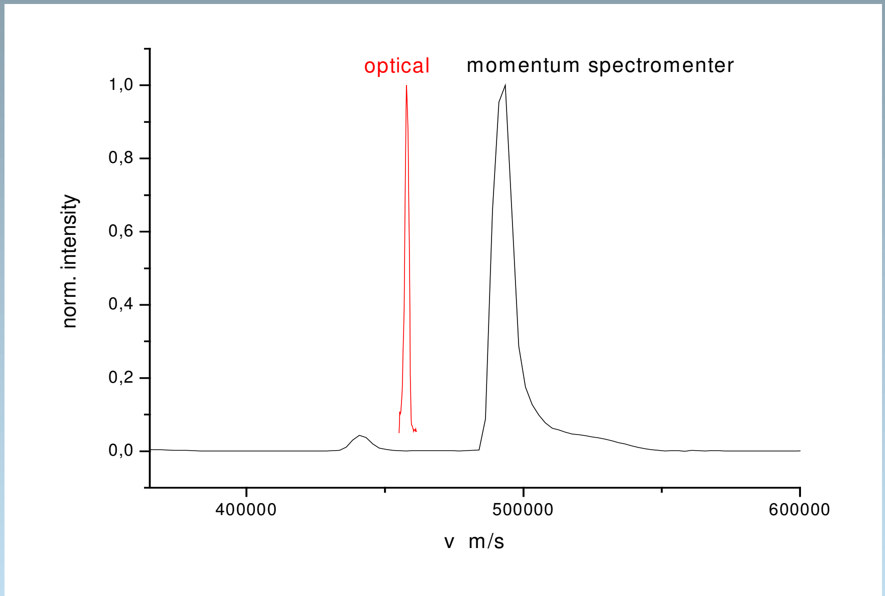
Doppler Shift of Emitted Ions

He II; 656,01nm



Comparison:



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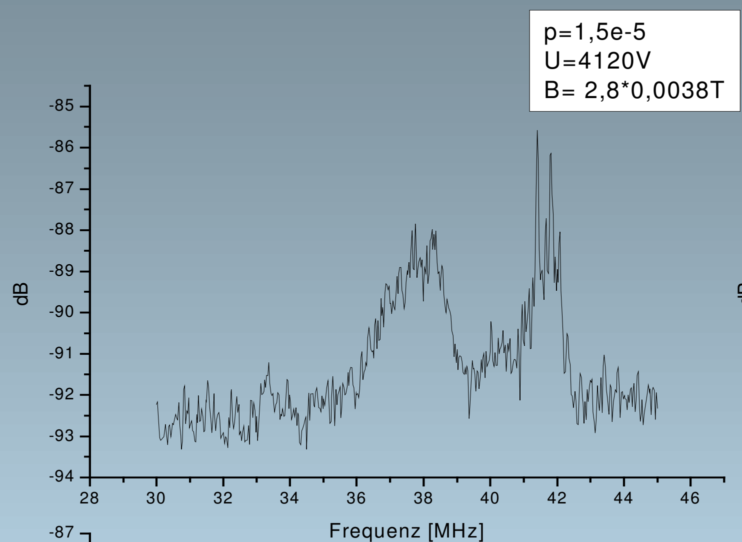
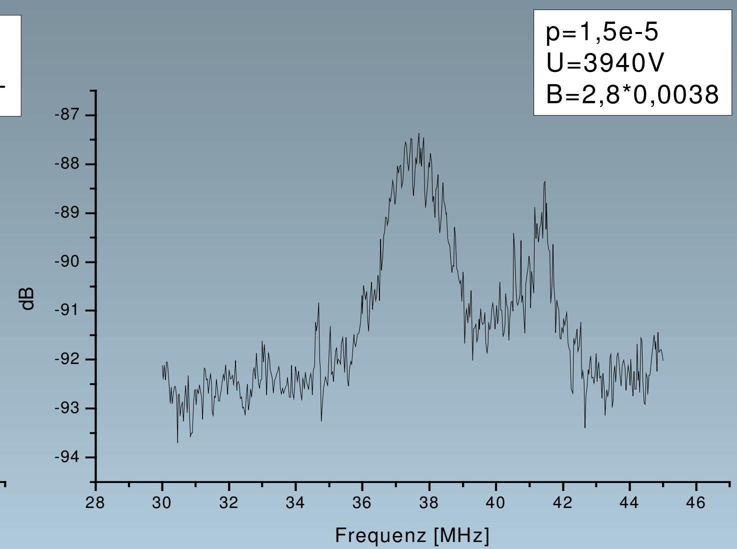
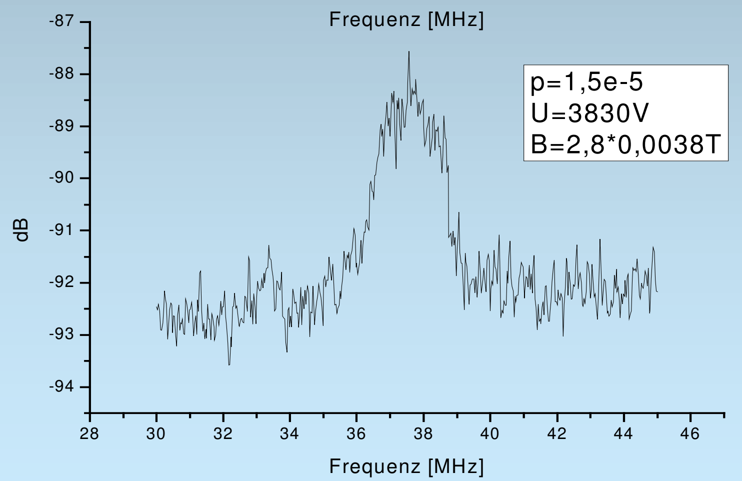
HF Probe







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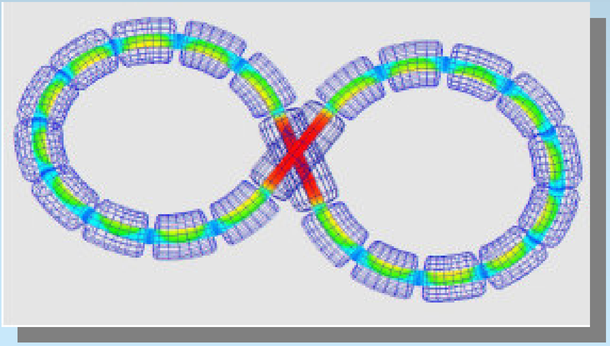
Diagnostic Techniques

non interceptive:

- CCD-Camera
- Monochromator
- HF-Probe
- LASER (Thomson-Scattering)

interceptive:

- Momentum Spectrometer
- Faraday Cup
- EMI



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Outlook

- evaluation of electron temperature
- numerical calculated electron temperature and density compared to measurement
- analyses of different diagnostic techniques

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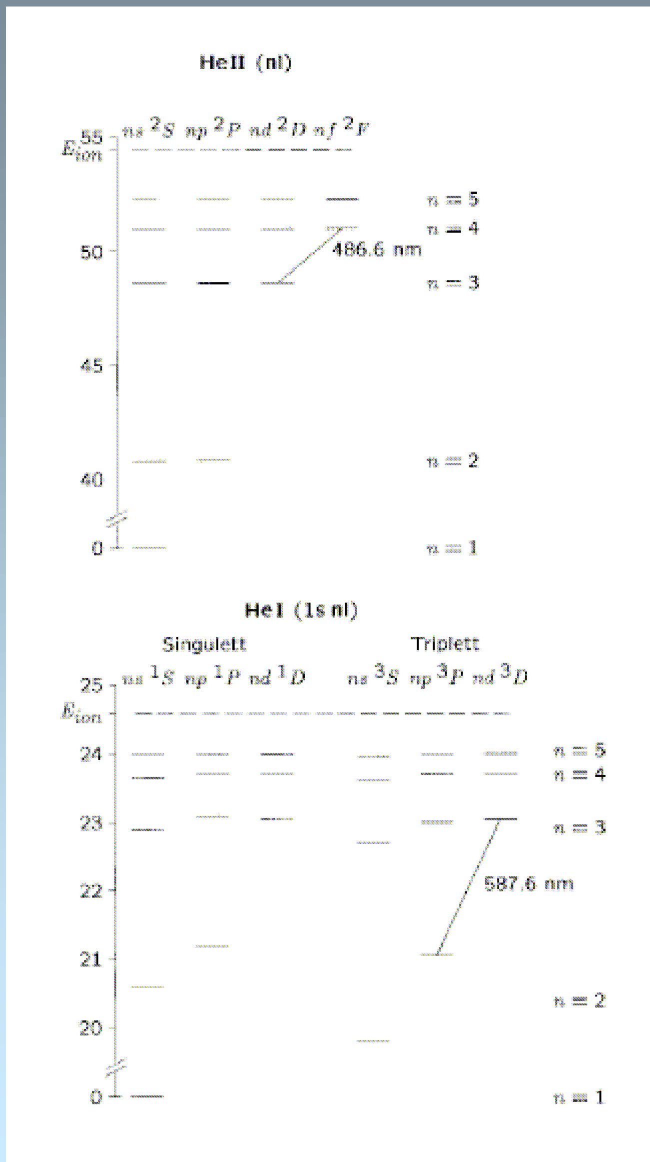
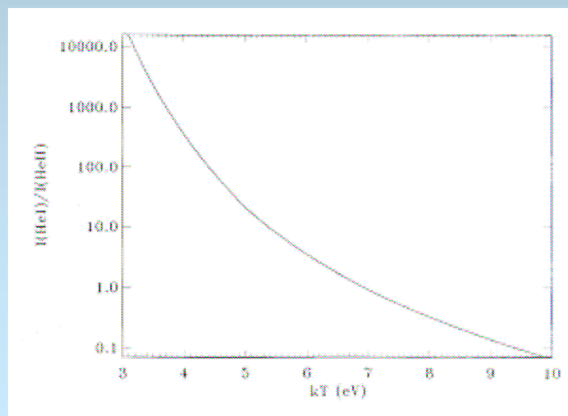
Temperature Measurement



$$\frac{I_{z-1,ll'}}{I_{z,kk'}} = \frac{A_{ll'}}{A_{kk'}}\,\frac{\nu_{ll'}}{\nu_{kk'}}\,\frac{g_{z+1,1}}{g_{z,1}}\,\frac{g_{z-1,l}}{g_{z,k}}\,e^{\frac{-\chi_{z,k}-\chi_{z-1,l}}{kT_e}}\,F$$



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