Characterization of Nonneutral Plasmas Confined in a Gabor Lens

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IAP Workshop 2012
• proposal by D. Gabor in 1947
• linear electric space charge field in case of homogeneous electron density distribution
• focussing independent of ion mass
• space charge compensation
Plasma- and Astrophysics

- nonneutral plasma properties: $n_e=10^{14}-10^{15}$ m$^{-3}$, $T_e=100-1000$ eV
- study of plasma properties under laboratory conditions
- investigation of new diagnostic techniques
Gabor Plasma Lens

- solenoid
- ground electrode
- anode
- ground electrode
Confinement Principle

Radial Confinement

Radial force balance for an axicentred, circular electron orbit:

- Electrostatic + centrifugal force
- Magnetic force

Longitudinal Confinement

Potential depression by confined electrons:

\[ \Phi_{r} = 0 \]

\[ \Phi_{r} = -\frac{\Phi_{A}}{2} \]

\[ \Phi_{r} = -\Phi_{A} \]
Space Charge Lenses at IAP
Electron Production

1. Several residual gas atoms are ionised by natural radioactivity or cosmos radiation in the lens volume.

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.

3. Additionally secondaries are produced by the interaction of particles with the surface of the electrode.

4. In case of use as focussing optics electrons are produced by beam ions.

Study of production and loss mechanisms on the basis of emitted xray radiation.

Bachelor Thesis, Stephan Klaproth
Electron Density Measurement Scheme

Trajectories of Emitted Residual Gas Ions

Detected Ion Energy Distribution

Localization of Production

Potential Depression by Confined Electrons

Mean Electron Density

\[ n_e = \frac{4 \varepsilon_0 \Delta \Phi_A}{er^2} \]

\[ \Delta \Phi = \Phi_A - \Phi_p \]
Temperature Measurement Scheme

Ratio of Emission Cross Sections

\[ \frac{\Phi_{ij}}{\Phi_{ab}} = \frac{\int_{E_1}^{\infty} Q_{ij}(E) \exp \left( -\frac{E}{kT_e} \right) EdE}{\int_{E_2}^{\infty} Q_{ab}(E) \exp \left( -\frac{E}{kT_e} \right) EdE} \]

Optical Emission Cross Section:

\[ Q_{ji} = \frac{\Phi_{ji}}{I/e \cdot n_0} \]

\[ \Phi_{ji} = \frac{\text{photons}}{t \cdot \Delta x} = \frac{I_{ji}}{t \cdot \Delta x} \]

John B. Boffard et al., University of Wisconsin, 2004
Time-resolved Diagnostics

Measured Ion Current

Time-resolved Measurement of an Instability

Measured Intensity

\[ \Phi = 3400 \text{V} \]
\[ B = 12 \text{ mT} \]
\[ p = 7.9 \text{-} 4 \text{ hPa (He)} \]

Date: 18072011

Bachelor Thesis, Benjamin Glaeser
Experimental Set-up

beam parameters:
pulse length=1.25 ms, rep. rate=1 Hz
Excerpt from the Results

$\varepsilon_{\text{rms},100\%} = 0.170 \, \pi \, \text{mm mrad}$

$I_{\text{DT1}} = 30 \, \text{mA}$

$\Phi_A = 0 \, \text{kV}, \ B_z = 0 \, \text{mT}$

$\varepsilon_{\text{rms},100\%} = 0.247 \, \pi \, \text{mm mrad}$

$I_{\text{DT1}} = 35 \, \text{mA}$

$\Phi_A = 9.8 \, \text{kV}, \ B_z = 10.8 \, \text{mT}$

Beam parameters:
$\text{Ar}^{1+}, 3.1 \, \text{keV/u}$
Thank you for your attention!