§10. Electron Density Measurements of Railgun Plasma Armatures

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Small bore railguns[1] have been developed to demonstrate the acceleration of frozen hydrogen pellets which are used to refuel magnetically confined fusion reactors. Measurements of electron density using Stark broadening of the H_α line[2] are performed to investigate the behavior of plasma armatures in railguns with an augmenting magnetic field. The railgun has a total length of 50 cm and a bore of 5 mm square section. A magnetic flux density of 0.53 T was applied to the acceleration tube by using a permanent magnet. Driving currents of 20 kA are supplied to the railguns, which generates the propulsive pressure of 6 MPa for the acceleration.

The line profile due to Stark broadening is Lorentzian and hence is expressed as

$$I(\lambda) = \frac{A}{(\lambda_0 - \lambda)^2 + (B/2)^2}, \qquad (1)$$

where $I(\lambda)$ is the light intensity at a certain wavelength, λ_0 is the central wavelength of the line, and A and B are constants. In plasmas with electron densities of more than 5 x 10^{18} cm^{-3}, the H_α line profile coming from Stark broadening is distorted due to self-absorption[3], as shown in Figure1, and the electron density is overestimated. In order to revise the distorted profile, constants A and B are adjusted to fit the ideal profile determined by (1) on the experimental data, especially at the foot of profile. The axial distribution of electron density in the plasma armature is composed by shot-to-shot measurements. Also the temporal change of electron density is observed by putting a quartz fiber cable at positions z of 5, 10 and 20 cm from the initial position of the pellet.

The distribution of the electron density at different positions z in the railgun is summarized in Figure 2. Zero on the horizontal axis indicates the front edge of the plasma, which is in contact with the pellet. The electron density in the middle of plasma is on the order of 10^{19} cm^{-3} at z = 10 cm. The electron density increases gradually, and the high electron density area spreads toward the back of the plasma armature during the acceleration of pellet.

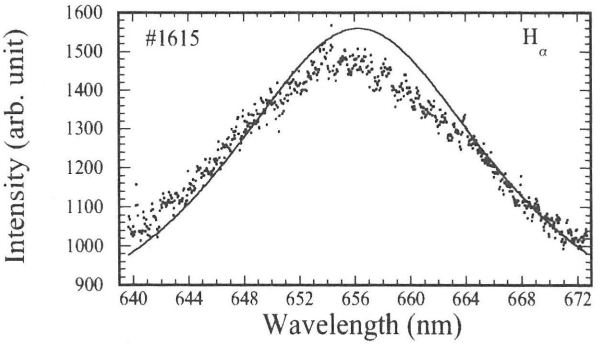

Fig. 1. H_α line spectrum coming from the railgun plasma with n_e= 1.2x10^{19} cm^{-3}. Solid curve shows the ideal Lorentz profile determined by eq.(1).

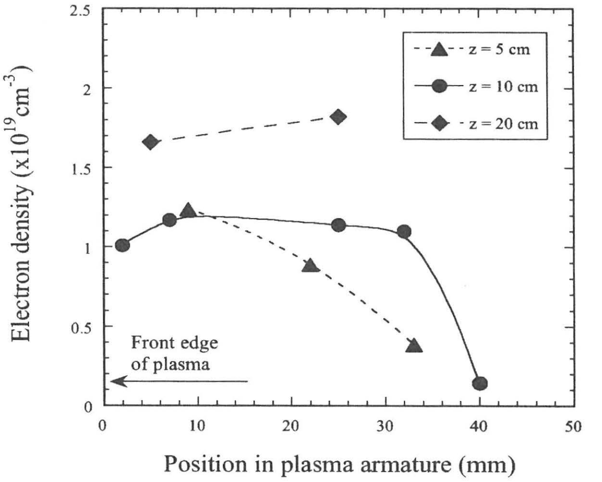

Fig. 10. Electron density distribution in the plasma armature at different positions of z = 5, 10, and 20 cm in the augmented railgun.

References

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2) Griem, H. R., Plasma Spectroscopy (McGraw-Hill 1964).
3) Ashkenazy, J., Kipper, R., Canner, M., Phys. Rev. A, 43 (1991) 5658.