Theory and application of hairpin resonator probe in magnetized plasmas


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Hairpin probes have been widely used in collisionless non-magnetized plasma having isotropic plasma permittivity \( \varepsilon_p \) which depends only on the electron plasma frequency \( f_{pe} \). However, in the presence of an external magnetic field the permittivity perpendicular to the field lines is modified by the electron cyclotron frequency \( f_{ce} \). In this paper, we systematically studied the effect of the external magnetic field on the probes resonance signal and obtained a general formula for calculating the electron density in magnetized plasma. Comparison of the electron density using the improved formula shows very good agreement with the positive ion density measured by a planar Langmuir probe in the Kamaboko-III negative ion source (Fig-1). At very strong field strengths the resonance frequency \( f_r \) displays a negative shift (Fig-2b) with the increasing density. The reason for the observed negative shift is discussed based on a quantitative model of the plasma permittivity in the presence of external magnetic field.

Some results of the work have been accepted in Contribution to Plasma Physics Journal 2010.

Acknowledgement: This work is supported by the Enterprise Ireland Technology Development Grant TD-335/2007.