Effects of electric field and neutral pressure on rotating spokes in partially magnetized ExB plasma

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Many low energy plasma applications such as electric space propulsion, ion sourcing and magnetron sputtering etc. operate on a partially magnetized E x B plasma. In this configuration, magnetized electrons E x B drift under crossed electric and magnetic fields, and unmagnetized heavier ions are transported along the electric field lines.

While the setup is widely used for the extraction and propulsion of the heavier plasma component, it has the free energy of differential flow between the electrons and ions that can lead to disruptive instabilities associated with the E x B drift and density gradients.

One such instability mechanism is the Lower Hybrid Instability (LHI). In its linear analytical form LHI can be described as a collisionless Simon-Hoh type instability modified by electron inertia as well as collisions.[1] Co-aligned electric fields and density gradients drive this instability in the differentially rotating plasma. It manifests as rotating density spokes in the discharge.

We studied the Lower Hybrid Instability in the Penning-type configuration of a cylindrical magnetron.[2,3] The 2D3V PIC-MCC simulation developed an Argon discharge produced by a pulsed radial injection of electrons from an inner cylindrical cathode into a homogeneous neutral backgroud.

It was found that with growth of the discharge, the electric field penetrating the quasi-neutral plasma reduces causing the long wavelength LHI modes to nonlinearly transit to short scale spoke-on-spoke structures (see Figure 1). The application of a neutral pressure reduction reversed the short-scale structures back into a long spiral spoke though a turbulent radial expansion process.

Plasma phenomena connected to the rotating spoke include the anomalous radial transport and loss of electrons through the spoke, azimuthal dragging of ions by the spoke's field, plasma temperature modulations by the spoke structure, and formation of electron vortices around equipotential islands, in some cases with opposing rotations to the underlying ExB drift. Electron scattering from non-ionizing collisions with neutrals also have minor influence on the instability.

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References

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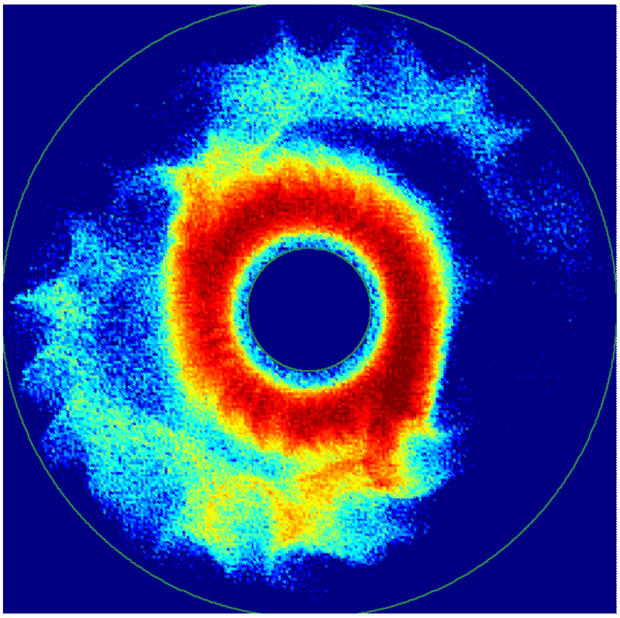

Figure 1. Ion density map in the nonlinear phase of the Lower Hybrid Instability showing short scale spoke-on-spoke structures riding on a long wavelength m=2 rotating spoke, where m is the azimuthal mode number.