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Dispersion relation of helicon waves with dissipation

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Electric thrusters, characterized with high specific impulse, are considered to be useful for long term space missions such as those to outer planets. On the other hand, the performance of many of the conventional electric thrusters (e.g., ion engines) is limited by electrode wastage. In order to overcome this difficulty, we have initiated the HEAT (Helicon Electrodeless Advanced Thruster) project, in order to pursue research and development of completely electrodeless (i.e., no direct contact of electrodes with plasma) thrusters.

The electrodeless thrusters are composed of a plasma generation part and the plasma acceleration part. While efficient plasma production using a ”helicon wave” is well established experimentally, there still remains a number of unsolved issues regarding how the plasma is generated using the helicon wave. This is due to the complexity of the problem: one needs to understand how the helicon waves propagate in the plasma, how electrons are accelerated by the waves, how neutrals are ionized, how the wave dispersion relation is modified as the ionization rate is increased, and how these processes interact with one another.

As a first step to solve this problem, we have invetsigated what kind of electric field can be generated when the helicon wave propagates into non-uniform plasma and how it accelerates the electrons. The dispersion relation of helicon waves is obtained in a non-uniform cylindrical plasma. The frequency range of helicon waves is w_{ci}(ion cyclotron frequency)$<<w<<w_{ce}$(electron cyclotron frequency). Thus, helicon waves are a kind of whistler waves propagating at some oblique angle with respect to the back ground axial magnetic field B_0. We assume a bounded cylindrical chamber and axial wave number is fixed by some boundary condition. From the dispersion relation, we obtain the helicon wave (long wavelength: propagating at nearly parallel angle for B_0) and the so-called TG wave (short wavelength: propagating at nearly perpendicular angle to B_0) as solutions. These waves can linearly couple in a non-uniform plasma. In particular, dispersion curves for these waves merge at a certain location, implying that an efficient mode conversion should take place. Previous studies show that an electrostatic TG wave is excited as the helicon wave propagates into the non-uniform plasma. Then, these TG waves efficiently accelerate the electrons and plays a crucial role in the plasma production. First, we discuss dispersion relation of helicon waves in a non-uniform plasma including dissipation using a fluid model. Then, we analyze the dispersion relation using a full PIC simulation.

Keywords: Electric thrusters, The electrodeless thrusters, Helicon wave, TG(Trivelpiece-Gould)wave