Wave propagation and absorption in plasma with a strong magnetic field driven by a polarization controlled long-wavelength laser pulse

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INTRODUCTION

Electromagnetic wave propagation and absorption in plasma is one of the fundamental issues on plasma physics since its dawn in relation to wave dispersion relation in discharged materials. For discharge plasma with density less than solid density, plasma production or its heating have been conducted in external magnetic field using plasma dispersion relation such as cyclotron resonance [1]. For plasma with density beyond the solid density, most wave-plasma interactions were conducted without the external magnetic field.

Experiments of generation of laser-driven kT class magnetic field [2] have opened theoretical or simulation investigation of laser-plasma interaction with external magnetic field with density close to solid [3,4]. Extensions of these theoretical or numerical estimations into experiment condition can lead to bulk solid plasma heating by laser pulse in potential.

The 1 kT magnetic field provides cyclotron resonant frequency that corresponding to the CO_2 laser; wavelength of 10 μm. Therefore, the laser-plasma interaction with CO_2 laser under kT-class magnetic field can expect experimental investigation of plasma heating of bulk solid plasma. The purpose of this study is an estimation of electromagnetic wave propagation and absorption of CO_2 laser pulse (wavelength of 10 μm) in plasma with solid density (0.1 g/cc for hydrogen) region under 10-kT class magnetic field. This estimation is supposing a tuning polarization of CO_2 laser pulse.

THEORITICAL MODEL

To investigate wave propagation in plasma under external magnetic field, a simple setup is proposed as shown in Fig. 1. The uniform external magnetic field normalized by cyclotron resonant magnetic field B_{ext}/B_c is induced in the slab plasma with thickness of laser wavelength. The induced laser pulse contains linear polarization combined with both right-hand and left-hand circular polarized waves. The induced laser pulses (linear polarization: right-hand circular polarization and left-hand circular polarization) propagate through the plasma in relation to the plasma dispersion relation described in Eqs. (1-3).

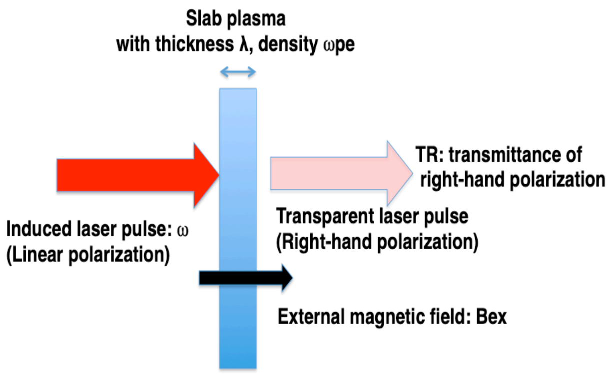

Fig. 1. Schematics of wave propagation

$$T_R=2/(N_R+1),\ T_L=2/(N_L+1) \qquad (1),$$

$$N_R=\{1-(\omega_{pe}/\omega)^2/(1-\omega_{ce}/\omega)\}^{1/2} \qquad (2),$$

$$N_L=\{1-(\omega_{pe}/\omega)^2/(1+\omega_{ce}/\omega)\}^{1/2} \qquad (3),$$

where, $T_{R,L}$ is transmittance of Right-hand or Left-hand laser pulse, $N_{R,L}$ is refractive index of Right-hand or Left-hand laser pulse, ω_{pe}/ω is electron density normalized by laser frequency, ω_{ce}/ω is cyclotron frequency normalized by laser frequency, respectively.

RESULTS

The transmittance of right-hand part increases as a function of external magnetic field in relation to the plasma density. Figure 2 shows result of Eq. (1,2) as a function of external magnetic field. Here we consider right-hand part that provides cyclotron resonance. By considering CO_2 laser with wavelength of 10 μm, the cut-off density is 1.1×10^{19} n/cc, the cyclotron resonant magnetic filed Bc is 1.07 kT, and $(\omega_{pe}/\omega)^2 = 2364$ corresponds to solid density 0.086 g/cc of hydrogen. These values are within scope on experiments.

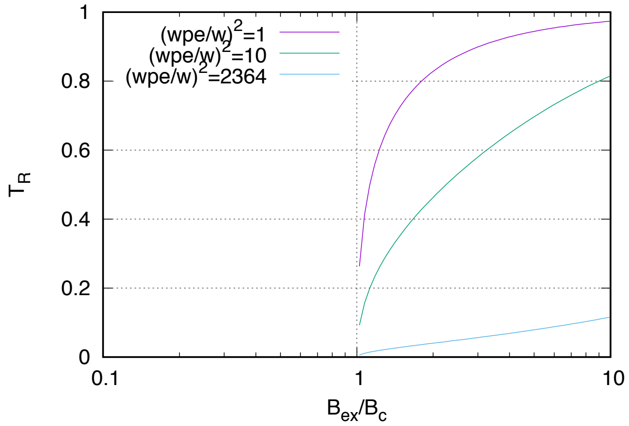

Fig. 2. The transmittance of right-hand wave.

From Fig. 2, the T_R depends on normalized electron density: ω_{pe}/ω. Therefore, when the bulk slab density is confirmed, we can investigate external magnetic field from this dispersion relation. This relation leads to probe an external magnetic field in the plasma. By considering collisions in the slab plasma, we can evaluate more sophisticated dispersion relation that relevant for the experiments.

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REFERENCES

[1] F. F. Chen, Introduction to Plasma Physics and controlled Fusion 2_{nd} ed, Springer (1984).
[2] S. Fijioka, et al., Sci. Report,**2**, 31 (2013).
[3] Y. H. Yang et al., Appl. Phys. Letters **106**, 224103 (2015).
[4] T. San et al., Phys. Rev. E **96**, 043209 (2017).