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# Electron ion inverse bremsstrahlung absorption in magnetized fusion plasma

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## ABSTRACT

- In this work we are interested in the study of the electron-ion (e-i) inverse bremsstrahlung absorption (IBA) of the laser energy in magnetized plasma in the magneto-inertial fusion (MIF) frame .
- Scaling laws for IBA in MIF plasma and for magnetic confinement plasma are established.
- The numerical treatment of the model equations shows the influence of the magnetic field and the polarization of the wave on the absorption.

## INTRODUCTION

- In order to formulate the propagation of a laser pulse through magnetized collisional plasma in non-relativistic regime, we consider an inhomogeneous plasma heated by a circularly polarized laser wave in the presence of an axial magnetic field. It is judicious to use the Fokker-Planck equation to describe magnetized collisional plasma [1] .
- The distribution function is supposed to constitute of two contributions: a fast oscillation distribution, which follows the laser wave time variation, and a quasi-static distribution .
- The time-average power dissipated per unit volume by the electron-ion inverse bremsstrahlung mechanism is calculated [2] .
- We derive the scaling law for the *e-i* inverse bremsstrahlung in magnetized laser-fusion plasma and magnetically confined plasma heated by an electromagnetic wave which corresponds to the microwave heating.

## BASIC EQUATION

Following the notation of Braginskii, the electrons Fokker-Planck equation (FP) is presented as:

$$\frac{\partial f}{\partial t}+\vec{v}.\frac{\partial f}{\partial \vec{r}}-\frac{e}{m_e}\left(\vec{E}+\vec{v}\times\left(\vec{B}+\vec{B_0}\right)\right).\frac{\partial f}{\partial \vec{v}}=C_{ei}(f).$$

- $f(\vec{v},t)$ is supposed to be as:
  $f(\vec{v},t)=f^{(s)}(\vec{v},t)+Real(f^{(h)}(\vec{v},t))$.
- $f^{(s)}(\vec{v},t)$ is developped on the Legendre polynomials:
  $f^{(s)}(\vec{v},t)=\sum_{l=0}^{\infty} f_l^{(s)}(v,t)\,P_l(\mu)$
- $f^{(h)}(\vec{v},t)$ is developped on the associated Legendre polynomials: $f^{(h)}(\vec{v},t)=\sum_{l=0}^{\infty} f_l^{(h)}(v,\varphi,t)\,P_l^{\pm 1}(\mu)$,
- we consider a parallel circularly polarized laser wave propagating in the direction of an applied magnetic field ($z$) and oscillating in the perpendicular plane:

$$\vec{E}(t,z)=Re\left[\frac{E(z)}{\sqrt{2}}(\vec{u_x}\pm j\vec{u_y})exp(-j\omega t)\right],\vec{B}(t,z)=Re\left[\frac{B(z)}{\sqrt{2}}(j\vec{u_x}\mp\vec{u_y})exp(-j\omega t)\right]\quad \text{and } \vec{B_0}=B_0\vec{u_z},$$

- The lth ansotropic of $f^{(h)}$is calculated as:

$$f_l^{(h)}=\frac{e}{m_e}\left(\frac{exp(-j(\omega t\mp\varphi))}{-j(\omega\mp\Omega_{ce})+l(l+1)\frac{v}{v^3}}\right)\left[\frac{E}{\sqrt{2}}\left(\begin{array}{c}\frac{1}{2l+3}\left(\frac{1}{v^{l+1}}\frac{\partial}{\partial v}\left(v^{l+1}\right)+\frac{1}{v}\right)f_{l+1}^{(s)}\\-\frac{1}{2l-1}\left(v^{l}\frac{\partial}{\partial v}\left(\frac{1}{v^{l}}\right)+\frac{1}{v}\right)f_{l-1}^{(s)}\end{array}\right)\pm Bf_l^{(s)}\right].$$

## THE ELECTRON-ION INVERSE BREMSSTRAHLUNG ABSORPTION RATE

The time-average power dissipated per unit volume by the electron-ion inverse bremsstrahlung mechanism, $\Gamma=\langle\vec{E}.\vec{J}\rangle_T$ is:

$$\Gamma=\frac{8\sqrt{3}}{15(2\pi)^{\frac{3}{2}}}m_e\tilde{I}\frac{\omega^2 n_e}{(\omega\mp\Omega_{ce})^2}\nu_{ei}\,v_{th}^2 G(a).$$

where $G(a)=G_{1,4}^{4,1}\left(\frac{a}{27}\middle|\begin{array}{c}0\\0,\frac{1}{3},\frac{2}{3},1\end{array}\right)$ is the Meijer function with argument $a=\left(\frac{\nu_{ei}}{\sqrt{2}(\omega\mp\Omega_{ce})}\right)^2$.

$\tilde{I}=\frac{v_0^2}{v_{th}^2}$ ,$v_0=\frac{e|E|}{m_e\omega}$ is the peak oscillating-electron velocity in the (*hf*) laser electric field, $\nu_{ei}=\frac{v_{th}\sqrt{2}\,n_e e^4 ln\Lambda}{12\pi\sqrt{\pi}\varepsilon_0^2 T_e^2}$ is the e-i collision frequency, $v_{th}=\sqrt{\frac{T_e}{m_e}}$ is the electron-thermal velocity, whereas $T_e$ is the electron temperature.

The fusion plasma is created by an intense laser pulse. Consequently, the plasma parameters are given by the laser field parameters. the absorption for laser MIF plasma can be expressed as:

$$\Gamma=\frac{1.8\times10^{22}\lambda^{-4}}{(10720.7\mp\lambda\,B_0)^2}\times\left(1-\frac{1.6\times10^{28}I^{-2}\lambda^{-6}}{(10720.7\mp\lambda\,B_0)^2}\right).$$

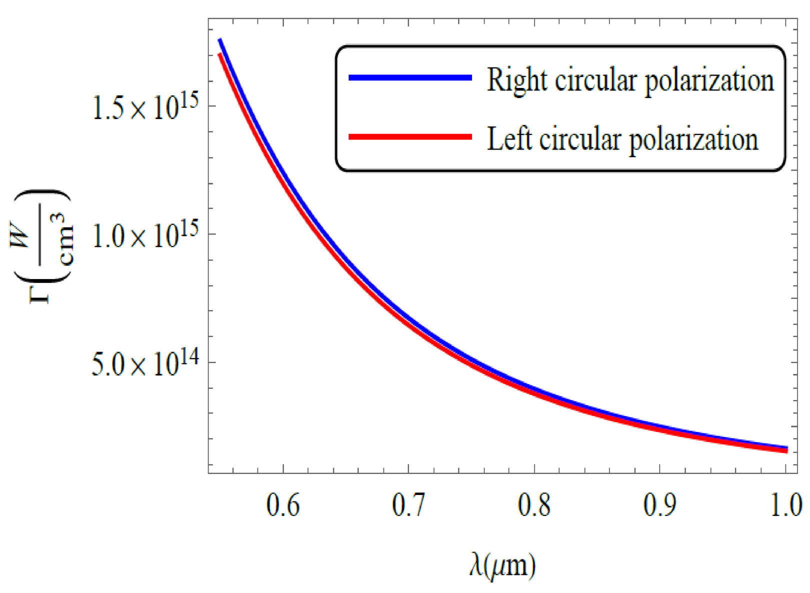


*Figure. 1 Plot of $\Gamma$ as function of the laser wavelength $\lambda$*

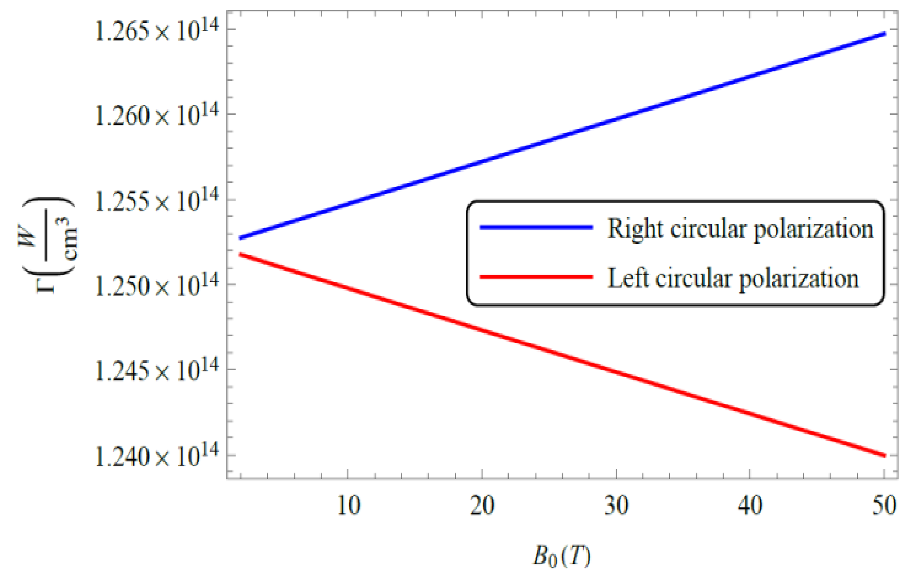


*Figure. 2 Plot of $\Gamma$ as function of the applied magnetic field $B_0$*

## CONCLUSION

- In this work we explicitly calculated the absorption as a function of the laser pulse parameter.
- We have shown that the magnetic field affects the absorption and that its effect depends on polarization direction.
- We derived useful scaling laws for IBA in a magnetized inertial fusion plasma and for magnetically confined plasma, heated by radiofrequency electromagnetic waves.
- We found that the absorption is actually slightly larger for right polarization and is slightly smaller for left one (figure 1,2,3,4).
- This study allows us to optimize the laser pulse parameters in order to obtain an efficient absorption.

## REFERENCES

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