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WEIBEL INSTABILITY IN A BI-MAXWELLIAN LASER FUSION PLASMA

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We are interested in this paper to analyse the Weibel instability driven by the plasma temperature anisotropy in the corona of a high intense laser created plasma. The unperturbed electronic distribution function, f, of the anisotropic corona is supposed to be a bi-maxwellian. That $T_{//} = T_{\perp} + W_O$, where $W_O = \frac{1}{4} m_e v_O^2$ is the averaged electron quiver energy in the laser electric field. The first and the second anisotropies of f projected on the Legendre polynomials are calculated as function of the scaling parameter, $\frac{W_O}{T_{\perp}}$. The Weibel instability parameters are explicitly calculated as function of the scaling parameter. For typical parameters of the laser pulse and the fusion plasma, it has been shown a very unstable Weibel modes: $\gamma \approx 10^{11} s^{-1}$ excited in the corona.

1. Introduction:

In the inertial confinement fusion (ICF) targets, produced by an intense laser pulse, the incident laser wave can produce anisotropy in the formed plasma temperature. This is due to the fact that the formed plasma is preferentially heated in the direction of the laser wave electric field. This goes to an anisotropic plasma temperature. It has been showed that this anisotropic distribution provokes unstable Weibel modes [1].

The temperature anisotropy can be interpreted, in the frame of the kinetic theory, as an anisotropy in the electrons velocities distribution [2,3].

If this instability is excited, the target may have a possibility to give rise to energy loss and the implosion characteristics of the target are influenced.

In this work, we are interested in studying the Weibel instability excited in the laser fusion plasma corona. The corona is the direct interaction region between the incident laser pulse and the formed plasma. That, it is characterized by a plasma frequency, ω_p, less than the laser wave frequency, ω_L : $\omega_p < \omega_L$.

2. Distribution function:

In our model, the electronic distribution function, f, is supposed to be a local bi-Maxwellian.

$$f = \left(\frac{m_e}{2\pi}\right)^{3/2} \frac{n_e}{T_\perp T_\parallel^{1/2}} \exp\left(-\frac{1}{2}\frac{m_e v_\perp^2}{T_\perp}\right) \exp\left(-\frac{1}{2}\frac{m_e v_\parallel^2}{T_\parallel}\right), \qquad (1)$$

where $e, m_e, n_e, T_\parallel, T_\perp$ are respectively the elementary electric charge, the electron mass, the electrons density, the parallel temperature to the anisotropy direction and the temperature in the perpendicular plane.

In the case of the linear polarized laser pulse, with an electric laser wave oriented in the parallel direction: $T_\parallel = T_\perp + W_O$, where W_O is the average, on the laser cycle, of the oscillating energy communicated the electron by the laser wave. But in the case of the circularly polarized laser wave, with an electric laser wave oscillating in the perpendicular plane: $T_\parallel = T_\perp - W_O$.

3. Compute of the electron quiver energy:

W_O is calculated using the fluid electron motion equation by considering the collisions, so:

$$W_O = \frac{e^2}{8\varepsilon_0 c m_e} \frac{I}{{\omega_L}^2} \left(1 - \frac{1}{2}\left(\frac{\nu_c}{\omega_L}\right)^2\right), \qquad (2)$$

where ε_0, c, I and $\nu_c \sim n_e/(T)^{3/2}$ are respectively the vacuum electric permittivity, the speed of light in vacuum, the laser pulse intensity and the collisions frequency, where $T = \int_0^\infty f\left(\frac{m_e}{2}v^2\right) v^2 dv / \int_0^\infty f\, v^2 dv$ is the mean electrons kinetic energy on the bi-maxwellian distribution.

The isotropic distribution function, the first and the second anisotropies of f truncated on the Legendre polynomial, $P_l(\mu = \frac{v_\parallel}{v})$, are calculated as:

$$f_0 = \left(\frac{m_e}{2\pi T_\perp}\right)^{3/2} n_e \exp(-y)\left\{(1+\widetilde{W_o})^{-1/2} + \frac{y}{3}\widetilde{W_o}(1+\widetilde{W_o})^{-3/2}\right\} \qquad (3)$$

$$f_1 = 0 \qquad (4)$$

$$f_2 = \left(\frac{m_e}{2\pi T_\perp}\right)^{3/2} n_e \exp(-y)\left\{\frac{2y}{3}\widetilde{W_o}(1+\widetilde{W_o})^{-1/2}\right\}, \qquad (5),$$

where $y = \frac{m_e v^2}{2T_\perp}$ and $\widetilde{W_o} = \frac{W_o}{T_\perp}$.

4. Dispersion relation:

It has been shown in the reference [2] that that the growth rate of the excited Weibel mode depend to the second anisotropy [eq. 6] and its group velocity depend to the first anisotropy [eq. 4] , so.

$$\gamma_{max} = \frac{2^{15/4}}{3^{5/2}\sqrt{\pi}} \frac{v_t^{5/4}}{\sqrt{n_e}} \frac{\omega_p}{c} \frac{\left[\int_0^\infty \sqrt{y} f_2\, dy\right]^{3/2}}{\int_0^\infty f_0 dy} \qquad (6)$$

$$v_g = \frac{v_t}{\sqrt{2}} \frac{\int_0^\infty \sqrt{y} f_1 dy}{\int_0^\infty f_0 dy}, \qquad (7)$$

where $v_t = \sqrt{T/m_e}$ is the electrons thermal velocity.

5. Numerical Analysis:

Numerical analysis of these set of equations (1-7) shows that the growth rate of the most unstable γ_{max} mode is $\gtrsim 10^{11} s^{-1}$ (eq. 6) in the vicinity of the critical layer, $\omega_L = \omega_p$. The excited Weibel modes by this mechanism are not convective. That, $v_g \sim f_1 = 0$. But other Weibel sources, such that due to the gradient of temperature and density, in the corona, can participate to the convection of these modes. The growth rate calculated in this model gives the results of the Fokker-Planck simulations for low values of the scaling factor, $\widetilde{W_o}$.

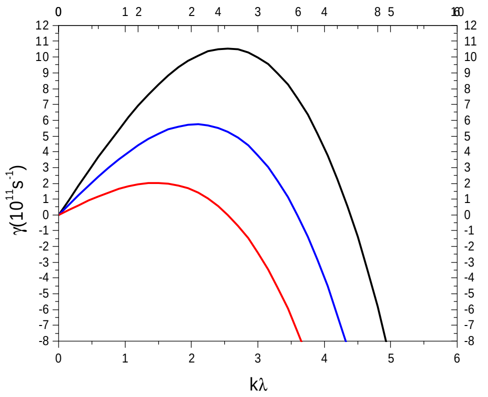

Fig. 1: *Weibel instability growth rate spectrum:* $\gamma(k\lambda)$.

k *is the wave number of the Weibel mode and* λ *is the mean free path of the electron. The red curve correspond to* $\tilde{W} = 0.01$, *the blue one correspond to* $\tilde{W} = 0.02$ and the black one correspond to $\tilde{W} = 0.03$

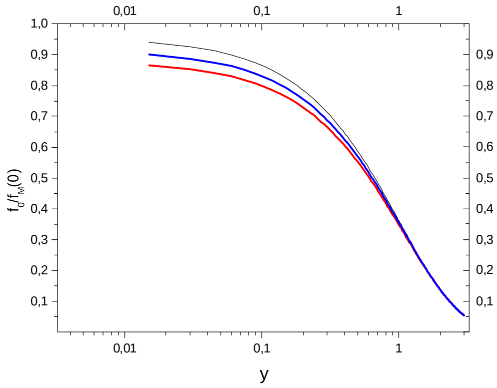

Fig. 2: *Isotropic distribution function as function of* y *for several values of the scaling parameter* $\tilde{W}$.

The red curve correspond to $\tilde{W} = 0.01$, *the blue curve correspond to* $\tilde{W} = 0.02$ and the black one correspond to $\tilde{W} = 0.03$.

References

[1] E. S. Weibel, Phys. Rev. Lett. 2, 83 (1959).

[2] A. Bendib, K. Bendib and A. Sid, Phys. Rev. E 55, 7522 (1997).

[3] A. Sid, Physics of Plasmas, 1, 214 (2003).
A. Sid and A. Bendib, 30th EPS Conference on controlled Fusion and Plasma Physics, St. Petersburg, Russia, 7-11 July 2003.

[4] J. P. Matte, A. bendib and J. F. Luciani, Phys. Rev. Lett. 58, 2067 (1987).