STIMULATED BRILLOUIN SCATTERING AND FILAMENTATION INSTABILITIES IN HIGH TEMPERATURE PLASMAS

K. Bendib-Kalache, A. Bendib and H. Benmakrelouf

Laboratoire Electronique Quantique, Faculty of Physics, USTHB, Algiers, Algeria

Email: k.bendib.kalache@gmail.com

Currently there is growing interest in studying high temperature plasmas. Indeed, with the advancements in laser technology, powerful laser pulses are now available, and their interaction with solid targets, as in inertial confinement fusion (ICF), can produce high temperature plasmas reaching up to 20 keV [1]. At such high temperatures, electron rest energy $m_e c^2$ becomes non negligible compared to the electron thermal energy T_e where m_e is the electron rest mass, *c* is the speed of light, and T_e is the electron temperature in energy units. The relevant parameter quantifying relativistic effects is therefore given by $z = \frac{m_e c^2}{T_e}$.

In the context of ICF, we present a study of stimulated Brillouin scattering (SBS) and filamentation instability (FI) in high temperature plasmas.

Plasmas in presence of an electromagnetic (EM) wave are described by the continuity equation, the momentum and energy balance equations using linear relativistic and collisionless hydrodynamic model [2],

$$-i\omega\delta n + ik\delta V\, n_0 = 0 \tag{1}$$

$$-i\omega\delta V\, G\, n_0 m_e + ik(n_0\delta T + T_0\delta n) + ik\,\delta\Pi_{xx} = q_e n_0 \delta E + \delta F_{pe} + \frac{i\omega}{c^2}\,\delta q \tag{2}$$

$$-i\omega n_{0e}\,(-1 + z^2(1 - G^2) + 5zG)\delta T + i\omega T_0 \delta n + ik\delta q = \langle \delta(\vec{j}_{HF} \cdot \vec{E}_{HF}) \rangle \tag{3}$$

where $G(z)$ is the relativistic inertial factor, $\delta q = -K_T \frac{d\delta T}{dx} + \alpha_V n_0 T_0 \delta V$ is the generalized heat flux, $\delta\Pi_{xx} = -\eta \frac{d\delta V}{dx} + \alpha_T n_0 \delta T$ is the generalized stress tensor, K_T is the thermal conductivity, η is the viscosity coefficient and $\alpha_T = \alpha_V$, the off-diagonal transport coefficients. Additionally, the ponderomotive force δF_{pe} and the absorption rate of the EM wave $\langle \delta(\vec{j}_{HF} \cdot \vec{E}_{HF}) \rangle$ are taken into account. These model equations coupled with the Maxwell's equations are used to study the SBS [3] and FI [4], in the temperature range beyond 10 keV. We give in Figs. 1 and 2 the spatial growth of the FI as function of the wavenumber k for respectively the thermal and ponderomotive sources. The plasma parameters used are the electron temperatures $T_{e0} = 1\ keV$ (dashed line), $T_{e0} = 3\ keV$ (dotted line) and $T_{e0} = 20\ keV$ (solid line), the underdense electron density $n_{e0} = 0.1 n_c$ where n_c is the electron critical density, the laser wavelength $\lambda_L = 1.06\ \mu m$ and the ion charge number $Z_i = 6$.

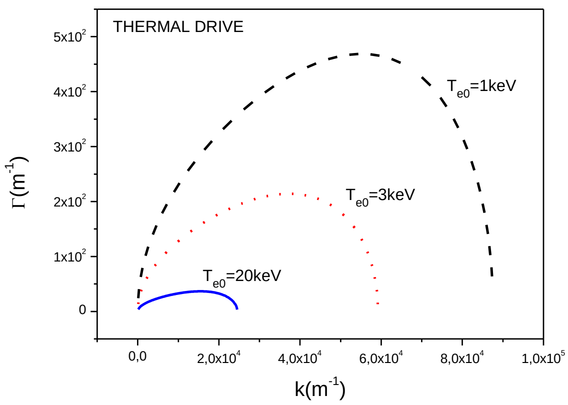

Fig.1

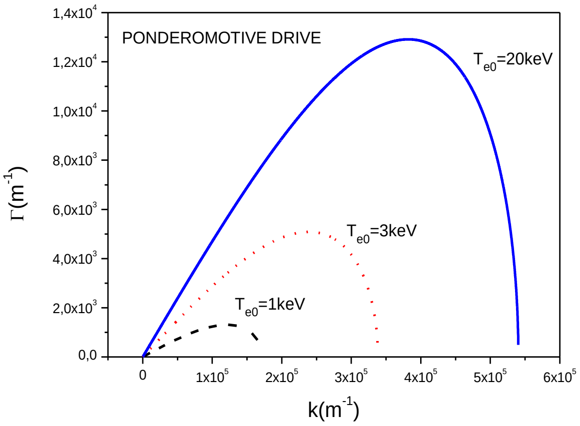

Fig.2

The analysis of these instabilities reveals strong spatial growth rates. Additionally, the relativistic effects on SBS and FI are examined through the relativistic transport coefficients and the factor $G(z)$. We also find that for these instabilities, the ponderomotive source is more efficient than the thermal source. A comparison between SBS and FI is presented based on their wave vectors (magnitude and direction) and their growth rates.

In conclusion, in hot plasmas with a temperature exceeding 10 keV, the SBS and FI can play a detrimental impact in the context of ICF as they lead to significant laser energy loss and compromise the symmetry of the target implosion.

Acknowledgments

This work has been carried out by University of Science and Technology HB, Algeria within the framework of the PRFU 2023-2026 (Projet de Recherche et de Formation Universitaire) and under grant agreement No B00L02UN160420230002.

References

[1] A. Bers, I. P. Shkarosfsky, and M. Shoucri, Phys. Plasmas 16, 022104 (2009)

[2] K. Bendib, A. Bendib, and G. Matthieussent, Phys. Plasmas 11, 4254 (2004).

[3] Yao Zhao, Jun Zheng, Min Chen, Lu-Le Yu, Su-Ming Weng, Chuang Ren, Chuan-Sheng Liu, and Zheng-Ming Sheng, Phys. Plasmas 21, 112114 (2014).

[4] V. Yu. Bychenkov, W. Rozmus, A. V. Brantov, and V. T. Tikhonchuk, Phys. Plasmas 7, 1511 (2000).