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STIMULATED RAMAN SCATTERING INSTABILITY OF LASER BEAM IN A PLASMA CHANNEL INCLUDING THE EFFECT OF THERMAL CONDUCTION

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ABSTRACT

This paper presents an analysis of the Stimulated Raman scattering instability of a laser beam in a plasma channel. Considering the nonlinearity to arise from collisional and thermal – conduction phenomena and following the approach of Sodha et al. [1] and Short et al. [17] the phenomenon of Stimulated Raman scattering instability including the effect of thermal conduction is studied. Thermal conduction plays an important role in temperature equilibrium when the electron mean free path λ_m is greater than the beam. Inside a filament, the laser undergoes stimulated Raman backscattering (B-SRS). A nonlocal theory of stimulated Raman scattering (SRS) reveals that growth rate and the threshold power for B-SRS is significantly reduced due to the geometrical factor and enhanced temperature inside the filament. It remains an important process in laser produced plasma. It is also a limiting process in a plasma- loaded free electron laser (FEL).

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Laser beam, stimulated Raman scattering, self-focused filament, Langmuir wave, thermal conduction

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[I] INTRODUCTION

It has been shown in recent years [1-3] that a high amplitude electromagnetic beam propagating in plasma is unstable to small-amplitude perturbations. This instability causes the breaking of the beam into filaments and is known as filamentation instability [1]. On the time scale $t>\tau_h$ (which is more relevant to laser – plasma interactions), where τ_h is the heating time of electrons, the nonlinearity arises through nonuniform heating and redistribution of electrons [4]. The understanding of filamentation of laser light may be important to the success of laser fusion. In the long scale length plasmas envisioned for reactor targets, local intensity hot spots caused by self-focusing or laser light filamentation can drive the plasma above parametric instability thresholds. These instabilities tend to be saturated by the creation of super thermal electrons [5]. The hot electrons can penetrate deeply into the pellet, heating the interior, making high compressions difficult. Directly driven targets require very uniform driving pressures. Filamentation could spoil this uniformity, making large compressions difficult. The laser light absorption, penetration, and conversion to X-rays could also be affected by self-focusing [1] and filamentation. The earlier investigations of filamentation of laser beams on a long time scale are restricted to large-scale perturbations where the thermal conduction effects may be neglected [6]. But in the cases of real interest one is much more concerned about the growth of small-scale perturbations where thermal conduction could play a dominant role in determining the energy dissipation of electrons. The relative size of perturbations depends on the ratio m_i/m, since beam radius r_o is generally of the same order as electron mean free path λ_m. In this paper we have studied the filamentation of laser beams in plasmas where both collisional and thermal-conduction losses are present simultaneously. At short wavelengths collisional effects considerably influence laser plasma interaction. The nonlinear process of stimulated Raman scattering is seen to require laser power greater than a threshold value, determined by collisions. In several experiments the observed values of threshold power are far below the values predicated theoretically [7-19]. Liu and Tripathi [14] have developed self-consistent theoretical model to obtain B-SRS growth rate in a cylindrical filament in collisionless plasma. They take the size of the filament to correspond to the maximum linear spatial growth rate for the filamentation instability, with the result that for typical laser intensities the SRS growth rate is only marginally changed from its value in the unfilamented incident beam. Afshar-rad et al. [15] have studied the evidence of stimulated Raman scattering occurring in laser filaments in long scale length plasmas. Drampyan [16] has studied the evidence of self-focusing and stimulated Raman scattering beam break-up into several filaments and filament

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development in a self-focused beam, as a result of azimuthal-angle instability. Sajal et al [19] have studied the relativistic forward stimulated channel in a plasma Raman scattering of laser in a plasma channel. Recently Yin et al. [20] have studied Onset and saturation of backward stimulated Raman scattering of laser in trapping regime in three spatial dimensions. Ghanshyam et al. [21] have studied model of stimulated Raman scattering from underdense collisional plasma without considering thermal conduction in which the laser intensity profile and plasma density have been modified by the filamentation instability. A circularly polarized Gaussian laser beam propagating through a low density plasma creates a partially electron depleted channel. The laser generates stimulated forward Raman scattering, producing a plasma wave and two radially localized electromagnetic sideband waves. The laser and the sideband waves exert an axial ponderomotive force on electrons driving the plasma wave. The latter couples with the pump to drive the sidebands. The radial width of the electromagnetic sideband is of the order of the spot size of the pump, r_0, whereas the radial width of the plasma wave is determined by the growth rate of the Raman process. The localization effect reduces the region of interaction and the growth rate. There is a significant motivation to operate free electron laser (FEL) in a plasma medium. The plasma aids electron beam guiding via charge and current neutralization and allows beam current higher than the vacuum limit. It may also help radiation guiding [17] via optical duct formation. Plasma, however, is a nonlinear medium. When FEL interaction takes place in a plasma medium and laser radiation acquires large intensity, it may bring about the onset of parametric instability, e.g., stimulated Raman scattering and Brillouin scattering that may stabilize the FEL instability and increase radiation band width. If one limits the plasma density to a lower level, then the Langmuir wave generated in the Raman process possesses smaller phase velocity and undergoes Landau damping. SRS is considered to be an important process in laser produced plasma also, here severely limits the deposition of the light energy. In this process, intense laser light interacts with a Langmuir wave and is scattered backward. The scattered wave and the laser pump exert a Ponderomotive force on the electron driving the Langmuir wave.

In this paper, we examine stimulated Raman backscattering of laser radiation in a performed plasma channel considering the effect of thermal conduction and follow the approach adopted by Short et al. [17] and Tripathi et al. [14]. The channel provides radial localization of the pump and decay waves. However, since the mode structure of three interacting waves is different, the nonlinear coupling coefficients are significantly diminished. In section 2, we examine fluid equations and Maxwell's equations to the coupled mode equations inside the filaments. These equations are solved using first-order perturbation theory neglecting pump depletion effects. The result is a nonlinear dispersion relation which is solved to obtain growth rate. In section 3, we discuss the results.

[II] METERIAL AND METHODS

2.1. Instability analysis

Let us consider the propagation of a plane uniform laser beam in collisional plasma along the z-axis,

$$\vec{E} = \vec{A}_0 (r, z) \exp[-i(\omega t - k_o z)], \qquad (1)$$

$$k_o = (\omega/c)\left(1-\frac{\omega_{po}^2}{\omega^2}\right)^{\frac{1}{2}}, \qquad (2)$$

$$\omega_{po}^2 = 4\pi n_o e^2/m \qquad (3)$$

and ω, ω_{po}, c, -e, m and n_o are the frequency of the main beam, the unperturbed plasma frequency of the medium, the velocity of light, the electron charge, the electron mass and the unperturbed concentration of the plasma respectively. In the presence of the field (1), the electrons acquire drift velocity in accordance with the momentum balance equation

$$m\frac{\partial \vec{v}}{\partial t} = -e\vec{E} - m\nu_{ei}\vec{v}, \qquad (4)$$

where ν_{ei} is the electron collision frequency. Expressing the variation of $\vec{v}$ as exp [-i(ωt-kz)], we obtain, in the limit $\omega^2 \gg \nu_{ei}^2$,

$$\vec{v} = \frac{e\vec{E}}{im\omega}\left(1-\frac{i\nu_{ei}}{\omega}\right). \qquad (5)$$

Besides this, the electrons absorb energy from the wave at the rate of $-e\vec{E}\cdot\vec{v}$. Whose time average is

$$-\frac{1}{2} e\vec{E}^*\cdot\vec{v} = \frac{e^2 A_o A_o^*}{2m\omega^2}. \qquad (6)$$

In the steady state the rate of energy gain must balance with the rate of energy loss through collisions and thermal conduction. Hence

$$-\nabla\cdot\left(\frac{\chi}{n}\nabla T_e\right)+\frac{3}{2}\delta\nu_{ei}(T_e - T_o) = \frac{e^2\nu_{ei}A_o A_o^*}{2m\omega^2},$$

where (7)

$$\frac{\chi}{n} = \frac{v_{th}^2}{\nu_{ei}},$$

$\delta = 2m/m_i$

is the fraction of excess energy lost per electron-ion energy exchange collision, T_e is the nonlinear field – dependent electron temperature and $v_{th} = (2T_o/m)^{\frac{1}{2}}$ is the electron

THE IIOAB JOURNAL
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thermal speed. For $\nu_{ei} r_o^2 / v_{th}^2 < (\delta \nu_{ei})$ thermal conduction is important, and we solve the energy – balance equation in the perturbation approximation. For a beam of finite extent we express

$$T_e = T_o + \Delta T_e, \quad (8)$$

where $\Delta T_e << T_o$. Then Eq. (7) can be recast as

$$\nabla^2(\Delta T_e) - \frac{3}{2}\frac{\delta \nu_{ei}{}^2}{v_{th}^2}(\Delta T_e) = -\frac{e^2 v_{ei}^2}{2m\omega^2 v_{th}^2}|A_o|^2 \quad (9)$$

Now we perturb the beam by a perturbation

$$A_1 (r, z) \exp[-i(\omega t - kz)], \quad (10)$$

where A_1 (x,z) is not necessarily a slowing varying function of space variables. The total electric vector of the laser may now be written as

$$\vec{E} = A_o + A_1 (r, z) \exp[-i(\omega t - kz)], \quad (11)$$

Where $r = (x^2 + y^2)^{1/2}$ refers to a cylindrical polar co-ordinate, A_o is the amplitude in the absence of fluctuations (polarized in the y direction) and A_1 is the amplitude of the fluctuations, which is a spatially slowly varying function. The combined effect of these two fields is to heat the electrons and exert a pressure-gradient force, causing redistribution of plasma via ambipolar diffusion. The nonlinear field-dependent electron temperature T_e in the steady state may be obtained by solving Eq. (9) only the x and y dependence of A_1 is known. Taking $\mathbf{A_1} \propto e^{\mathbf{iq.r}}$ with $q_{\|} << q_{\perp}$, where $q = q_{\perp} + q_{\|}$ is the scale length of the perturbation (the subscripts $\|$ and $\perp$ referring to components parallel and perpendicular to the z direction), T_e may be written as

$$T_e - T_0 = \frac{e^2 \left[A_0 \cdot \left(A_1 + A_1^*\right) + A_0^2\right]}{3m\omega^2 \delta^{/}} \quad (12)$$

Where $\delta^{/} = \delta + \frac{2}{3}\frac{q_{\perp}{}^2 v_{th}^2}{3 v_{ei}^2}$

As a result of non-uniformity in heating, the plasma is redistributed so that

$$n(T_e + T_0) = n_0(T_{e0} + T_0), \quad (13)$$

where $T_{e0} = T_0 + \frac{e^2 A_0^2}{3m\omega^2 \delta^{/}}$. (14)

Using Eq. (12), (13) and (14), the modified electron density may be written as

$$n = n_0 \left[1 - \frac{e^2 A_0 \cdot \left(A_1 + A_1^*\right)}{3 T_0 m\omega^2 \delta^{/} \left(2 + e^2 A_0^2 / 3m\omega^2 T_0 \delta^{/}\right)}\right]. \quad (15)$$

The dielectric constant of the plasma may be written as

$$\in = \in_0 + \in_2 A_0 \cdot \left(A_1 + A_1^*\right), \quad (16)$$

where

$$\in_2 = \frac{\omega_{po}^2}{\omega^2}\frac{\alpha P}{2 + \alpha P A_0^2}$$

$$P = \frac{1}{1 + 2q^2 v_{th}^2 / 3 v_{ei}^2 \delta}$$

and

$$\alpha = \frac{e^2}{3m\omega^2 T_0 \delta}.$$

Substituting E, from Eq. (1) into the wave equation and using $\nabla \cdot (\in E) = 0$ and linearizing in A_1, we obtain the following equation for A_1:

$$2i k_0 \frac{\partial A_1}{\partial z} + \frac{\partial^2 A_1}{\partial r^2} + \frac{1}{r}\frac{\partial A_1}{\partial r} + \frac{\omega_{p0}^2}{c^2}\frac{\alpha A_o^2 p\left(A_1 + A_1^*\right)}{\left(1 + \alpha p A_o^2\right)} = 0, \quad (17)$$

following Sodha *et al.*[1] and expressing $A_1 = A_{1r} + iA_{1i}$ Eq.(17) splits into two coupled equations for A_{1r} and A_{1i} :

$$2 k_0 \frac{\partial A_{1r}}{\partial z} + \frac{\partial A_{1i}}{\partial r^2} + \frac{1}{r}\frac{\partial A_{1i}}{\partial r} = 0, \quad (18)$$

$$-2 k_0 \frac{\partial A_{1i}}{\partial z} + \frac{\partial^2 A_{1r}}{\partial r^2} + \frac{1}{r}\frac{\partial A_{1r}}{\partial r} + \frac{2\omega_{p0}^2}{c^2}\frac{p\alpha A_o^2}{\left(1 + p\alpha A_o^2\right)} A_{1r} = 0$$

For $A_{1r}, A_{1i} \sim J_o(q_{\perp} r)\, e^{\Gamma z}$ Eq. (18) straight way yields the spatial growth rate

$$\Gamma = \frac{q_{\perp}}{2k_o}\left[-q_{\perp}^2 + 2k_o^2 \frac{\in_2 A_o^2}{\in_o}\right]^{1/2}. \quad (19)$$

The spatial growth maximizes to

$$\Gamma_{max} = \frac{\omega_{p0}^2}{2k_o^2 c^2}\frac{p\alpha A_o^2}{1 + p\alpha A_o^2} \quad (20)$$

at

$$q_{opt} = \frac{\omega_{p_o}}{c}\left(\frac{p\alpha A_o^2}{1 + p\alpha A_o^2}\right)^{1/2},$$

where $\alpha A_o^2 = \frac{1}{6}\frac{V_o^2}{c_s^2}, V_o = \frac{e|Ao|}{m\omega_o}, c_s = \left(\frac{2T_o}{m_i}\right)^{1/2}$ and m_i is the mass of ion. The first zero of J_o occurs at $q_{\perp} r = 2.4$ .The amount of power tends to localize in maximally growing filament can be expressed as

$$P^{/} = \frac{c}{8\pi}\pi r^2 A_o^2$$

$$= 4.3\frac{c^3 c_s^2 m^2 \omega_0^2}{e^2 \omega_{po}^2}\left(1 + p\alpha A_o^2\right). \quad (21)$$

Following Sodha et. al. [1] the temperature and density profile in the filament can be written as

$$T_e = T_o \left[1+2\alpha p A_o^2\right] \left[1+2\alpha_1 p E_o^2(r)\right],$$

$$n_o^{/} = \frac{n_o}{\left[1+\alpha_1 p E_o^2(r)\right]},$$

$$\nu = \nu_o \left(\frac{T_e}{T_o}\right)^{-3/2} \left(\frac{n_o^{/}}{n_o}\right), \qquad (22)$$

and

$$\alpha_1 = \frac{\alpha}{1+2\alpha p A_o^2}, \qquad (23)$$

where $\vec{E}_o$(r) is the total electric field of filament at r and ν_o is collision frequency corresponding to n_o and T_o, Expressing $\vec{E}_o$(r) for cylindrically symmetric beam, as $\vec{E}_o = \vec{A}$(r, z) exp {-i(ω_o t – k_o z)}and neglecting $\frac{\partial^2 A}{\partial z^2}$ in wave equation which implies that the characteristic distance (in the z directions) of the intensity variation is much greater than the wavelength and following Sodha et al.[1] a self-consistent solution of the wave equation under the modified density and temperature profile turns out to be

$$A = A_0(r,z) \exp(-ikS),$$

$$A_0^2(r,z) = \frac{E_{00}^2}{f^2} \exp\left(-r^2/r_0^2 f^2\right),$$

$$S(r,z) = \frac{r^2}{2}\beta(z) + \Psi(z), \qquad (24)$$

$$\beta = \frac{1}{f}\frac{df}{dz},$$

where f is the ratio of the beam diameter to its value at z = 0, β corresponds to the inverse radius of the curvature of the wave front. The beam width parameter, f (z), scales the beam radius. As f (z) decreases, the intensity increases as $1/f^2(z)$ in order to conserve energy. The eikonal gives an ordinary differential equation for f(z) if it is expanded to order r^2. This expansion is known as the paraxial ray approximation since it emphasizes the importance of the paraxial (those near r = o) rays. The aberration less and paraxial ray approximations are essentially synonymous since they yield a set of solutions characterized by a single parameter that scales the shape of the beam. We obtain equation for the beam width parameter f:

$$\frac{d^2 f}{dz^2} = \frac{1}{R_d^2 f^3} - \frac{E_{00}^2}{r_0^2 f^3}\phi^{/}\left(\frac{E_{00}^2}{f^2}\right),$$

$$\frac{d^2 f}{dz^2} = \frac{1}{R_d^2 f^3} - \frac{1}{R_n^2 f^3} \qquad (25)$$

where $\phi^{/}$ is the derivative of ϕ with respect to its arguments and terms of order higher than r^2 have been neglected. Employing paraxial ray approximation, the radius of nonlinear steady state self-trapped cylindrical filament propagating through a homogeneous plasma can be obtained from Eq. (25) balancing diffraction and self-focusing terms,

$$R_d^2 = R_n^2 \qquad (26)$$

where

$$R_d = k_o r_o^2$$

and

$$R_n = \frac{\omega_o^2}{\omega_{po}^2} r_o^2 \frac{\left(1+\alpha_1 p E_{oo}^2\right)^2}{\alpha_1 p E_{oo}^2}.$$

Equation (24) determines the radius r_o of a self-trapped filament,

$$r_o = \frac{c}{\omega_{po}} \frac{\left(1+\alpha_1 p E_{oo}^2\right)}{\left(\alpha_1 p E_{oo}^2\right)^{1/2}}, \qquad (27)$$

where E_{oo} is the amplitude of the filament of radius r_o, in the nonlinear state, on the axis. The corresponding power in nonlinear steady state is

$$P = \frac{c}{8\pi}\pi r_o^2 E_{oo}^2$$

$$= \frac{c^3}{8\omega_{po}^2} \frac{\left(1+\alpha_1 p E_{oo}^2\right)^2}{\alpha_1 p}.$$

Equating the power contained in the filament p to $p^{/}$ one obtains

$$\alpha_1 p E_{oo}^2 = \left[2.4 \frac{\left(1+\alpha p A_o^2\right)^{1/2}}{\left(1+2\alpha p A_o^2\right)^{1/2}} - 1\right]. \qquad (28)$$

Thus the radius and field intensity in a self-trapped filament are dependent of the initial power density of the incident beam. The modified density, temperature and collision frequency variation near the axis of the filament can be obtained by expanding $n_o^{/}, T_e$ and ν around r ≅ 0

$$n_o^{/} = n_o^o\left(1+\frac{r^2}{a^2}\right), \qquad (29)$$

$$T_e = T_o^o\left(1-\frac{r^2}{b^2}\right), \qquad (30)$$

$$\nu = v_o^o\left(1+\frac{r^2}{d^2}\right), \quad (31)$$

where

$$a^2 = \frac{r_o^2\left(1+\alpha_1 pE_{oo}^2\right)}{\alpha_1 pE_{oo}^2}, \quad (32)$$

$$b^2 = \frac{r_o^2\left(1+2\alpha_1 pE_{oo}^2\right)}{2\alpha_1 pE_{oo}^2}, \quad (33)$$

$$d^2 = \frac{2a^2b^2}{3a^2+2b^2} \quad (34)$$

$$n_o^o = \frac{n_o}{\left(1+\alpha_1 pE_{oo}^2\right)}, \quad (35)$$

$$T_o^0 = T_o\left(1+2\alpha pA_o^2\right)\left(1+2\alpha_1 pE_{oo}^2\right) \quad (36)$$

and

$$v_o^o = v_o\left(\frac{n_o^o}{n_o}\right)\left(\frac{T_o^o}{T_o}\right)^{-3/2}. \quad (37)$$

The self –trapped laser decays into a low frequency Langmuir wave with scalar potential

$$\phi = \phi(r)\, e^{-i(\omega t - kz)} \quad (38)$$

and a backscattered electromagnetic wave

$$\vec{E}_1 = \vec{E}_1(r)e^{-i(\omega_1 t - k_1 z)} \quad (39)$$

and

$$\vec{B}_1 = \frac{c\vec{k}_1\times\vec{E}_1}{\omega_1},$$

where

$$\vec{k}_1 = \vec{k} - \vec{k}_o$$

and

$\omega_1 = \omega - \omega_o$.

The pump and sideband waves exert a low frequency Ponderomotive force $\mathbf{F_p}$ on the electrons [1]

$$\vec{F}_p = e\nabla\phi_p = -\frac{m}{2}\left[\vec{v}_o.\nabla\vec{v}_1 + \vec{v}_1.\nabla\vec{v}_o\right] - \frac{e}{2c}\left[\left(\vec{v}_o\times\vec{B}_0\right)\right] \quad (40)$$

where ϕ_p is the Ponderomotive potential. Solving (40), one obtains

$$\phi_p = \frac{e\vec{E}_o.\vec{E}_1}{2m\omega_o\omega_1}, \quad (41)$$

driving the Langmuir wave

$$\frac{\partial^2\phi}{\partial r^2}+\frac{1}{r}\frac{\partial\phi}{\partial r}+\left[\left\{\frac{\omega^2-\omega_{po}^2-k^2v_{tho}^2+i\omega v_o^o}{v_{tho}^2}\right\}-\left\{r^2\frac{\omega_{po}^2}{a^2v_{tho}^2}\left(1-\frac{iv_o^o\omega}{\omega_{po}^o}\frac{a^2}{c_1^2}\right)\right\}\right]\phi = -\frac{\omega^2|v_o}{2\omega_o v_{th}^2}E_1 \quad (42)$$

where

$$v_{tho} = \left(\frac{2T_o^o}{m}\right)^{1/2},$$

$$v_o = v_{osc}\exp\left(-\frac{r^2}{2a^2}\right), \quad (43)$$

$$v_{osc} = \frac{eE_{oo}}{m\omega_o},$$

$$c_1^2 = \frac{b^2d^2}{b^2+d^2},$$

$\omega_{po} = \left(\frac{4\pi n_o^o e^2}{m}\right)^{1/2}$ and we have assumed only collisional damping.

The current density at the side band frequency can be written as

$$\vec{J}_1 = -n_o^o e\vec{v}_1 - \frac{1}{2}ne\vec{v}_o \quad (44)$$

$$= \left[\left\{-\frac{n_o^o e^2\vec{E}_1}{im\omega_1}\right\}-\left\{\frac{k^2}{4\pi}\frac{e^2\vec{E}_o\phi}{2im\omega_o}\right\}\right], \quad (45)$$

Using Eq. (45) in the wave equation we get

$$\frac{\partial^2E_1}{\partial r^2}+\frac{1}{r}\frac{\partial E_1}{\partial r}+\left(\frac{\omega_1^2-\omega_{po}^2-k_1^2c^2}{c^2}-\frac{\omega_{po}^2}{a^2}\frac{r^2}{c^2}\right)E_1 = -\frac{k^2\omega_o|v_o|}{2c^2}\phi. \quad (46)$$

It is considered that the sideband wave is not affected by Landau damping. However, it may suffer damping due to collisions.

One obtains

THE IIOAB JOURNAL ISSN: 0976-3104

$$\frac{\partial^2 E_1}{\partial r^2}+\frac{1}{r}\frac{\partial E_1}{\partial r}+\left[\left\{\frac{\omega_1^2-\omega_{po}^2\left(1-i\frac{v_o^o}{\omega_1}\right)-k_\ell^2c^2}{c^2}\right\}-\left\{\frac{\omega_{po}^2}{a^2}\frac{r^2}{c^2}\left(1-\frac{iv_o^o a^2}{\omega_1 d^2}\right)\right\}\right]E_1$$

$$=-\frac{k^2\omega_o|v_o|}{2c^2}\phi \tag{47}$$

Equations (42) and (47) are coupled nonlinearly. When nonlinear coupling is ignored, the solutions of (42) and (47) are written as [17, 18]

$$\phi=\phi_l=\Gamma_\ell L_\ell\left(\frac{r^2}{b_1^2}\right)\exp\left(-\frac{r^2}{2b_1^2}\right)\exp\left(\frac{ir^2}{4b_1^2}\frac{v_o^o\omega}{\omega_{po}^2}\frac{a^2}{c_1^2}\right),$$

$$E_1=E_{1m}=\Gamma_m L_m\left(\frac{r^2}{b_2^2}\right)\exp\left(-\frac{r^2}{2b_2^2}\right)\exp\left(\frac{ir^2}{4b_2^2}\frac{v_o^o}{\omega_1}\frac{a^2}{d^2}\right),$$

where (48)

$$b_1=\left(\frac{av_{tho}}{\omega_{po}}\right)^{1/2},$$

$$b_2=\left(\frac{ca}{\omega_{po}}\right)^{1/2},$$

$$L_\ell(\xi)=e^{\xi}\frac{d^\ell}{d\xi^\ell}\left(\xi^\ell e^{-\xi}\right)$$

where l= 0,1,2,.... , m = 0,1,2... and Γ_l and Γ_m are normalization constants. Since the pump field (hence v_o) scales as $\exp\left(-\frac{r^2}{2a^2}\right)$, the most unstable backscatter mode would correspond to m = 0. In the presence of nonlinear coupling terms, it is possible to express ϕ in terms of an orthogonal set of wave functions ϕ_l where as E_1 in terms of E_{10}. Where as E_1 can be taken to be dominant mode:

$$\phi=\sum_l s_l\phi_l,$$

and

$$E_1=TE_{10}. \tag{49}$$

Substituting for ϕ and E_1 in (42) and (47) and multiplying the resulting equation by ϕ_l and E_{10}, respectively, and integrating over rdr, one obtains

$$\left[\left\{\frac{\omega^2-\omega_{po}^2-k^2v_{tho}^2+i\omega v_o^o}{v_{tho}^2}\right\}-\left\{2(\ell+1)\frac{\omega_{po}}{av_{tho}}\left(1-\frac{1}{2}\frac{v_o^o\omega}{\omega_{po}^2}\frac{a^2}{c_1^2}\right)\right\}\right]s_\ell$$

$$=-\frac{\omega^2T}{2\omega_oV_{tho}^2}\int rdr|v_o|\phi_\ell E_{lo}\left(1+\frac{r^2}{b^2}\right), \tag{50}$$

$$\left[\left\{\frac{\omega_1^2-\omega_{po}^2\left(1-\frac{iv_o^o}{\omega_1}\right)-k_1^2c^2}{c^2}\right\}-\left\{\frac{2\omega_{po}}{ac}\left(1-\frac{1}{2}\frac{iv_o^o}{\omega_1}\right)\right\}\right]T$$

$$=-\frac{k^2\omega_o}{2c^2}\sum_\ell S_\ell\int rdr|v_o|\phi_\ell E_{lo} \tag{51}$$

leading to a nonlinear dispersion

$$\left[\left\{\omega_1^2-\omega_{po}^2\left(1-\frac{iv_o^o}{\omega_1}\right)\right\}-\left\{k_1^2+\frac{2\omega_{po}}{ac}\left(1-\frac{1}{2}\frac{iv_o^o}{\omega_1}\frac{a^2}{d^2}\right)\right\}c^2\right]$$

$$=4\Gamma_o^2\omega\omega_o\times$$

$$\sum\frac{\left(I_l^2+\frac{I_l.I_l(1)}{b^2}\right)}{\left[\left(\omega^2-\omega_{po}^2+i\omega v_o^o\right)-\left\{k^2+\frac{(2l+1)\omega_{po}}{av_{tho}}\left(1-\frac{1}{2}\frac{v_o^o\omega a^2}{\omega_{po}^2c_1^2}\right)\right\}v_{tho}^2\right]} \tag{52}$$

where

$$I_\ell=\int_0^\infty rdr\phi_\ell E_{lo}\exp\left(-\frac{r^2}{2a^2}\right), \tag{53}$$

$$I_\ell(1)=\int_0^\infty r^3dr\phi_\ell E_{lo}\exp\left(-\frac{r^2}{2a^2}\right), \tag{54}$$

$\Gamma_o=\frac{1}{4}(kv_{osc})(\omega/\omega_o)^{1/2}$ is uniform medium growth rate and we have used $v_o\cong v_{osc}e^{-r^2/2a^2}$. Since ϕ_1 is localized in a narrow region around $r\lesssim_1<<a$. $I_1(1)$ may be simplified to become

$$I_1\cong\frac{\sqrt{2}}{b_2}\int_0^\infty r^3dr\phi_\ell \tag{55}$$

and

$$I_l(1)\cong\frac{\sqrt{2}}{b_2}\int_0^{oo}r^3dr\phi_\ell. \tag{56}$$

Expressing ω = ω + iΓ, the maximum growth rate can be expressed as [21]

THE IIOAB JOURNAL
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$$\Gamma = \Gamma_o \frac{2b_1}{b_2}\left(1 + \frac{2b_1^2}{b^2}\right) \quad (57)$$

and the uniform growth rate

$$\Gamma_{oo}^{/} = \frac{1}{4} k V_o \left(\frac{\omega}{\omega_o}\right)^{1/2}$$

one obtains

$$\frac{\Gamma}{\Gamma_{oo}^{/}} = \frac{v_{OSC}}{V_o} 2\left(\frac{v_{tho}}{c}\right)^{1/2}\left(1 + \frac{2b_1^2}{b^2}\right).$$

The threshold intensity can be expressed as .

$$P_{th}^{//} = \left(\frac{v_{osc}}{c}\right)^2_{SRS-th} = \frac{1}{4}\left(\frac{\omega_{po}}{\omega_o}\right)^2 \frac{v_o^{o2}}{\omega_o \omega_{po}} \frac{yz}{x} \quad (58)$$

where

$$y = \left(1 + \frac{v_{tho}}{a\omega_{po}} \frac{a^2}{c_1^2}\right),$$

$$z = \left(1 + \frac{c}{a\omega_{po}} \frac{a^2}{d^2}\right), \quad (59)$$

and

$$x = \frac{b_1^2}{b_2^2}\left(1 + \frac{2b_1^2}{b^2}\right).$$

The threshold condition for B-SRS, when background plasma and intensity of laser beam is uniform is written as [21]

$$P_{th}^{/} = \left(\frac{V_o}{c}\right)^2_{SRS-th} = \frac{1}{4}\left(\frac{\omega_p^2}{\omega_o^2}\right)\frac{v_o^2}{\omega_o \omega_p}. \quad (60)$$

[III] RESULTS AND DISCUSSION

A uniform–laser beam propagating through collisional plasma is unstable to a transverse perturbations, and break up into filaments. An optimum value of $q_{\perp}$ of the perturbation is required for a maximum growth rate. A uniform plane wave does not cause redistribution of carriers. However, as a result of perturbations in the intensity distribution along the wave front, electrons do become redistributed. The process of B-SRS in a filament is aided by the enhancement of power density over its initial value but it is inhibited by the localization of Langmuir wave and hence of the interaction region. The Process of B- SRS is inhibited by thermal conduction and it is observed that the power density inside the filament is much greater than the initial power density of the laser beam. Hence, the enhanced intensity in laser filament reduces collisional damping of backscatter light wave, diminishing the threshold power for B-SRS. The onset of B-SRS is strongly correlated with intensity threshold of the filamentation instability that depends on thermal conduction. The growth rate of SRS is reduced by a geometrical factor I_l and $I_l(1)$ depending on the mode structure of the pump and decay waves. The growth rate scales linearly with the amplitude of the laser wave.. In a plasma filled FEL, the Raman instability would limit the growth of FEL instability via diverting FEL wave energy into the Langmuir and the sideband waves.

[IV] REFERENCES

[1] Sodha MS, Ghatak AK and Tripathi VK. [1976] Self focusing of laser beam in plasmas and Dielectrics. *Prog Opt* 13:169 – 265.

[2] Kaw PK, Schmidt G and Wilcox T. [1973] Filamentation and trapping of electromagnetic radiation in *plasmas. Phys Fluids* 16: 1522–1525.

[3] Palmer AJ. [1971] Stimulated Scattering and Self-Focusing in Laser-Produced Plasmas. *Physics of Fluids, Phys Fluids* 14: 2714–2718.

[4] Estabrook K, Kruer WL and Lasinski BF. [1980] Heating by Raman backscatter and forward scatter. *Phys Rev Lett* 45: 1399–1403.

[5] Kruer WL. [1987] The Physics of Laser-Plasma Interactions, Addison- Wesley Publishing Company, California.

[6] Barr HC, Boyd TJM and Coutts GA. [1986] Stimulated Raman scattering in the presence of filamentation in under dense *plasmas.Phys Rev Lett* 56: 2256–2259.

[7] Baldis HA. [1983] Stimulated scattering in laser produced plasmas. *Plasma Phys* 25: 1297–1310.

[8] Shepard CL , Tarvin JA, Berger, Gare RL, Busch R, et al. [1986] Phys. Raman scattering in experiments with planar Au targets irradiated with 0.53 µm laser light. *Phys Fluids* 29 (2): 583–593.

[9] Amini B and Chen FF.[1986] The stimulated Raman threshold .I *.experiment.Phys Fluids* 29: 3864–3871

[10] Seka W, Williams EA, Craxton RS, Goldman LM, Short RW and Tanaka K. [1984] Convective stimulated Raman scattering instability in UV laser plasmas. *Phys Fluids* 27: 2181–2186.

[11] Tarvin JA, Busch GE, Gabl EF, Schroeder RJ, Shepard CL. [1986] Laser and plasma conditions at the onset of Raman scattering in an under dense plasma. *Laser Part Beams* 4: 461–471.

[12] Simon A and Short RW. [1984] New model of Raman spectra in laser produced plasma. *Phys Rev Lett* 53:1912–1914.

[13] Sharma AK and Tripathi VK. [1987] Two-Plasmon Decay of Self-Trapped Laser Radiation in a Plasma.*IEEE Trans Plasma Sci* 15(3): 257– 260.

[14] Liu CS and Tripathi VK. [1986] Consequence of filamentation on stimulated Raman *Scattering.Phys Fluids* 29: 4188– 4191.

[15] Afshar-rad T, Coe SE, Willi O and Desselberger M. [1992] Evidence of stimulated Raman scattering occurring in laser filaments in long-scale-length plasmas. *Phys Fluids* B4 (5):1301–1322.

THE IIOAB JOURNAL
ISSN: 0976-3104

[16] Drampyan RK. [2004] Break-up as a result of self-focusing and stimulated Raman scattering of a laser beam in a Kerr medium. *J Opt A Pure Appl Opt* 6: 213–216.

[17] Short R, Seka W and Bahr R. [1987] Stimulated Raman scattering in self focused light filaments in Laser produced plasmas.*Phys Fluids* 30: 3245–3251.

[18] Spiegel MR. [1968] Mathematical Handbook, McGraw-Hill, New York .

[19] Sajal V. [2006] Relativistic forward stimulated Raman scattering of a laser in a plasma channel. *Phys Scr* 74: 484–488.

[20] Yin L, Albright BJ, Rose HA, Bowers KJ and Bergen B. [2009] Onset and saturation of backward stimulated Raman scattering of laser in trapping regime in three spatial dimensions. *Phys Plasmas* 16: 113101–113113.

[21] Ghanshyam and Tripathi VK. [2005] Stimulated Raman scattering instability of laser beam propagating through collisional plasma in a self-focused filament. *Indian J Phys* 79 (5): 515–521.

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BIO PHYSICS