where $g_h = n_h/(N_h - n_h)$, $\rho_{1h}$

$= \text{cov}(y_h, x_h)/\sigma_{y_h}\sigma_{x_h}$,

$\rho_{2h} = \text{cov}(y_h, z_h)/\sigma_{y_h}\sigma_{z_h}$, $\rho_{3h} = \text{cov}(x_h, z_h)/\sigma_{x_h}\sigma_{z_h}$,

$c_{y_h} = \sigma_{y_h}/\overline{Y}_h$, $c_{x_h} = \sigma_{x_h}/\overline{X}_h$, $c_{z_h} = \sigma_{z_h}/\overline{Z}_h$.

*Theorem 5*—Bias and MSE of the combined estimator to the first order are

$$B(\hat{\overline{Y}}_c) = \sum_{h=1}^{L} g\left(\frac{N_h - n_h}{N_h n_h}\right) W_h^2 (\beta\rho_{3h}\sigma_{x_h} - \rho_{2h}\sigma_{yh})(\sigma_{z_h}/\overline{Z}) - \text{cov}(b, \overline{x}_{st}), \quad (26)$$

and

$$M(\hat{\overline{Y}}_c) = \sum_{h=1}^{L}\left(\frac{N_h - n_h}{N_h n_h}\right) W_h^2 \Big[\sigma_{y_h}^2 + \beta^2\sigma_{x_h}^2 + g^2(\overline{Y}/\overline{Z})^2\sigma_{z_h}^2 - 2\beta\rho_{1h}\sigma_{x_h}\sigma_{y_h} + 2g(\overline{Y}/\overline{Z})\sigma_{z_h}(\rho_{2h}\sigma_{y_h} - \rho_{3h}\sigma_{x_h})\Big]. \quad (27)$$

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# DISPERSIVE OPTICAL BISTABILITY IN PLASMAS

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## ABSTRACT

A model for the dispersive optical bistability in plasmas is suggested. Using the theory of coherent wave–wave interactions in plasmas, and the Vlasov–Maxwell equations, the conditions for the existence of optical bistability, satisfying the constraints of perturbative expansions, are derived for the general case of a cômplex coupling constant between the driven and the driving modes.

## INTRODUCTION

Optical bistability (OB) has been extensively studied in recent years. Mean field approximation has been used in the theory of absorptive[1,2] and dispersive[3] OB. Bonifacio and Lugiato gave the theory of absorptive and dispersive OB incorporating the incident radiation[4]. The photon statistics of absorptive[5] and dispersive[6] OB have also been found. An anharmonic oscillator model[7] was proposed to describe dispersive OB and the switching characteristics studied[8], in the case of the incident radiation being damped either very slowly or very quickly with respect to the oscillator.

This paper studies the occurrence of OB in an electron-ion plasma using the anharmonic oscillator model. The non-linear processes in the plasma are assumed to give rise to the anharmonicity in the model. The nonlinear theory of laser-plasma interaction is studied in the kinetic picture. The most general conditions for the existence of OB in a dispersive medium have been derived, the special cases of which agree with those in literature.

### Model

Consider a warm, fully ionized electron-ion plasma with a plane-polarised laser radiation incident on it. The plasma acts as a dispersive medium. Let the low frequency ion-acoustic waves of frequency $\omega_a$ be maintained at a constant amplitude by an external agent. The incident laser radiation has a frequency $\omega_L = \omega_p + O(\omega_a)$, where $\omega_p$ is the electron plasma frequency. [$O(\omega_a)$ means that, since $\omega_L$ and $\omega_p \gg \omega_a$, we take both $\omega_L = \omega_P + \omega_a$ and $\omega_L = \omega_P + 2\omega_a$ as possible interactions in our analysis]. The wavevectors of the laser, plasma and acoustic waves are taken to be collinear. A constant electron drift with velocity $U_0$ is maintained perpendicular to the wavevectors. This current is necessary to couple the laser and the plasma waves.

A schematic diagram of the model is given in figure 1. Here $k$ is the wave-vector, **E** and **B** are the electric and magnetic fields, and the subscripts $L$, $P$ and $a$, stand for the laser, plasma and acoustic waves respectively. The nonlinear interactions considered are shown in figures 2 and 3. Figure 2a corresponds to the nonlinear process satisfying $\omega_L = \omega_P + 2\omega_a$ while figure 2b shows the case $\omega_L = \omega_P + \omega_a$. Figure 3 shows the coupling of four-plasma waves and is in our model, the analog of the anharmonic oscillator potential. The laser field in the plasma is assumed to be a dipole field ($k_L \ll k_P, k_a$).

The nonlinear interactions are incorporated in the nonlinear Vlasov equation as a perturbation expansion

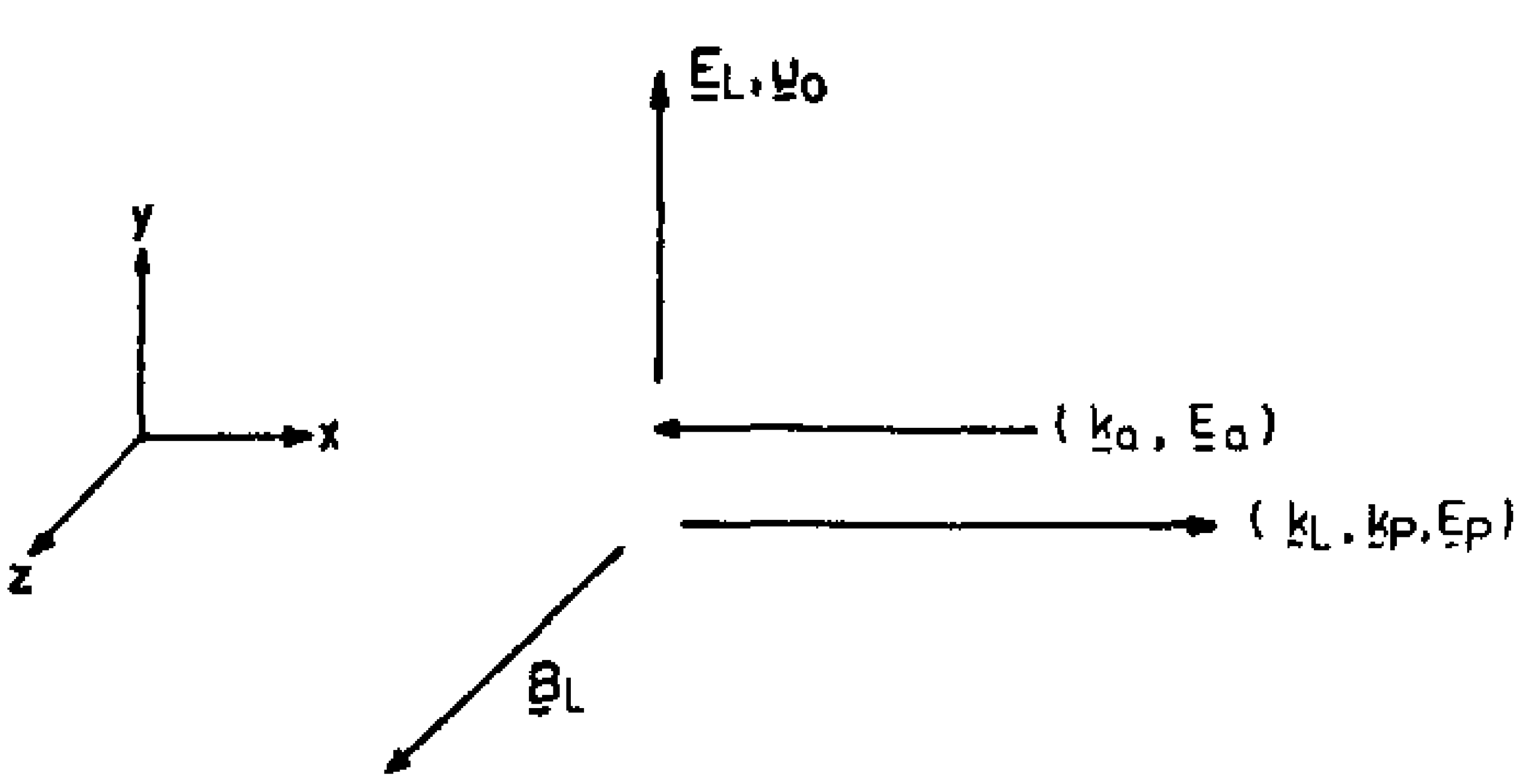


**Figure 1.** Schematic configuration of the plasma interacting with the laser. $E_L$, $E_P$ and $E_a$ are the electric fields respectively of the laser, plasma wave and ion acoustic wave, $k_L$, $k_P$ and $k_a$ their wavevectors, $B_L$ is the magnetic field of the laser, $u_0$ is the velocity of the drifting electrons.

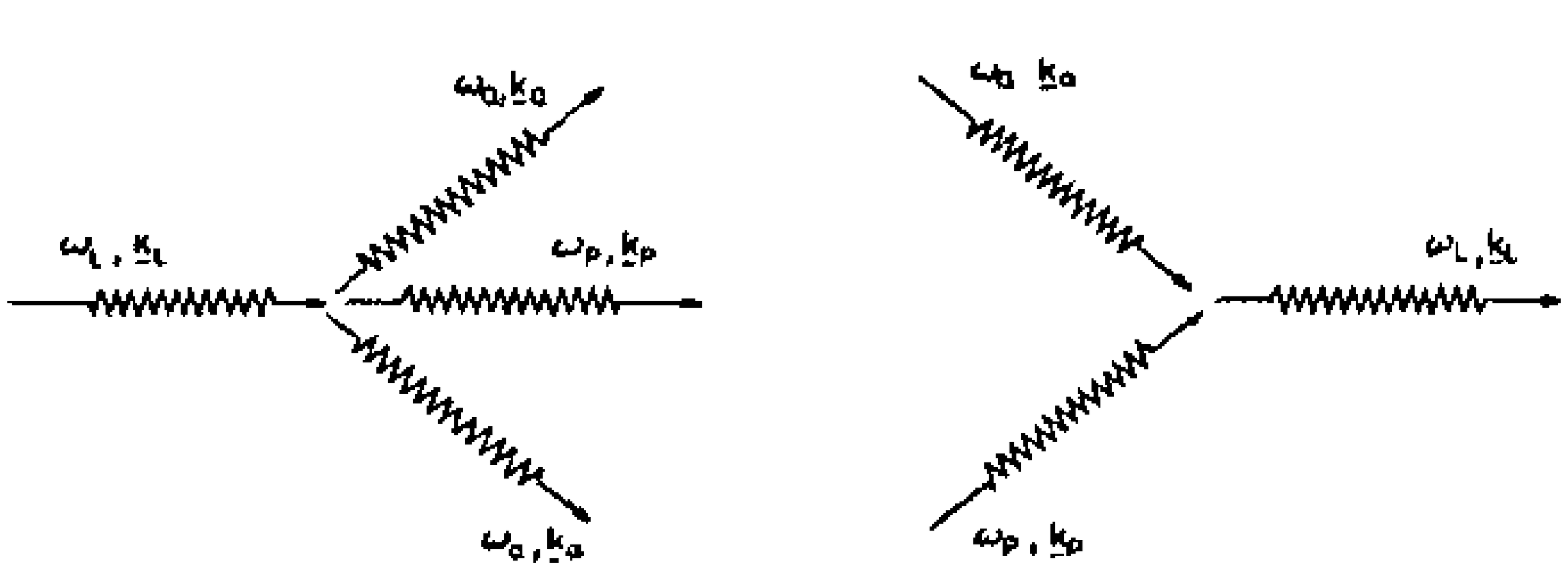


**Figure 2.** Laser plasma interactions: (**a**) Four-wave interaction involving two ion acoustic waves, a plasma wave and the laser. (**b**) Three-wave interaction.

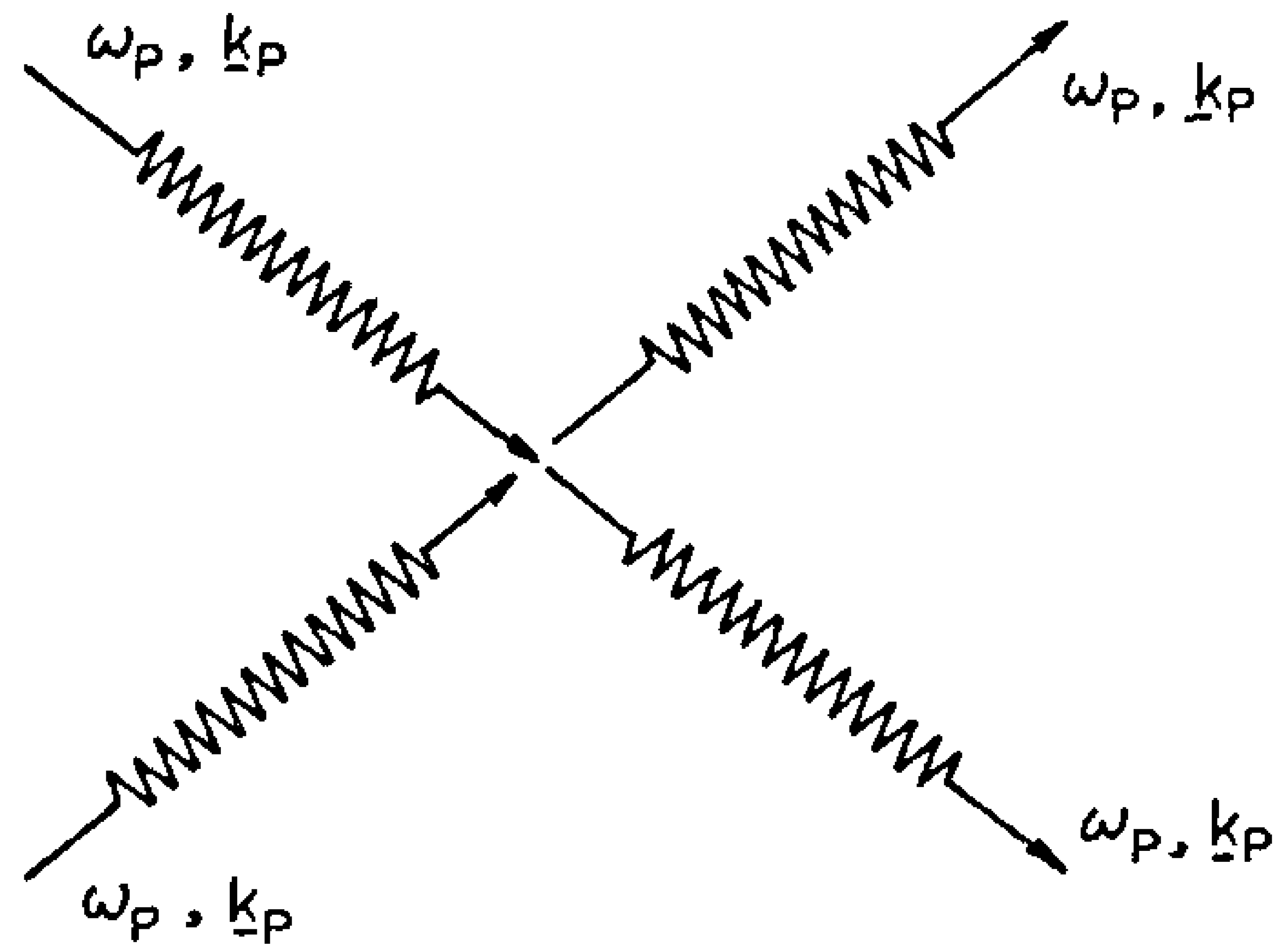


**Figure 3.** Plasmon-plasmon interaction.

in the electric field amplitudes[9]. If the amplitudes of the electric fields vary very slowly in space (time) as compared to the characteristic length (time) of the wave, then the space (time) variation of the electric fields can be written in terms of the nonlinear polarizations or currents[10]. Thus one obtains a set of coupled, nonlinear differential equations in $E_L$ and $E_P$ and conditions for existence of OB will be derived.

## FORMALISM

The derivation of the equation of motion for $E_P$ is given in detail. That for $E_L$ follows in a similar manner.

Let the equilibrium distribution functions for the electrons and the ions be denoted by

$$f_{0e}(\mathbf{V}) = \frac{n_{0e}}{(\sqrt{\pi}\, v_{0e})^3} \exp[-(v_x^2 + (v_y - u_0)^2 + v_z^2)/v_{0e}^2] \tag{1}$$

$$f_{0i}(\mathbf{V}) = \frac{n_{0i}}{(\sqrt{\pi}\, v_{0i})^3} \exp[-(v_x^2 + v_y^2 + v_z^2)/v_{0i}^2]$$

respectively, where $n_{0s}$ is the equilibrium species number density ($s = e, i$) and

$$v_{0s} = (2kT_s/m_s)^{1/2} \quad (s = e, i)$$

with $T_s$ being the species temperature.

We impose the following conditions

(a) $T_e \gg T_i$, so that the ion-acoustic waves are weakly damped.

(b) $u_0 \ll v_{0i}$, which is the Penrose criterion to prevent the build-up of ion-acoustic instability[11].

Also for the fully (but singly) ionised plasma,

$$n_{0e} = n_{0i} = n_0$$

The velocity distribution function for each species is written in a perturbative series as

$$f_s(\mathbf{X},\mathbf{V},t)=f_{0s}(\mathbf{V})+f_{1s}(\mathbf{X},\mathbf{V},t)+f_{2s}(\mathbf{X},\mathbf{V},t)+f_{3s}(\mathbf{X},\mathbf{V},t)+\ldots \quad (2)$$

where $f_{ms}$ is the $m$th term in the series and is a monomial of degree $m$ in the electric field amplitudes, and arises due to all possible interactions of $(m+1)$ waves, $\mathbf{V}$ is the velocity variable. Thus figure 2b contributes to $f_2(\mathbf{X},\mathbf{V},t)$, figures 2a and 3 contribute to $f_3(\mathbf{X},\mathbf{V},t)$ while all linear processes obviously contribute to $f_1(\mathbf{X},\mathbf{V},t)$.

The variables $\mathbf{X}$, $t$ are Fourier–Laplace transformed to $\mathbf{k}$, $\omega$ and the resulting linear and non-linear polarizations are found from the $f_{ms}(\omega,\mathbf{k})$. These polarisations are then used to find the equations of motion. The conservation of momentum and energy is automatically incorporated.

Below we give expressions $f_1(\omega,\mathbf{k})$, $f_2(\omega,\mathbf{k})$ and $f_3(\omega,\mathbf{k})$ which have been used to find the nonlinear polarizations and currents. The $\mathbf{A}_\omega$ occurring in the expressions is the Fourier component of the acceleration on the charged particle due to the electric and magnetic fields.

$$f_1(\omega,\mathbf{k})=\frac{-i}{\omega-\mathbf{k}\cdot\mathbf{V}}\mathbf{A}_\omega\cdot\frac{\partial}{\partial\mathbf{V}}f_0$$

$$f_2(\omega,\mathbf{k})=\frac{(-i)^2}{\omega-\mathbf{k}\cdot\mathbf{V}}\sum_{\omega',\mathbf{k}'}\mathbf{A}_\omega\cdot\frac{\partial}{\partial\mathbf{V}}\left[\frac{1}{\omega-\omega'-(\mathbf{k}-\mathbf{k}')\cdot\mathbf{V}}\mathbf{A}_{\omega-\omega'}\cdot\frac{\partial}{\partial\mathbf{V}}\right]f_0$$

which show a coupling between three waves having frequencies $\omega$, $\omega'$ and $\omega-\omega'$ and wavevectors $\mathbf{k}$, $\mathbf{k}'$ and $\mathbf{k}-\mathbf{k}'$ respectively.

$$f_3(\omega,\mathbf{k})=\frac{(-i)^3}{\omega-\mathbf{k}\cdot\mathbf{V}}\sum_{\substack{\omega',\omega''\\ \mathbf{k}',\mathbf{k}''}}\mathbf{A}_\omega\cdot\frac{\partial}{\partial\mathbf{V}}\times\left[\frac{1}{\omega-\omega'-(\mathbf{k}-\mathbf{k}')\cdot\mathbf{V}}\mathbf{A}_{\omega''}\cdot\frac{\partial}{\partial\mathbf{V}}\times\left(\frac{1}{\omega-\omega'-\omega''-(\mathbf{k}-\mathbf{k}'-\mathbf{k}'')\cdot\mathbf{V}}\mathbf{A}_{\omega-\omega'-\omega''}\cdot\frac{\partial}{\partial\mathbf{V}}\right)\right]f_0$$

Showing coupling of 4 waves with frequencies $\omega$, $\omega'$, $\omega''$ and $(\omega-\omega'-\omega'')$ and wavevectors $\mathbf{k}$, $\mathbf{k}'$, $\mathbf{k}''$ and $\mathbf{k}-\mathbf{k}'-\mathbf{k}''$ respectively.

The formalism of such coherent nonlinear interactions of waves as well as a diagrammatic representation of $f_m(\omega,\mathbf{k})$ have been given by Al'tshul and Karpmann[9].

The following inequalities have been used in finding out the polarization:

(a) $\omega_L(\omega_P)\gg k_L(k_P)v_{0e}$,

(b) $k_a v_{0i}\ll\omega_a\ll k_a v_{0e}$,

(c) $k_P, k_a\gg k_L$ (dipole approximation),

(d) $\omega_L\approx\omega_P\gg\omega_a$,

(e) $B_L/c=k_L E_L/\omega_L$.

*Equations of Motion*

The polarizations and currents are proportional to the velocity integrals of the various $f_{ms}(\omega,\mathbf{k})$. Below we obtain the equation of motion for $E_P$. That for $E_L$ can be obtained in a similar manner.

The contribution to the linear polarization is found to be

$$\int f_{1e}(\omega_P,\mathbf{k}_P,\mathbf{V})d\mathbf{V}=\frac{-in_0k_P}{m_e\omega_{Pe}^2}E_P. \quad (3)$$

The ions make a similar contribution.

The second order distribution for figure 2b yields

$$\int f_{2e}(\omega_P,\mathbf{k}_P,\mathbf{V})d\mathbf{V}=-\frac{2e^2k_Pk_Ln_0u_0}{m_e^2\omega_{Pe}^2k_av_{0e}^2\omega_L}E_a^*E_L \quad (4)$$

The ions have no drift velocity and hence their contribution is identically zero.

The third order nonlinear polarization has contributions coming from figures 2a and 3.

The interaction in figure 2a gives us

$$\int f_{3e}(\omega_P,\mathbf{k}_P,\mathbf{V})d\mathbf{V}=\frac{i2e^3n_0k_Pk_Lu_0}{m_e^3k_a^2\omega_P^3v_{0e}^4}(\mathbf{E}_a^*)^2\,\mathbf{E}_L. \quad (5)$$

Again the ions do not contribute because they have no drift. Figure 3 yields

$$\int f_{3e}(\omega_P,\mathbf{k}_P\,\mathbf{V})\,d(\mathbf{V}=\frac{i45n_0e^3k_P{}^3}{4m_e^3\omega_{Pe}^6}|E_P|^2E_P. \quad (6)$$

The contribution from the ions is smaller by a factor of $(m_e/m_i)^3$ and hence has been neglected.

Writing the total variation of $E_P$ in terms of nonlinear polarizations[10], we get

$$\frac{dE_P}{dt}=\frac{\partial E_P}{\partial t}+v_{gP}\frac{\partial E_P}{\partial x}=-\gamma_PE_P-i\omega_PE_P-i\left[\frac{4\pi e^4n_0k_Lu_0}{m_e^3k_a^2\omega_{Pe}^2v_{0e}^4}(E_a^*)^2-i\frac{4\pi e^3k_Lu_0n_0}{m_e^2\omega_{Pe}^2k_av_{0e}^2}E_a^*\right]\times E_L-i\frac{45\pi e^4n_0k_P^2}{2m_e^3\omega_{Pe}^5}|E_P|^2E_P, \quad (7)$$

where $v_{gP}$ is the group velocity of the plasma wave and $\gamma_P$ is the damping term introduced.

We show in appendix A that $v_{gP}/v_{0e}$ can be ignored, while for $E_L, v_{gL} = -\alpha\gamma_L$ where $\alpha$ is $E_L$ at $x = 0$ and $\gamma_L$ is the damping constant for the laser mode.

## APPENDIX-A

(a) For the electrostatic plasma wave, the dispersion relation is

$$\omega^2 \approx \omega_{Pe}^2 + k_P^2 v_{0e}^2.$$

Hence the group velocity is

$$v_{gP} \approx k_P v_{0e}^2/\omega_{Pe}$$

From inequality (a) given in the section under formalism, and for small $v_{0e}$, we get $v_{gP}/v_{0e} \ll 1$ and can thus be ignored.

(b) The dispersion relation for a laser mode in a plasma is

$$\frac{k^2C^2}{\omega_L^2} = 1 - \frac{\omega_{Pe}^2}{(\omega_L + i\gamma_L)^2},$$

where $\gamma_L$ is the electron-ion collision frequency. Setting $k = k_L + i\beta$ ($k_L$ and $\beta$ real) we get

$$\beta = -\gamma_L\omega_{Pe}^2/k_L C^2\omega_L,$$

$$\omega_L^2 = \omega_{Pe}^2 + k_L^2 C^2.$$

The gradient $\partial E_L/\partial x$ can be written as $\alpha\beta$ where $\alpha$ is $E_L$ at $x = 0$. Now the group velocity $v_g = k_L C^2/\omega_L$. Thus

$$v_{gL}\frac{\partial E_L}{\partial x} = -\frac{\gamma_L\omega_{Pe}^2}{\omega_L^2}\alpha \approx -\gamma_L\alpha.$$

$$\frac{dE_L}{dt} = \frac{\partial E_L}{\partial t} + v_{gL}\frac{\partial E}{\partial x} = \frac{\partial E_L}{\partial t} - \alpha\gamma_L. \quad \text{(A1)}$$

Writing the equations in the rotating frame of the plasma wave, we have

$$\frac{\partial E_P}{\partial t} = -\gamma_P E_P - i\left[\frac{4\pi e^4 n_0 k_L u_0}{m_e^3 k_a^2 \omega_{Pe}^2 v_{0e}^4}(E_a^*)^2 - i\frac{4\pi e^3 k_L u_0 n_0}{m_e^2\omega_{Pe}^2 k_a v_{0e}^2} E_a^*\right]E_L - i\frac{45\pi e^4 n_0 k_P^2}{2m_e^3\omega_{Pe}^5}|E_P|^2 E_P. \quad (8)$$

The equation for $E_L$ can found (using equation A1)

$$\frac{\partial E_L}{\partial t} = -\gamma_L(E_L - \alpha) - i(\omega_L - \omega_P)E_L - i\left[\frac{4\pi e^4 n_0 k_L u_0}{m_e^3 k_a^2\omega_{Pe}^2 v_{0e}^4}(E_a^*)^2 - i\frac{4\pi e^3 k_L u_0 n_0}{m_e^2\omega_{Pe}^2 k_a v_{0e}^2}E_a^*\right]E_P. \quad (9)$$

In deriving the above equations, the energy density of the ion-acoustic wave is high enough to be regarded as a pump. The laser pulse is launched into the plasma after the acoustic wave has had enough time to establish itself as a collective phenomenon. One of the many ways to populate ion-acoustic waves is to launch an Alfven wave at the plasma surface. In real-life phenomenon, the plasma is generally embedded in an ambient magnetic field. In such a situation, the role of the acoustic waves in our model can be played by either a magneto-acoustic wave, an ion-cyclotron wave or an Alfven wave, though the effect of an external magnetic field would then have to be considered in the theory.

Introducing $\varepsilon$ as the ratio of the acoustic wave energy density to the electron thermal energy density ($\varepsilon$ has to be obviously $\ll 1$ for perturbative cut off in the acoustic waves to be valid) (see appendix B) we get

$$\frac{\partial E_P}{\partial t} = -\gamma_P E_P - i\left[\frac{2}{27}k_L u_0\varepsilon - i\frac{2k_L u_0\varepsilon^{1/2}}{\sqrt{54}}\right]E_L - i\frac{45k_P^2}{32\pi n_0\omega_{Pe}m_e}|E_P|^2 E_P \quad (10)$$

$$\frac{\partial E_L}{\partial t} = -\gamma_L(E_L - \alpha) - i(\omega_L - \omega_P)E_L - i \times\left[\frac{2k_L u_0\varepsilon}{27} - i\frac{2k_L u_0\varepsilon^{1/2}}{\sqrt{54}}\right]E_P. \quad (11)$$

## APPENDIX B

The dispersion relation for an ion-acoustic wave is

$$D \equiv 1 - \frac{\omega_{Pi}^2}{\omega^2} + \frac{2\omega_{Pe}^2}{k_a^2 v_{0e}^2} = 0,$$

gives

$$\omega_a^2 \approx k_a^2\left(\frac{kT_e}{m_i}\right).$$

The energy density in the ion-acoustic waves is

$$\varepsilon_a = \frac{1}{8\pi}\omega_a|E_a|^2\left.\frac{\partial D}{\partial\omega}\right|_{\omega=\omega_a} = \frac{n_0 e^2}{kT_e k_a^2}|E_a|^2, = \frac{1}{2\pi}\frac{\omega_{Pe}^2}{k_a^2 v_{0e}^2}|E_a|^2$$

The thermal energy density is $\frac{3}{4}m_e n_0 v_{0e}^2 = \varepsilon_{th}$.

$$\therefore \quad \varepsilon = \varepsilon_a/\varepsilon_{th} = \frac{2\omega_{Pe}^2}{3\pi k_a^2 v_{0e}^4 m_e n_0}|E_a|^2 \quad \text{(B1)}$$

Introducing dimensionless variables

$$X = \frac{g^{1/2}\lambda}{\gamma_P^{3/2}} E_L,\ Y = \frac{g^{1/2}\lambda}{\gamma_P^{3/2}} \alpha,\ B = \frac{g^{1/2}}{\gamma_P^{1/2}} E_P,\ \tau = \gamma_L \tau$$

with

$$g = -\frac{45k_P^2}{32\pi n_0 \omega_{Pe} m_e},\ \lambda = \left(\frac{\varepsilon}{27} - \frac{\varepsilon^{1/2}}{\sqrt{54}}\right) 2k_L u_0$$

we get

$$\frac{\partial B}{\partial \tau} = -\gamma_P/\gamma_L [B + i|B|^2 B + iX]$$

$$\frac{\partial X}{\partial \tau} = -(X - Y) - idX - iC(1 + d^2)B \quad (12)$$

where

$$d = \frac{\omega_L - \omega_P}{\gamma_L},\ C = \frac{\lambda^2}{\gamma_L \gamma_P} \frac{1}{(1 + d^2)}$$

Equation (12) is identical to the one obtained by Selloni *et al*[7].

$\gamma_L$ and $\gamma_P$ have to be identified for the plasma system as follows: In a fully ionized plasma, the damping of the electromagnetic wave is given by the electron-ion collision frequency[12]

$$\nu = \frac{5{\cdot}5 n_0}{T_e^{3/2}} \ln\left(\frac{220 T_e}{n_0^{1/3}}\right) \equiv \gamma_L,$$

and $\gamma_P \approx \gamma_L$.

Eliminating $X$ in (12), we obtain a cubic equation

$$z^3 + \{1 + (1 + d^2)|C|^2 + 2(\mathrm{Re}(C) + d(\mathrm{Im}(C)) - \tfrac{4}{3}[d\,\mathrm{Re}(C) - \mathrm{Im}(C)]^2\} z$$
$$+ \frac{Y^2}{1 + d^2} - \tfrac{2}{3}[d\,\mathrm{Re}(C) - \mathrm{Im}(C)][(1 + d^2)|C|^2 + 2(\mathrm{Re}(C) + d\,\mathrm{Im}(C)) + 1]$$
$$+ \tfrac{16}{27}[\mathrm{Im}(C) - d\,\mathrm{Re}(C)]^3 = 0, \quad (13)$$

where Re($C$) and Im($C$) are the real and imaginary parts of $C$ and

$$z = |B|^2 + \tfrac{2}{3}\mathrm{Im}(C) - \tfrac{2}{3} d\,\mathrm{Re}(C).$$

The above equation has real roots when

$$3[1 + |C|^2(1 + d^2)] + 6[\mathrm{Re}(C) + d\,\mathrm{Im}(C)] - 4d^2[\mathrm{Re}(C)]^2 - 4[\mathrm{Im}(C)]^2 + 4d\,\mathrm{Re}(C)\,\mathrm{Im}(C) \leqslant 0. \quad (14)$$

If the three-wave coupling (figure 2b) were absent, *i.e.* Im($C$) = 0 then (14) reduces to

$$d > \sqrt{3},$$

which is the inequality obtained by Selloni *et al*[7].

If on the other hand, $\mathrm{Im}(C) \gg \mathrm{Re}(C)$ (*i.e.* the interaction shown in figure 2b dominates over that shown in figure 2a), then

$$3[1 + |C|^2(1 + d^2)] + 6d\,\mathrm{Im}(C) - 4[\mathrm{Im}(C)]^2 \leqslant 0, \quad (15)$$

is the condition for the existence of OB.

## DISCUSSION

Thus (14) is a general condition to be satisfied in a dispersive medium if the medium has to exhibit OB. We have considered the most general case where the coupling constant between the driving (the laser) and the driven (plasma wave) modes is complex. The results of Selloni *et al*[7] turn out as a special case of our analysis, by restricting the coupling constant to be real.

Plasmas are a class of systems whose particle density can be varied in the laboratory by many orders of magnitude, going all the way to about $\sim 10^{22}$/cc. The drift velocity in the plasma can be controlled at will. Similarly the temperature can be varied to a large degree. Therefore one concludes that the quantitative features of the bistability phenomenon can be varied with relative ease, when it is excited in a plasma.

## ACKNOWLEDGEMENT

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# SYNTHESIS OF SOME (BENZOXAZOLYL-2)-ALKYL/ARALKYL SULPHIDES AND SULPHONES AS POTENTIAL PESTICIDES

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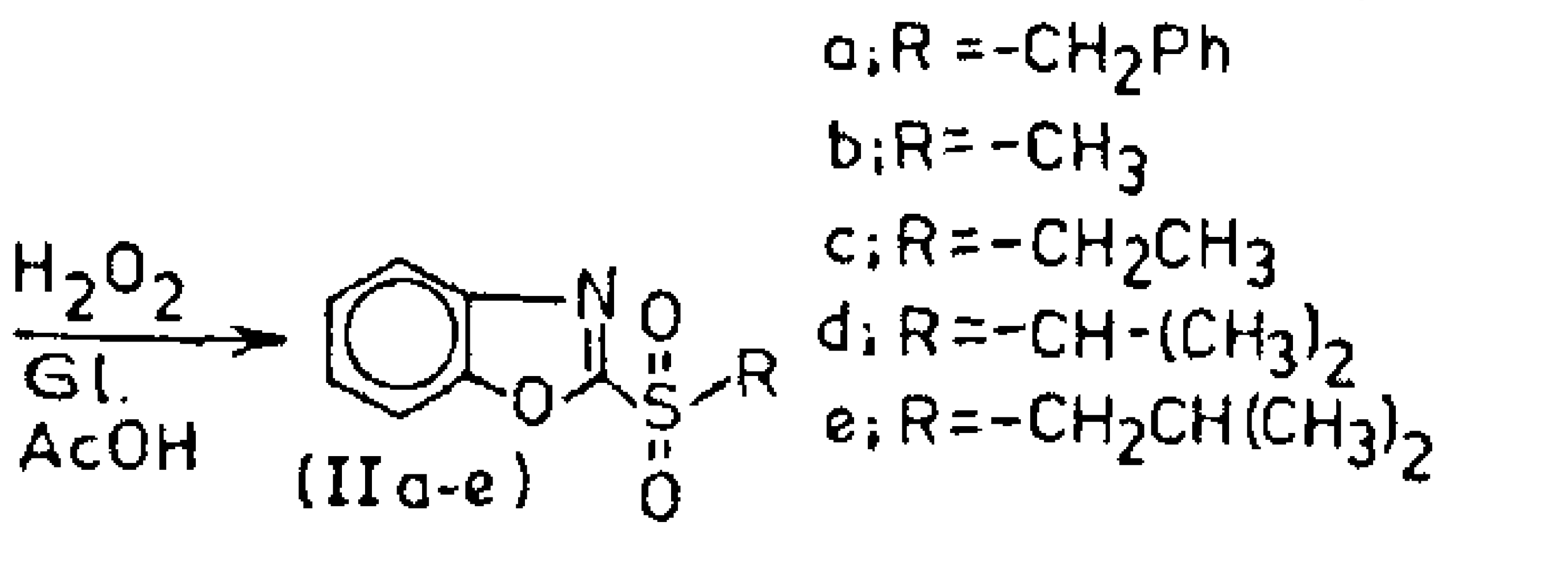
## ABSTRACT

Several new (benzoxazolyl-2)-alkyl/aralkyl sulphides and their respective sulphones have been synthesised and screened for their fungicidal activity against *Alternaria tenuis* and *Helminthosporium oryzae*; and two of them have been tested for their molluscicidal activity against *Lymnea acuminata*. The sulphides synthesised herein are fluorescent compounds.

## INTRODUCTION

A NUMBER of sulphides containing aryl, benzyl and heteroaryl radicals display acaricidal and insecticidal properties[1-5]. There are records[6,7] that a compound containing a thiol group placed adjacent to heteroatom in a nitrogen heterocycle often induces fungicidal power to it. Aryl and heteroaryl sulphones have been investigated in large numbers as fungicidal and miticidal agents[8,9]. Since benzoxazolyl sulphides and sulphones do not seem to have been investigated for pesticidal properties, the synthesis and bioassay of the title sulphides and sulphones were undertaken.

These sulphides ($I_{a-e}$) have been prepared by the reaction of 2-mercaptobenzoxazole with different alkyl halides or benzyl chloride in alkaline medium. These sulphides were oxidized with hydrogen peroxide in glacial acetic acid to yield the respective sulphones ($II_{a-e}$) (Scheme 1).




**Scheme 1**

The authenticity of these compounds has been confirmed by their elemental analysis and IR spectral analyses. It is interesting to note that all sulphides synthesised emitted intense fluorescence.

## EXPERIMENTAL

IR spectra and elemental analyses (C, H, N and S) of the compounds are compatible with their structures. Melting points were taken in open capillaries and were uncorrected. IR spectra in KBr were recorded on Beckmann's spectrophotometer. TLC was performed on silica gel-G. 2-Mercaptobenzoxazole has been prepared following a method given in literature[10].

*(Benzoxazolyl-2)-alkyl/aralkyl sulphides ($I_{a-e}$):*

2-Mercaptobenzoxazole (1.1 M) dissolved in NaOH solution was refluxed with alkyl halides or benzyl chloride (1 M) for 4–6 hr. The reaction mixture was then poured into ice-water and the sulphide was taken into ether. After removal of the ether, the sulphides were obtained which were crystallised from ethanol. Yield 70–50%. $I_a$: m.p. 54° [IR spectrum reveals characteristic absorption frequencies at 1740 cm$^{-1}$ (C-N=C< stretching), 1280 cm$^{-1}$ (C-O-C stretching), 720 cm$^{-1}$ (C-S-C stretching) and 1590 cm$^{-1}$,