SCATTERING AND GUIDED PROPAGATION OF LASER BEAMS IN PLASMAS

by

Ram Pal Sharma

Thesis submitted to the Indian Institute of Technology, Delhi
for the award of the Degree of
DOCTOR OF PHILOSOPHY

Department of Physics
Indian Institute of Technology, Delhi
May, 1975

ACKNOWLEDGEMENTS

The author expresses his deep gratitude to Professor M.S.Sodha for his valuable guidance, ever-lasting encouragement and inspiration given to him without which the present work would not have been possible. The author feels greatly indebted to Dr. V.K.Tripathi for his guidance and kind help at various stages of the work.

The author is also grateful to Prof.A.K.Ghatak and Dr. D.P.Tewari for their kind encouragement and advice envisaged in the present work. The author expresses his sincere thanks to Dr. S.K.Sharma, Dr. U.P.Phadke, Mr. S.C.Kaushik, Mr. Arun Kumar, Mr. S.P.Singh and other colleagues of the Electro-physics Group for their cooperation and various discussions during the preparation of the thesis. Thanks are also due to Mr. T.N. Gupta for his efficient typing of the thesis.

The author is thankful to the Council of Scientific and Industrial Research (India) for financial assistance.

R.P. Sharma
31.5.75
(Rampal Shar

ACKNOWLEDGEMENTS

The author expresses his deep gratitude to Professor M.S.Sodha for his valuable guidance, ever-lasting encouragement and inspiration given to him without which the present work would not have been possible. The author feels greatly indebted to Dr. V.K.Tripathi for his guidance and kind help at various stages of the work.

The author is also grateful to Prof.A.K.Ghatak and Dr. D.P.Tewari for their kind encouragement and advice envisaged in the present work. The author expresses his sincere thanks to Dr. S.K.Sharma, Dr. U.P.Phadke, Mr. S.C.Kaushik, Mr. Arun Kumar, Mr. S.P.Singh and other colleagues of the Electro-physics Group for their cooperation and various discussions during the preparation of the thesis. Thanks are also due to Mr. T.N. Gupta for his efficient typing of the thesis.

The author is thankful to the Council of Scientific and Industrial Research (India) for financial assistance.

R.P. Sharma
31.5.75
(Rampal Shar

PREFACE

For intense electromagnetic waves in a plasma the refractive index is a function of the intensity of the wave and consequently the propagation is nonlinear. In a collisionless plasma the refractive index is real for the propagating waves and the nonlinearity menifests itself in the phenomenon of self-phase modulation. In a collisional plasma the nonlinear attenuation of waves results in self-distortion of the amplitude envelope of the wave. Besides these nonlinear effects, the phenomena of harmonic generation, wave mixing, parametric excitation of instabilities, stimulated scattering and anomalous absorption of electromagnetic waves and heating of plasmas are also observed at high powers. Recently the phenomenon of self-focusing of electromagnetic beams in plasmas has become important as it requires considerably lower powers to observe it and also because it results in higher power densities which in turn enhance the efficiency of almost all nonlinear processes. The present thesis is devoted to the study of self-focusing of electromagnetic beams in plasmas under stationary and nonstationary conditions and to the study of effect of self-focusing on the scattering of electromagnetic beams and on the stability of the intensity distribution of the beam.

The earlier investigations (for a review see

Akhmanov, Sukhorukov and Khokhlov; 1968) of self-focusing were confined to dielectrics. The critical power for self-focusing of laser beams in dielectrics was accessible by contemporary technology. In a typical case of a ruby laser beam propagating in CS_2 the critical power P_{cr} is 25 Kw; a beam of initial diameter 0.05 cms and power 90 Kw is focused to a spot size of .005 cm in a distance of 12 cm. The point focusing is not observed because the dielectric breaks down before the focus. Recently Bloembergen (1971), Loy and Shen (1973) have studied the self-focusing of picosecond laser pulses in dielectrics in considerable detail and the breaking of the pulse into more than one pulse; moving focii phenomenon, temporal change of the pulse, frequency spectrum broadening of the pulse, self-modulation, stimulated scattering and other nonlinear effects in dielectrics have also been observed.

Recently the phenomenon of self-focusing of laser beams in plasmas has attracted considerable attention on account of its relevance to laser plasma interaction, ionospheric propagation and various high power laboratory experiments. A plasma is an absorbing, dispersive medium whose response to an electromagnetic beam is determined by free electrons which are characterized by high mobility, long mean free path and slow rate of energy exchange with heavy particles. The nonlinearity arises through the nonlinear relationship between the free electron current density and the electric vector. The current density depends not only on the instantaneous value of the electric vector of the wave but also on its values at earlier times (giving rise to the dispersive nature).

The self-focusing of electromagnetic beams in plasma has been discussed by Askar'yan (1962), Talanov (1964) and Chiao, Garmire and Townes (1964). The usual theory (Akhmanov, Sukhorukov and Khokhlov, 1966) of self-focusing in dielectrics also applies to an isotropic plasma; the self-focusing depends on the specific mechanisms of nonlinearity and the relaxation processes. Litvak (1970), Prasad and Tripathi (1973) have investigated the self-focusing of electromagnetic beams in homogeneous collisional plasmas where the nonlinearity arises through the inhomogeneous heating and redistribution of electrons. Inhomogeneous heating occurs on account of a nonuniform transverse distribution of intensity (EE^*) along the wavefront of the electromagnetic beam. The collision frequency is also modified due to heating of the electrons but this effect is mainly responsible for the nonlinear attenuation of the beam and does not lead to appreciable self-focusing (Sodha, Ghatak and Tripathi 1974). Sodha, Tewari, Kumar and Tripathi (1974) have studied the self-focusing of high power electromagnetic beams in a collisional plasma by using rigorous kinetic approach for evaluation of nonlinear current density. The velocity dependence of collision frequency is crucial in determining the redistribution of electron density and the dielectric constant of the plasma. The saturation of effective dielectric constant and periodic focusing is predicted. Sodha, Khanna and Tripathi (1973) have investigated the problem of self-focusing in a plasma in which collisions are less frequent and the energy dissipation is caused by thermal conduction. Even at low powers of the electromagnetic beams when the dielectric constant of the plasma is not saturated the periodic focusing of the beam has also been predicted. Stenflo and Yu (1973), Chandra and Tripathi (1975) have recently studied the self-focusing of electromagnetic beams in gaseous plasmas showing Ramsauer effect which is present only in few gases.

Self-focusing of electromagnetic beams in collisionless plasma has also been studied in recent years by Hora (1970), Kaw, Schmidt and Wilcox (1973), Drake, Kaw, Lee, Schmidt, Liu and Rosenbluth (1974), Manheimer and Ott (1974). In collisionless plasmas the ponderomotive force (Hore, 1969) determines the redistribution of the electrons causing the beam to focus. Max, Arons and Langdon (1974) have recently studied the self-focusing of the electromagnetic beam in the plasma due to weak relativistic effects and the $\vec{v} \times \vec{B}$ force (where $\vec{v}$ is the drift velocity of the electron and $\vec{B}$ is the magnetic vector of the wave). Even weak v^2/c^2 relativistic corrections can produce interesting self-modulation and focusing for parameters of high-power lasers (presently existing or under construction). Sodha, Kaushik and Kumar (1975) studied the self-focusing in a moving plasma. Armand (1971) has studied the self-focusing of radio waves in an inhomogeneous plasma.

In recent years self-focusing of electromagnetic beams in collisional and collisionless magnetoplasma has also been investigated by Litvak (1970), Sodha, Mittal, Kumar and Tripathi (1974). The nonuniform heating and consequent redistribution of carriers on account of inhomogeneous intensity distribution of the beam has been considered to be the source of nonlinearity in collisional magnetoplasma. In collisionless magnetoplasma the ponderomotive force is the main source of nonlinearity and carriers are redistributed in the plasma to cause self-focusing of the beam. In the presence of a magnetic field two modes of propagation exist. The heating of electrons and the ponderomotive force on electrons on account of the extraordinary mode display marked cyclotron resonance and consequently the self-focusing of the beam occurs at much lower powers. In collisional magnetoplasmas self-focusing of ordinary mode is possible in the frequency range $\omega > \nu$ where ω is the frequency of the wave and ν is the collision frequency. But the extraordinary mode is focused only in the range $\omega > \omega_c$ where ω_c is the electron cyclotron frequency. For $\omega < \omega_c$ defocusing of extraordinary mode occurs. In collisionless magnetoplasmas extraordinary mode shows a peculiar behaviour on reversing the direction of ponderomotive force on electrons in going from $\omega < \omega_{c/2}$ to $\omega > \omega_{c/2}$ range. Therefore, the self-focusing of extraordinary mode is possible in all frequency range except $\omega_{c/2} < \omega < \omega_c$. Self-focusing of ordinary mode is retarded on account of magnetic field but that of extra-ordinary mode is enhanced. Tewari and Kumar (1975) have studied the self-focusing of electromagnetic beam in magnetoplasma. Dielectric constant of the magnetoplasma is saturated and periodic focusing of the beam occurs. Sodha, Khanna and Tripathi (1974) have studied self-focusing in magnetoplasma when the collisions are few and the energy dissipation is caused by conduction. The important result is that even at low powers of the beam when the dielectric constant is not saturated periodic focusing of the beam occurs. All these investigations in magnetoplasma are limited by considering only one mode at a time. Thus these theories cannot be used for studying Faraday rotation, ellipticity and cross-focusing of the two modes.

Recently self-focusing of electromagnetic beams in solid state plasmas has also aroused considerable attention because of its relevance in characterisation, diagnostics and understanding the free carrier nonlinearities in solid state plasmas. Critical power for self-focusing in solid state plasmas is less than that in dielectrics but more than in gaseous plasmas. Tzoar and Gersten (1972) studied the self-focusing in InSb semi-conductor plasma where the nonlinearity arises through the carrier mass modulation by the drift energy of the electrons. In steady state the drift energy is much less than the excess random energy of the electrons hence the nonlinearity arising through the mass modulation of electron by the excess random energy is more important than that caused by drift energy. Sodha, Tewari, Kamal and Tripathi (1972) studied the self-focusing of microwaves in an n-InSb due to the electron mass modulation by excess random energy of electrons. Dubey and Paranjape (1972) studied the self-focusing on account of energy dependent relaxation time of carriers. Tripathi, Tewari, Pandey and Agarwal (1973) have shown that the non-linearity arising through the energy dependent relaxation time is not significant in self-focusing the beam and it is mainly responsible for the attenuation of the beam. Tripathi, Sodha and Tewari (1973) studied the self-focusing of Gaussian electromagnetic beams on account of nonuniform heating and redistribution of carriers. Sodha, Khanna and Tripathi (1973) studied the self-focusing of e.m. beams in InSb and the nonlinearity appearing through the nonuniform heating and redistribution of carriers is attributed to be more important than that on account of energy dependence of carrier mass. Guha and Tripathi (1972) studied the self-focusing of laser beams in GaAs on account of intervalley transfer mechanism of the carriers. Recently self-focusing of e.m. beams in degenerate solid state plasmas has also been investigated by Sodha, Kaushik and Tripathi (1974).

In contrast to the extensive experimental work on self-focusing of e.m. beams in dielectrics, the experimental studies on self-focusing in gaseous and solid state plasmas are very much limited. Batanov and Silin (1971) observed self-trapping of e.m. beams in an overdense collisionless plasma. Eremin, Litvak and Poluyakhtov (1972) carried out an experiment with a decaying discharge tube plasma with initial electron concentration $N_e^0 \simeq 5 \times 10^{11}$ cm^{-3}, temperature $T_0 \simeq 2.5 \times 10^3$ ^oK, and electron-neutral particle collision frequency $\nu_{e-n} \simeq 7 \times 10^7$ sec^{-1}. At one end of the plasma a converging e.m. beam (of free space wavelength $\lambda_0 \simeq 3$cm) was made incident from a lens. The initial radius of the beam was 10 cm and the distribution of intensity in the transverse plane to be Gaussian. In the absence of the plasma the beam is focused at a distance of $z \simeq 20$ cm and its radius 3 cm. When the space is filled by the decaying discharge plasma the spot size is further reduced to a radius of $\simeq$ 2.5 cm at $z \simeq 20$ cm and the beam of initial power $P \simeq 100$ watt is focused at a distance of $z_F \simeq 70$ cm. The critical power for self-focusing was found to be 10 watt. Recently self-focusing of laser beams has also been studied in the computer simulation experiments by Ott, Manheimer and Klein (1974), Langdon and Lasinski (1975).

It would be useful here to summarise the various nonlinear effects in the plasma. Physically the nonlinear behaviour of the plasma may be understood as follows:

The free carriers acquire momentum and energy from the field which are lost in collisions with ions and neutral particles. In an idealized collision momentum is alsmost completely randomized. In equilibrium (i.e. in the absence of an electric field), the temperature of electrons is the same as that of the heavy particles so that the net energy exchange between electrons and heavy particles is zero. When an electric field is applied, the electrons gain energy from the field and in the steady state attain a temperature higher than that of the heavy particles such that the power gained by the electrons from the field equals the power lost by the electrons in collisions (Ginzburg, 1970).

When the applied laser beam has a nonuniform distribution of intensity along the wavefront, the carrier temperature is also nonuniform and a corresponding variation in electronic concentration takes place. The space charge field generated in this process makes ions to follow the electrons. Due to this redistribution of carriers, a transverse gradient of effective dielectric constant is established which leads to self-focusing of the beam.

In collisionless plasmas this mechanism of non-linearity is not operative and the nonlinearity arises on account of the ponderomotive force (Hora, 1969). Ponderomotive force arises because of the interaction of the electron drift velocity with the magnetic field of the wave and the motion of the electrons in the inhomogeneous electric field. When the intensity distribution of the beam is nonuniform, the force on account of this interaction has a finite time independent component in a direction perpendicular to that of propagation. On account of this force a redistribution of electronic concentration takes place. The ions are also dragged by the electrons in view of the strong Coulomb interaction between them. This effect makes the effective dielectric constant nonlinear and self-focusing of beams may occur. This nonlinearity is dominant in plasmas where the duration of the electromagnetic beam is much smaller than the energy relaxation time ($t \ll \tau_E$) of electrons; such situations occur in the case of fast pulse laser interaction with strongly ionized collisionless plasmas. In the case when $t \gtrsim \tau_E$, the nonlinearity appearing through the heating of carriers is much more important than the ponderomotive force effect. The nonlinearity because of ponderomotive force is set up in a time of the order of r_0 / v_s where r_0 is the dimension of the beam and v_s is the ion sound speed. This time is usually smaller than the time required by the hot carrier nonlinearity to set up.

The nonlinearity in the effective dielectric constant of a plasma may also arise through the heating and modulation of collision frequency of electrons. This mechanism of nonlinearity has been investigated in detail. However, it does not cause appreciable self-focusing (Sodha, Ghatak and Tripathi, 1974). The nonlinearity arising through the breakdown of the plasma is also not effective in the self-focusing of the beam because the nonlinear dielectric constant of the plasma (on account of this mechanism) is a decreasing function of intensity of the beam.

In relativistic plasmas (Kaw and Dawson, 1970) where the velocity of the electron is comparable to the velocity of light (i.e. $v \simeq c$) the nonlinearity due to the relativistic variation of the mass of the electron may arise but this nonlinearity is important only at very high powers of the laser beams ($\simeq 10^{16}$ watt /cm^2).

An additional mechanism of nonlinearity has been recently investigated by Stenflo and Yu (1973), Chandra and Tripathi (1975) in the gaseous plasmas showing Ramsauer effect i.e. in which according to Harp Model, the collision frequency may be assumed to be very low below some critical speed of electrons $v = v_0$ and above which the collision frequency may be taken as infinite. Thus only those electrons contribute to the current density which have speed below v_0 . When the electric field (of the wave) is applied to a plasma the electrons below $v = v_0$ (on assuming ν to be small but finite) are heated i.e. transferred to high velocity range $v > v_0$. Hence the effective number density of electrons responsible for current density is reduced. This non-linearity gives rise to self-focusing of a Gaussian laser beam at accessible powers. However, this effect is confined only to few gases hence is not considered in the present thesis.

The nonlinear phenomena discussed so far are very much affected by the application of an external magnetic field. The current density in a magnetoplasma due to an electric field is not aligned along the electric field;

i.e. the conductivity and the effective dielectric constant of the plasma are tensors. Thus the plasma becomes anisotropic and the effective dielectric tensor of the magnetoplasma is not symmetrical. Two independent modes (in general elliptically polarized) of propagation exist in the limit of linear theory in such a medium.(Ginzburg, 1970). When the direction of the phase velocity coincides with the external magnetic field the two modes are circularly polarized. The right handed circularly polarized mode is sensitive to electron cyclotron resonance because both the electric and the external magnetic field rotate the electrons in the same sense.

It is instructive here to understand the phenomenon of self-focusing in a medium where the refractive index is an increasing function of the intensity (EE^*) of the beam (say $n = n_0 + n_2 EE^*$ where n is the refractive index of the medium, n_0 and $n_2 EE^*$ are the field independent and field dependent components of n respectively). We consider a plane uniform wavefront incident on a circular aperture (of radius r_0) in a nonlinear medium (see Fig.1). The portion of the medium illuminated by the beam has a refractive index ($n = n_0 + n_2 EE^*$) higher than that of the non-illuminated portion. Therefore, the secondary wavelets diverging at an angle θ from the wave normal suffer total internal

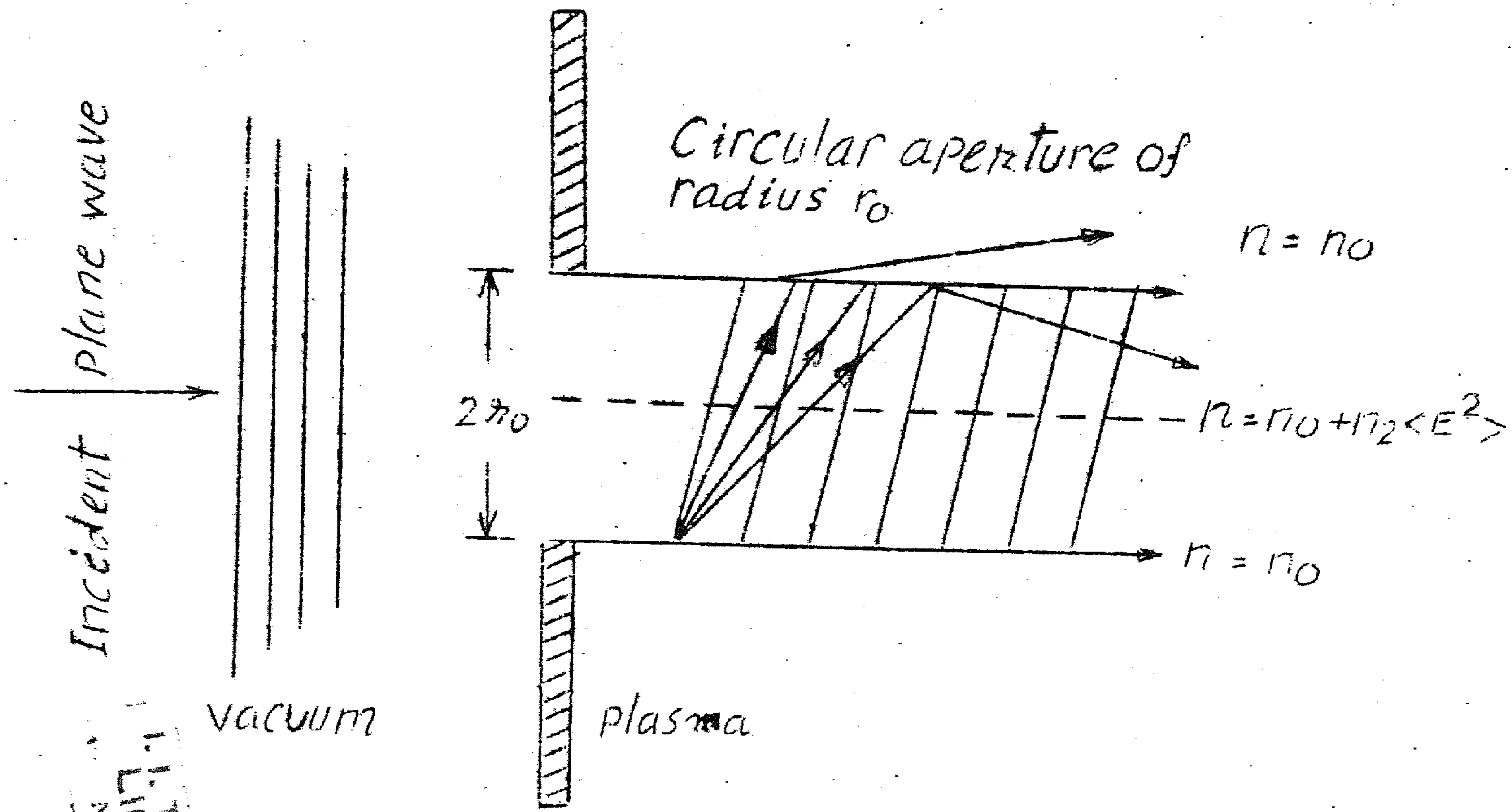
Incident plane wave
vacuum
Circular aperture of radius r_0
$2r_0$
$n = n_0$
$n = n_0 + n_2 \langle E^2 \rangle$
$n = n_0$
plasma

FIG. 1

reflection at the boundary of the fictitious cylinder of radius r_0 when

$$\theta < \theta_c$$

where

$$\theta_c \simeq \cos^{-1}\{n_0/(n_0 + n_2 EE^*)\}$$

corresponds to the critical angle. It is also known from the diffraction theory that a very large fraction of the power will be carried by rays making an angle less than θ_D with the axis,

$$\theta_D \simeq 0.61\,\lambda_0 / 2 r_0 n_0$$

where λ_0 is the wavelength of the radiation in free space. Now three possibilities may arise.

(i) when $\theta_D > \theta_c$, the beam will diverge due to predominance of diffraction effects.

(ii) when $\theta_D = \theta_c$, the beam should propagate in the self-made waveguide. The corresponding power of the beam can easily be shown to be given by

$$P \equiv P_{cr} = (1.22)^2 \lambda_0^2 c / 128\, n_2$$

where P_{cr} is the critical power of the beam and c is the velocity of light in vacuum and

$n = n_0 + n_2 EE^*$. As the beam gets focused due to nonlinearity, the intensity increases causing enhancement of the nonlinearity and hence in the extent of nonlinear focusing.

In case the beam is stronger near the axis than at the edges, i.e. there is an intensity distribution along the wavefront (which is indeed true for laser beams ; Yarive, 1971), the refractive index at the edges will be less than the refractive index at the central portion of the beam and hence the rays will tend to bend towards the axis. In case this tendency is stronger than the tendency to diverge by diffraction, focusing will occur and vice versa. On the other hand, a beam, in which the intensity decreases with increasing radius, will defocus in a medium where $n = n_0 + n_2 EE^*$ and n_2 is positive because the refractive index will be higher at the boundary of the beam than at the axis, causing the rays to bend away from the axis; similarly focusing will be observed when n_2 is negative for such beams. Since beams having increasing intensity with increasing radius do not commonly occur, such type of beams will not be considered in the thesis.

In the proposed thesis author has investigated (i) the nonstationary self-focusing of a Gaussian (in space) laser beam in an isotropic plasma when the amplitude of the beam is modulated and the modulation frequency is comparable to the nonlinearity relaxation frequency, (ii) cross focusing of extra-ordinary and ordinary modes in a magnetoplasma, (iii) instability in the intensity distribution of an initially Gaussian laser beam in an isotropic plasma (iv) scattering of a Gaussian laser beam from the turbulent plasma and the effect of self-focusing on the scattering has been shown explicitly. Besides this the author has (v) worked out a model intensity distribution of an electromagnetic beam propagating in a homogeneous magnetoplasma for which the diffraction divergence is minimum i.e. the beam propagates in self-made waveguide.

In the inertial confinement of the plasma the main problem is to couple the energy of the laser beam to the plasma where scattering and instabilities play a dominant role. In the outer region of the pallet i.e. in the subcritical region possibilities of scattering are more. In this region self-focusing of the laser beam also takes place. Hence the effect of self-focusing on scattering is of distinct relevance to laser fusion. Study of the instability in the intensity distribution of the laser beam is also important in understanding the formation of the filaments in the plasma because in the presence of the filaments the electrostatic waves are trapped in the filaments and their amplitudes grow, thus enhances the heating of the plasma.

Nonsteady self-focusing is important due to present trends in heating the plasma by short duration laser pulses, besides it directly leads to determination of the characteristic time of electron heating and redistribution.

Simultaneous propagation of the two modes and cross focusing highlights the nature of the coupled modes in the nonlinear magnetoplasma which are encountered in laser produced plasmas in the presence of self generated magnetic field.

With the present trend towards the use of narrow beams in laser plasma interaction and other laboratory experiments the phenomenon of diffraction divergence becomes important and it is much desirable to investigate under what parametric conditions the diffraction effects would be compensated and the beam propagates in the uniform waveguide mode.

The thesis has been divided into five chapters; a chapterwise summary is given below:

Chapter-I: A Uniform Magnetoplasma Waveguide

In this chapter propagation of an electromagnetic beam having nonuniform distribution of intensity along its wavefront has been studied in a homogeneous collisionless magnetoplasma in the linear regime when the static magnetic field is in the direction of the wave propagation. A beam having radial distribution of intensity as $J_0(\beta_0 r)$ always propagates without convergence or divergence i.e. in a uniform waveguide mode. Such type of radial field distribution is rather uncommon hence the theory has been extended for general intensity profiles. The condition on the parameters of the plasma has been imposed for vanishing diffraction divergence i.e. for the beam to propagate without convergence or divergence. The condition for the extra-ordinary mode is $\omega_p^2/\omega^2 = (1-\omega_c/\omega)/(1-\omega_c/2\omega)$ and for ordinary mode $\omega_p^2/\omega^2 = (1+\omega_c/\omega)/(1+\omega_c/2\omega)$. To study the convergence or divergence of the beam on account of diffraction, the wave equation has been solved by using the technique of Akhmanov, Sukhorukov and Khokhlov (1968) and explicit expression for the dimensionless beam width has been obtained.

Chapter-II: Cross Focusing of Extraordinary and Ordinary Modes in a Magnetoplasma

In this chapter cross focusing of extraordinary and ordinary modes have been investigated when both of these modes are propagating simultaneously in the collisional magnetoplasma along the direction of the static magnetic field having Gaussian intensity distribution. The nonlinearity arises in the magnetoplasma on account of nonuniform heating and consequent redistribution of carriers in the presence of inhomogeneous beam. The nonlinearities induced by the two modes are additive therefore the self-focusing of one mode is enhanced by the presence of the other mode. In a typical case of one mode is propagating in a self-made uniform waveguide, the other weak mode propagates in an oscillatory waveguide. When the initial intensity of the two modes is equal self-focusing of extraordinary mode is still rapid than that of ordinary mode. Knowing the intensity on the axis of the two modes phenomena of ellipticity and Faraday rotation has been investigated. Faraday rotation is almost unaffected by self-focusing and it varies almost linearly as the beam advances in the magnetoplasma. Ellipticity is affected by self-focusing and it increases with the distance of propagation near the focus. Since solid state plasmas and gaseous plasmas have almost similarity, the treatment has also been extended to Ge and n-InSb. The nonlinearity in Ge arises on account of nonuniform heating and consequent redistribution of electrons and holes. In n-InSb the energy dependence of the mass of carriers has been chosen the sole source of nonlinearity. The results are the same as in plasmas.

Chapter-III: Self Distortion of an Amplitude-Modulated Electromagnetic Beam in a Plasma

In this chapter propagation of an amplitude modulated electromagnetic beam having Gaussian intensity distribution in a weakly ionized plasma has been studied. Following a phenomenological approach an expression for the nonlinear current density has been evaluated in the presence of the beam. This expression has been used to study the nonstationary self-focusing of the beam. The nonuniform heating and consequent redistribution of carriers by the Gaussian beam is the source of nonlinearity. Redistribution of the carriers leads to self-focusing of the beam, high and low amplitude portions of the beam are focused by different rates; the higher amplitude portion is focused nearer than the lower amplitude portion giving rise to moving focus. Thus the overmodulation of the beam occurs. In addition to self-focusing when the energy relaxation time is comparable to the modulation period, relaxation effects in the plasma become important i.e. the current density not only depends on the instantaneous value of the electric field of the wave but also on its previous values. This leads to a shift of the amplitude envelope of the wave on time scale.

Chapter-IV: Instability of Intensity Distribution of a Laser Beam in a Plasma

In this chapter the growth of a sinusoidal perturbation in the intensity distribution of a two dimensional Gaussian laser beam in a plasma has been studied. In collisional plasma nonlinearity arises on account of nonuniform heating and consequent redistribution of the carriers. In collisionless plasmas ponderomotive force on electrons is the main source of nonlinearity. When the beam travels in the self-made uniform waveguide (i.e. when the power of the beam is equal to the critical power for self-focusing) the intensity distribution is stable for small scale perturbations. For beams converging on account of self-focusing the amplitude of perturbation decreases/increases much faster with distance than the axial amplitude in the absence of perturbation. The decrease or increase of the growth rate of perturbation depends on (i) the initial power of the main beam (the maximum growth rate occurs at an optimum value of the beam power), (ii) the nature of electron scattering, when the nonlinearity of the dielectric constant is caused by the heating of carriers by the beam. The growth of a two dimensional Gaussian perturbation in a plane beam of uniform intensity has also been analysed.

Chapter-V: Nonlinear Scattering of a Gaussian Laser Beam from a Turbulent Plasma

In this chapter the author has proposed a possibility of minimizing the scattering loss of laser energy from the plasma by the phenomenon of self-focusing. For the sake of convenience the incoherent scattering has been chosen as an example. In the presence of high power Gaussian laser beam the carriers in the plasma are redistributed on account of (i) nonuniform heating (in a collisional plasma) and (ii) ponderomotive force (in a collisionless plasma). The electron density is maximum in the field free region and minimum on the axis of the beam i.e. the beam propagates in a plasma of lower electron density as compared to the equilibrium value. The reduction in the effective number of interacting particles must result in the reduction of scattering. Also, the redistribution of carriers causes the self-focusing of the beam and hence the scattered power is further reduced. To have a quantitative estimate of the reduction in the power density of scattered wave by the nonuniformity in the electronic concentration caused by the beam the modified correlation function has been evaluated and then using the Maxwell's equations the scattered power density has been evaluated.

The thesis is partly based on the following publications:-

1. A Uniform Magnetoplasma Waveguide, J.Phys.D: Appl.Phys., 7, 866 (1974).

2. Cross Focusing of Extraordinary and Ordinary Modes in a Magnetoplasma, Communicated.

3. Self Distortion of an Amplitude Modulated Electromagnetic Beam in a Plasma:-Relaxation Effects, Appl.Phys. (W. Germany) 5, 153 (1974).

4. Instability of Intensity Distribution of a Laser Beam in a Plasma, J.Phys.D: Appl.Phys., 7, 2471 (1974).

5. Nonlinear Scattering of a Gaussian Laser Beam from a Turbulent Plasma, Communicated.

In addition to the above mentioned publications the author has also been associated with the following publications which have not been included in the thesis:

1. Collapse of Langmuir Waves by the Pump Wave, Communicated.

2. Hot Carrier Drift Induced Wave Instability in a Magnetoactive Solid State Plasma, J.Phys.Chem.Solids (In Press), 1975.

3. Thermal Self-focusing/defocusing of Laser Beams in an Absorbing Moving Medium: Convection Effects, Optica Acta (In Press), 1975.

4. Transient Self-focusing of Electromagnetic Waves in a Decaying Plasma, Communicated.

5. Self-focusing of Laser Beams in a Degenerate Non-parabolic Semiconductor, Communicated.

CONTENTS