# NONLINEAR ELECTROMAGNETIC WAVE INTERACTIONS WITH PLASMAS

D. SUBBARAO

Thesis submitted to the Indian Institute of Technology, Delhi

for the award of the Degree of

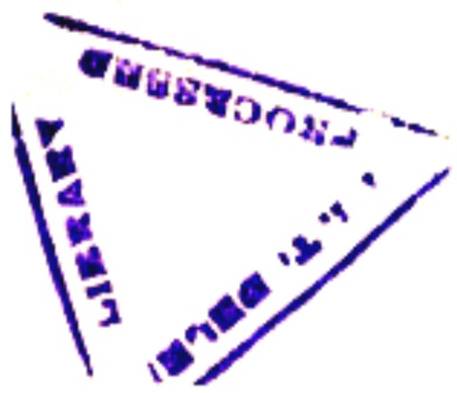
DOCTOR OF PHILOSOPHY

Department of Physics

Indian Institute of Technology, Delhi

June, 1980



## ACKNOWLEDGEMENTS

It has been a privilege of immense value to me to have had the opportunity to work with Professor M.S.Sodha. The unhindered encouragement associated with the patient, deep-sighted and unfailing 'course-corrections' that he provided, created a congenial and 'positive-feedback' environment most suitable for the growth of research potentialities and I have greatly benefited from this. heartily thank him for his guidance and kind care.

The work that I carried out on the 'Goos-Haenchen Effect' with Professor A.K.Ghatak during my M.Sc. has been of much padagogical use in the thesis. I thank him for the many illuminating discussions and the encouragement that he always provided.

My sincere thanks are to Dr. V.K.Tripathi for the many fruitful discussions I had with him and his constant friendship. I have to thank Dr. D.P.Tewari for many discussions and constant encouragement. I have also to thank Professor S.S.Mathur for much encouragement during the work.

The Electrophysics Group had provided a homely environment full of cooperation and friendship. My heartfelt thanks are to everyone of the members who had been in and out of the group in the past few years and also to many other friends in the Physics Department and the Centre of Energy Studies. Many thanks are to Dr.Ishwar Rattan and Dr. R.R.Sharma for help in the final preparation of the thesis.

It is possibly superfluous to acknowledge the contribution of my parents since too much of myself and the thesis have been formed under their care. I would just wish to put on record that the patience they exhibited has been a matter of consternation to me. It is the irony of events that this thesis should go down in time in association with the happy memories of my late father. My hearty thanks go to my sisters and brother among many things for their considerate cooperation.

Mr. T.N.Gupta has done the efficient and neat job of the typing of the thesis and I would like to thank him for his constant cooperation.

D. Subbarao

(D. Subbarao)

## ABSTRACT

High power laser interactions with plasmas with fusion applications and similarly motivated nonlinear radiowave interactions with plasmas guided the selection of topics in the present thesis.

Self-focusing theory with an angular spectrum representation of the electromagnetic field of the beam has been formulated without restricting the generality of the dielectric constant. Detailed analysis of the paraxial and non-paraxial field structures and also the non-WKBJ modifications for a beam in a focusing medium has been presented. Normal and anomalous self-trapping have been predicted using the newly formulated paraxial theory and the Liapounoff phase-space techniques. Above threshold, a self-focusing beam has been shown to undergo oscillatory focusing till the beam-width amplitude decays to a value dictated by a self-trapping curve. Linear and nonlinear absorptions have been shown to enhance the possibility of such a beam trapping. The paraxial theories give the same results for self-trapping in non-absorbing media as the moments or variational theories for self-trapping after renormalisation of the beam-power. The latter two theories have been shown to lead to identical results for self-focusing and have also been shown to be equivalent to the reformulated paraxial theories provided focusing is very slow. Nonlinear penetration of an electromagnetic beam

into an overcritical plasma has been shown to lead to resonance absorption and profile steepening in its cross-sectional plane.

Parametric instabilities in a homogeneous and isotropic plasma have been reformulated using vector and scalar potentials of the electromagnetic and fluid velocity fields and as an initial value problem. Growth characteristics have been shown to depend on the form of the initiating perturbation.

Stimulated Raman and Brillouin scatterings in a plasma with waves propagating along or against a magnetostatic field have been shown to lead to growth and threshold resonances. The five-wave interaction which ensues when the pump is elliptically polarised has also been investigated.

Ponderomotive force and redistribution of the plasma when a magnetostatic field is azimuthal to the propagation direction of a plane and homogeneous electromagnetic wave has been investigated. It is shown that the creation of a density dip at the axis and also the generation of additional magnetic fields in the azimuthal direction can lead to wave focusing.

Debye screening modifications on ponderomotive redistribution have been investigated. Results in agreement with recent experiments on electron/ion expulsion by the ponderomotive force of a high power laser beam in a tenuous plasma have been obtained.

CONTENTS

CHAPTER III

PONDEROMOTIVE EFFECTS IN A PLASMA