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Faculty of Science

Waves Interaction and Generation In Inhomogeneous Plasma

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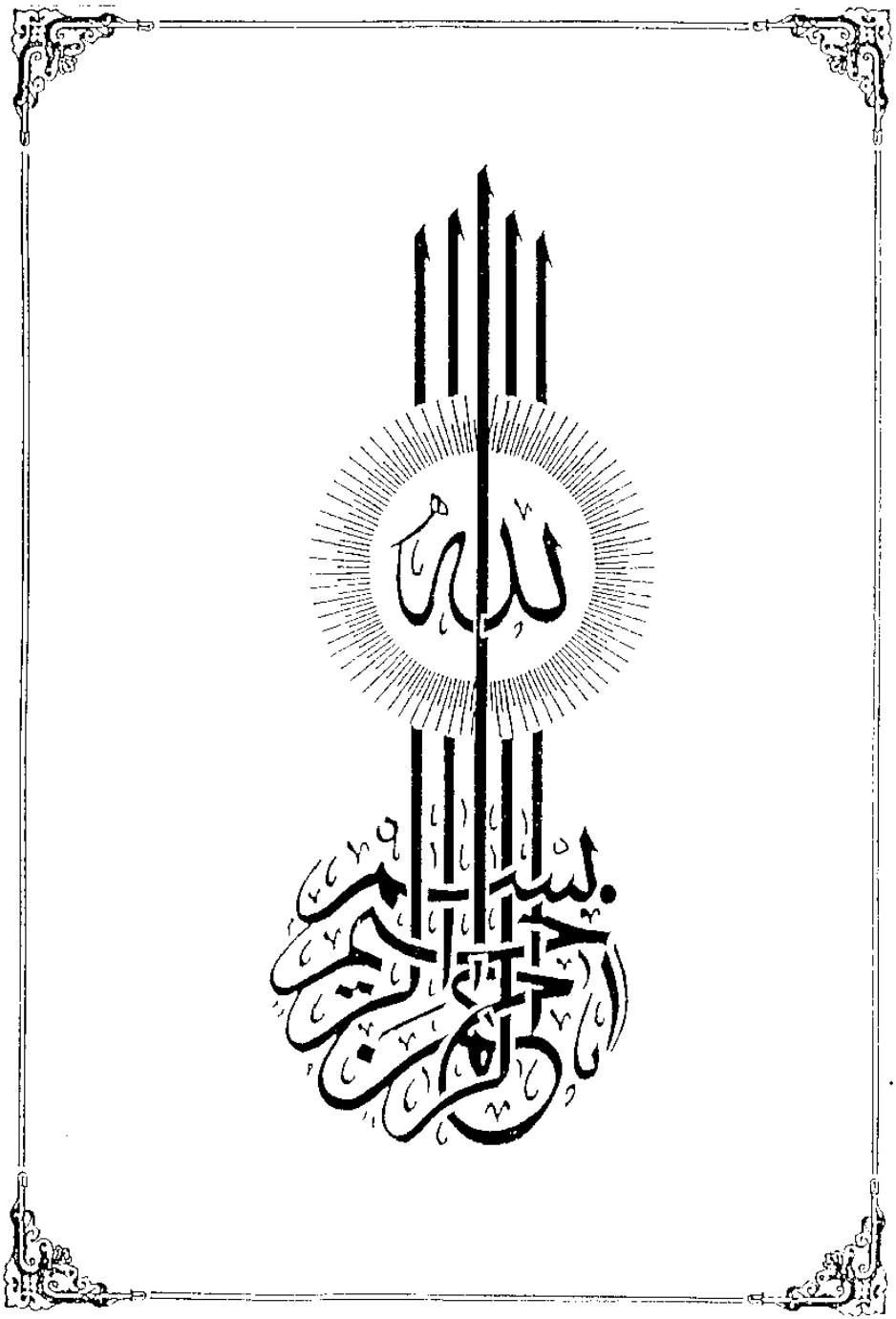

This thesis is deticated to the memory of
My father

Ibrahim Mahdy

and to My friend and Professor

Dr.Zayed Kamal

Both of whom had not only the gift of life within them. But the courage to live it to the end.
I miss you.

Contents

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Abstract

The wave Generation of electromagnetic and surface wave due to nonlinear interaction of light waves with a thin inhomogeneous cold and warm plasma layer is investigated.

In chapter 2 the nonlinear excitation and generation of surface waves (SW) in a thin inhomogeneous magneto-active plasma layer due to nonlinear interaction of obliquely incident P-polarized light waves with S-polarized surface wave in the presence of external static magnetic field is investigated. S-polarized SW are generated with large amplitude at combination frequencies while P-polarized are generated at second harmonics of incident wave and fundamental surface wave. For low dense plasma the generated waves are radiated with equal amplitudes at the plasma boundaries. The normal incident of light wave reduces the amplitudes of generated SW at double the fundamental frequency.

In Chapter 3 generation of waves at second harmonics and combined frequencies due to nonlinear interaction of obliquely incident pumping P-polarized light wave with S-Polarized surface wave in an inhomogeneous plasma is investigated. The effect of an external oscillating inhomogeneous magnetic field $\overline{H}_{ext} = \bar{e}_z H_o(x) exp(-i\omega_m t)$ is considered. Effect of polarization types on the generated waves is studied. Further, the applicability of our results for rarefied plasma and normal incidence are also studied

Chapter 4 contains the studies of the nonlinear generation of waves at combined frequencies in a thin inhomogeneous plasma layer due to interaction of waves which have similar polarization (either S- or P-polarized) . The effect of an external inhomogeneous magnetic field that oscillates at high frequency is also considered. Inhomogeneity, oscillation of the magnetic field and type of polarization are found to affect, strongly,

the generated waves.

The effect of finite electron temperature on the generated waves is also studied. Besides, numerical properties of these waves have been investigated for Nd laser falling on inhomegenous dense plasma.

Chapter 1

INTRODUCTION

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In recent years great interest has been paid to the study of the interaction of electromagnetic waves with a plasma. As an example, surface wave excitation, their propagation, interaction, and nonlinear phenomena in connection with them have showed a particular interest when considering the stability of some devices based on the use of charged particle beams, interfaces, thin films and solid state plasmas.

Furthermore, wave generation at harmonics and combined frequencies in the wave-plasma system is one manifestation of the nonlinear properties of the plasma. The wave-plasma interaction consists not only of reflection or absorption but also of other interesting effects like breakdown, particle's acceleration, trapping, self focusing and other nonlinear effects. In general, nonlinear wave generation is a subject of practical interest via plasma diagnostic's techniques and in studying the interaction of intensive electromagnetic waves with matter (laser-fusion reaction).

From all above it was of great interest to study and investigate through the next 3 chapters some problems related to wave-plasma interaction and wave generation in both cold and warm plasma, under the effect of an oscillating, inhomogeneous magnetic field.

1.1 Nonlinear Phenomena and Wave-Plasma Interaction.

In the last years, the rate of development of scientific research is so enormous, particularly in the study of nonlinear wave processes in plasma. This development has been brought by attempts to solve many of the plasma physical problems accompanying the tremendous growth experimental research.

The nonlinearity in plasma takes place even at comparatively easily attained fields. Associated with this are phenomena of nonlinear interaction of waves propagating in (or incident onto) plasma. The nonlinearity in plasma is due to slowness in the transfer of energy from electrons to heavy particles, which is associated with the smallness of the mass of electrons to that of heavy particles, at the same time, electrons in plasma may receive a large amount of energy from the field, since the length of the free path is usually quite considerable.

The nonlinear theory is based on three main types of interactions.

1. The nonlinear wave-wave interaction.

2. The quasilinear particle-wave interaction.

3. The nonlinear wave-particle-wave interaction.

In fact, nonlinear processes can be classified according to the magnitude of the electromagnetic fields, the characteristic times in which the interaction becomes pronounced, and, finally the characteristic lengths[66].

The investigation of nonlinear effects, can provide the answers to questions about the importance of many of any kind of plasma instabilities, heating of plasma, plasma radiation, plasma confinement, plasma diffusion and wave generation.

A nonlinear system may possess a wide variety of periodic oscillations in addition to those which have the same period as the external force.

The perturbations caused in plasma by a powerful wave not only affect the nature of its propagation but also, influence other waves passing through the disturbed region, so if powerful unmodulated waves are propagated then perturbing the plasma, in the first place they cause change in the electron's temperature, conductivity, and dielectric permitivity of the medium as well. Therefore, in the perturbed region the conditions for propagation of all other waves are changed.

In addition there arise other and weaker variable perturbations with frequencies, that are multiples of the frequency of the perturbing wave such perturbations lead to the occurrence of waves with harmonics and combination frequencies.

Due to nonlinearity, the fundamental physical concepts will change strongly to more complex situations. As example the interaction of the electromagnetic waves or laser with plasma and the corresponding wave generation.

1.2 Surface Wave

Surface Wave phenomena are of fundamental important in many branches in physics. In particular, the problem of nonlinear surface wave propagation has recently gained much attention in the study of optical acoustics, condensed matter, and fluids, as well as in laboratory and space plasma[2].

Recently, there has been much interest in the problem of wave propagation on plasma layers, since experiments and numerical simulation have shown that surface waves and their stability are important in inertial fusion as well as solid stat plasmas.

In fact The nonlinear interaction of surface waves in a plasma is also a subject of active research. The simplest model for describing the properties of surface waves is a semi-finite plasma bounded by dielectric with a dielectric constant, ϵ = constant.

All laboratory plasmas are bounded in some manner, the existence of a plasma boundary can introduce an phenomena such as emission and absorption of waves , for the wave that propagate in all direction , called addition wave, for the wave that propagates at the boundary of the medium called of surface wave.

Surface wave can appear near a surface of density discontinuity, also near discontinuities of other physical quantities such a pressure, magnetic field, plasma composition, velocity, etc. Surface waves propagate along the boundary of the medium even when it curved.

There is also situation in which smaller scaled surface waves might play important

role in tokamak with divertors or limiters which are introduced to remove edge impurities and prevent plasma wall contact. Space anisotropy induced surface waves can alter the orbits of the particle's trajectories at the boundary of the plasma and hinder the efficiency of these devices as well as affect the stability of edge plasma.

The tearing mode that is of great importance in tokamak plasma can be discussed as a surface wave. It could be considered as surface mode because its eigen function is mainly localized near a certain surface, called the rotational surface.

Moisan et. al. [19] have demonstrated that He- Ne laser excited by surface waves, and it can be versatile may to excite lasers.

The surface electromagnetic waves at the interface of a gas discharge plasma with a dielectric may be used for contactless plasma diagnostics. Interformation on the plasma properties so incorporated in the dispersion characteristics of these waves, but there are some difficulties in determining this characteristics[64].

The interest in nonlinear surface waves has increased in recent years. Applications are found in fluid dynamics, plasma and solid state physics[65].

The possibility of plasma heating in finite system by means of large-amplitude waves gas considerably stimulated the interest in nonlinear wave interaction and nonlinear wave propagation of surface modes.

Surface waves can also be excited by a homogeneous beam which localized either inside or outside the plasma [9,10,55-57], by inhomogeneous relativistic electron beam