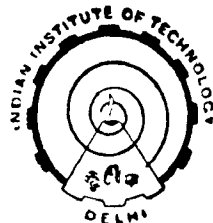


ELECTROSTATIC AND ELECTROMAGNETIC INSTABILITIES IN PLASMAS

**BY
SALIL KUMAR DAS
DEPARTMENT OF PHYSICS**

**SUBMITTED
IN FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY**



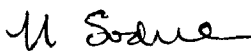
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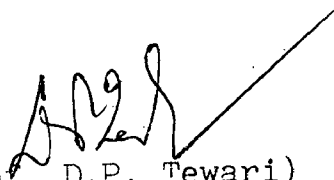
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C E R T I F I C A T E

This is to certify that, the thesis entitled, "ELECTROSTATIC AND ELECTROMAGNETIC INSTABILITIES IN PLASMAS" being submitted by Mr. Salil Kumar Das to the Indian Institute of Technology, Delhi, for the award of the degree of 'Doctor of Philosophy in Physics', is a record of bonafide research work carried out by him. Mr. Salil Kumar Das has worked with our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge, has reached the requisite standard.

The results contained in this dissertation have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.


(Prof. M.S. Sodha)


(Prof. D.P. Tewari)

Supervisors of the Candidate

Abstract

In this thesis, we have developed nonlocal theory of whistler instabilities in inhomogeneous plasmas and ion-cyclotron instabilities in bounded plasmas. We have also studied the modulation instability of an extraordinary electromagnetic electron cyclotron wave with the electrostatic zero-frequency convective cells as the low-frequency mode. These instabilities are relevant to mirror machines, bumpy torii, tandem mirrors, ionosphere, and some other laboratory plasmas. This is devoted to the theoretical investigation of some of the linear and nonlinear instabilities in magnetized plasmas.

The convective instability of various possible decay processes of a normally incident whistler wave in magnetized and fully ionized inhomogeneous plasmas are analyzed in the approximation of fluid theory. Using the methods of perturbation theory the regions of resonant interaction and the coefficients of spatial amplification of the scattered waves are deduced for different decay channels. It is shown that the length of the interaction region as well as the expressions for amplification coefficient strongly depend on the wave and medium parameters and also on the angle of scattering. Some calculations have been made with the magnetospheric plasma parameters.

force and its nonlinear propagation modifications introduced on the wave characteristics of arbitrarily polarized electromagnetic waves in a magnetoplasma. Since the dielectric constant variation in this case is sinusoidal in space, a corresponding cumulative effect modifying the angle of rotation of the Faraday rotated wave has been worked out. Of significance is also the prediction of satellite Faraday rotated components of the electric field which originate because of the spatial harmonics of the electromagnetic wave in the sinusoidal inhomogeneous medium. Quasi-longitudinal propagation has been studied as an example of these effects.

We have studied the propagation of a whistler wave through a preformed magnetic trap and obtained the structure of different modes of propagation. We also examined the possibility of exciting one of these modes by the temperature anisotropy of electrons inside the trap. The study is relevant for duct propagation of whistlers in the magnetosphere and to explain the expected whistler instability in Elmo Bumpy Torus.

We have investigated the excitation of low frequency electrostatic ion-cyclotron modes with frequency $\omega \geq n\omega_{ci}$ by an $\vec{E} \times \vec{B}$ drift which can arise due to space charge effects in a magnetized plasma penetrated by an electron beam. The radial electric field at the edge of the beam combining with the static axial magnetic field B_0 produces $\vec{E}_r \times \vec{B}_0$ drift on charge particles. However, as the ρ_i (the ion larmor radius) is much larger than the scale length of the radial electric field, the ions do not get influenced by this drift. Therefore, a situation develops where electrons are drifting in an azimuthal direction with a velocity $\vec{v}_e = \frac{\vec{E}_r \times \vec{B}_0}{B_0^2}$ with respect to the background ions. This relative motion of the two-species is a source of free-energy which can drive the modes with $\omega = k_e v_e$ unstable. This is the instability mechanism

which we have investigated in detail in a slab-model consisting of background ion component and electrons having a drift \vec{v} transverse to the direction of the axial magnetic field assumed to be in z-direction. The frequency and growth rate of the instability are determined.

Zero-frequency electrostatic convective cells have been invoked to explain Bohm diffusion in a magnetized plasma. They have been observed in computer simulation studies and laboratory experiments. But the suprathreshold level of these fluctuations observed in laboratory plasmas cannot be explained by linear processes. Therefore, a nonlinear mechanism is presented in which an extraordinary electromagnetic electron cyclotron mode is shown to parametrically excite the convective cells. The growth rate is obtained and is found to be small for typical tokamak parameters.

Faraday rotation as a technique for measuring nonlinear effects in plasma introduced by high-power electromagnetic waves has been studied. At high instabilities, in particular, ponderomotive force because of an electromagnetic wave comes into play and modifies the internal density distribution and the dielectric constant of the plasma. It has been found useful to incorporate the recent results on ponderomotive

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C O N T E N T S

Page No.

CHAPTER - 1

INTRODUCTION

1

CHAPTER - 2

DECAY INSTABILITY OF A WHISTLER IN AN INHOMOGENEOUS
PLASMA

2.1	INTRODUCTION	16
2.2	NONLINEAR DISPERSION RELATIONS	28
2.3	AMPLIFICATION COEFFICIENTS	33
2.4	DISCUSSION	42
	REFERENCES	46

CHAPTER - 3

WHISTLER INSTABILITY IN A MAGNETIC TRAP

3.1	INTRODUCTION	49
3.2	MODAL ANALYSIS	53
3.3	EFFECT OF HOT ELECTRONS	56
3.4	DISCUSSION	57
	REFERENCES	59

CHAPTER - 4

ELECTROSTATIC INSTABILITY DRIVEN BY $\vec{E} \times \vec{B}$
DRIFT IN A SLAB MODEL

4.1	INTRODUCTION	61
4.2	BASIC EQUATIONS AND MODEL	64

	<u>Page No.</u>	
4.3	DISPERSION RELATION	66
4.4	RESULTS AND DISCUSSIONS	71
	REFERENCES	74
CHAPTER - 5		
EXCITATION OF CONVECTIVE CELLS BY AN EXTRAORDINARY ELECTROMAGNETIC MODE		
5.1	INTRODUCTION	76
5.2	GENERAL FORMULATION	86
5.3	LINEAR DISPERSION RELATION	92
5.4	NONLINEAR DISPERSION RELATION	92
5.5	DISCUSSION	99
	REFERENCES	101
CHAPTER - 6		
NONLINEAR FARADAY ROTATION OF ELECTROMAGNETIC WAVES IN MAGNETOPLASMA		
6.1	INTRODUCTION	103
6.2	WAVE EQUATION	112
6.3	PROPAGATION CHARACTERISTICS	114
6.4	FARADAY ROTATION	116
6.5	SATELLITE FARADAY ROTATION	118
6.6	CONCLUSIONS	128
	REFERENCES	130