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FINAL RESEARCH REPORT

FOR

SUBMISSION TO PAKISTAN SCIENCE FOUNDATION

1. Project	C-QU/Phys(36)
2. Project Title	Some Aspects of Thermonuclear Fusion
3. Name of Institution	Department of Physics Quaid-i-Azam University, Islamabad.
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6. Report period	From 1.5.1982 to 30.4.1983 and From 1.11.1985 to 31.10.1987.
7. Signature of the Principal Investigator.	G. Murtaza

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PAKISTAN SCIENCE FOUNDATION

RESEARCH REPORT

During the report period, we investigated various aspects of the controlled thermonuclear fusion which are briefly summarized below:

I. The problem of anomalous electron heat and particle transport is of great interest and importance. It is generally believed that the particle transport is due to electrostatic convective cells, while the anomalous heat transport is associated with magnetic fluctuations. Attempts have been made to understand these mechanisms. We have shown, "On the basis of the structure of the mode coupling equation, that if the plasma β exceeds the square of the inverse aspect ratio, $(a/R)^2$, both the energy and the particle transport are greatly enhanced due to the magnetic drift modes and convective cells even in the presence of magnetic shear".

This work has been published and the reference is given below

EFFECT OF FINITE β ON LOW FREQUENCY WAVES
G. Murtaza, H.U. Rahman and M. Salahuddin
Phys. Lett. 102, 235 (1984).

II. It is well known that linear drift waves are stable and their phase velocity approaches the diamagnetic drift velocity of the medium. The non-linear electrostatic drift waves have also been studied in the frame work of reductive perturbation method by several authors who found that these waves can propagate as solitary waves. On the other hand it is found that these waves are modulationally unstable in a weakly inhomogeneous low β-plasma, assuming their propagation at an angle to the external constant magnetics field. As the density gradient steepens, the growth increases but the region of instability contracts. The opposite

happens when the d.c. magnetic field is increased. We have shown that, "The non-linear drift waves are modulationally stable in a weakly inhomogeneous low β-plasma, when the propagation is perpendicular to the density gradient and the magnetic field. We have further shown that the presence of electron and ion temperature gradients does not effect the stability".

This work was presented at the "Tenth International Nathiagali Summer College on Physics and Contemporary Needs (1985)" with the title,

NONLINEAR DRIFT WAVES IN THE PRESENCE OF ELECTRON AND ION TEMPERATURE GRADIENTS
M. Zakaullah (Speaker)

III. The magnetostatic fluctuations have been observed experimentally in toroidal plasma devices. A number of authors have proved theoretically that these fluctuations can be nonlinearly excited to suprathermal level in the presence of density gradient in such mechanisms. Some of the authors have proposed that an electrostatic drift wave can parametrically interact with the magnetostatic mode giving rise to an electron cross field diffusion. The estimated growth rate and threshold values were applied to typical tokamak discharge parameters. We proposed that a finite amplitude ion-cyclotron wave can also act as a pump wave in a similar 3-wave resonant interaction mechanism mentioned above. The growth rate of instability turns out to be sizeable suggesting the present process as a possible candidate responsible for the observed magnetostatic fluctuations. We have applied our results to a particular toroidal machine.

This work has been published and its reference is given below:

PARAMETRIC EXCITATION OF MAGNETOSTATIC FLUCTUATIONS BY ION CYCLOTRON WAVES
H. Saleem, M. Salahuddin and G. Murtaza
Physics Lett. 115A, 150 (1986)

IV. It has been shown that in a magnetized plasma with ion temperature T_i greater than electron temperature T_e, the electron acoustic mode is nonlinearly excited by extraordinary waves in radio frequency heating. To achieve and maintain the fusion temperatures, the radio frequency auxiliary heating of the plasma is very important. Although the condition ($T_i >> T_e$) is very restrictive yet it is achieved in theta pinches and some mirror machines. However, the systems become unstable in a time less than a nanosecond due to instabilities which could arise because of a variety of linear and nonlinear mechanisms yet not fully understood. Such a possible nonlinear mechanism has been investigated. It has been shown that an extraordinary electromagnetic wave (which is used in rf heating of plasma) can parametrically decay into an electrostatic upperhybrid and a low frequency electron acoustic oscillation while propagating magnetized plasma with $T_i >> T_e$. The threshold power and growth rate of this instability are obtained. The results of this investigation has been applied to 2XIIB mirror machine as an illustration. The parameters of this machine plasma are taken to be

density ~ 10^{14} cm^{-3}

magnetic field ~ 10^{4} gauss

electron temperature ~ 1.3 KeV

ion temperature ~ 13 KeV

Assuming the pump wavelength of 1.26 cm - the typical wavelength of the gyrotron, the e-folding time for this instability turns out to be 0.01 msec. The threshold power flux is found to be about 20 $W.cm^{-2}$. Our results are general and in addition to laboratory plasma can be applied to plasmas wherever the condition $T_i >> T_e$ is valid.

This work has been published and its reference is given below:

NONLINEAR EXCITATION OF ELECTRON-ACOUSTIC WAVES
H. Saleem and G. Murtaza
J. Plasma physics (1986), vol. 36, part 2, pp. 295-299

V. In the inertial confinement fusion (ICF), when the laser energy is deposited in a region of plasma upto the critical density, many absorption mechanisms (e.g. Resonance absorption, two plasmon decay (TPD) instability and stimulated Raman scattering (SRS) instability) can lead to the creation of very high energy electrons known as suprathermal electrons. The energy of these electrons ranges from a few KeV to few hundreds of KeV. We have analysed that perhaps the most likely explanation of the production of these electrons involves a wavebreaking process induced by resonance absorption. Various experiments have confirmed the presence of these electrons. These electrons have been the subject of experimental and theoretical studies of ICF because their presence strongly influences the design and performance of laser driven targets due to the fact that they can penetrate into the target and preheat the fuel before the final compression occurs. This preheating effect reduces the achievable thermonuclear energy gain from the imploded target. Many efforts are being done to limit this effect. One of them is to surround the DT-fuel target with a high Z-shielding.

This work has been reviewed by Mr. Qaisar under the supervision of Dr. G. Murtaza in his M. Phil. dissertation entitled:

SUPRATHERMAL ELECTRONS IN ICF

Signature of the Principal Investigator G. Murtaza

Signature of the Institutional Head

Vice-Chancellor,
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