Plasma is commonly referred to as the Fourth State of Matter. A state resulting from adding energy to matter to break the individual bonds of its individual atoms, ionizing those atoms and freeing electrons. When this happens to a significant number of atoms, the resulting collection of electrically charged particles forms an ionized gas, or “plasma” with unique properties.

The importance of material states in our world should in fact be put in reverse order with ‘plasma’ in the first place. The Big Bang beginning of our Universe was dominated by high-temperature plasma; and plasma continues today to comprise more than 99% of our visible universe. In general, materials in various states in our universe was not formed by heat added to a more strongly bonded state, rather, it was formed by heat removed from a hotter, more weakly bonded state. The high temperature that existed early in the universe clearly corresponds to the presence of plasma, not the lower temperature gases, liquids and solids which developed later in this order.

Plasma is present not only in the sun, stars and vast interstellar space, but is also in our surroundings. It is present in lightning, in computer chip manufacturing, in neon and other lamps, in the propulsion fuel of space crafts, flat panel television and also in electric power which will be generated in future by fusion.

In many cases the interaction between the charged particles and the neutral particles is important in determining the behavior and usefulness of the plasma. The type of atoms in a plasma, the ratio of ionised to neutral particle energies all result in a broad spectrum of plasma
types, characteristics and behaviors. Figure 1 and 2 in Chapter I explicitly shows the various kinds of plasmas (191).

For the purpose of our study we divide plasma in two types namely, Classical plasma and Solid State or Quantum Plasma. The Classical or Gaseous plasma has less charge or particle density and High temperature. Therefore, the B-E or Classical Statistics may be employed to deal with such systems. On the other hand, the solid state plasma contains large number of charge carriers and therefore have high charge density along with relatively low temperatures. Following Bohm-Pines (1951, 1952, 1953, 1954) such plasma can be regarded as a quantum plasma since in solids the electrons are closely packed and hence only quantum mechanics and quantum statistics can deal with such systems.

The Collective description of a collection of electrons, based on the organized behavior produced by interactions in a electro gas of high density, results in oscillations of the system as a whole, is the so called 'plasma oscillations'. The long-range correlations in the electron position bought about by their Coulomb interactions is responsible for the organized or collective behavior.

In a treatment of these organized oscillations, one considers a particular Fourier component of the average field, proportional to,

$$\exp \left[ i (k \cdot x - \omega t) \right]$$

for small amplitudes, the linear approximation is valid, and an arbitrary field can therefore be expanded as a sum of such trigonometric terms. In response to this oscillating field, each electron undergoes a small corresponding trigonometric change in its velocity and in its contribution to the mean charge density. Owing to the long range of the Coulomb force, the mean field at each point can be quite large as a result of the cumulative effects of small
contributions arising from each particle. The condition for sustained oscillations is that the field arising from the response of the particle must be consistent with the field producing this response. This requirement leads to a dispersion relation connecting $\omega$ and $k$. For longitudinal waves the approximate dispersion relation, good for long wavelengths,

$$\omega^2 = \left( 4\pi n_0 e^2 / m \right) + 3 k^2 \kappa T / m$$

(ii)

$n_0$ is the electron density, $T$ is the temperature, $\kappa$ is the Boltzmann constant. For infinite wavelength, this reduces to the well-known plasma frequency,

$$\omega_p^2 = 4\pi n_0 e^2 / m$$

(iii)

A quantum of plasma oscillations is called “Plasmon”. The energy of a plasmon may be given by,

$$\hbar \omega_p = \hbar \left( 4\pi n_0 e^2 / m^* \right)^{1/2}$$

(iv)

Where, $m^*$ is the effective mass of the electron.

The solid-state plasma and its effects can be viewed or observed during X-ray emission, absorption, Raman, and Compton scattering etc. The work during the last 30 years prove the involvement of plasmons during these processes. On the theoretical ground, Ferrell (1956), Nozieres and Pines (1959) and Parratt (1959) were amongst the initial workers who studied the possibilities of excitations of plasmons in the electron gas during X-ray emission and absorption. It means that X-ray emission and absorption spectra is complicated by the long range part of the Coulomb interaction which will result in the appearance of a new line or band. According to Rooke (1963) this is observed experimentally. According to him X-Ray satellite lines have been observed towards the low energy side of the $L_{2,3}$ bands of Mg, Al and Na at a plasmon energy distance from the parent band. According to Rooke, the valence electron during transition excites a plasmon before filling a vacancy in the $L_{2,3}$ core levels of
the atom, which results into sharing of energy of the main emission line between X-ray photon and a plasmon. Such phenomenon may be treated as a collective counter-part of the usual “Auger effect”.

In the other process, if the plasmons are already present due to one or more reasons, then on decay, it can transfer its energy \( (h\omega_p) \) to the transiting valence electrons which will enhance the energy of the emitted photon by an amount \( h\omega_p \) on the high energy side of the main X-ray emission line. These structures may be called high-energy plasmon satellites. Actually they are non-diagram lines since they cannot be conventionally be fitted into the energy level diagram. It is also possible to observe the effect of plasma oscillations during the process of X-ray absorption, by passing X-ray photon through a metal, which may dislodge one of the inner electrons, resulting in the appearance of main absorption edge of the metal. In case of involvement of plasma oscillations it gives rise to fine structure of the absorption edge on the high energy side.

According to some workers, such as DasGupta (1959-64), Priftis et al. (1968-74) and Suzuki et al. (1969, 1975), it is also possible to observe Raman and Plasmon scattering simultaneously. Survey of literature shows that a close resemblance exists in the energy between characteristic energy loss values or Plasmon loss values of electrons in metals and the fine structure observed towards the short wave-length side of the X-ray absorption edge. Mande et al. (1966), Padalia et al. (1975), Bhide et al. (1952) have claimed on the basis of energy equivalence the presence of plasmon structure in the X-ray absorption Spectra.

It is also possible to observe plasmon satellites at an energy distance of \( \frac{h\omega_p}{\sqrt{2}} \) (if the geometry of the specimen is plane) from the main line in the X-ray emission spectra. The work of Tsusumi et al. (1976), Krause et al. (1975) and Tsusumi et al. (1959) explores the
possibility of such satellites. However, the surface Plasmas were first predicted by Ritchie (1957), Powell and Swan (1960) have been able to detect the surface plasma oscillations in both Magnesium and Aluminium by reflection of fast incident electrons, at energies close to those predicted by Ritchie. It has also been found by experimentalists that the low lying characteristic losses are very sensitive to sample preparation, and yield lower energy losses and weaker intensity than predicted. The resonant frequency for surface waves is given by,

$$\omega_r = \omega_p / (1 + \varepsilon)^{1/2}$$  \hspace{1cm} (v)

For a plasma bounded by vacuum we must set $\varepsilon = 1$ and we obtain Ritchie's result. But if $\varepsilon$ is significantly greater than 1 for an actual dielectric medium, then we find a significant relaxation in the resonant frequency given by (v).

In what was probably the first clear evidence that surface plasma oscillations on thick metal foils do indeed radiate, Boersch et al (1965) studied the visible and ultraviolet radiation emitted from electro-bombarded thick silver targets.

Excitation of surface plasmons (SP) in a degenerate semiconductors by tunneling electrons has been observed in metal-semiconductors junction by Tsui (1969). Subsequent theory based on an inelastic surface plasmon interaction model yield results which agree with experiment both in magnitude and line shape was proposed by Ngai et al. (1969). Precise measurements by Lander et al.(1969) with low-energy electron diffraction (LEED) of the inelastic spectra of electrons in the system W (100-Cs) have revealed SP excitation in the Cs surface layer. Infrared - reflectivity measurements by Marschall et al. (1971) on InSb surfaces having inscribed line gratings yield the first complete dispersion relation for surface plasmons. Bennett (1969) has also shown on the basis of Microwave experiments that a series of surface plasmon resonance modes are observed rather than just the single -surface mode frequency. In fact
resonant frequencies which included both dipole and quadrupole plasma oscillations have also
been proposed.

This shows the extensive work on surface plasmons and the Bloch hydrodynamical model
extended by later by Ritchie and Wilems (1969) is used to study the surface plasmons.
Boardman et al (1988,89,90) used the double well model to deal with the problem of surface
plasmon oscillations. Several other workers have also taken up this problem. Harsh and
Agarwal (1988,89,90) successfully treated this problem by obtaining the dispersion relations.
The tendency of surface plasmons to interact with transverse waves is well known. The subject
of interaction of surface plasmons with surface phonons in a dielectric is a very interesting one.
Several workers such as Yokotu (1961), Varga (1965) and Kheifets (1965) have worked on
this problem theoretically, whereas Anderson et al. and Reshina et al studied this problem
experimentally.

In the present work, I have studied the problem of Surface Plasmons using the Bloch
hydrodynamical model.

The hydrodynamical model, although owes its origin to fluid dynamics, is a very appropriate
and convenient tool for studying surface modes. A good description of the collective behavior
of an electron gas moving against a stationary compensating positive background is obtained
by coupling Maxwell’s equations to a rather straightforward equation of motion. Due to
organized behavior of the electrons, the high degree of interlocking makes the hydrodynamic
equations, in terms of the velocity and density prevailing at each point, a good approximation
to the actual motion. The idea of essentially using hydrodynamics to study the electron gas
originates with Bloch, and slightly later work by Jensen. The model is easily quantised and has
been used extensively by Ritchie and coworkers to study plasmon–photon and plasmon-electron interactions.

Although the problem of magnetoplasma surface waves has been solved by many workers, the problem of involvement of magnetic field and hence the modification in the surface modes has not been studied by using the Bloch Hydrodynamical model. By making use of this model, we can in a simplified manner study the effect of magnetic field on the surface plasma modes in metal-vacuum interface, in vacuum-semiconductor interface by introduction of the dielectric constant which behaves like a tensor in presence of a magnetic field.

Thus the dynamics of the radiation field coupled with an electron gas are studied according to the model given by Ritchie and Wilems (48).

The dispersion relation which we obtain is as follows,

$$\frac{1}{2}\omega_p^2 + \frac{1}{2} kd \left( 1 - i\omega_c^2 d/c\beta^2 \right) \left( 1 - 1/2 \left( \omega_p/2c\beta^2 \right)^2 \right) = \omega^2$$  \hspace{1cm} (vi)

The dispersion relation for surface modes in the rectangular boundary for normal and tangential modes have already been derived. The problem has been extended to include the cylindrical geometry as well as toroidal surfaces.

This is surface plasmon dispersion relation for the cylindrical bounded electron gas. This equation is valid when the medium in which the cylinder is placed is vacuum.

$$J_1(\ell'R)/2R = J'_1(\ell'R) \left[ 1/(2\ell) + \beta^2\ell^*\ell*\omega_p^2 \right]$$  \hspace{1cm} (vii)

If on the other hand, the dielectric constant of the medium is $\varepsilon_\pm$, in which the slab is embedded, the dispersion relation becomes

$$J_\ell(\ell'r)/2R = J'_\ell(\ell'R) \left[ 1/\ell(1 + \beta^2\ell^*\ell\omega_p^2) \right] \left( \varepsilon_+ - \ell + \ell/\varepsilon_+1 \right)$$  \hspace{1cm} (viii)
$\varepsilon_\infty$ is the dielectric constant of medium of the dielectric embedded in vacuum. If $\varepsilon_\infty = 1$ in the above equation, then the dispersion relation for a metallic cylinder may be obtained.

Surface modes in semiconductors are also studied by incorporating the background dielectric constant $\varepsilon_\infty$. Thus the interaction of the surface plasmon–surface optical phonons is also studied through the dispersion relation.

The dispersion relation for the polar semiconductor may be approximated as,

$$\{ \varepsilon_\infty \left( \frac{\omega^2 - \omega_\infty^2}{\omega_\infty^2} \right) \left( \frac{\omega_p^2}{\omega_\infty^2} \right) + \left[ \varepsilon_\infty \left( \frac{\omega^2}{\omega_\infty^2} - \varepsilon_0 \right) \left( \frac{\omega_\infty^2}{\omega^2} \right) \right] \left( \frac{\omega^2}{\omega_\infty^2} \right)^2 \} J_2(\ell R)/J_0(\ell R)$$

$$= \varepsilon_\infty \left( \frac{\omega^2 - \omega_\infty^2}{\omega_\infty^2} \right) \left( \frac{\omega_p^2}{\omega_\infty^2} \right) - \varepsilon_\infty \left( \frac{\omega^2}{\omega_\infty^2} \right) \left( \frac{\omega_\infty^2}{\omega^2} \right) \varepsilon_0 \left( \frac{\omega^2}{\omega_\infty^2} \right)$$

(ix)

here it has been assumed that $\varepsilon = 0$ and $\ell = 1$.

The problem of obtaining the dispersion relation for Surface modes in a toroidal geometry has been successfully solved. Here we encounter the difficulty that the wave equation is not separable from the coordinates in any form. For this a technique evolved by M.Sita Janaki et al. (1990) has been applied here, whereby the Helmholtz equation is solved.

The dispersion relation for a toroidal plasma is,

$$\frac{1}{k s_0} \frac{P_{0n}}{P'_{0n}} = \frac{(2n+1)/(2(n+1))}{(n+1)/(2(n+1))} \{ (\omega^2 - \omega_p^2)/(\omega_p^2) - (n+1)/(2(n+1)) \}$$

(x)

One can see that the solutions are obtained in terms of Hypergeometric functions. These solutions therefore can lead us to obtain a generalized dispersion relation from which surface modes in various geometries such as cylinders, spheres, conicals, paraboloids etc. may be obtained.

Thus the presence of Bulk, surface plasmons as well as multiple plasmons have been established.
The study of plasma is therefore becoming increasingly important in all spheres of physics. Whether it is in the field of optics, Material science, Electric power, electronics, Statistical mechanics and Kinetic theory, magnetohydrodynamics, Computer applications, Spectroscopic atomic physics, non-linear dynamics, microwave generation, particle and fields detection, and Lasers. Therefore our theoretical study of surfaces through surface modes on various geometries is an important study.