5.1 Introduction:

The first observation of far infrared light emission from a 2-Dimensional (2-D) plasmon oscillation at the inversion layer of a MOSFET, was made by Tsui et al. in 1980 [71]. The general principle of excitation of 2-D plasmon is similar to that of a Travelling Wave Transistor (TW) [72]. In this case the inversion layer plasmon is excited by highly energetic electrons which relax the electromagnetic energy to the plasma medium while moving from source to drain. The exciting electrons have a kinetic energy in excess of their thermal equilibrium energy. Since the velocity of hot electrons is not very high, they may lose energy to surrounding clouds of electrons by coulombic interaction. Hence the study of hot electron relaxation process requires the knowledge of collective interaction phenomena of charged carriers in inversion layer. In this chapter the work concerning the type of electromagnetic oscillations of an inversion layer is presented. The inversion layer in a Si-MOSFET constitutes a 2-D electron plasma [73] whose frequency can be changed by varying the gate voltage of the device. Earlier experiments [74,75] have already demonstrated the excitation of the inversion layer plasma by
high energy optical beams falling on the device. Most of the reported works have been experimental and little attention has been paid to the study of the absorption and emission phenomena theoretically. We present our study of the 2-D plasmon oscillation in some detail and the various factors influencing its coupling with the plasmons in the gate electrode of the MOSFET. Recently a detailed review on inversion layer plasmon oscillation (both theory and experiment) is given by Theis [76].

Ngai et al [77] have reported the work done on the dispersion relation of a surface plasma wave in a simple MOS structure. Nakayama has further improved the result by taking the inversion layer plasma at the interface of a metal-semiconductor structure into consideration. Stiles et al [79] and Egiluz [80] have reported the work of the effect of magnetic field and gate electrode plasma on the 2-D plasma dispersion relations respectively.

In this chapter the study of the inversion layer plasmon oscillation is presented. We report here the nonradiative type only whereas radiative type solution is presented in the next chapter. The theory based on Maxwell's equations of wave propagation in 2-D inversion layer plasma is given in section 2. Section 3 contains the solution of non-radiative type dispersion relation. Various factors influencing the coupling of 2-D plasma oscillation such as insulator thickness, inversion layer carrier density and gate electrode plasma
frequency are considered in section 4. Finally section 5 contains the conclusion arrived at in this work. The conclusion we reached in this study is that a MOSFET with suitable geometry can act as a tunable infrared emitting source.

5.2 Formulation of the Problem

The semiinfinite semiconductor medium is considered. Charge carriers at the surface are coupled to an electromagnetic field extending into space. The structure of the three media model under consideration is shown in Fig. 5.1. The first medium is a < 100 > p-type silicon, the second a SiO₂ layer and the third a semimetallic gate region. The study of plasma wave propagation is based on Maxwell's equation together with a constitutive equation relating the vector \( \vec{D} \) with electric field \( \vec{E} \) [81]. We have the set of Maxwell's equations as,

\[
\begin{align*}
\nabla \cdot \vec{D} &= 0 \\
\nabla \cdot \vec{H} &= 0 \\
\n\nabla \times \vec{E} &= \frac{1}{4\pi \varepsilon_0} \frac{\partial \vec{H}}{\partial t} \\
\n\nabla \times \vec{H} &= \frac{1}{4\pi \mu_0} \frac{\partial \vec{D}}{\partial t} \\
\vec{E} &= c(\omega) \vec{E}
\end{align*}
\]

A thin inversion layer at Si-SiO₂ interface which behaves as a 2-D conducting sheet is considered. The sets of conditions of continuity are taken for certain components across the boundaries whereas the properties of the medium change discontinuously. The types of solutions of our interest correspond
FIG. 5-1
to wave propagation along a direction parallel to the boundary i.e. x-axis (in Fig. 5.1) with z-axis normal to the surface. We further assume that there is no y-dependence of any of the components and that \( H_x = H_z = E_y = 0 \) in all the media. Thus we restrict ourselves to the so called electric or 'TM' waves and neglect other solutions i.e. magnetic or 'TE' waves, since the electric field is continuous in y-direction and so no surface charge is produced. We have made the following approximations in our calculation keeping in view the possible experimental structure.

1) The thickness of the inversion layer (\(< 100 \AA\)) is neglected.

2) Inversion layer is characterized by its conductivity tensor which depends on the carrier density and operating frequency of the device.

3) Since the range of frequencies is much higher than the acoustic phonon frequency of the semiconductor, the optical dielectric constant (11.7) of silicon is taken for computation.

4) A semimetallic gate electrode is taken and its dielectric constant is given by

\[
\varepsilon_3 = \frac{\omega_p^2}{\omega^2}
\]  

(5.2)

where \( \omega_p \) is the plasma frequency of the gate electrode given as \( \omega_p = (ne^2/m^*\varepsilon_0)^{1/2} \) and \( n, e, m^* \) are free carrier density, electronic charge and effective mass of the carrier in the medium. \( \varepsilon_0 \) is the permittivity of free space.
v) The phase matching of the wave (i.e. same value of the propagation constant $K_x$ in $x$-direction) is assumed at the boundary of all the three media.

vi) Creation and annihilation of carriers in the depletion layer of the semiconductor are neglected.

The field components for the given geometry can be expressed as

$$E(x, z, t) = E(z) e^{i(\omega t - K_x x)} \quad \ldots (5.3)$$

In general $K_x$ is a complex quantity. With the conditions $\text{Real } K_x > 0$ and $\text{Im } K_x < 0$, the wave travels with attenuation in the positive $x$-direction. With the help of Eqn (5.3) we get the following relation for field components from the above Maxwell's equations.

$$\frac{\partial^2}{\partial z^2} E_{z \gamma} - K_{\gamma} E_{z \gamma} = 0 \quad \ldots (5.4)$$

$$H_{z \gamma}(z) = -\frac{\omega \epsilon_{\gamma}}{K_{z \gamma}} E_{z \gamma} \quad \ldots (5.5)$$

$$K_{z \gamma}(z) = -\frac{i}{K_{z \gamma}} \frac{\partial}{\partial z} E_{z \gamma} \quad \ldots (5.6)$$

where $K_{\gamma} = (K_x^2 - \epsilon_{\gamma} \omega^2/c^2)^{1/2}$ is the $z$-component of the propagation constant in three different media with $\gamma = 1, 2, 3$ for semiconductor, oxide and metal region respectively. The general solution of Eqn (5.4) is a linear combination of the two independent solutions $e^{K_{\gamma} x}$ and $e^{-K_{\gamma} x}$. $K_{\gamma}$ can be real or imaginary according to the conditions $K_x^2 > \epsilon_{\gamma} (\omega^2/c^2)$ or $K_x^2 < \epsilon_{\gamma} (\omega^2/c^2)$ respectively. These two conditions result in nonradiative or radiative case \([82]\).
a) Nonradiative mode plasma oscillation

If \( K_y \) outside the device is real, \( E_z \) decays exponentially with \( z \) and it is a nonradiative mode. In this case \( K_x > \varepsilon \gamma (\omega / c) \) and the dispersion relation curve lies to the right of the light line. This type of solution is discussed in section 5.3.

b) Radiative type plasma oscillation

If \( K_y \) outside the device is imaginary, the field component has an oscillatory behaviour and this gives a radiative type mode. This implies \( K_x < \varepsilon \gamma (\omega / c) \) and the dispersion relation curve lies to the left of the light line. We discuss the general behaviour of this mode of propagation in Chapter VI.

5.3 Nonradiative Type Wave Propagation

In general, a nonradiative plasma wave is characterized by the exponential decrease of the field vector outside the medium. In Fig. 5.1, \( z = 0 \) plane separates the semiconductor (\( z < 0 \)) from the oxide medium and \( z = d \) plane separates the oxide (\( 0 < z < d \)) from the semiinfinite metal region (\( z > d \)). We can write out the expressions for the field components in the three media (the field should remain finite at infinity).

For \( z < 0 \), \( E_{x1} = E_1 e^{+K_1 z} \exp (iK_x x - \omega t) \)

\[ E_{x1} = \frac{-iK_1}{K_x} E_1 e^{+K_1 z} \quad \ldots \quad (5.8) \]

\[ H_{y1} = \frac{-i\omega \varepsilon_1}{c K_1} E_{x1} \]
\[
0 < z < d \quad E_{z2} = (E_z e^{K_z^2 z} + E'_z e^{-K_z^2 z}) \exp i(K_x x - \omega t)
\]

oxide
\[
E_{x2} = \frac{-iK_x}{K_x} (E_z e^{K_z^2 z} + E'_z e^{-K_z^2 z}) \quad \ldots (5.9)
\]
\[
H_{y2} = \frac{-i\omega E_z}{cK_x} (E_x - E_x')
\]

\[
z > d \quad E_{z3} = E_z e^{-K_z z}
\]
metal
\[
E_{x3} = \frac{iK_z}{K_x} (E_z e^{-K_z z}) \quad \ldots (5.10)
\]
\[
H_{y3} = \frac{-i\omega E_z}{cK_z} E_x
\]

The general dielectric constant expressions in three media may be written as

\[
\varepsilon_3(\omega) = \varepsilon_3(1 - \omega^2/\omega_p^2(1 - i\omega \tau_m)) \quad \text{for metal}
\]
\[
\varepsilon_2(\omega) = \varepsilon_2 \quad \text{for oxide}
\]
\[
\varepsilon_1(\omega) = \varepsilon_1(1 - \omega^2/\omega_s^2(1 - 1/\omega \tau_s)) \quad \text{for semiconductor}
\]

where \(\tau_m\) and \(\tau_s\) are relaxation times for the metal and semiconductor respectively. For the frequency region of the present study \(\omega \tau_m \ll 1\) and \(\omega \tau_s \gg 1\) (assumption (iii)), we can write the dielectric constant values from above formula as

\[
\varepsilon_3(\omega) = \varepsilon_3(1 - \omega^2/\omega_p^2), \quad \varepsilon_2(\omega) = \varepsilon_2, \quad \varepsilon_1(\omega) = \varepsilon_1
\]

The electromagnetic field vectors in the three media satisfy the following two boundary conditions,
i) The parallel component of the electric field is continuous.

ii) The tangential component of the magnetic field is discontinuous due to the surface current of 2-D plasma.

With these boundary conditions, a system of four linear homogeneous equations for the four unknowns $E_1$, $E_2$, $E_3$, $E_4$ is obtained. Nonzero solutions exist only when the determinant of the coefficients is zero, a condition from which the following dispersion relation is obtained (as given in Appendix A).

$$(i\omega \epsilon_2/K_2 - \sigma^*_{xx}/\epsilon_0 + i\omega \epsilon_1/K_1) e^{2K_2d} = (\epsilon_2/K_2 - \epsilon_3/K_3)$$

$$(i\omega \epsilon_2/K_2 + \sigma^*_{xx}/\epsilon_0 - i\omega \epsilon_1/K_1) = (\epsilon_2/K_2 + \epsilon_3/K_3)$$

The complex conductivity tensor with relaxation time $\tau_r$ of carrier in the inversion layer is given by [83],

$$\sigma^*_{xx} = \frac{N_s \epsilon^2 \tau_r}{m^*_s} \left[ \frac{1 + i\omega \tau_r}{1 + (\omega \tau_r)^2} \right]$$

where $N_s$ is the surface carrier density of the inversion layer. Since in the infrared frequency region $\omega \tau_r \gg 1$, the imaginary part of the conductivity tensor predominates and the following approximation is considered:

$$\sigma^*_{xx} = \frac{iN_s \epsilon^2}{m^*_s \omega}$$

Where $m^*_s$ is the effective mass of the electron in the inversion layer. Since in the high frequency limit the ratio of the distance covered by the electrical charge to the time taken for its transfer from one medium to other is much less than the
velocity of propagation of the electromagnetic wave, the retardation effect can be neglected. Therefore we have

\[ K_1 = K_2 = K_3 = K_x \]

with 2-D plasma frequency \( \omega_p = \frac{N_s e^2}{m_s c} \), Eqn. (5.11) leads to the following relation,

\[
(\varepsilon_2 + \varepsilon_3) (\varepsilon_2 - \varepsilon_1 (\omega_p^2/\omega^2) K_x + \varepsilon_1) \\
= (\varepsilon_2 - \varepsilon_3) (\varepsilon_2 + \varepsilon_1 (\omega_p^2/\omega^2) K_x - \varepsilon_1) e^{-2K_x d} \quad \cdots (5.13)
\]

where \( \varepsilon_1 = \varepsilon_c/\omega_p \). This is a transcendental equation having both real and imaginary roots. The propagation constant \( K_x \) is a complex quantity i.e. \( K_x = K_r + iK_i \). To solve Eqn. (5.13) for both, real and imaginary parts of wave vector, we linearise the above equation substituting for \( K_x \) and then equating both real and imaginary parts of the obtained equation to zero.

The following two simultaneous equations are obtained:

\[
2R_2d^2((\varepsilon_2 - R_2K_r + \varepsilon_1)(1 + 2K_r(1 + K_r d)) - R_1(\varepsilon_2 - \varepsilon_1 + R_2K_r)) \\
+ ((\varepsilon_2 - R_2K_r + \varepsilon_1) - 2R_2d(1 + 2K_r d))(\varepsilon_2 - R_2K_r + \varepsilon_1) \\
(2d(1 + 2K_r d)) - (R_2(1 + 2K_r d (1 + K_r d)) - R_1 R_2) = 0
\]

\[
(\varepsilon_2 + R_2K_r + \varepsilon_1) (2d (1 + 2K_r d) - R_2 (1 + 2K_r d + 2d^2 (K_r^2 K_i^2) + R_1)) = 0
\]

where \( R_1 = (\varepsilon_2 - \varepsilon_3)/(\varepsilon_2 + \varepsilon_3) \)

\( R_2 = \varepsilon_1 (\omega_p^2/\omega^2) \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \·
computer by using the bisection method [84]. All the constants taken for computation are given in Table 5.1.

<table>
<thead>
<tr>
<th>Name of the constant</th>
<th>Symbol</th>
<th>Computational value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric constant of silicon</td>
<td>$\varepsilon_1$</td>
<td>11.7</td>
</tr>
<tr>
<td>Dielectric constant of SiO$_2$</td>
<td>$\varepsilon_2$</td>
<td>3.9</td>
</tr>
<tr>
<td>Inversion layer plasma frequency (for particular $N_0$ value)</td>
<td>$\omega_s$</td>
<td>$1.0 \times 10^{13}$</td>
</tr>
<tr>
<td>Gate electrode plasma frequency</td>
<td>$\omega_p$</td>
<td>$2.2 \times 10^{13}$</td>
</tr>
</tbody>
</table>

Figure 5.2 shows the family of curves of $\omega$ versus $K_T$ drawn from the above computational results. It is seen that for lower values of $\omega$, $K_T$ increases exponentially and approaches a saturation value as $\omega$ approaches $\omega_s$. The solution for $K_T > 0$ shows the growth of the wave in the given frequency range less than the 2-D plasma frequency $\omega_s$. The results for $\omega$ versus $K_I$ are drawn in Fig. 5.3 for various values of insulator thickness. It shows that for $K_I > 0$, the wave propagates in the medium in the same frequency range. Figure 5.4 is drawn with $\omega$ versus $K_T$ for various values of $\omega_s$ which is varied by varying inversion layer carrier density $N_0$ value. From a comparative study of Fig. 5.2 for various insulator thicknesses and Fig. 5.4 for various plasma frequencies, it is concluded that an increase in the plasma frequency has an effect similar to a decrease in oxide thickness.
Fig. 5-2
5.4.1 Coupling of 2-D Inversion Layer Plasma with the Gate Electrode of a MOSFET

From the general dispersion relation (5.13) for 2-D plasma oscillation, it is seen that the roots of this equation depend on three variables, namely, insulator thickness $d$, 2-D plasma frequency $\omega_s$ and the plasma frequency of the gate electrode $\omega_p$. The attenuation as well as the propagation of a surface electromagnetic wave are affected by the presence of any medium other than vacuum, adjacent to a plasma medium \[85\]. Among the various parameters of the adjacent medium, polarization property and thickness, affect the attenuation of the plasma wave. Various factors effecting the coupling between inversion layer plasma and gate electrode plasma are considered separately.

5.4.2 Effect of the Oxide Thickness

a) For $K_2 d >> 1$ i.e. the oxide thickness much greater than the wavelength of propagations, both the plasma modes such as at the semiconductor oxide interface and oxide gate electrode interface, get decoupled. In this case equation (5.13) splits into the following two relations

$$\varepsilon_3 K_2 + \varepsilon_2 K_3 = 0$$

$$\omega^2 = \frac{\varepsilon_1 \omega_s^2 K_1}{(\varepsilon_1 + \varepsilon_2)}$$

The above two equations are obtained with the limit $d \to \infty$ when we put the left-hand side of equation (5.13) to zero. These two equations represent the dispersion relation for plasma oscillations at the metal insulator (Eqn. 5.16) and the
semiconductor insulator interface (Eqn. 5.17) respectively. Dispersion relation curves for these two interfaces are plotted from the solutions of the above two equations with all other constants as given in Table 5.1. These two relations are shown in Fig. 5.5(a) and (c). In this case no coupling exists between the inversion layer plasmon and that of gate electrode. It is seen for the lower frequency values, \( \omega \) varies linearly with \( \sqrt{K_x} \) and for higher values, it saturates. These two curves intercept at \( K_x = 11.3 K_p \), if there is no coupling between them and it is given by the point 'A'.

b) For \( K_d \ll 1 \), strong coupling exists between the plasma wave of the semiconductor inversion layer and that of the gate electrode. The finite thickness of the insulator allows the field to have a finite amplitude at the opposite side of the oxide layer. On the other hand, the image charges due to the plasma wave at the metal insulator interface are screened by the inversion layer plasma at the semiconductor insulator interface. For this coupled mode, Eqn. (5.13) is solved and plotted for various values of oxide thickness as shown in Fig. 5.5 (b), (c) and (d). It is seen that as the thickness is increased, for lower values the dispersion curve approaches that at the metal insulator dispersion line, and at higher \( \omega \) values it approaches the semiconductor insulator dispersion curve. The coupled plasma wave vector is less than that of the uncoupled mode which implies an increased wavelength for the coupled mode.
5.4.3 Effect of the 2-D Plasma Frequency

Due to the discontinuity in the surface charges, surface plasma wave propagation can take place in a MOS structure. Assuming that there is no inversion layer i.e. for ideal flat band condition, we put \( \omega_s = 0 \) in the Eqn. (5.13) and get the following dispersion relation:

\[
\frac{\epsilon_2/\epsilon_3}{\epsilon_2} \left( K_1 K_3 \epsilon_1 \epsilon_3 \right) + \left( K_2 \epsilon_3 + K_1 \epsilon_1 \right) \coth K_2 d + K_2/\epsilon_2 = 0
\]

...(5.18)

This is similar to Eqn. (2.13) of reference [77]. The above equation is solved for two values of insulator thickness. The range of frequencies is chosen by trial and error method in determining the roots of the equation. Dispersion relations are plotted as shown in Fig. 5.6 (I) and (II) for \( d = 0.1 \mu \) and \( 0.2 \mu \) respectively. Equation (5.13) is solved taking \( \omega_s \) into consideration and the results are plotted for two \( \omega_s \) values as shown in Fig. 5.6 (III) and (IV). The inversion layer carrier density, on which the 2-D plasma frequency depends, is a linear function of the gate voltage and given by

\[
N_s = C_0/\epsilon \left( V_g - V_T \right)
\]

where \( C_0 \) is the oxide capacitance per unit area and \( V_g, V_T \) are gate and threshold voltage respectively. From a comparative study of dispersion relation curves (i) in the absence of inversion layer (Fig. 5.6(I) and (II)) and (ii) in the presence of inversion layer (Fig. 5.6 (III) and (IV)), it is seen that surface plasma wave exists for higher frequency range in presence of inversion layer.
layer. For same frequency range, plasma wave vector is less in presence of inversion layer than the same in its absence.

Conclusion

The dispersion relation for a 2-D inversion layer plasma oscillation is derived from Maxwell's equations. In the infrared frequency range, the plasma wave propagates with attenuation in the direction perpendicular to the interface. Figure 5.2 evaluates the values of real part of wave vector \( K_r \) from which the range of plasma wave in the medium can be evaluated using the reciprocal value \( 1/K_r \) [87]. It is seen that for the coupled mode the decrease of oxide thickness has an effect similar to an increase of the inversion layer carrier density which in turn increases the plasma frequency. The increase of the gate electrode plasma frequency has an effect similar to the increase of the inversion layer plasma frequency. By decreasing the insulator thickness, the screening due to the gate electrode plasma of the image charges becomes pronounced. Hence the coupled plasma wavelength is more than the uncoupled mode. In the case, insulator thickness \( d \to \infty \), both the plasma modes get decoupled and are confined to semiconductor oxide and oxide-metal interface only. For finite values of insulator thickness, there exists a strong coupling effect between inversion layer plasmon and gate electrode plasmon. It is predicted that excitation of the inversion layer plasmon by source-drain longitudinal field results in an IR emission corresponding to the plasma frequency. All the physical parameters taken in the theoretical calculation correspond to a practical device structure.