INTRODUCTION

0.1 Motivation and Background

High speed communication is an essential part of every day life which demands better performance and a low cost RF solution. Due to the ability to integrate microwave and optical component into a single slice, there is scope for development of microwave optoelectronic system. Optical systems have many advantages over traditional communication systems, and these are,

1. Huge bandwidth (in the range of GHz)
2. Low losses
3. Low cost per bit
4. High data rate
5. Electrical Isolation
6. Immunity to EMI (lightning, interference)
7. Security (no tapping)
8. Reliability
9. Once installed, requires less maintenance, thereby reducing the breakdown period

In an optical communication system the light is used to carry information using electronic devices. Essential parts of any optical communication link are the optical transmitter which encodes the input signal into light or optical signal, the optical link to carry the optical signal to its destination and the optical receiver which reproduces the original message. Optical fibre is the most common type of optical link used in optical communication. Free space optical communication have some distinct advantages over conventional RF and optical fibre communication systems by virtue of their high carrier frequency that permit large capacity, enhanced security, high data rate and so on. Figure 1 shows a typical optical communication system.

![Figure 1: Typical Optical Communication Link.](image)

At the receiver end to decode the encoded signal into its original form, an optical detector is required which converts the optical signal into electric signal (voltage or current form) to recover the transmitted message faithfully. A low power optical receiver demands three key requirements:
1. A high speed photodetector with high responsivity and low parasitics

2. Power-efficient very-large-scale-integration (VLSI) receiver circuits

3. Integration that has low parasitics.

A number of devices could be used for optical detection but the semiconductor detectors provide the best solution for detection. Signal detection using these detectors involves the following steps[1],

1. Carrier generation due to incident light,

2. Carrier transport by drift or diffusion mechanism and

3. Interaction with the external circuit to provide output signal, either voltage or current.

Detectors convert optical signals into electrical impulses that are used by the receiving end of the fiber optic data, video, or audio link. The most common detector is the semiconductor photodiode, which produces current in response to incident light. Detectors operate based on the principle of the p-n junction. An incident photon striking the diode gives an electron in the valence band, sufficient energy to move to the conduction band, creating a free electron and a hole. If the creation of these carriers occurs in a depleted region, the carriers will quickly separate and create a current. As they reach the edge of the depleted area, the electrical forces diminish and the current ceases. Due to its weak output, the p-n diodes are insufficient detectors for fiber optic systems, both PIN photodiodes and avalanche photodiode (APD) are designed to compensate for the drawbacks of the p-n diode. Table 1.1 illustrates comparative discussion of these detectors along with photomultipliers[2].

<table>
<thead>
<tr>
<th>Devices</th>
<th>Principal of working</th>
<th>Noise</th>
<th>Applications</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMT</td>
<td>multiplication in tube on photo cathod vacuum (photons are incident)</td>
<td>low signal and background noise</td>
<td>free space optional communication</td>
<td>low reliability</td>
</tr>
<tr>
<td>PD</td>
<td>when photon energy, E.g. electrons are swept from valance to conduction band</td>
<td>high background noise</td>
<td>heterodyne systems</td>
<td>no internal gain, requires further amplification</td>
</tr>
<tr>
<td>APD</td>
<td>random multiplication of generated carriers in the device itself</td>
<td>limited thermal noise</td>
<td>high speed optical fiber link</td>
<td>less response time</td>
</tr>
</tbody>
</table>

Table 1: Comparison of Detectors for Optical Communication.
It is seen from table 1.1 that the Photo Multiplier Tube (PMT) are less reliable where as photo-diodes require further amplification. Further, performance of these detectors can be observed by varying their material.

Table 1.2 illustrates typical characteristics of photodiode with different materials [1,2]. From table 1.2, it is seen that Silicon has the least dark current highest gain. Performance of Si APD is better than that of a PIN photodiode. InGaAs is the next material that can be considered for detection purposes.

Table 2: Typical Characteristics of Photodiode.

<table>
<thead>
<tr>
<th>Material</th>
<th>structure</th>
<th>Rise Time (ns)</th>
<th>wavelength (µm)</th>
<th>Responsivity (A/W)</th>
<th>Dark Current (A)</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>PIN</td>
<td>0.5</td>
<td>300-110</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ge</td>
<td>PIN</td>
<td>0.1</td>
<td>500-1800</td>
<td>0.7</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>InGaAs</td>
<td>PIN</td>
<td>0.3</td>
<td>900-1700</td>
<td>0.6</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Si</td>
<td>APD</td>
<td>0.5</td>
<td>400-1000</td>
<td>75</td>
<td>15</td>
<td>150</td>
</tr>
<tr>
<td>Ge</td>
<td>APD</td>
<td>1.0</td>
<td>1000-1600</td>
<td>35</td>
<td>700</td>
<td>50</td>
</tr>
<tr>
<td>InGaAs</td>
<td>APD</td>
<td>0.25</td>
<td>1000-1700</td>
<td>12</td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>
Since photodiodes require further amplification of detected signal to be used in the external circuit, transistors were used as a photodetector called as phototransistor. Recent development in the transistor technology has led to potential research in the area of optical characterization of FET devices operating at microwave frequency. They are mainly JFET, MESFET, MOSFET, MISFET, ISFET, FINFET, SGFET etc [1,3,4]. These FET devices are sensitive to light. Due to its ability of integrating microwave and optical component into a single slice there is a scope for development of microwave optoelectronic systems. Optical signal can be converted into electrical signal by means of a photodetector, giving rise to the possibility of using optical signals to control microwave devices. This is due to following attractive features [6],

1. No additional extra circuit is required to process the detected signal or any parasitic component
2. Isolation from electromagnetic interferences (EMI)
3. Provides an extra Optical control port to the microwave devices
4. They have small dimensions, low losses and short reaction time
5. Possibility of high package density

The integration of the microwave optical device as an optical microwave monolithic integrated circuit (OMMICS) has a greater impact on the communication industry which demands highly integrated and reliable systems. Recent advances in high speed modulation of optical carriers have increased focus on transmission of microwave signals. For microwave application MMICs, the GaAs, HEMT and HBT are primary active devices. Although exhibiting remarkable microwave gain, these devices suffer from limited range in logic operation.

Major contribution to the detectors is provided by GaAs MESFET [5,7-9]. They have some limitation on their enhancement. Germanium detectors were used for photo detection which were found to be noisier with large dark current due to their narrow band gap. Extended research was done in the field of Germanium detectors on silicon (hetero junction) to extend the detectable wavelength region towards the infrared spectrum and to increase the bandwidth of the Silicon-based detectors into several-ten Giga-Hertz range [3,10]. Compound III/V photodetectors are superior because their band-gaps can be modified to the desired value by changing the relative concentrations of their constituents, resulting in lower dark currents and good response at desired wavelength. The price of III/V photodetectors and OEICs (Opto Electronic Intregrated Circuit) is simply too high.

For high-frequency applications the goal is to scale down the size of the device. CMOS devices (MOSFETs) are becoming an attractive alternative to GaAs and Bipolar devices for optoelectronics application. High gain, speed, power handling capacity, low cost and dense packing density of IC viz. OEIC, MMIC, VLSI, etc are considerations that have pushed the MOSFET to the status of the most widely used device in communication technology hardware. The quality of the
Sil/SiO₂ interface is good enough to allow electrons and holes moving near the interface to have reasonable mobility. With this there is the possibility of integration of complete communication systems on single chip (SOC).

Silicon photodetectors and receiver OEICs, therefore, are the only choice when high volumes are needed and the price has to be low for use in consumer electronics. It needs rigorous mathematical modelling to characterize the device and obtain various parameters to get the operational behaviour of the device working in various operating conditions. In the recent decades, added interest has been shown by researchers towards modelling of the optical effects on MOSFET with submicron channel length. It is mainly because this device is expected to emerge as the potential device to be integrated as MMIC, OEIC and ASIC for optical based systems particularly optical communication.

0.2 Optical Absorption of Semiconductor Materials

Optical absorption and emission are fundamental processes which are exploited when optical energy is converted into electrical energy and vice versa. Optoelectronics is based on these energy conversion processes. Light emitters such as light-emitting diodes (LEDs) and diode lasers convert electrical energy into optical energy. Photodetectors convert optical energy into electrical energy. The energy of a photon can be transferred to an electron in the valence band of a semiconductor, which is brought to the conduction band, when the photon energy is larger than the bandgap energy \( E_g \). The photon is absorbed during this process and an electron-hole pair is generated. Photons with energy smaller than \( E_g \), however, cannot be absorbed and the semiconductor is transparent for light with wavelengths longer than \( \lambda_c = h c_0 / E_g \). The optical absorption coefficient \( \alpha \) is the most important optical constant for photodetectors. The absorption of pho-
tons in a photodetector produces carrier pairs which leads to photo current, thus a photocurrent depends on the absorption coefficient $\alpha$ of the semiconductor which is used to fabricate the detector. Figure 2 shows the absorption coefficient of various materials (Y-axis) plotted against the wavelength (X-axis). Figure illustrates that Germanium covers almost all the wavelengths of spectrum. As wavelength of semiconductor material increases, it’s absorption coefficient decreases but its penetration depth $1/\alpha$ increases.

Table 3: Characteristics of Semiconductor Materials with Respect to Bandgap and Wavelength

<table>
<thead>
<tr>
<th>Material</th>
<th>Band-gap type</th>
<th>Band-gap (eV)</th>
<th>Wavelength ($\mu$m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>Indirect</td>
<td>1.12</td>
<td>0.6-0.9</td>
</tr>
<tr>
<td>Ge</td>
<td>Indirect</td>
<td>0.66</td>
<td>0.9-1.8</td>
</tr>
<tr>
<td>GaAs</td>
<td>Direct</td>
<td>1.42</td>
<td>0.87</td>
</tr>
<tr>
<td>InP</td>
<td>Direct</td>
<td>1.35</td>
<td>0.4-0.7</td>
</tr>
<tr>
<td>6H-SiC</td>
<td>Wide band</td>
<td>3.03</td>
<td>0.2-0.4</td>
</tr>
<tr>
<td>InGaAs</td>
<td>Direct</td>
<td>0.95-1.24</td>
<td>1.3-1.7</td>
</tr>
<tr>
<td>InGaAsP</td>
<td>Direct</td>
<td>0.73-1.35</td>
<td>0.9-1.7</td>
</tr>
<tr>
<td>AlGaAs</td>
<td>Direct</td>
<td>1.4-1.55</td>
<td>0.8-0.9</td>
</tr>
</tbody>
</table>

Table 1.3 highlights characteristics of different semiconductors with respect to bandgap and their wavelength [5,6].

InGaAs and Ge cover the widest wavelength range including the wavelengths 1.35 and 1.24 $\mu$m respectively, which are used for long distance optical data transmission via optical fibers. The absorption coefficients of GaAs and InP are high in the visible spectrum ($\approx 400 - 700 nm$). $In_xGa_{1-x}As$ is a ternary alloy. It is primarily used in optoelectronic devices. It is used in the detection and generation of infrared light. In the area of electronics, it has found a favored use in FET applications[11]. It is a favorable candidate for high-speed and high frequency applications. It offers excellent transport properties for applications in microwave circuits.

The composition that is the most prominent among all the other compositions is $In_{0.53}Ga_{0.47}As$. The reason being that $In_xGa_{1-x}As$ is primarily grown by using the method of epitaxial growth, or epitaxy (the technique of growing an oriented single-crystal layer on a substrate wafer, which can be of similar material as the grown layer or a different material with a similar lattice constant). InP can be grown on $In_xGa_{1-x}As$ substrates with $x = 0.53$ only, since the lattice constants of InP is between the values of the two binary parents of InAs and GaAs. It has been
shown that unmatched layers (called strained layers) can be grown too, if the mismatch and the layer thickness do not exceed certain limits.

The absorption coefficient determines the penetration depth \(1/\alpha\) of the light in the semiconductor material according to Lambert-Beer’s law, is given as photocurrent, \(I(y) = I_0 e^{\alpha y}\), where \(y\) is the direction of the penetration.

The absorption coefficients strongly depend on the wavelength of the light. For wavelengths shorter than \(\lambda_c\), which corresponds to the bandgap energy \(\lambda_c = h\nu_0/E_g\), the absorption coefficients increase rapidly according to the so-called fundamental absorption. The steepness of the onset of absorption depends on the kind of band-band transition. The steepness is large for direct band to band transitions and for the wide bandgap material the steepness of the onset of absorption is small. Figure 1.3 shows absorption coefficient of Si and InGaAs plotted against the wavelength of incident radiations[12]. Peak absorption coefficient of Si is \(10^4\) whereas for InGaAs, it is above \(10^5\).

![Figure 3: Absorption Coefficient of Si and InGaAs Semiconductor Material Vs Wavelength.](image)

Silicon detectors are appropriate for the visible and near infrared spectral range. The absorption coefficient of Si, however, is one to two orders of magnitude lower than that of the direct semiconductors in this spectral range. For Si detectors, therefore, a much thicker absorption zone is needed than for the direct semiconductors. The absorption coefficients of silicon for wavelengths which are the most important ones in practice are listed in Table 1.4[6]. As per the relation, \(\alpha = 4.\pi/\lambda\), as the wavelength of Si decreases, its absorption coefficient increases along with the intensity factor \(I_0\).
Table 4: Absorption Coefficients $\alpha$ of Silicon and Intensity Factors $I_0(\text{ehp cm}^{-3})$ for Several Important Wavelengths for a Constant Photon Flux Density of $\Phi = I_0/\alpha = 1.58 \times 10^{18}$ Photons/cm$^2$ [6]

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>$\alpha \mu m^{-1}$</th>
<th>$I_0$ (ehp cm$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>980</td>
<td>0.0065</td>
<td>1.03*10$^{20}$</td>
</tr>
<tr>
<td>850</td>
<td>0.06</td>
<td>9.50*10$^{20}$</td>
</tr>
<tr>
<td>780</td>
<td>0.12</td>
<td>1.89*10$^{21}$</td>
</tr>
<tr>
<td>680</td>
<td>0.24</td>
<td>3.79*10$^{21}$</td>
</tr>
<tr>
<td>635</td>
<td>0.38</td>
<td>6.00*10$^{21}$</td>
</tr>
<tr>
<td>565</td>
<td>0.73</td>
<td>1.16*10$^{22}$</td>
</tr>
<tr>
<td>465</td>
<td>3.6</td>
<td>5.72*10$^{22}$</td>
</tr>
<tr>
<td>430</td>
<td>5.7</td>
<td>9.00*10$^{22}$</td>
</tr>
</tbody>
</table>

In order to compare the quantum efficiencies of photodetectors for different wavelengths, it is advantageous to use the same photon flux for the different wavelengths. The photocurrents of photodetectors are equal for the same fluxes of photons with different energy, i.e., for different light wavelengths, when the quantum efficiency of the photodetector is the same for the different photon energies or wavelengths, respectively. According to the Lambert-Beer law, different intensity factors $I_0$ result for a constant photon flux. As an example, intensity factors are listed for the most important wavelengths in Table 1.4 for a certain arbitrary photon flux density.

0.3 Optical Effects

The major optical effects arising due to the illumination of the MOSFET are,

1. Photoconductive effect and
2. Photovoltaic effect.

0.3.1 Photoconductive effect

Photoconductive effect is the phenomenon in which optical illumination is converted into equivalent photo-current. This phenomenon takes place in the bulk region (channel). Photoconductive current is generated in addition to drain current when the device is illuminated. This occurs because of absorption of photon energy within the bulk region which generates excess carriers and reduces the resistivity of this region. This process is strongly dependent on drain to source biasing rather than the gate bias because this process arises from the separation and collection of generated electron-hole pairs along the longitudinal direction of the channel. The longitudinal electric field profile of the channel, which is primarily set by the drain voltage for a given gate voltage, determines the transport dynamics of the generated carriers and thus controls the photo-
conductive optical gain. This effect will increase the charges in the channel and hence increase
the device current by reducing the channel resistance [13].

0.3.2 Photovoltaic effect

Photovoltaic effect is the phenomenon in which optical illumination is converted into equiva-
 lent photo-voltage. It arises from the collection of photo generated carriers in the high electric
field of a space charge region. In FET’s this occurs transverse to the channel and the channel gets
modulated by additional photovoltage developed across this region thereby modulating the con-
ductivity of the channel. This is referred to as photovoltaic biasing. In a steady state, photovoltaic
effect increases that causes effective change in gate potential of the device. Their contribution to
optical gain is thus largely independent of the drain to source bias.

0.4 Characteristics of Photodetectors

Photodetectors are characterized by certain key parameters. Among them are spectral response,
photosensitivity, quantum efficiency, dark current, forward-biased noise, noise equivalent power,
terminal capacitance, timing response (rise time and fall time), frequency bandwidth, and cut off
frequency which are explained as below[14].

1. Spectral response: It relates the amount of current produced with wavelength, assuming
that all wavelengths are at the same level of light.

2. Photosensitivity: It is the ratio of light energy (in watts) incident on the device to the result-
ing current (in amperes).

3. Quantum efficiency: it is the number of generated electron-hole pairs (i.e. current) divided
by the number of photons.

4. Dark current: It is the amount of current that flows through the photodiode in the absence
of any light (dark), when the diode is reverse-biased. This is a source of noise when the
diode is reverse-biased.

5. Forward-biased noise: it is a (current) source of noise that is related to the shunt resistance
of the device. This is also called shunt resistance noise.

6. Noise equivalent power: It is defined as the amount of light (of a given wavelength) that is
equivalent to the noise level of the device.

7. Terminal capacitance: It is the capacitance from the p-n junction of the diode to the con-
nectors of the device; it limits the response of the photodetector.
8. Timing response of the photodetector: It is the time for the output signal to climb from 10% to 90% of its amplitude (rise time) and to drop from 90% to 10% (fall time).

9. Frequency bandwidth: It is the frequency (or wavelength) range in which the photodetector is sensitive.

10. Cut off frequency: It is the highest frequency (wavelength) at which the photodetector is sensitive.

Much research still continues on in optical receiver and optical sensor circuits. Present work covers the two devices, MOSFET and InGaAs MISFET which can be used for integrated opto-electronic circuits (OEICs) in silicon technologies and about their emerging possibilities. Present work applies embedding knowledge into pure simulation based methodology to observe and study the performance of FET devices (MOSFET and MISFET) for optoelectronic applications.

0.5 Objectives and Approach of Work

This section gives objectives of proposed work and approach of work done.

0.5.1 Work objective

1. To develop an analytical model for a Si MOSFET photodetector with transparent gate, uniformly doped channel, including all short channel effects, which includes:
   
   (a) Output Current model to understand sensitivity of the device towards light
   (b) Capacitance model to understand capacitive nature of the device
   (c) Small signal model to compute Y parameters
   (d) Noise model to investigate noise performance of the device
   (e) S parameter model to understand device behavior at RF

2. To Compare drain or output current of MOSFET and MISFET to study sensitivity of device towards the incident light.

3. To develop an analytical model for LNA (Low Noise Amplifier) as an application of OG-MOSFET and to carry out simulation using the CAD tool

4. To develop an analytical model for InGaAs MISFET and analyse its performance by studying detector characteristics for its optical windows

5. Overview of different approaches of modelling the optical effects
0.5.2 Proposed Approach of Work

1. Model which solves continuity equation for optically generated carriers is to be studied using first order differential equation for MOSFET as well as InGaAs MISFET.

2. Modelling of optical effect in channel which is assumed to be uniformly doped is based on the principle of photoconductive effect and that of in space charge or depletion region is based on the photovoltaic effect. Optical voltage generated across this region, modulates depletion width of space charge region which increases channel conductivity of the device.

3. Different AC and DC parameters such as drain current, transconductance, capacitances is to be studied so that a small signal model can be developed.

4. Using the small signal model one can compute Y parameters, noise parameters, S parameters of the device. Proposed model should incorporate the limitations of existing models such as frequency dependence of the device parameters.

5. Performance analysis, such as stability and gain analysis of the device can be done using S parameters. For this the device considered is unilateral having constant gain.

6. It is required to carry out modelling of the devices (both MOSFET and MISFET) for incomplete applications by researchers just as probability. Noise performance and gain analysis of the device shows that can used as low noise amplifier as an application of OGMOSFET.

7. When the device is expected to work as a Photodetector, it is characterized by main characteristics such as responsivity and quantum efficiency. The model is developed to investigate these characteristics.

8. Finally, it is required to conduct a review of different modelling techniques to check whether it agrees in principle with the current modelling technique.

9. For modelling and simulation the results are to be tested and tuned in basic MATLAB simulation tool.

0.6 Methodology

The physics of the devices is well known now. The equations describing the behaviour of the devices in most important cases are the semiconductor equations. Device simulation programs have been valuable tools for the development of semiconductor devices for many years. Much time and money can be saved with their help for such a purpose. They are also valuable for the development of photodetectors. We will simulate the device model in MATLAB and will compare it with reported results for accuracy.
The drift-diffusion model is developed which solves the Poisson equation, the transport equations, and the continuity equations for electrons and holes. To validate the results of the theoretical analysis, computer aided simulation have been carried out in MATLAB tool. Amplifier design based on S parameters is carried out in the ADS CAD tool. Validation of device characteristics in dark and illuminated condition is carried out in industry proven simulation tool, Visual TCAD. The simulation results are in good agreement with the conclusions of the theoretical analysis.

0.7 Thesis Organization

This section explores the outline of work presented in the thesis. It provides the objectives, methodology used and outcome of the investigation carried out in the research.

A review of research, carried out for related issues of the present work in the last few decades, is discussed extensively in chapter 2. A general review of the different models has been described for MOSEFT under dark condition. It includes a brief description of all major theoretical and experimental works reported so far in this area. It also focuses on selection of optical window, different device structures modified to improve optical response of the device and many more issues related to optical modeling. Analysis of various parameters of the special type of integrated circuit compatible optically controlled MOSFET photodetector is explored from chapters 3 to 6. Applications of proposed devices are provided in chapter 7 ad 8. Chapter 9 highlights an overview of the different modelling techniques.

Chapter 3 provides DC analysis of the device under dark and illumination condition. Although a number of models and device structures are presented for DC analysis of MOSFET to study optical interaction in the device, it is still required to provide detail insight into the basics of device physics. A model, based on inversion charge, is developed which gives optical effect on drain current of MOSFET and MISFET.

Initially device physics is understood with the help of an ideal MOS structure. Operation of the MOS diode is explained with help of a band diagram and detailed derivation for surface potential, depletion width and threshold voltage is carried out. Further, the structure, its working principle and optical modelling of the proposed device (OGMOSFET) is explained. Drain current and transconductance model of the device is developed to analyze detector output. The second proposed device structure that is to be studied as a photodetector, is InGaAs MISFET detector. Modelling of MISFET is carried out under illumination and transconductance model of MISFET is developed as well. Results of the simulation of above modelling are discussed with respect to output current.

At RF device capacitances should be taken into account. Small signal model of OGMOSFET is developed in chapter 4. It requires computation of various capacitances like overlap capacitances, junction capacitances, intrinsic capacitances etc. Present model is charges based and is formulated in symmetric terms of the forward and reverse normalized current, which is symmetrical for both drain and source sides. Short-channel effects such as charge-sharing and reverse
short-channel effects, are included in the dynamic model through the pinch-off voltage. Further capacitance model is developed for MISFET.

At high frequencies, device behavior is well understood with Y parameters. Y parameters of OGMOSFET are computed from small signal model. Comparison of dark and illumination is carried out at 1-10 GHz span of frequency to investigate optical effect on amplitude of different Y parameters.

Noise is an important issue at RF as it may corrupt the original signal and detoriates the quality of the receiver. Noise analysis is carried out in chapter 5. Sources of noise are inside the device itself which are mainly terminal resistances. Channel thermal noise is a prominent source of noise. Various noise parameters used in modeling, are explained. The device is represented as noisy and noiseless two port structure and a high frequency noise model of OGMOSFET is developed. Minimum noise figure NFmin is a figure of merit to measure the noise.

Chapter 6 computes S parameters of OGMOSFET and theoretically investigates optical effect on it. For this purpose, OGMOSFET is represented as a two port network and computes S parameters. To investigate S parameters of OGMOSFET, the device is considered with port termination of 50 ohm. Stability of the device is analyzed with the help of different stability tests. As the device works as an amplifier, gain analysis is carried out while neglecting the influence of the transistor feedback ($S_{12} = 0$) and assuming the amplifier to be single stage with constant gain. S parameters and noise parameters are arranged in the touchstone file format. ADS tool is used to design the amplifier. Noise and gain analysis predicts that the device can be used as a Low Noise Amplifier.

An analytical model is developed for low noise amplifier using OGMOSFET in chapter 7. Different topologies, used for LNA design, are discussed to select appropriate one. Cascode topology of common source amplifier with source degeneration is best suited for narrow band LNA design. Design steps of LNA are elaborated to design matching network of LNA. With this, the possibilities of integrated CMOS optoelectronics will be investigated thoroughly.

Optoelectronics usually implies involvement of the III/V semiconductor materials especially when ultra-high-speed photodetectors are required. Absorption of these materials is greater than Si semiconductor materials. Chapter 8 explores optical characteristics of MISFET detector involving III/V semiconductor materials. Responsivity and quantum efficiency are two important parameters of any photodetector. The model is developed to investigate these characteristics. Due to optical interaction in space charge region, threshold voltage decays which modulates output current of the detector. It gives insight on characteristics and performance of MISFET photodetector at terahertz.

Different techniques of modelling the optical effect in the FET device are reviewed in chapter 9. Summary of the major conclusions drawn from the results of the investigations presented in individual chapters is summarized in chapter 10.