Chapter 7. Conclusion and Future Scope of Work
7.1 Conclusion

The aspect of modeling is the ability to accurately predict the performance of new devices prior to fabrication and is fulfilled after verification of different models for GaAs MESFT. Six different types of analytical models for GaAs MESFET photodetectors have been developed and presented in this thesis and compared with the conventional papers. A complete DC model has been developed for GaAs MESFET. A microwave model has been developed for GaAs MESFET photodetectors.

The physics-based model developed and presented in this thesis takes into account all major factors that shape the characteristics of the device in the illuminated condition. The models developed here also make an attempt to give a better insight of various physical mechanisms operative in the device. The major effects considered in the modeling of the devices are photovoltaic effect, photoconductive effect and illumination effect on the minority carrier lifetime. For GaAs MESFET photodetectors, the effect of substrate photo generation has been taken into consideration by properly modeling the semi-insulating nature of the substrate. This model is one of the first of its kind. In the Modeling of MESFET based photodetector, the effect of illumination on the lifetime of the carrier and the surface potential are given due consideration. In all models, the losses of the potential radiation due to reflection at the various interfaces have been taken into account. The effect of surface traps states are also considered in the modeling of the devices. The model can be used as a basic tool for the design of various types of photodetectors. GaAs MESFET photodetectors have been modeled for DC operation. The effect of substrate generation has been neglected in microwave characterization of the device.
Analytical Model for Short Channel GaAs MESFET for the Distribution of potential and Threshold Voltage under dark and illuminated conditions are developed. The Output Characteristics (Id–Vd) and numerical modeling 3-D of a GaAs MESFET as Photodetectors are verified. Output characteristics of short channel GaAs MESFET is verified using MATLAB simulation software. Conclusion drawn from the MATLAB results, and are discussed as follows:

1. A 2D channel potential has been modeled for optically depleted GaAs MESFET device with a Gaussian-like doping profile in the vertical direction.

2. The potential distribution has been derived by solving 2D Poisson’s equation using superposition method. Optical radiation dependent on threshold voltage has been derived and compared with dark condition. The observed threshold voltage degradation due to short channel effects can be minimized by reducing channel thickness of GaAs MESFET. The proposed model results are matched with conventional values.

3. The effect of illumination on the Id–Vd characteristics of both non-self-aligned and self-aligned short-gate length GaAs MESFET is studied analytically by solving the two-dimensional Poisson’s equation using Green’s function technique. It is found that the drain to source current can be increased by not only reducing the gate length but also by exposing the device to light radiations having photon energy equal to or greater than the band gap energy of GaAs.

4. Device characteristics like potential distribution, field distribution and mobility distribution under dark and illuminated condition have been numerically estimated for uniformly doped GaAs MESFET. It is seen that the device has all
qualities that can be used as a photodetectors. The realization on GaAs MESFET provides accurate control on the gate-length and channel thickness.

5. The present work is confined to modeling of uniformly doped three-dimensional GaAs MESFET Photodetectors. A model for internal capacitances of GaAs MESFET has been developed. The charge for each part of the depletion region has been derived analytically for linear and saturation regions. The developed model may be suitably implemented for the design of photo-detectors.

6. A new and systematic way of modeling photo effects on the static I-V characteristics of GaAs MESFET’s in both linear and saturation regions is presented. Effect of illumination on the device is explained in terms of photovoltaic and photoconductive effects. Photoconductive current is shown to be small by several orders of magnitude than total drain-source current.

7. Finally, small signal parameters of MESFET such as transconductance and output resistance are derived from the modeled I-V characteristics. Since accurate dc modeling is key to accurate ac modeling, this model may be very useful for the designing of GaAs MESFET’s particularly in MMIC’s and Photodetectors.

7.2 Future Scope of Work

GaAs MESFET photodetectors, the microwave modeling of the device for transit-time analysis is done to examine its suitability as a detector of optical signal modulated at microwave frequency, and GaAs MESFET’s Capacitance Model for the Optically Controlled Short-Gate Length Using MATLAB. Also, the static I-V characteristics of Optically Controlled GaAs MESFET’S are verified.
The models of various photodetectors presented here are based on gradual channel approximation. Models that are more rigorous can be developed by using realistic velocity-electric field relationships for determining the I-V characteristics of the device in the illuminated condition.

From the above discussion, it is evident that there is scope for developing more rigorous models of the devices by giving consideration to the following factors:

1. The easy realization on GaAs MESFET can provide accurate control on the gate length and channel thickness.
2. A new and systematic way of modeling photo effects on the static I-V characteristics of GaAs MESFET’s in both linear and saturation regions that can help further modification
3. Effect of illumination on the device can be extended in terms of photovoltaic and photoconductive effects.
4. Photoconductive current can be shown to be small by several orders of magnitude than the total drain-source current.
5. Finite slope in the I-V characteristics in the saturation region of GaAs MESFET can be modified with the help of channel length modulation.

### 7.3 Applications of GaAs MESFET

GaAs MESFETs are the most commonly used active devices in microwave circuits, the other applications are as follows.

1. Optical communication in the range of low wavelength high frequency devices
2. Optically controlled microwave devices and systems have some advantages such as size reduction, signal isolation, large bandwidth and immunity to electromagnetic interface.

3. Microwave devices such as high-speed optical detector and converter for interaction of optical and microwave signals have been designed.

4. Presently high speed, low cost, monolithically integrated optically biased GaAs MESFETs are in high demand for high frequency application in optical communication systems.

5. Components of the opto-electronic family GaAs MESFET photodetectors to be widely used in broadband communication, optical computing, optical transformer, optical control, internet and local area networks to achieve high signaling rate.