EC 341 Microwave Laboratory
ECE, IIT-Guwahati

Experiment-5

Study of I-V Characteristics of Gunn Diodes

OBJECTIVES

1. V-I Characteristics
2. Output Power and frequency as a function of voltage.
3. Square wave modulation through PIN diode.

EQUIPMENTS

Gunn oscillator, Gunn power supply, PIN modulator, Isolator, Frequency meter, Variable attenuator, Detector mount, Waveguide stands, SWR meter, Cables and Accessories.

THEORY

GUNN Diodes (Transferred Electron Devices):
Gunn diodes are negative resistance devices which are normally used as low power oscillator at microwave frequencies in transmitter and also as local oscillator in receiver front ends. **J B Gunn** (1963) discovered microwave oscillation in Gallium arsenide (GaAs), Indium phosphide (InP) and cadmium telluride (CdTe). These are semiconductors having a closely spaced energy valley in the conduction band as shown in Fig. 5.1(a) for GaAs. When a dc voltage is applied across the material, an electric field is established across it. At low **E**-field in the material, most of the electrons will be located in the lower energy central valley Γ. At higher **E**-field, most of the electrons will be transferred in to the high-energy satellite L and X valleys where the effective electron mass is larger and hence electron mobility is lower than that in the low energy Γ valley. Since the conductivity is directly proportional to the mobility, the conductivity and hence the current decreases with an increase in **E**-field or voltage in an intermediate range, beyond a threshold value V_{th} as shown in Fig. 5.1(b). This is called the *transferred electron* effect and the device is also called 'Transfer Electron Device (TED) or Gunn diode'. Thus the material behaves as negative resistance device over a range of applied voltages and can be used in microwave oscillators.

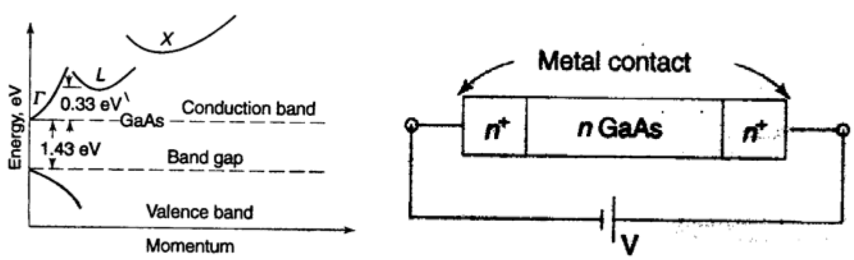


Fig. 5.1(a) Multi-valley conduction band energies of GaAs

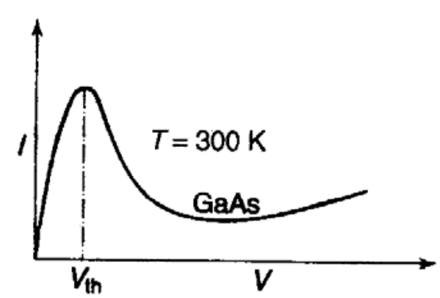
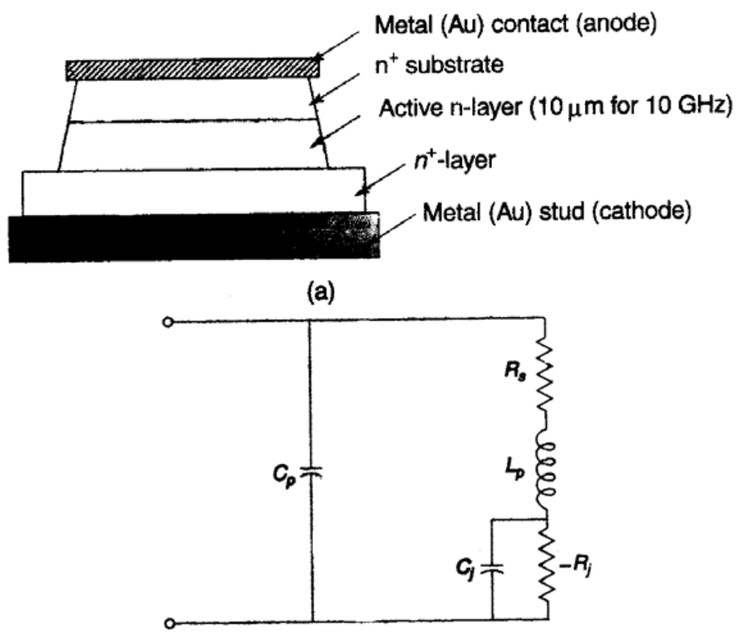


Fig. 5.1(b) Current-voltage characteristics of GaAs

The basic structure of a Gunn diode is shown in Fig. 5.2 (a), which is of n-type GaAs semiconductor with regions of high doping (n^+). Although there is no junction this is called a diode with reference to the positive end (anode) and negative end (cathode) of the dc voltage applied across the device. If voltage or an electric field at low level is applied to the GaAs, initially the current will increase with a rise in the voltage. When the diode voltage exceeds a certain threshold value, V_{th} a high electric field (3.2 KV/m for GaAs) is produced across the active region and electrons are excited from their initial lower valley to the higher valley, where they become virtually immobile. If the rate at which electrons are transferred is very high, the current will decrease with increase in voltage, resulting in equivalent negative resistance effect. Since GaAs is a poor conductor, considerable heat is generated in the diode. The diode will be bonded into a heat sink (Cu-stud).
The electrical equivalent circuit of a Gunn diode is shown in Fig. 5.2 (b), where C_j and $-R_j$ are the diode capacitance and resistance, respectively, R_s includes the total resistance of lead, ohmic contacts, and bulk resistance of the diode, C_p and L_p are the package capacitance and inductance, respectively. The negative resistance has a value that typically lies in the range –5 to –20 ohm.



(b)

Fig. 5.2 Constructional details and the electrical equivalent circuit of a Gunn Diode

Gunn Oscillator:

In a Gunn Oscillator, the Gunn Diode is placed in a resonant cavity. In this case the oscillation frequency is determined by cavity dimension than by the diode itself. Although Gun Oscillator can be amplitude-modulated with the bias voltage, we have used separate PIN modulator through PIN diode for square wave modulation.

Procedure:

1. Set the components and equipments as shown in the Fig. 5.3.
2. Initially set the variable attenuator for maximum attenuation.
3. Keep the control knob of Gunn Power Supply as below:
   Meter Switch - ‘OFF’
   Gunn bias knob - Fully anticlockwise
   Pin bias knob - Fully anticlockwise

Pin Mod frequency - Any position

4. Keep the control knob of VSWR meter as below:
   Meter Switch - Normal
   Input Switch - Low Impedance
   Range db Switch - 40 db
   Gain Control knob - Fully clockwise
5. Set the micrometer of Gunn Oscillator for required frequency of operation.
6. 'ON' the Gunn Power Supply, VSWR meter and Cooling fan.

A. Voltage-current characteristics

1. Turn the meter switch of 'Gunn power supply to voltage position.
2. Measure the Gunn diode Current Corresponding to the various voltage controlled by Gunn bias knob through the panel meter and meter switch. Do not exceed the bias voltage above 10 volts.
3. Plot the voltage and current readings on the graph as shown in Fig. 5.4.
4. Measure the threshold voltage which corresponds to maximum current.

NOTE: DONOT KEEP GUNN BIAS KNOB POSITION AT THRESHOLD POSITION FOR MORE THAN 10-15 SECONDS. READING SHOULD BE OBTAINED AS FAST AS POSSIBLE. OTHERWISE, DUE TO EXCESSIVE HEATING, GUNN DIODE MAY BURN.

B. *Output power and frequency as function of bias voltage*

1. Turn the meter switch of Gunn power supply to voltage position.
2. Increase the Gunn bias control knob.
3. Rotate PIN bias knob to around maximum position.
4. Tune the output in the VSWR meter through frequency control knob of modulation.
5. If necessary change the range db switch of VSWR meter to higher or lower db position to get deflection on VSWR meter. Any level can be set through variable attenuator and gain control knob of VSWR meter.
6. Measure the frequency by frequency meter and detune it.
7. Reduce the Gunn bias voltage in the interval of 0.5V or 1.0V and note down corresponding reading of output at VSWR meter and frequency by frequency meter.
8. Use the reading to draw the power vs Voltage curve and frequency vs voltage and plot the graph.
9. Measure the pushing factor (in MHz/Volt) which is frequency sensitivity against variation in bias voltage for an oscillator. The pushing factor should be measured around 8 Volt bias.

C. Square Wave Modulations

1. Keep the meter switch of Gunn Power Supply to volt position and rotate Gunn bias voltage slowly so that panel meter of Gunn Power Supply reads 10Volt.
2. Tune the PIN modulator bias voltage and frequency knob for maximum output on the oscilloscope.

3. Coincide the bottom of square wave in oscilloscope to some reference level and note down the micrometer reading of variable attenuator.
4. Now with the help of variable attenuator coincide the top of square wave to same reference level and note down the micrometer reading.
5. Connect VSWR to detector mount and note down the db reading in VSWR meter for both the micrometer reading of the variable attenuator.
6. The difference of both db reading of VSWR meter gives the modulation depth of PIN modulator.

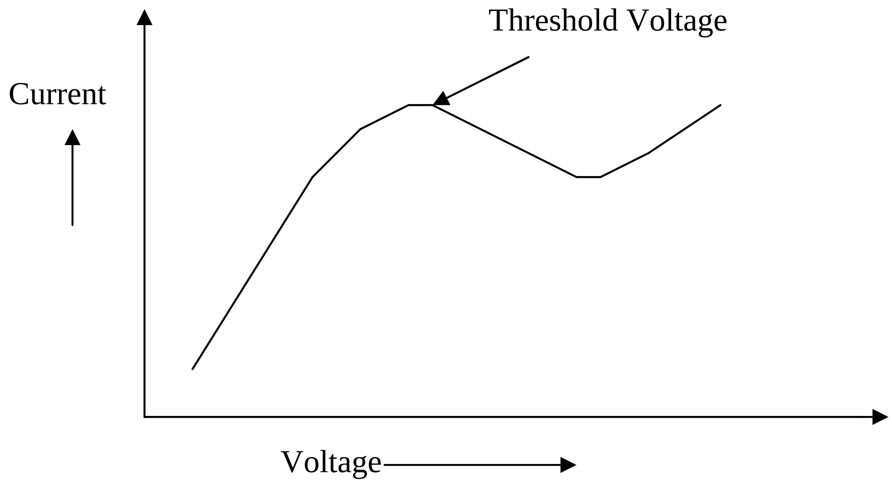
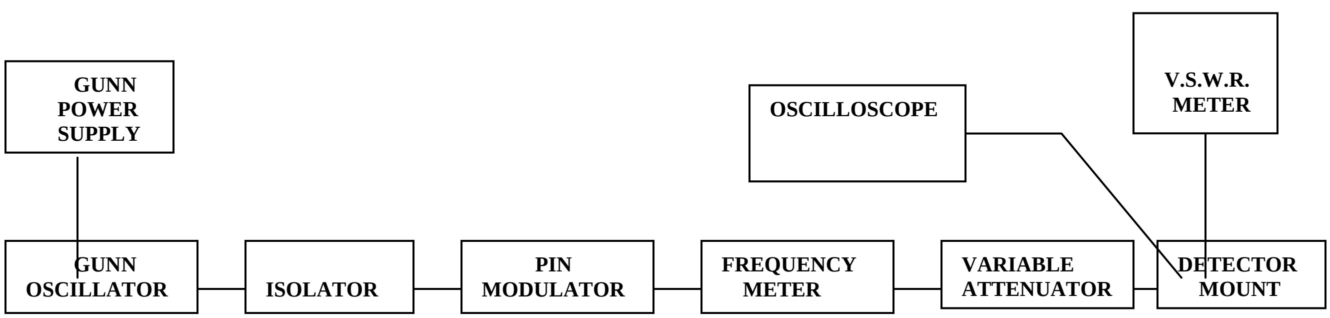


Fig. 5.4. V-I Curve of Gunn Oscillator



EC 341 Microwave Laboratory,
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Fig. 5.5 Set-up for study of Gunn Oscillator

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