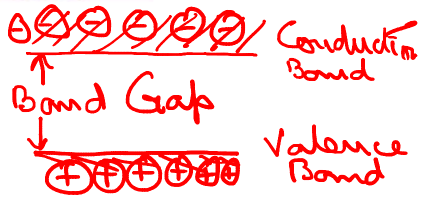
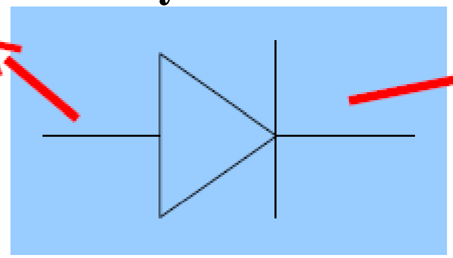
ESc201, Lecture 13: Diodes

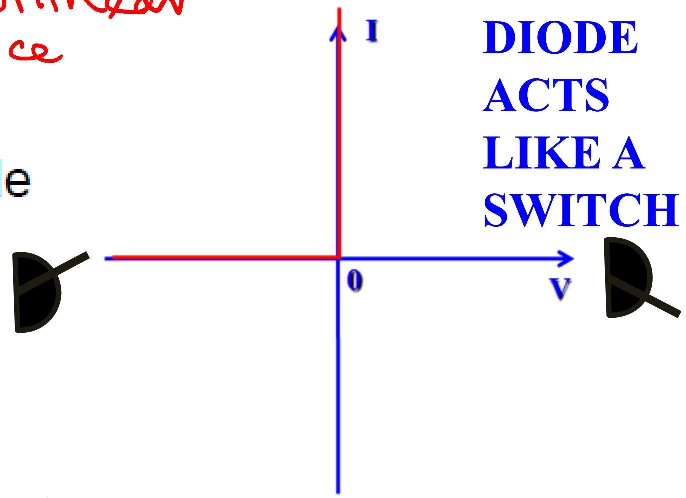
Not a bilinear device



Circuit Symbol for a Diode



Direction of current flow



IDEAL DIODE ACTS LIKE A SWITCH

Some Special Diodes:

- **Diode Solar Cell**
- **Photodiode (PD)**
- **Light Emitting Diode (*LED*)**
- **LASER Diode**
- **Tunnel Diode**
- **Varactor Diode**
- **Gunn Diode**

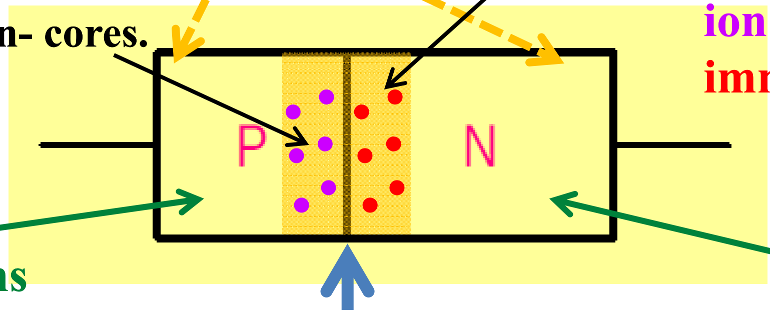
- **Schottky Diode**
- **Step Recovery Diode**

Could be two different materials or the same material with different kind of doping of impurities.

Electrons coming into a neutral material makes negatively charged ion- cores.

Electrons leaving a neutral material leaves positively charged ion-cores

ion cores are immobile



Lot of absence of free Electrons OR Lot of Vacancies.

Lot of free Electrons.

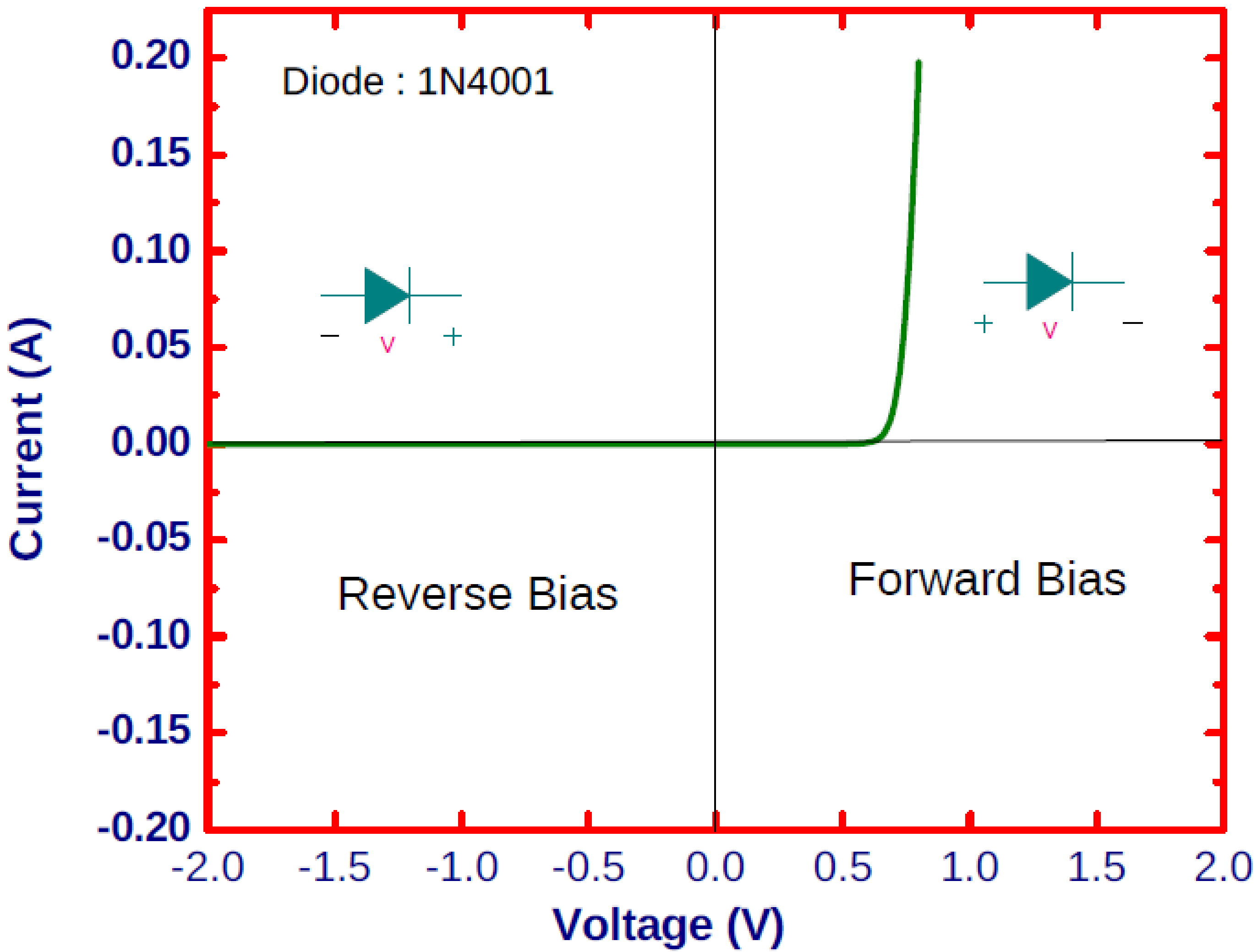
Large concentration Gradient at the junction and hence electrons and vacancies would inter-diffuse.

Separation of charges mean there is an Electric field

This gives rise to a Built-in Potential at the junction.

$E = -\frac{dV}{dx}$ and hence there must be a potential gradient

ESc201, Lecture 13: Diodes

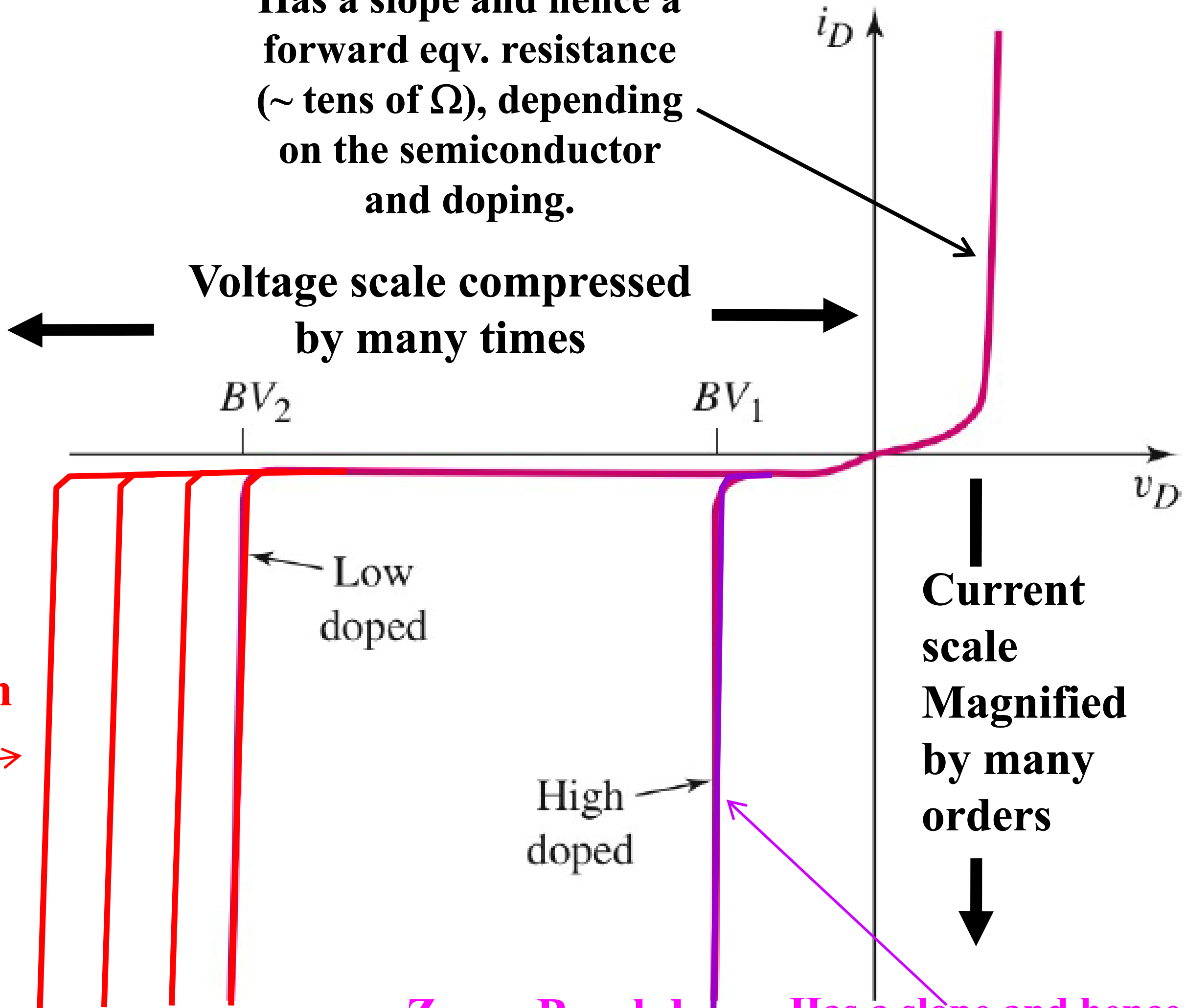


ESc201, Lecture 13: Diodes

Diodes having breakdown voltage 2-5 V may ***break down by a combination*** of both Avalanche and Zener mechanisms

Has a slope and hence a forward eqv. resistance (~ tens of Ω), depending on the semiconductor and doping.

Voltage scale compressed by many times



Current scale Magnified by many orders

Avalanche Breakdown

Has a slope and hence an equivalent resistance (< 100Ω) (BV_2 ~ 100-1kV) depending on the semiconductor and the diode structure.

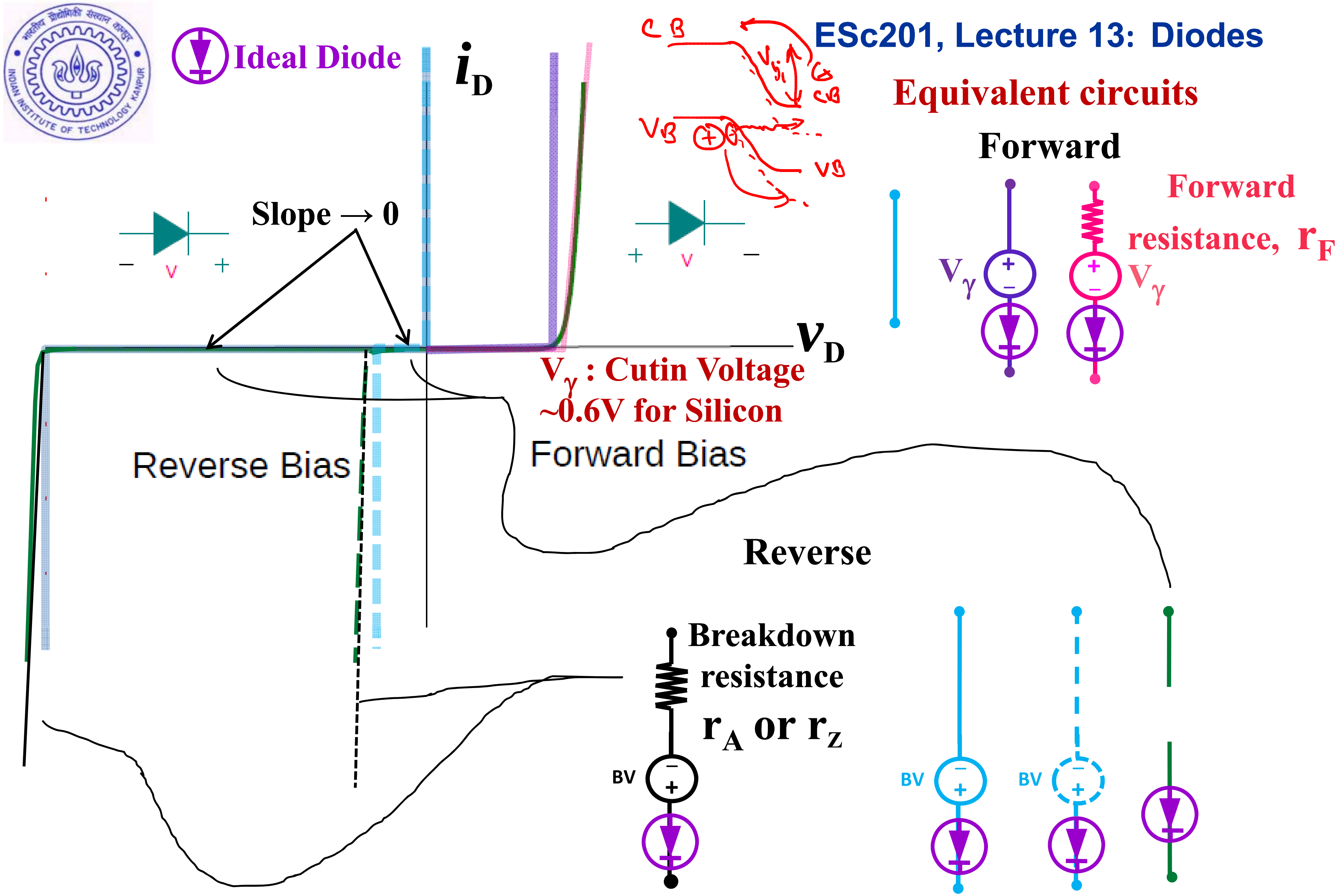
BV_2 increases with T

Zener Breakdown (BV_1 fairly independent of temperature)

Has a slope and hence an eqv. resistance (~ 50-200Ω), (BV_1 ~ 5-8V) depending on the semiconductor and doping.

ESc201, Lecture 13: Diodes

Equivalent circuits



ESc201, Lecture 13: Diodes

Diode I-V Relation : $$I_D = I_S[e^{q\frac{V_D}{nk_BT}} - 1]$$

$$V_T = (k_BT)/q$$
$$= 25.9mV \text{ at } 300^oK.$$
$$\approx 26mV \text{ at } 300^oK.$$

I_D is the diode current.

I_S is the reverse saturation current (~ tens of pA – few nA).

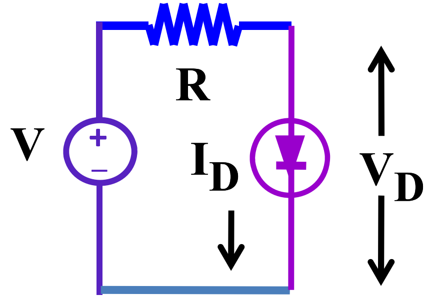
k_B is the Boltzman constant.

T is the absolute temperature.

n is the ideality constant (close to 1 for good diodes).

V_D is the voltage across the Diode.

When the diode is connected, at forward bias, in series with a Voltage Source and a Resistance .



For V_D positive (Forward Bias) and large with respect to V_T, I_D is exponential.

For V_D negative (Reverse Bias and less than Breakdown voltage), the exponential term rapidly decays and $I_D = - I_S$.

I_{DQ} quiescent operating current.

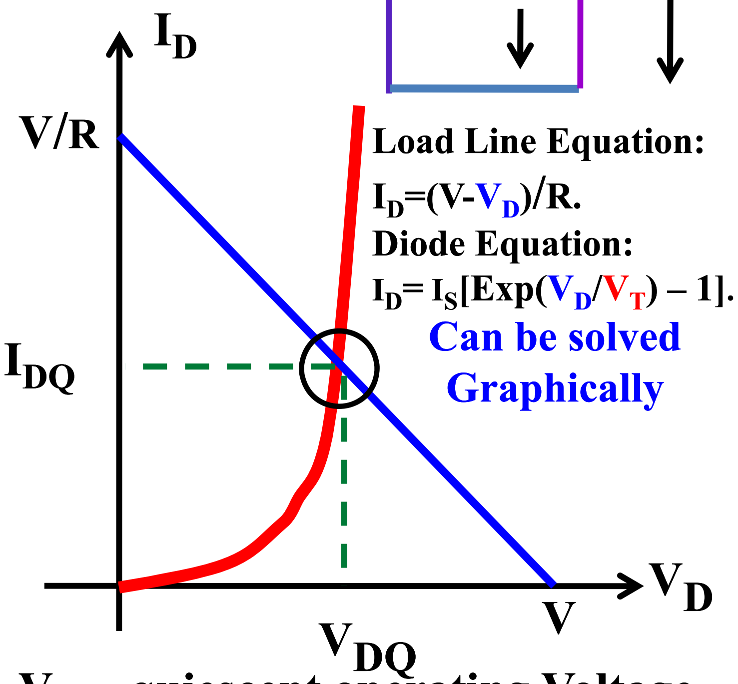
Load Line Equation:

$I_D=(V-V_D)/R$.

Diode Equation:

$I_D= I_S[Exp(V_D/V_T) – 1]$.

Can be solved iteratively.



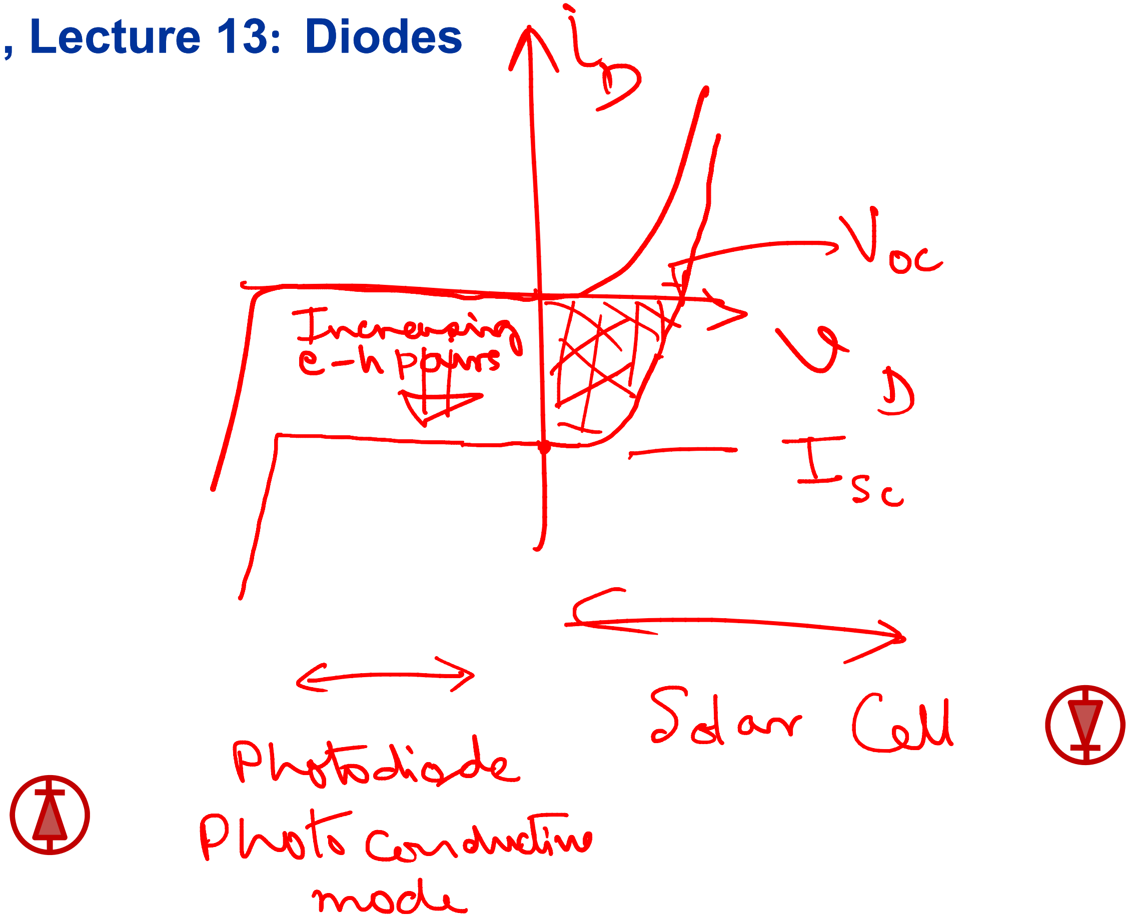
V_{DQ} quiescent operating Voltage.

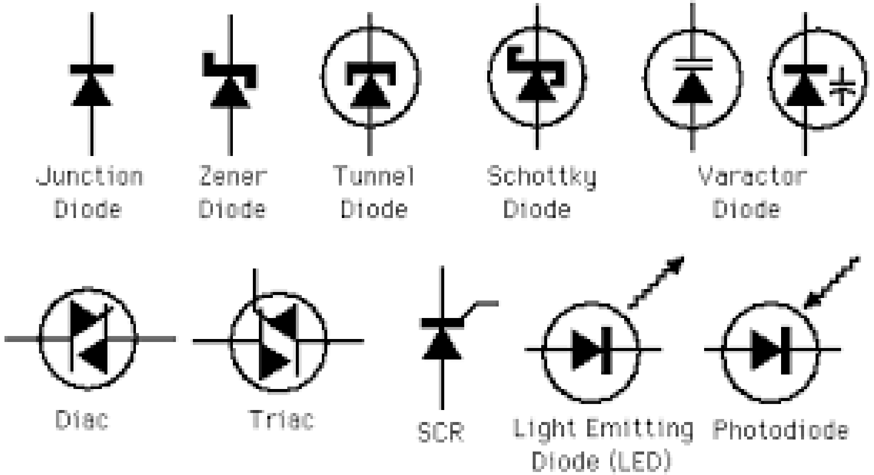
ESc201, Lecture 13: Diodes

Some Special Diodes:

– **Diode Solar Cell**

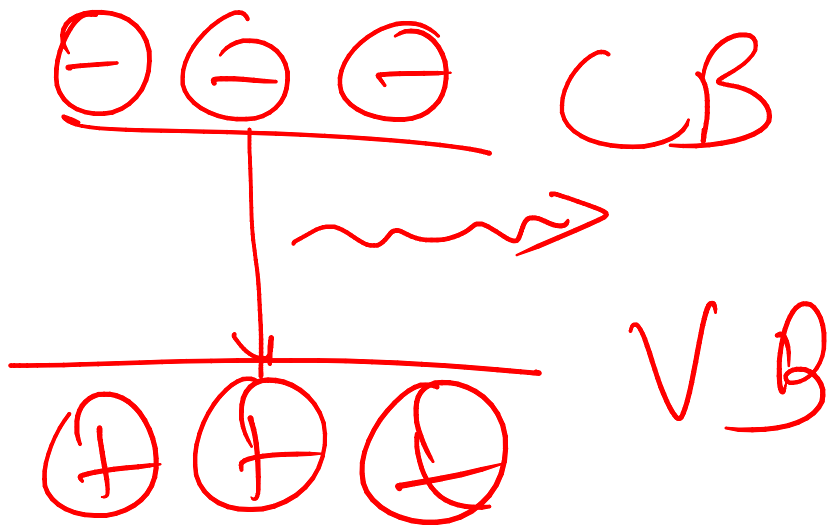
– **Photodiode (PD)**

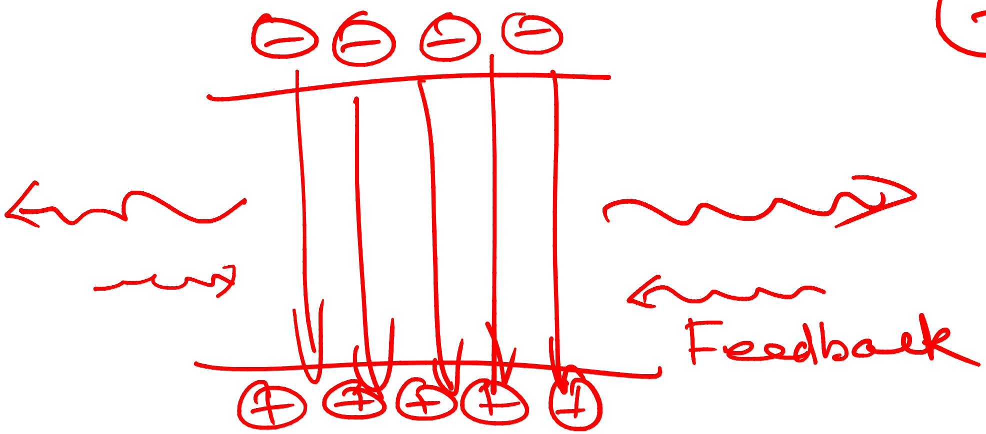


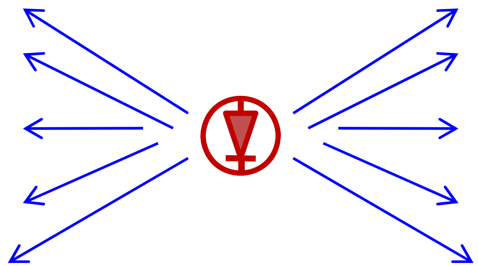


ESc201, Lecture 13: Diodes

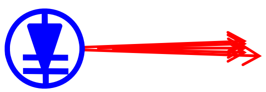
– **Light Emitting Diode (*LED)***
– **LASER Diode**







Wavelengths spread over a large spectrum.
No co-relation between the photons.



Same wavelength and polarization

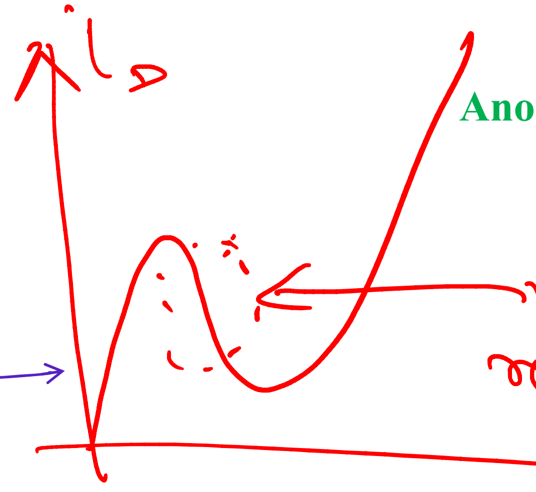
ESc201, Lecture 12: Diodes

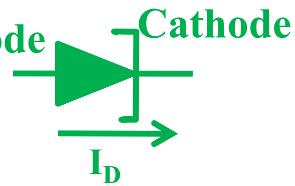
– Tunnel Diode

– Varactor Diode

– Gunn Diode

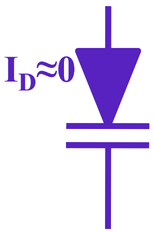
– Schottky Diode

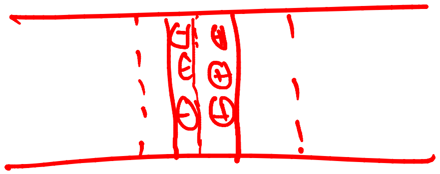




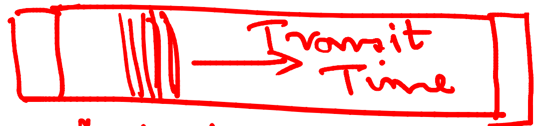
negative resistance

Used as an oscillator





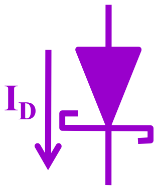
With bias the depletion width increases or decreases
∴ Separation of charge (Capacitor)
Capacitance value can be varied with applied voltage



Avalanche

Termed as transferred electron device.

Used as a high (GHz) frequency oscillator
But not much used now as the powers of these are very low.

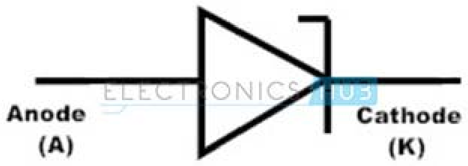


Metal/Semiconductor Junction
Holes and electrons do not conduct current. Only movement of electrons.
These are fast diodes (For high speed operation)

Low cut in voltage ($V_\gamma \approx$ 0.1-0.2V), low B_V, low capacitance

It can also use as an amplifier.

– Avalanche Breakdown Diode



specially designed to undergo breakdown at specific reverse voltage to prevent the damage.

– Step Recovery Diode

Stores the charge from positive pulse and uses in the negative pulse of the sinusoidal signals. The rise time of the current pulse is equal to the snap time. Due to this phenomenon it has speed recovery pulses.

Cut-off frequency range of 200-300 GHz. In the operations which are performing at 10GHz range these diodes plays a vital role.