The Gunn Effect

- For direct bandgap materials, like **GaAs: v_d *vs.* E** peaks before saturation & decreases again, after which it finally saturates.
- Because of this peak, there are regions in the **v_d *vs.* E** relationship that have:

$$(dv_d/dE) < 0$$

(for high enough **E**)

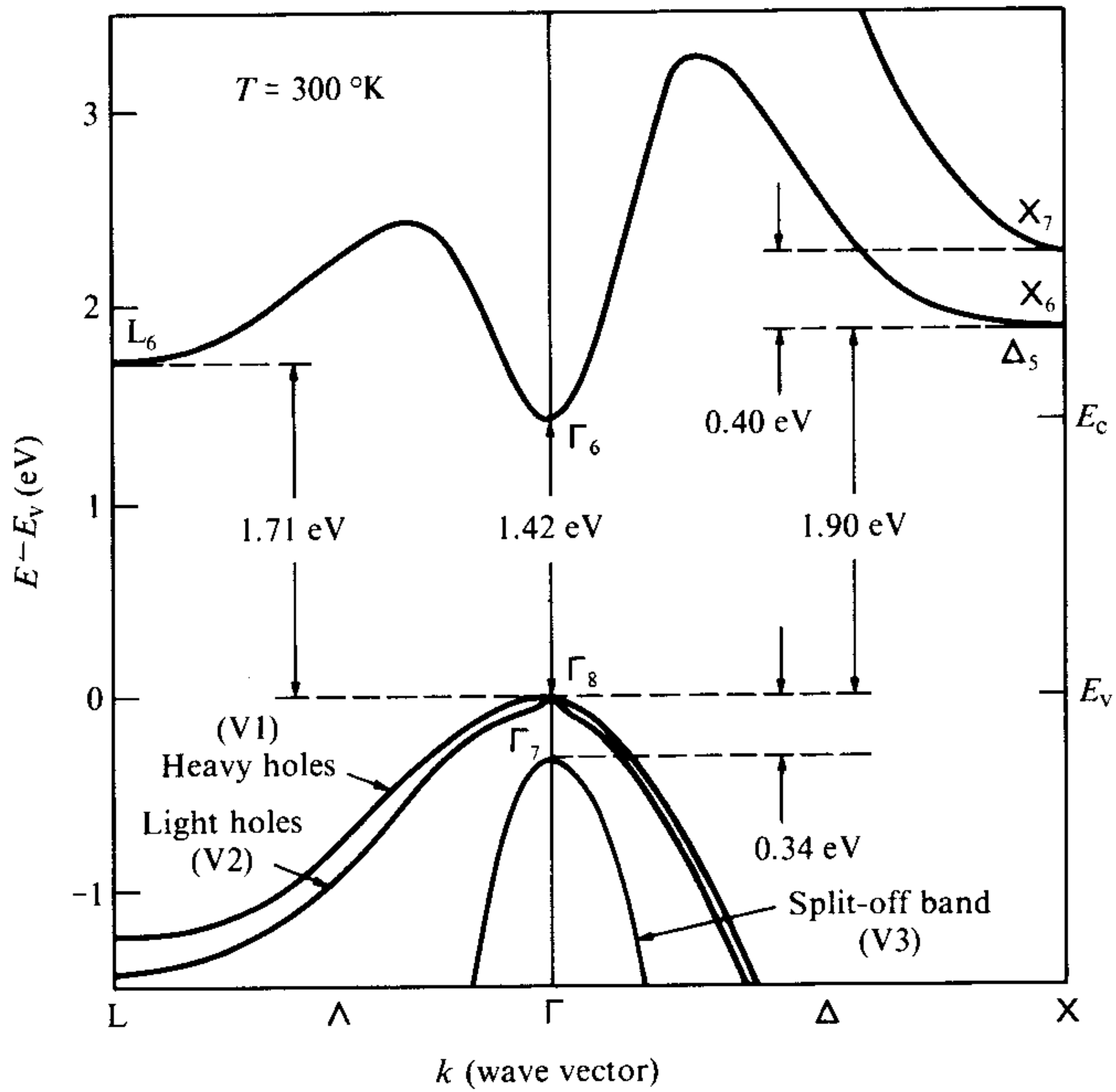
This effect is called

"Negative Differential Resistance"

or **"Negative Differential Mobility"**

or **"Negative Differential Conductivity"**

GaAs Bandstructure



- As the field increases, the electron drift velocity in gallium arsenide ***reaches a peak and then decreases***.
- As the **E**-field increases, the energy of the electron increases & the electron can be **scattered into the upper valley**, where the density of states effective mass is **0.55 m_0**

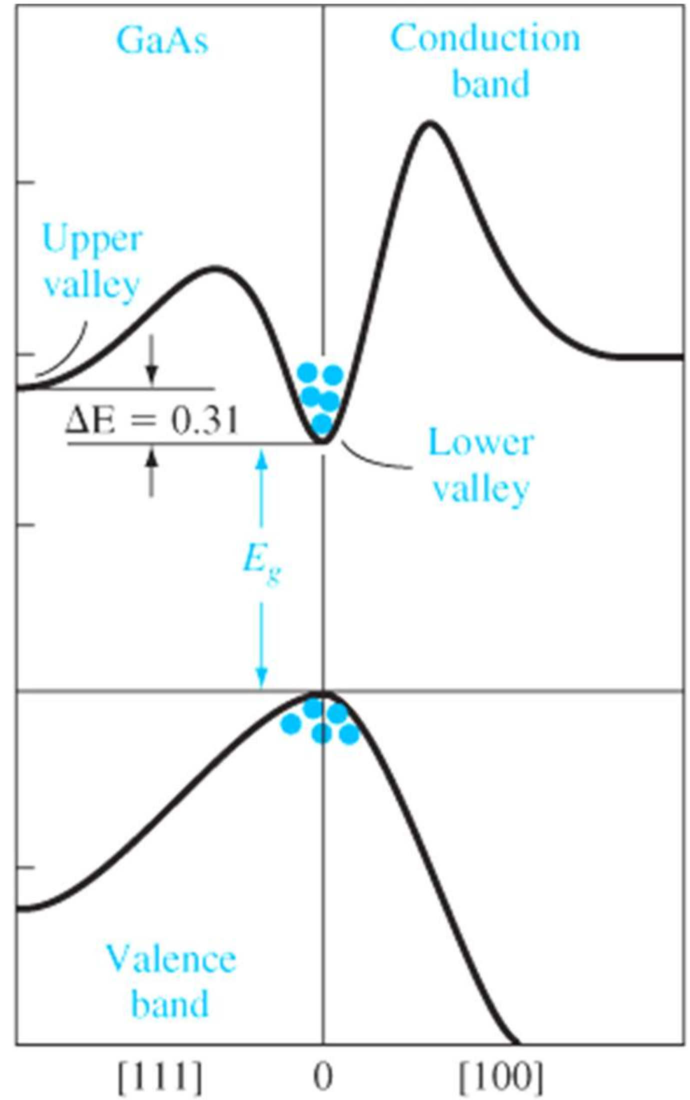
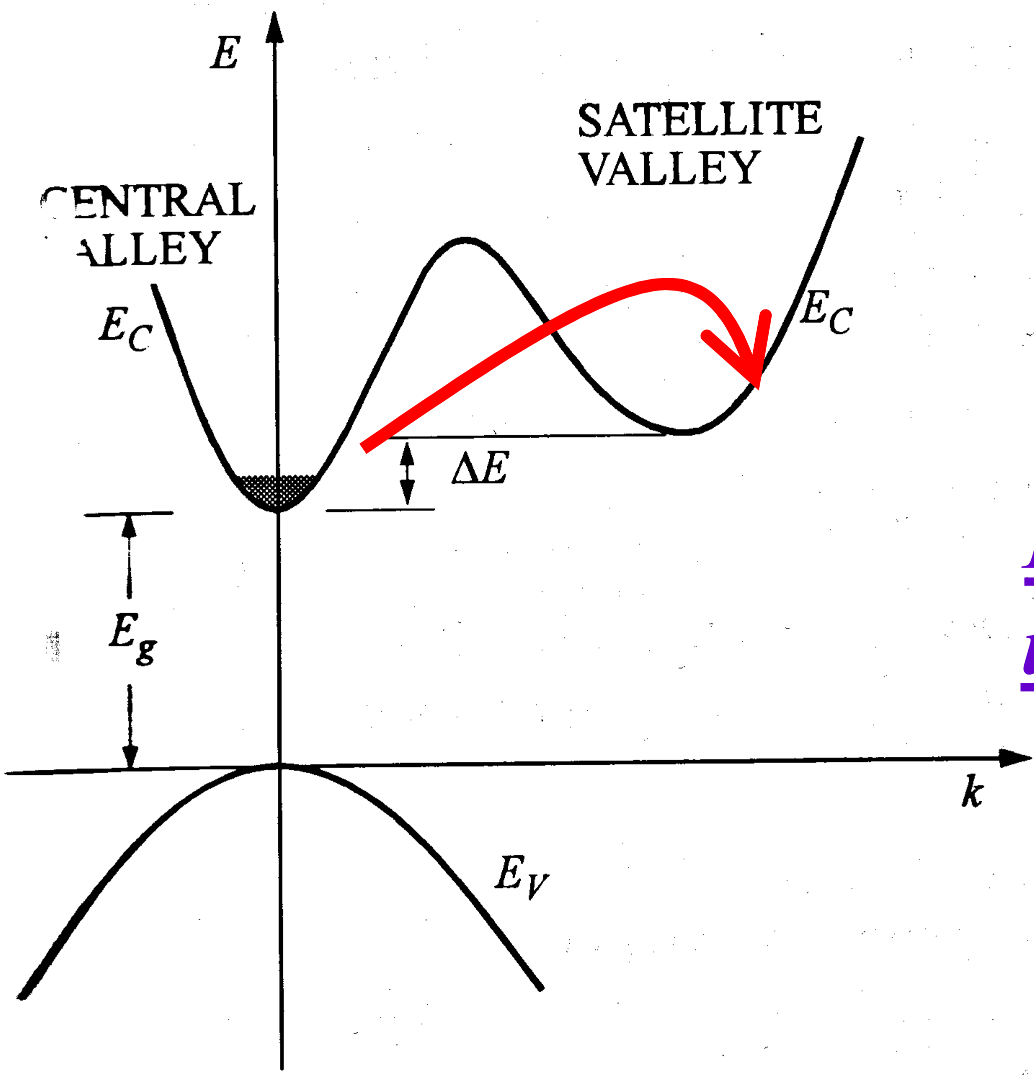


Figure 5.8 | Energy-band structure for gallium arsenide showing the upper valley and lower valley in the conduction band.
(*From Sze [15].*)

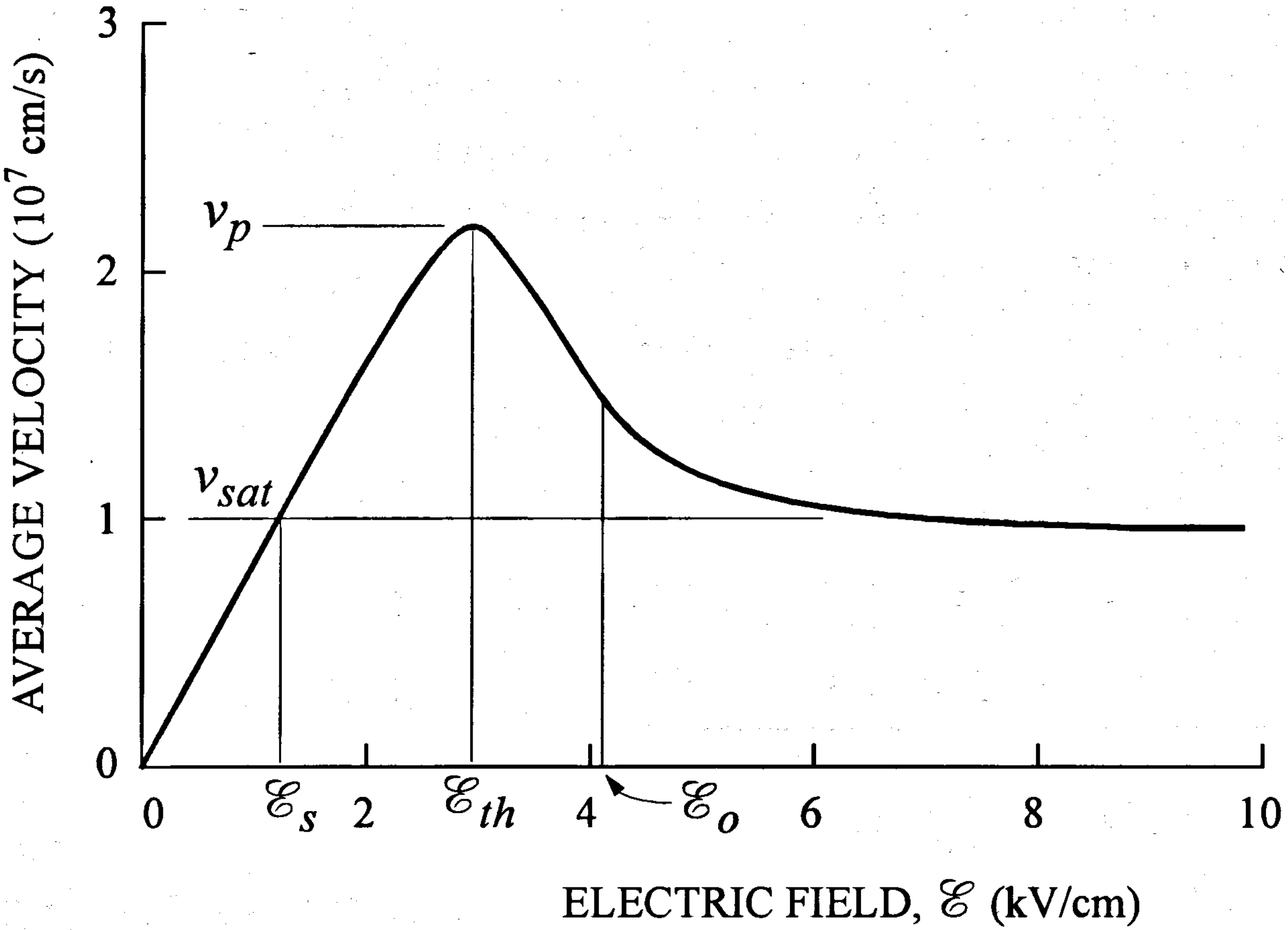
Transferred Electron Devices (Gunn Diode)



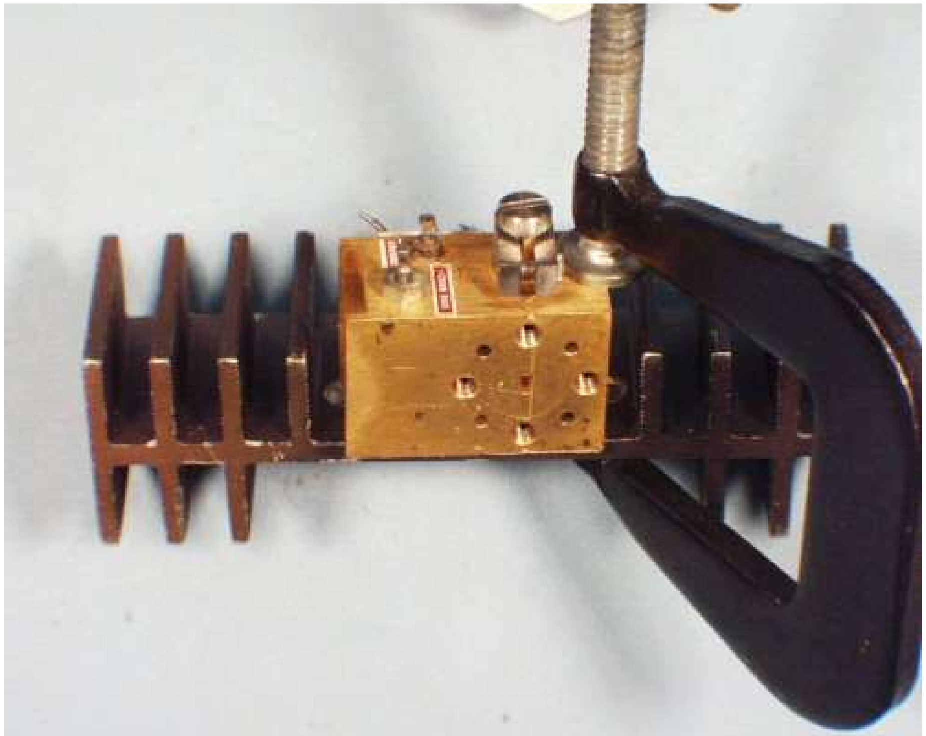
$\Delta E(GaAs) = 0.31$ eV

Effective Mass increases upon transfer under bias

Negative Differential Resistance (NDR)



Gunn Diode



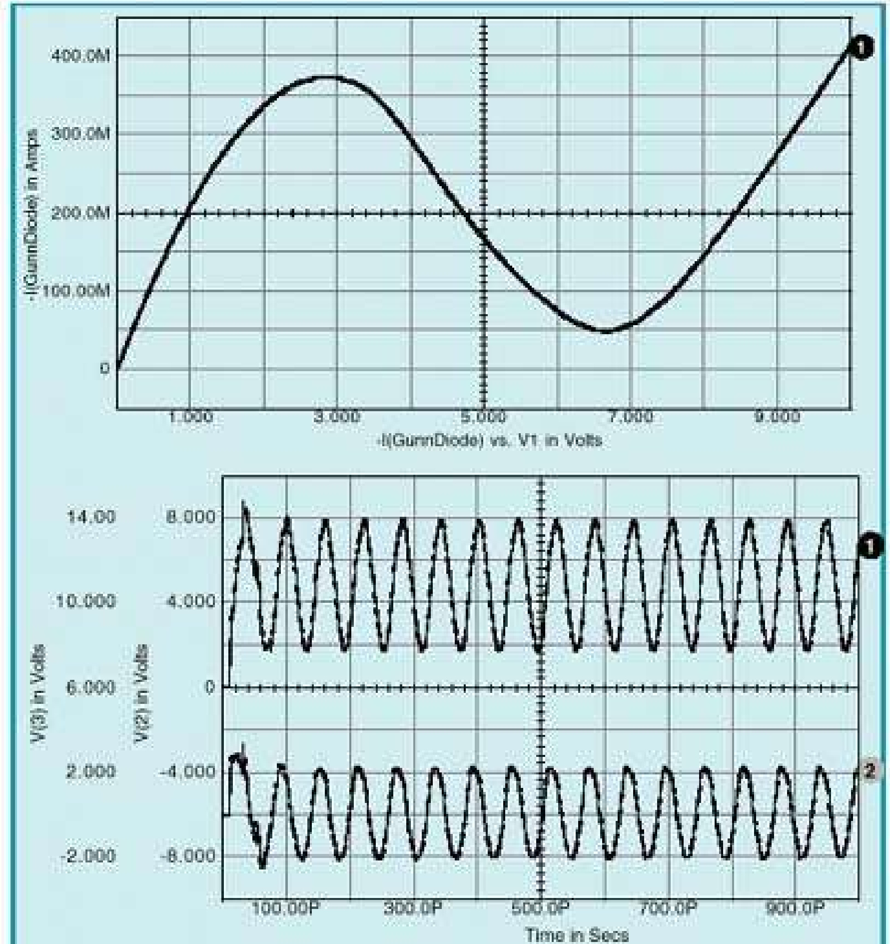
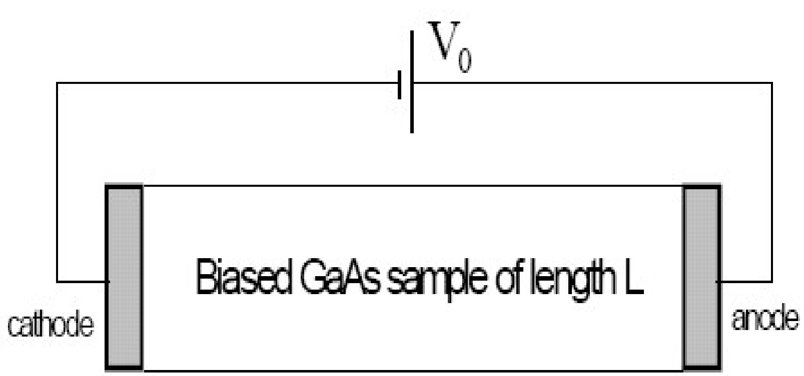


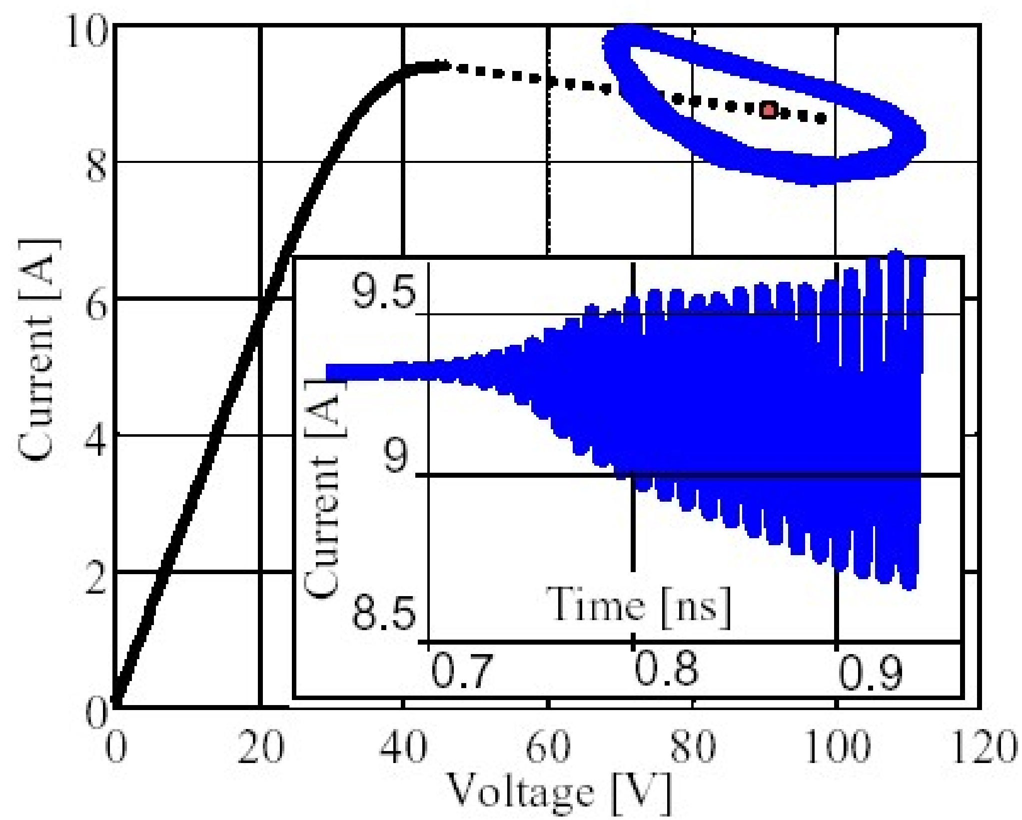
Figure 8 - The DC characteristics (top) and astable relaxation oscillator response (bottom) using the Gunn diode.

Can operate around NDR point to get an oscillator

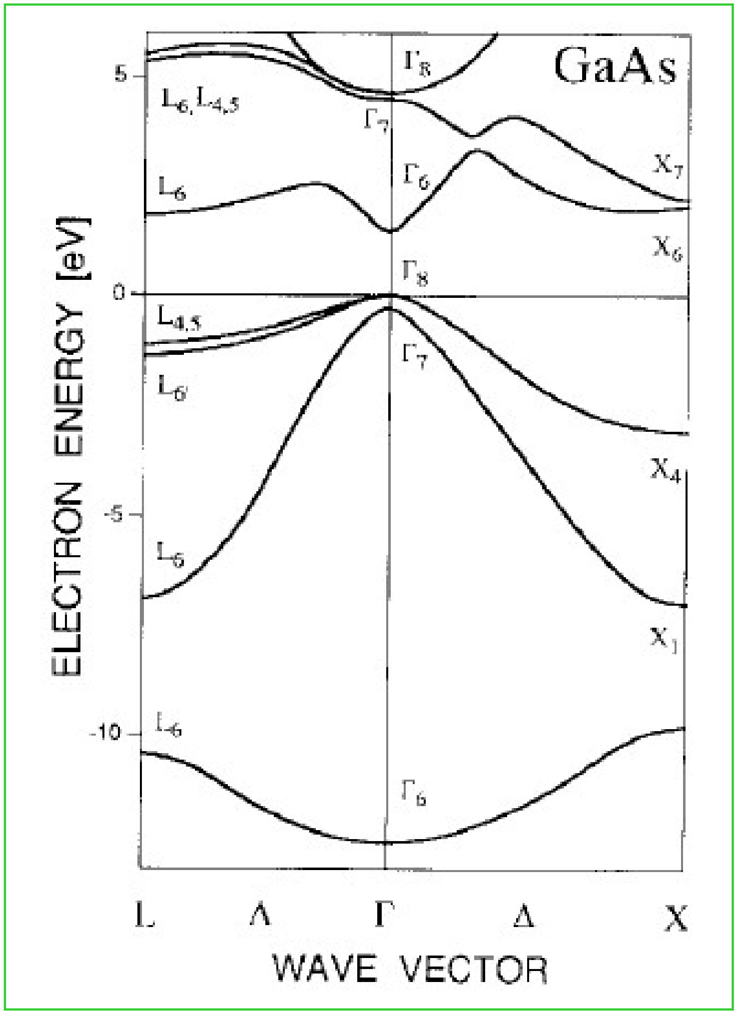
Gunn Effect

JB (Ian) Gunn discovered the Gunn-effect in February 1962. He observed random noise-like oscillations when biasing n-type GaAs samples above a certain threshold. He also found that the resistance of the samples dropped at even higher biasing conditions, indicating a region of negative differential resistance.

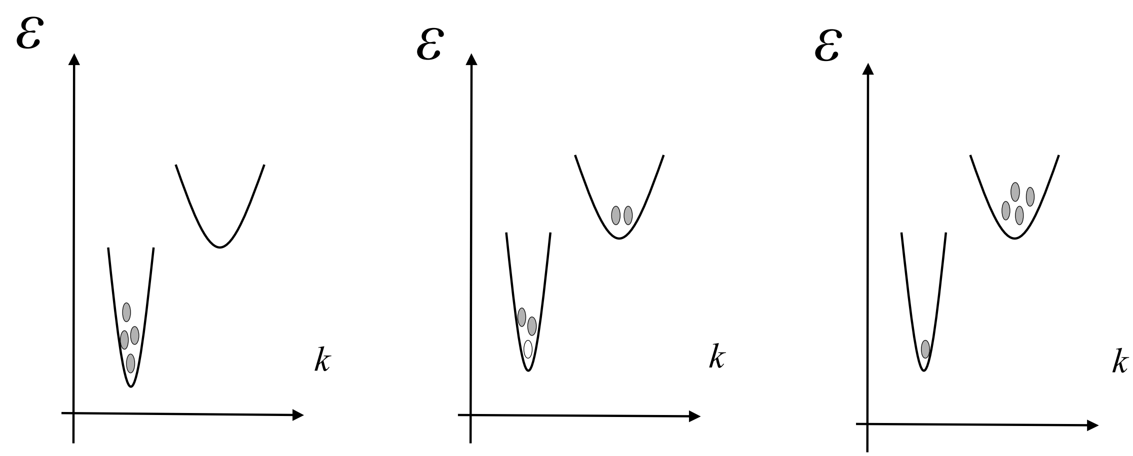




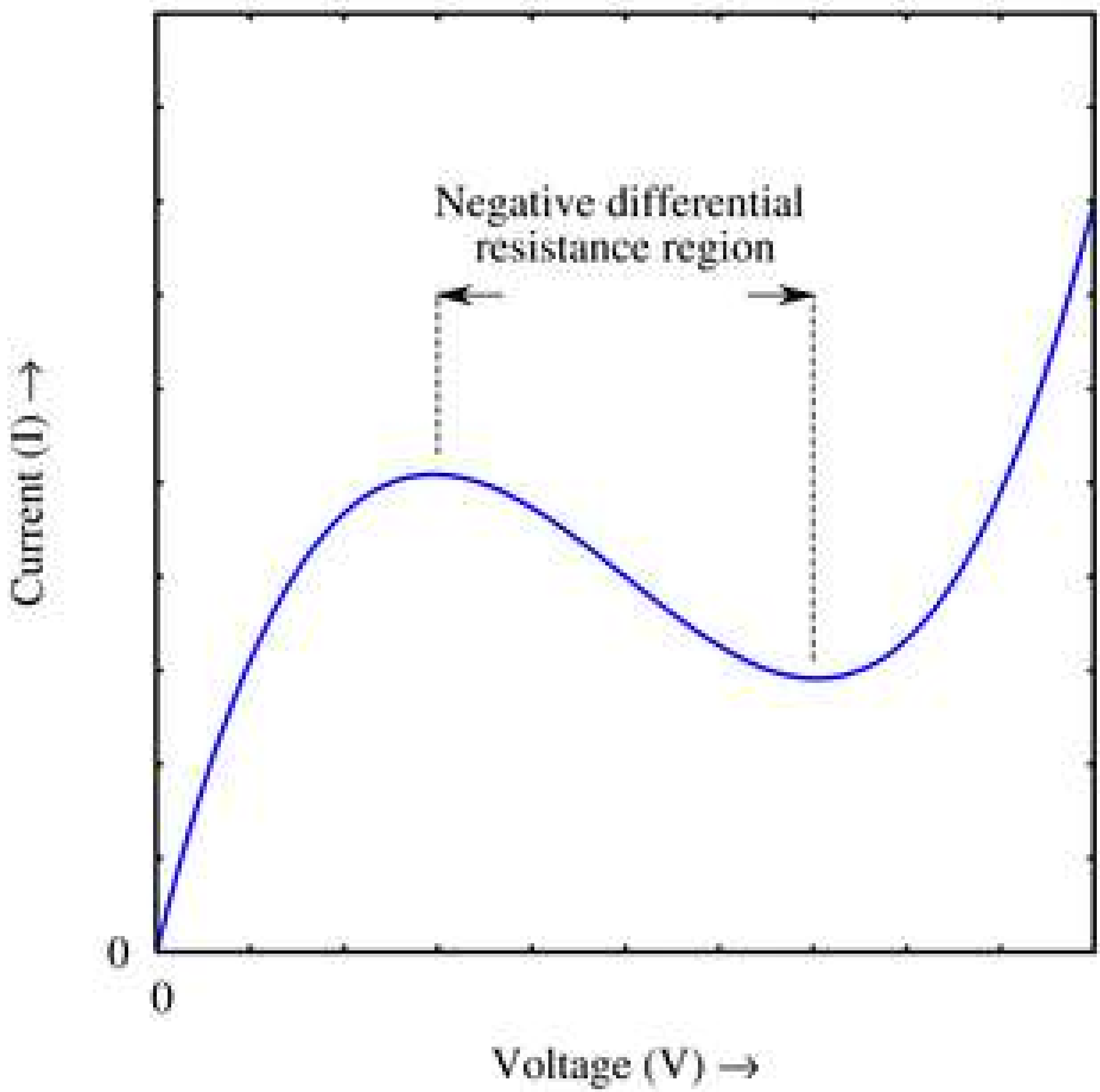
Gunn Effect



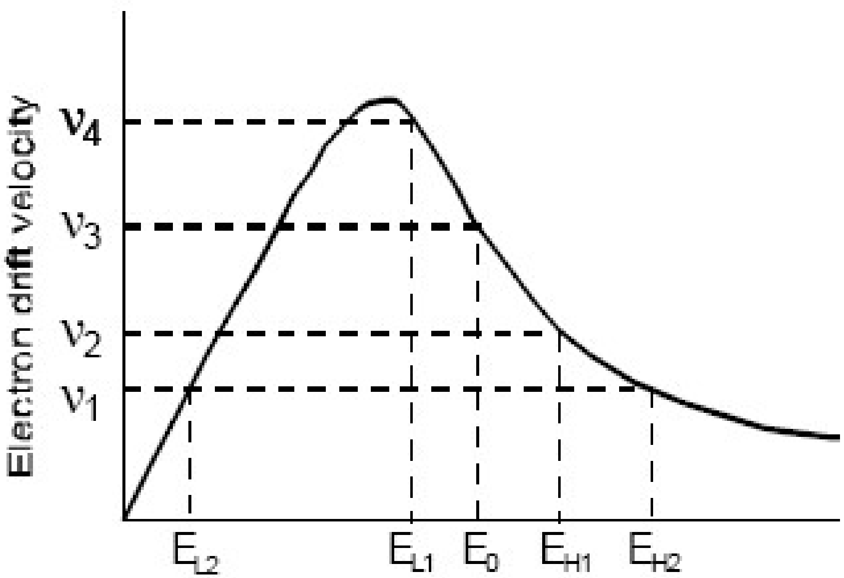
Materials which have the Gunn Effect, such as GaAs, InP, GaN, must be direct bandgap materials that have more than one valley in the conduction band & the effective mass & the density of states in the upper valley(s) must be higher than in the main valley.

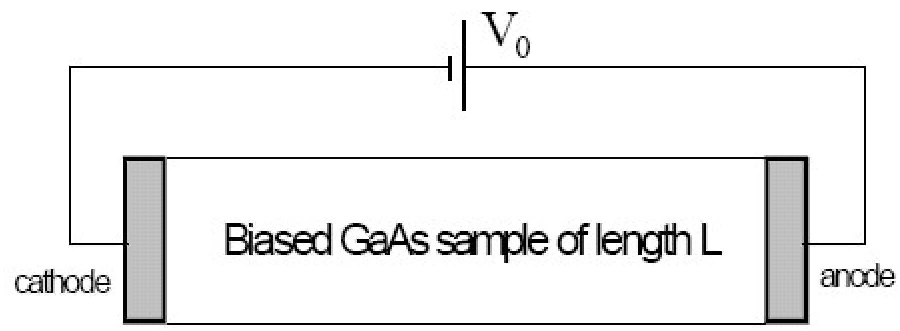


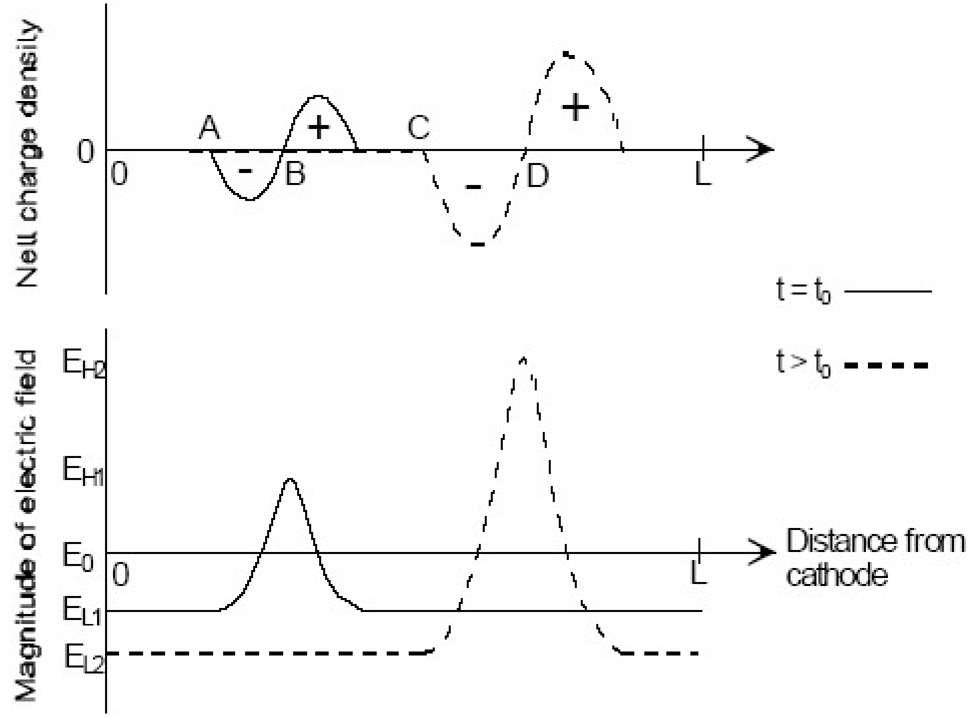
$\varepsilon < \varepsilon_{th}$ $\varepsilon_{\mathrm{th}} < \varepsilon < \varepsilon_{sat}$ $\varepsilon > \varepsilon_{sat}$


Negative differential
resistance region
Current (I) →
Voltage (V) →
0
0

Gunn Effect


Electron drift velocity
v4
v3
v2
v1
EL2
EL1
E0
EH1
EH2

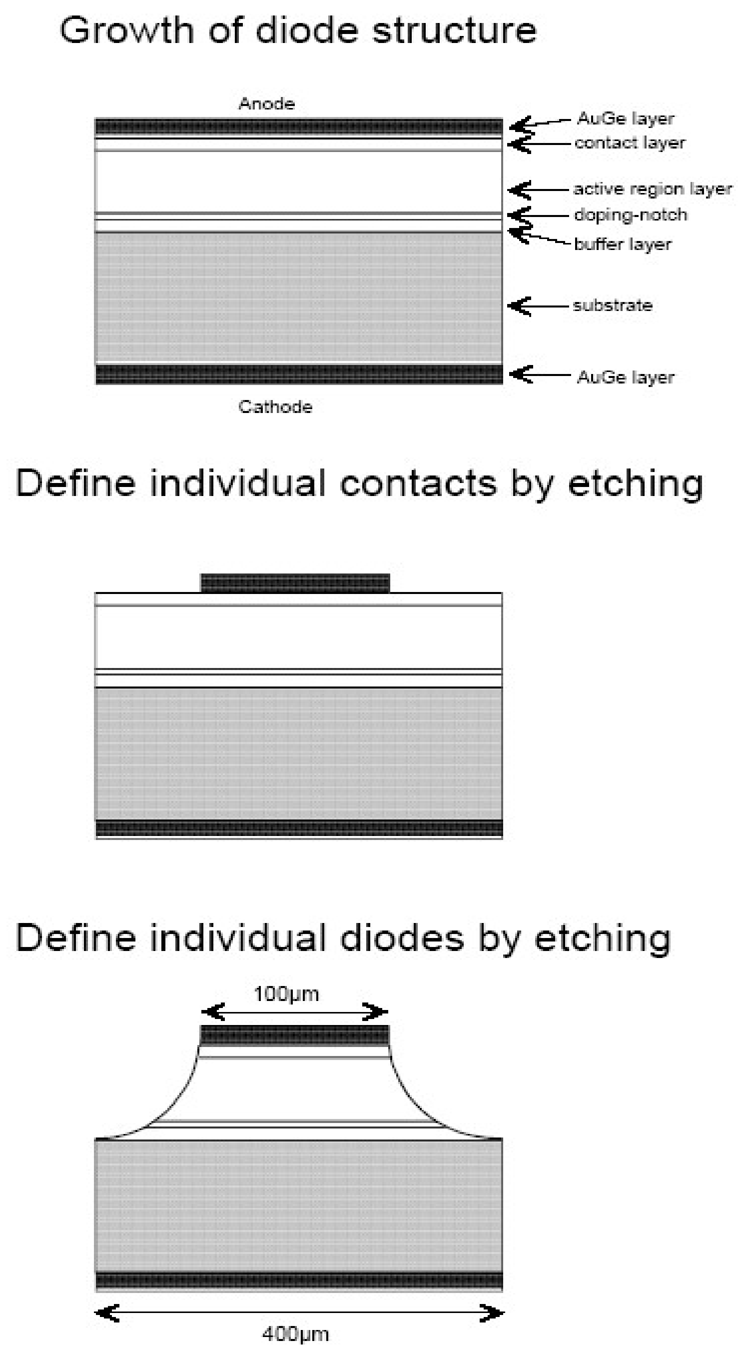

V0
Biased GaAs sample of length L
cathode
anode


Net charge density
0
A
B
C
D
L
+
-
t = t0
t > t0
Magnitude of electric field
EH2
EH1
E0
EL1
EL2
Distance from cathode

- It is important to note that the sample had to be biased in the NDR region to produce a Gunn-domain. Once a domain has formed, the electric field in the rest of the sample falls below the NDR region & will therefore inhibit the formation of a second Gunn-domain. As soon as the domain is absorbed by the anode contact region, the average electric field in the sample rises & domain formation can again take place.
- The successive formation & drift of Gunn-domains through the sample leads to ac current oscillations observed at the contacts. In this mode of operation, called the Gunn-mode, the frequency of the oscillations is dictated primarily by the distance the domains have to travel before being annihilated at the anode. This is roughly the length of the active region of the sample, L. The value of the dc bias will also affect the drift velocity of the domain, & consequently the frequency.

Gunn Diodes

Gunn diodes are semiconductor diodes that form a cheap and easy method of producing relatively low power radio signals at microwave frequencies. Gunn diodes are a form of semiconductor component able to operate at frequencies from a few Gigahertz up to frequencies in the THz region. As such they are used in a wide variety of units requiring low power RF signals.



Steady-State Results