14 Gunn Oscillators

Most of Gunn oscillators use the effect of high-filed domain instability

\[ j_p = qn_0 v_p \]

\[ j_s = qn_0 v_s \]
Current-voltage characteristics of the Gunn diode

I-Vs are needed to design the oscillator circuits
Main characteristics of the stable high-filed domains

Let the domain propagate in the sample with the velocity $u$;

We can now rewrite the equations describing the field and the current using *moving coordinate system.*

\[ Z = x - ut \]

\[ \frac{dF}{dZ} = \frac{q(n_0 - n)}{\varepsilon} \]

\[ I = qnv + qD(F) \frac{dn}{dZ} - \varepsilon u \frac{dF}{dZ} \]

\[ \rho = q(n_0 - n) \]

\[ \frac{dF}{dZ} = \frac{\rho}{\varepsilon} \]

\[ \frac{d\rho}{dZ} = \frac{qn[v(F) - v(F_r)] - \rho[v(F_r) + u]}{D(F)} \]
By dividing these two we have:

\[
\frac{dF}{dZ} = \frac{\rho}{\varepsilon} \\
\frac{d\rho}{dZ} = \frac{qn[v(F) - v(F_r)] - \rho[v(F_r) + u]}{D(F)}
\]
An integration of this equation results in

\[- \frac{\rho}{qn_0} - \ln \left(1 - \frac{\rho}{qn_0}\right) = \frac{\varepsilon}{qn_0} \left\{ \int_{F_r}^{F} \frac{[v(F') - v(F_r)]}{D(F')} dF' \right\} - [v(F_r) + u] \]

\[\times \int_{F_r}^{F} \frac{\rho/qn_0}{D(F')(1 - \rho/qn_0)} dF' \right\}.

At $F=F_m$ this side has to be $=0$

However, at $F=F_m$ this side $\neq 0$

When going through accumulation layer,

\[\rho_a/qn_0 < 0\]

When going through depletion layer,

\[0 < \rho_d/qn_0 < 1\]

The right hand side can only be $=0$ if:

\[u = -v(F_r)\]

and

\[\int_{F_r}^{F_m} \frac{v(F) - v(F_r)}{D(F)} dF = 0\]
Results:

1. The domain propagates at the velocity (negative sign of $u$ means that the domain propagates from the cathode towards the anode)

2. The maximum field in the domain can be found from a simple “equal areas rule”

$$\int_{F_r}^{F_m} [v(F) - v(F_r)] \, dF = 0$$
The equal areas rule allows to relate the field outside the domain to the peak field in the domain. The only additional relation needed is the voltage drop across the domain. When the electron concentration is not very high, the leading edge is fully depleted with electrons, therefore the charge and field distribution is similar to that of p-n junction

\[ U_D = \frac{\varepsilon \varepsilon_0 F_m^2}{2 q n_0} \]

Having \( F_r \) we know the \( v_r \), i.e. the current at the contacts can be found
Transferred Electron Oscillators (Gunn Oscillators)

Quenched mode:

the field drops below the threshold while the domain propagates

\[ U = U_0 + U_1 \cos \omega t \]
\[ I = I_0 + I_1 \cos \omega t \]
\[ U_0 - U_1 < F_s L \]
Transferred Electron Oscillators (Gunn Oscillators)

Delayed mode:
the domain reaches
the anode but the
next one cannot
grow due to low
field

\[ U = U_0 + U_1 \cos \omega t \]

\[ I = I_0 + I_1 \cos \omega t \]

\[ U_0 - U_1 < F_s L \]
The Power and Efficiency of Gunn Oscillators

\[ U = U_0 + U_1 \cos \omega t \]
\[ I = I_0 - I_1 \cos \omega t \]
\[ P_- = \frac{1}{2} U_1 I_1 \]

\[ \eta = \frac{P_-}{P_0} = \frac{1}{2} \frac{U_1 I_1}{U_0 I_0} \]

\[ \frac{I_1}{I_0} \leq \frac{I_p - I_s}{I_p + I_s} \]
\[ I_0 \approx I_s \]

\[ \eta_{\text{max}} \leq \frac{1}{2} \frac{1 - I_s/I_p}{1 + I_s/I_p} \]
\[ \eta_{\text{max}} \leq \frac{8}{\pi^2} \frac{1 - I_s/I_p}{1 + I_s/I_p} \]

\[ P_- = qv_s F_p \eta \frac{U_0}{U_p} n_0 L \]
The Power and Efficiency of Gunn Oscillators

$L = 50 \text{ um}; f = 2.2 \text{ GHz}$

1 – Accurate dynamic simulations
2 – Domain formation time = 0
Limited Space-charge accumulation mode:
The sample doping is above critical (Kroemer criterion)
Domain formation is prevented by the cavity large signal.

\[ \omega \tau_f > 1 \]

\[ \tilde{P}_\infty = \frac{qF_{ac}}{T} \int_0^T v \sin \omega t \, dt \]

\[ \tilde{P}_0 = \frac{qF_0}{T} \int_0^T v \, dt \]

LSA Oscillators have Highest efficiencies and operating frequencies