Example 2.7

A piece of germanium doped with 10^{16} cm^{-3} shallow donors is illuminated with light generating 10^{15} cm^{-3} excess electrons and holes. Calculate the quasi-Fermi energies relative to the intrinsic energy and compare it to the Fermi energy in the absence of illumination.

Solution

The carrier densities when illuminating the semiconductor are:

$$n = n_o + d\ n = 10^{16} + 10^{15} = 1.1\times10^{16}\ \text{cm}^{-3}$$

$$p = p_o + d\ p \cong 10^{15}\ \text{cm}^{-3}$$

and the quasi-Fermi energies are:

$$F_n - E_i = kT \ln\frac{n}{n_i} = 0.0259 \times \ln\frac{1.1\times10^{16}}{2\times10^{13}} = 163\ \text{meV}$$

$$F_p - E_i = -kT \ln\frac{p}{n_i} = 0.0259 \times \ln\frac{1\times10^{15}}{2\times10^{13}} = -101\ \text{meV}$$

In comparison, the Fermi energy in the absence of light equals

$$E_F - E_i = kT \ln\frac{n_o}{n_i} = 0.0259 \times \ln\frac{10^{16}}{2\times10^{13}} = 161\ \text{meV}$$

which is very close to the quasi-Fermi energy of the majority carriers.