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:

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

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

and the quasi-Fermi energies are:

$$F_n - E_i = kT \ln \frac{n}{n_i} = 0.0259 \times \ln \frac{1.1 \times 10^{16}}{2 \times 10^{13}} = 163 \text{ meV}$$

$$F_p - E_i = -kT \ln \frac{p}{n_i} = 0.0259 \times \ln \frac{1 \times 10^{15}}{2 \times 10^{13}} = -101 \text{ meV}$$

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

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

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