The FF is a function of V_{OC} (equation 3.134), so

$$\eta^{\text{Xsuns}} = \eta^{\text{1sun}} \left(\frac{FF^{\text{Xsuns}}}{FF^{\text{1sun}}} \right) \left(1 + \frac{\frac{kT}{q} \ln \text{X}}{V_{OC}^{\text{1sun}}} \right). \tag{3.165}$$

Both factors multiplying the 1 sun efficiency increase as the illumination concentration increases. Therefore, the efficiency of concentrator cells increases as the illumination concentration increases, as shown in Figure 3.25.

Of course, there are many obstacles to achieving this. Concentrator cells must be cooled, since an increase in operating temperature reduces V_{OC}, and hence the cell efficiency. The FF^{Xsuns} eventually decreases with increasing X and current due to the parasitic series resistance. Concentrator solar cells are discussed in more detail in Chapter 11.

3.5.6 High-level Injection

In high-level injection, the excess carrier concentrations greatly exceed the doping in the base region, so $\Delta p \approx \Delta n \approx n \approx p$ if the carriers are moving generally in the same direction. This occurs with back-contact solar cells, such as the silicon point-contact solar

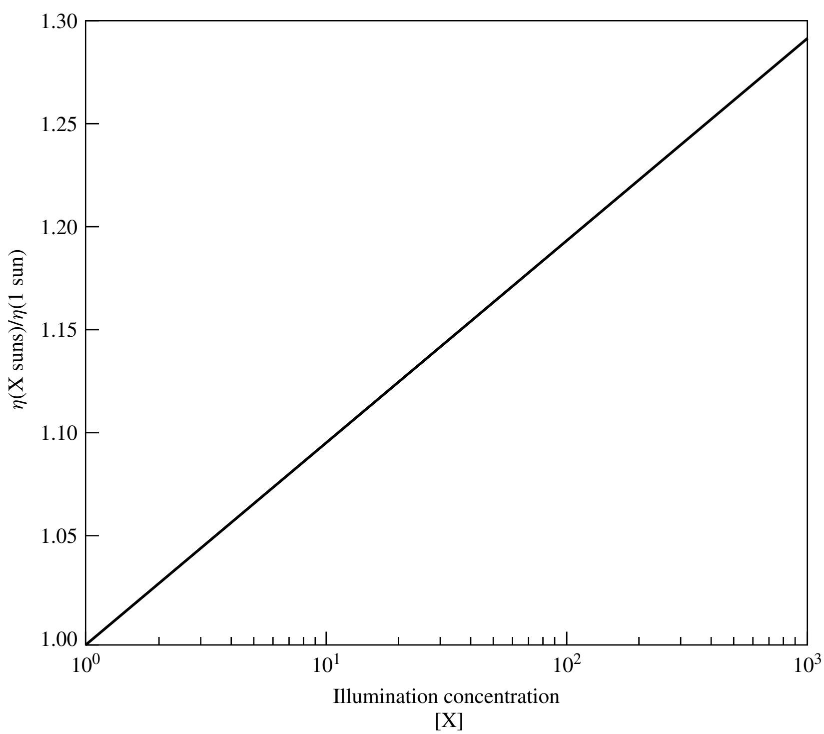

Figure 3.25 Relative efficiency as a function of illumination concentration