$\dot{W}_{\mathrm{lim}}$, can be obtained from equation (4.44) by setting the irreversible entropy-generation term to zero. Substituting the terms involving emitted radiation by their room-temperature luminescent equivalent, equation (4.44) becomes

$$\dot{W}_{\mathrm{lim}} = \int_{\varepsilon_g}^{\infty} \{[\dot{e}_s - T_a \dot{s}_s] - [\mu_x(\varepsilon)\dot{n}_x + \dot{\omega}_x]\}\,\mathrm{d}\varepsilon = \int_{\varepsilon_g}^{\infty} \dot{w}_{\mathrm{lim}}(\varepsilon, \mu_x)\,\mathrm{d}\varepsilon \tag{4.49}$$

The integrand should now be maximised [32] with respect to μ_x. For this, we calculate the derivative

$$\frac{\mathrm{d}\dot{w}_{\mathrm{lim}}}{\mathrm{d}\mu_x} = -\dot{n}_x - \frac{\mathrm{d}\dot{\omega}_x}{\mathrm{d}\mu_x} - \mu_x \frac{\mathrm{d}\dot{n}_x}{\mathrm{d}\mu_x} = -\mu_x \frac{\mathrm{d}\dot{n}_x}{\mathrm{d}\mu_x} \tag{4.50}$$

where we have used that the derivative of the grand potential with respect to the chemical potential is the number of particles with a change of sign. This equation shows that the maximum is achieved if $\mu_x = 0$ for any ε, or, in other words, if the radiation emitted is a room-temperature thermal radiation. This is the radiation emitted by all the bodies in thermal equilibrium with the ambient. However, the same result will be also achieved if the emitted radiation is any radiation whose room-temperature luminescent equivalent is a room-temperature thermal radiation.

Now, we can determine this efficiency, according to Landsberg [33], as

$$\begin{aligned}\eta &= \frac{\left(\dfrac{H_{sr}}{\pi}\right)\left[\left(\sigma T_s^4 - \dfrac{4}{3}\sigma T_a T_s^3\right) - \left(\sigma T_a^4 - \dfrac{4}{3}\sigma T_a^4\right)\right]}{(H_{sr}/\pi)\sigma T_s^4} \\ &= 1 - \frac{4}{3}\left(\frac{T_a}{T_s}\right) + \frac{1}{3}\left(\frac{T_a}{T_s}\right)^4\end{aligned} \tag{4.51}$$

which for $T_s = 6000$ K and $T = 300$ K gives 93.33% instead of 95% of the Carnot efficiency.

No ideal device is known that is able to reach this efficiency. Ideal solar thermal converters, not considered in this chapter, have a limiting efficiency of 85.4% [34, 35] and therefore do not reach this limit. Other high-efficiency ideal devices considered in this chapter do not reach it either. We do not know whether the Landsberg efficiency is out of reach. At least it is certainly an upper limit of the technical efficiency of any solar converter.

4.5 VERY HIGH EFFICIENCY CONCEPTS

4.5.1 Multijunction Solar Cells

A conceptually straightforward way of overcoming the fundamental limitation of the SQ cell, already pointed out by SQ, is the use of several solar cells of different band gaps to convert photons of different energies. A simple configuration to achieve it is by just stacking the cells so that the upper cell has the highest band gap and lets the photons pass through towards the inner cells (Figure 4.5). The last cell in the stack is the one with the narrowest band gap. Between cells we put low-energy pass filters so that the