and this allows for writing the efficiency, using the equations (4.63) to (4.65) as

$$\eta = \frac{\dot{Q}_r}{H_{sr}\sigma_{\mathrm{SB}}T_s^4/\pi}\frac{\dot{W}}{\dot{Q}_r} = \left(1-\frac{T_r^4}{T_s^4}\right)\left(1-\frac{\dot{Q}_c}{\dot{Q}_r}\right) = \left(1-\frac{T_r^4}{T_s^4}\right)\left(\frac{qV_c/\varepsilon - qV_r/\varepsilon}{1-qV_r/\varepsilon}\right) \tag{4.66}$$

As said before, the TPH converter has an extra degree of freedom in the design, as compared to the TPV. It is the hot cell voltage $V_r$. The hot cell temperature in the monochromatic case depends on the same parameter $H_{rc}\Delta\varepsilon/H_{rs}\varepsilon$ as in the TPV case. When this parameter tends to infinity, the cold cell tends to be in open circuit, $V_{\mathrm{coc}}$, given by

$$\frac{(\varepsilon - qV_{\mathrm{coc}})}{kT_a} = \frac{(\varepsilon - qV_r)}{kT_r} \Rightarrow qV_{\mathrm{coc}} = \varepsilon\left(1-\frac{T_a}{T_r}\right) + qV_r\frac{T_a}{T_r} \tag{4.67}$$

Using this equation in equation (4.66), we obtain the same limit equation for the efficiency as the one for the TPV converter (equation 4.57):

$$\eta = \left(1-\frac{T_r^4}{T_s^4}\right)\left(1-\frac{T_a}{T_r}\right) \tag{4.68}$$

An interesting feature of this formula is that it holds for any value of $V_r$. Thus the TPH converter has the same upper limit as the TPV one. Furthermore, $T_r$ is the same as in the TPV.

To our knowledge, this novel concept has not yet been fully explored. However, we present in Figure 4.10 the efficiency versus the cold cell voltage $V_c$ (usually, in other contexts, we call efficiency to the maximum of this curve) for $V_r$ in forward bias, zero bias (TPV mode) and reverse bias. In Figure 4.11, we present the hot cell temperature. We can

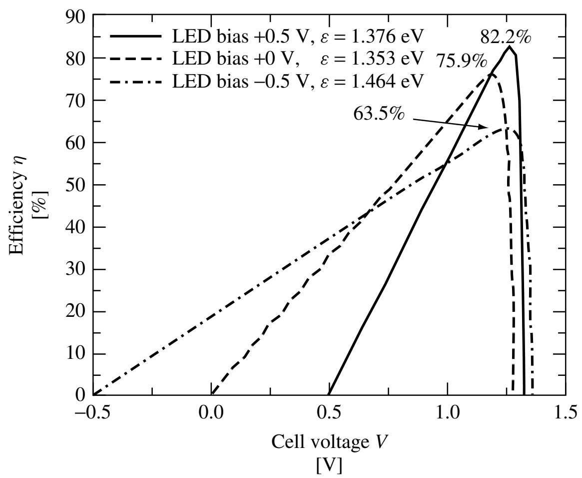


**Figure 4.10** TPH efficiency versus $V_c$ for three values of $V_r$ for $H_{rc}\Delta\varepsilon/H_{rs}\varepsilon = 10/\pi$. The energy $\varepsilon$ has been optimised