we shall obtain a larger open-circuit voltage across the top junction than that across the bottom junction. This is the "spectrum-splitting" effect.

For specificity, consider a tandem cell that bases the bottom junction on material with a 1.55 eV electrical band gap and bases the top junction on material with 1.80 eV electrical band gap material. In the absence of the top, 1.80-eV junction, the 1.55-eV junction might deliver about $J_{SC} = 20$ mA/cm^2 at an open-circuit voltage of 0.65 V. Assuming a fill factor (*FF*) of 0.7, the power output will be 9.1 W/m^2. When assembled in tandem, the current through each junction is about half this value, but the open-circuit voltage will more than double ($V_{OC} = 0.65 + 0.90 = 1.55$ V). The power output rises to 11.2 W/m^2 – for a 19% spectrum-splitting improvement over the single-junction device.

For ideal semiconductors arranged with optimal band gaps, the maximum efficiencies for single, tandem, and triple-junction solar cells under concentrated sunlight are 31%, 50%, and 56%, respectively [144]. Figure 12.22 shows the conversion efficiency contour plot calculated using an a-Si:H-based computer model for two-junction tandem cells; the two axes are the band gaps for the top and bottom component cells [145, 146]. The best efficiency of over 20% occurs with a combination of a 1.8-eV intrinsic layer in the top *pin* junction and a 1.2-eV layer in the bottom. Of course, these model results have not yet been achieved in practice!

We can distinguish three reasons for improved efficiency in a-Si-based multijunction cells over single-junction cells. The first is the spectrum-splitting effect we have just

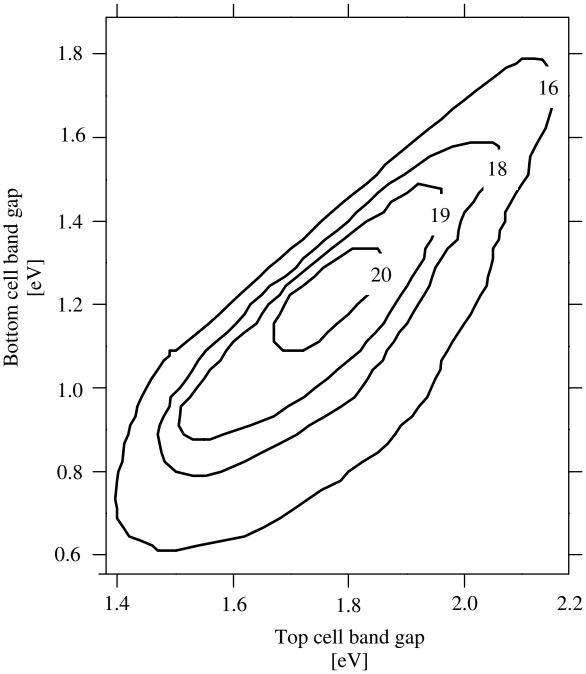

Figure 12.22 Contour plot of constant solar conversion efficiency for a-Si-based tandem solar cells for varying band gaps E_G of the top cell and the bottom cell [145]