where

$$X = [n_2(n_3n_4 - n_2n_4t_2t_3 - n_2n_3t_2t_4 - n_3^2t_3t_4) + i\, n_1(n_3n_4t_2 + n_2n_4t_3 + n_2n_3t_4 - n_3^2t_2t_3t_4)]/[n_1n_4(n_2n_3 - n_3^2t_2t_3 - n_3n_4t_2t_4 - n_2n_4t_3t_4) + i\, n_2n_4(n_2n_3t_2 + n_3^2t_3 + n_3n_4t_4 - n_2n_4t_2t_3t_4)] \quad (9.17b)$$

and

$$t_\mathrm{j} = \tan(2\pi\, n_\mathrm{j}\, \mathrm{d_j}/\lambda) \quad (9.17c)$$

Although this approach incorrectly assumes that there is no absorption from the layers of the top subcell, and completely neglects all the deeper layers in the cell stack, in practice, it gives results that agree reasonably well with more rigorous approaches [24], and it has the virtue of simplicity. The AR coating calculations that illustrate the following discussion were done using equations (9.17). Note, however, that more complex problems such as the calculation of backside AR coats needed for mechanical stacks require the more rigorous formalism.

9.5.8.3 Current matching

Figure 9.9(a) shows the modeled reflectance for a GaInP cell with a MgF_2/ZnS AR coating, for several different combinations of the layer coating thicknesses [25], using optical constants from the literature [26, 27]. The dependence of the reflectance on the layer thicknesses can, roughly, be broken down into two parts, that is, the ratio of the two thicknesses and the total thickness of each layer. Proper choice of the ratio, as for the layer thicknesses in Figure 9.9(a), yields a reflectance with a flat, low, notch-shaped minimum. With this ratio held constant, the total thickness of the coating determines the position of the minimum, with increasing thickness shifting the notch position to lower photon energy. The width of the notch is less than the solar spectral range, so regardless of the position of the notch, the photocurrents of the subcells will be less than what they would be for the ideal case of zero reflectance. Shifting the notch to higher photon energy will send more light to the top subcell at the expense of the bottom subcell, and vice versa; the AR coating thus affects the current matching in the cell. Figure 9.9(b) shows the photocurrent of a GaInP(1.85 eV)/GaAs(1.42 eV) tandem cell as a function of ZnS/MgF_2 AR coating layer thicknesses, for the AM1.5 direct spectrum. As the top-subcell thickness increases, the optimal AR coating thickness increases, to compensate by directing more of the light to the bottom subcell.

9.5.9 Concentration

Terrestrial application of high-efficiency multijunction solar cells is generally in concentrator systems, given the high solar cell costs. These types of cells are well suited for concentrator operation, not only because of their high one-sun efficiencies, but also because these high efficiencies can be maintained up to concentration levels exceeding 1000 suns. This section discusses the adaptations needed for the one-sun devices to be made suitable for concentrator operation, and describes the resulting concentrator