a simulator whose spectral match is close to the reference spectrum but brings in extra light that can be filtered at will for each junction [114]. The primary disadvantage of this approach is that the supplemental light sources are not collinear with the broadband light, giving the possibility of large variations in the spectral irradiance in the test plane. A fiber-optic solar simulator shown schematically in Figure 16.5(c) is useful because a wide variety of laser and incoherent light sources can be combined into one fiber bundle, which then illuminates the test plane [110, 115, 116]. This approach has the disadvantage of being restricted to small illumination areas, typically less than 2 cm in diameter at one sun. Another approach shown in Figure 16.6(d) is to place filters and apertures close to the integration optics of a large-area solar simulator [110, 114, 115]. This method is particularly useful for large-area (>100 cm^2) samples. Its primary drawback is that the light sources are not separately adjustable for each junction. This concept can also be applied to pulsed simulators, where the distance between the flash lamp(s) and the test plane is usually large and a wide range of intensities is possible. This method works for any multijunction technology because standard high-pass, low-pass, and band-pass filters are available to cover any combination of band gaps.

An entirely new procedure has recently been developed in which the light sources are set only once [111, 117, 118]. The approach is based on a simulator setup with multiple light sources arranged so that the intensity of each source may be adjusted without causing a change in the relative spectral irradiance. Each light source, $E_{S,i}(\lambda)$ for each junction, j can therefore be characterized by its relative irradiance. The adjustment of the intensity of the ith light source to an absolute level is mathematically described by the scaling factor C_i. Under these premises, the condition $I_j^{T,S} = I_j^{T,R}$ yields a system of j linear equations,

$$\sum_i C_i \int E_{S,i}(\lambda) S_{T,j}(\lambda)\, d\lambda = \int E_{ref}(\lambda) S_{T,j}(\lambda)\, d\lambda \tag{16.30}$$

which can easily be solved for the unknown scaling factors C_i. The intensity of the ith light source $E_{S,i}(\lambda)$ for the jth junction of the test device $S_{t,j}(\lambda)$ is adjusted until the measured short-circuit current of reference cell $I_j^{T,R}$ with an absolute spectral response $S_{R,j}(\lambda)$ is obtained using

$$I_j^{T,R} = C_i A \int E_{S,i}(\lambda) S_{R,j}(\lambda)\, d\lambda \tag{16.31}$$

The system of equations requires only relative spectral responses and relative irradiances and is therefore equivalent to the calculation of the mismatch factor in equation (16.29). The equations allow for the same reference cell to be used to set the simulator sources [111, 117, 118]. This procedure only requires one adjustment of each light source. This procedure also requires that the relative spectral irradiance be measured only once for each light source unlike the procedure described by equations (16.28) and (16.29), which requires a spectral irradiance measurement after each simulator adjustment. This allows the performance of a multijunction PV device under varying reference spectra or current-matching conditions to be rapidly determined.