Limiting the current is normally achieved by illuminating the other junctions *not* being measured with a DC bias light whose spectral irradiance covers their response range [154]. To measure $S(\lambda)$ for the *top* cell in a two-junction device, the bottom cell must be illuminated with "red" light that is absorbed mostly in the bottom cell. To measure $S(\lambda)$ for the *bottom* cell in a two-junction device, the top cell must be illuminated with "blue" light that is absorbed mostly in the top cell. In practice, the intensity of the bias light is increased until $S(\lambda)$ for the junction being measured is a maximum and $S(\lambda)$ values for the other junctions are minima. If the multijunction device terminals are at zero volts, then the cell being measured is at some reverse-bias voltage since the other junction is forward-biased owing to the bias light [154]. Because $S(\lambda)$ can depend on voltage, the cell being measured should be at zero volts, [154] which is accomplished by forward-biasing the multijunction cell. If each junction of a two-terminal device has about the same V_{OC}, then the cell should be forward-biased to half the V_{OC} of the tandem cell. In practice, the V_{OC} of the individual junctions is not well known; therefore, the forward-bias voltage must be adjusted to maximize the $S(\lambda)$ of the cell being measured and to minimize the $S(\lambda)$ of the other junctions. In practice, for an unknown multijunction device the procedure of increasing the bias light intensity and adjusting the bias voltage to maximize $S(\lambda)$ of the cell being measured while minimizing $S(\lambda)$ of the other junctions is an iterative process.

16.4.1 Filter-based Systems

A filter-based spectral responsivity $S(\lambda)$ measurement system is characterized by shining broadband light through interference filters and directing the light to the device under test, as shown in Figure 16.9 [147]. The filter wheel can be rotated with stepping solenoids controlled by digital logic or stepper motors. The use of the shutter shown in Figure 16.9 is essential when using an AC voltmeter to measure the signal when no monochromatic light is incident on the sample; it is less important though when using a lock-in amplifier to measure the periodic monochromatic signal. The monochromatic beam power is measured with a pyroelectric radiometer and calibrated Si detector. The reference detector can measure the power real time or the power versus wavelength data can be stored in a file. The advantage of real-time calibrations is that intensity fluctuations in the monochromatic beam can be corrected. The advantage of a stored calibration file is that the measured power is much higher, minimizing sensitivity to background light, and polarization effects associated with a beam splitter are not present.

It is often desirable to measure $S(\lambda)$ of modules consisting of multiple cells in series. The simplest approach would be to illuminate the whole module with AC monochromatic and AC broadband light with the module at 0 V, just as in the case of cells. Because of their high monochromatic light power density and large-beam area, filter-based $S(\lambda)$ systems are capable of fully illuminating any commercial module. The problem with this method is that different cells may be current limiting at various wavelengths, and the bias point of the current-limiting cell whose $S(\lambda)$ is being measured is not at 0 V. This problem is solved by voltage biasing, similar to the multijunction $S(\lambda)$ measurements [104, 154]. Figure 16.10 illustrates the geometry for measuring the spectral responsivity of an individual cell in a packaged module in which the individual cells are inaccessible.