Table 16.9 Spectral responsivity error sources related to the monochromatic light

I.	Bandwidth, filter defects, polarization variation with wavelength
II.	Wavelength offset, wavelength error, wavelength variation with room temperature
III.	Beam wanders with wavelength
IV.	Beam larger than the test device
	A. Detector area versus PV area, position of detector and PV different, spatial uniformity of beam
V.	Beam smaller than detector and device area
	A. Partially shaded regions, spatial variation in responsivity of PV

16.5 MODULE QUALIFICATION AND CERTIFICATION

PV modules are designed to last 20 years or more in the field with no maintenance. Modules are designed to withstand daily thermal cycling, hail, wind, sand and storms, along with prolonged exposure to UV light. For safety reasons, PV cells and wiring must be isolated from the frame, edges, or module surface to prevent a hazardous electrical potential from forming. To verify that a particular product is reliable, domestic and international consensus standards have been developed for the design qualification and type approval of terrestrial crystalline silicon and thin-film modules [159–162].

Ideally, modules should be subjected to long-term exposure under natural conditions. Flat-plate silicon PV modules had poor reliability in the first years of development. An extensive program was conducted in the late 1970s and early 1980s by the JPL for the US government in an effort to improve the reliability of PV modules [163]. The 13 principal flat-plate module degradation mechanisms are open-circuited cell regions, shorted cells, open-circuited interconnects, gradual cell power degradation, optical degradation of the module package, front-surface soiling, glass breakage, open circuits in the module wiring, hot-spot failures of cells in a module, shorted bypass diodes, shorts to the frame or ground, delamination of the module encapsulant, and life-limiting wear out [163].

Accelerated testing procedures have been developed to simulate 20 or more years of exposure in the field and to identify the major failure mechanisms. Accelerated tests have been developed by various governmental organizations such as ASTM [161] or the Commission of European Communities [162, 164–166]. The tests described are from the International Electrotechnical Commission, the international standards organization relevant for photovoltaics [159, 163]. These tests include safety tests, mechanical integrity tests, and thermal cycling. The thermal-cycle test determines the ability of a module to withstand thermal expansion coefficient mismatch, fatigue, and other stresses caused by repeated changes in temperature, and it includes 200 thermal cycles from -40°C to $+85^{\circ}$C. The damp-heat test, designed to determine the module's ability to withstand the effects of long-term exposure to moisture in high-humidity environments, consists of 1000 h at 85% relative humidity at 85°C. The humidity-freeze test determines the ability of the module to withstand the effects of high temperature and humidity followed by subzero temperatures, and it consists of 10 cycles from 85% relative humidity and 85°C to -40°C. This is not a thermal-shock test because the maximum change in temperature with time above freezing temperatures is $100^{\circ}\text{C h}^{-1}$. This humidity-freeze test reveals the detrimental accumulation of liquid water inside the module under high-humidity