# know your response

Using the substitution method with a monitor detector will improve the accuracy of absolute spectral power responsivity measurements.

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Many applications require the determination of the absolute spectral power responsivity of photodetectors. The absolute spectral power responsivity is the ratio of the output of a photodetector (in amperes or volts) to the spectral radiant flux (in watts) input to the photodetector.

Using monochromatic radiation, we can use the substitution method to determine the responsivity of a photodetector via the following equation:[1]

$$S_x = \frac{Y_x}{Y_s} \cdot S_s \qquad (1)$$

where $S_x$ is the detector responsivity, $Y_x$ is the signal from the detector under test, $Y_s$ is the signal from the standard detector, and $S_s$ is the responsivity of the standard. To perform the measurement, we need a broadband source, a monochromator, focusing optics, and a standard detector. The radiant flux $\Phi$ is the output flux from the source that enters the monochromator. The spectral radiant flux $\Phi_\lambda$ is the output flux from the monochromator and $\tau_\lambda$ is the transmittance of the optical components (and atmosphere) between the monochromator and the detector. The spectral radiant flux received by the detectors ($\Phi^D{}_\lambda$) is given by

$$\Phi^D{}_\lambda = \tau_\lambda \cdot \Phi_\lambda \qquad (2).$$

As the name suggests, in the substitution method we measure spectral radiant flux for the standard detector and for the detector under test and use equation (1) to calculate the result.

To determine spectral power responsivity, the flux must underfill the detectors. It is critical to use the same geometry to illuminate both detectors. Often an aperture is used to limit the active area of the detector; otherwise the measurements can be affected by possible nonuniformities in the responsivity of the photodiodes. Polarization sensitivity of the detectors, windows, or filters can introduce errors caused by inter-reflections, especially with coherent sources.

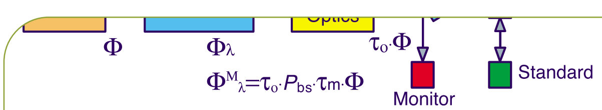
Equation (2) assumes the source is stable over the comparison time. This is not necessarily true for arc sources used in the UV. To eliminate the effect of power fluctuations, we use a beamsplitter to divert part of the beam to a monitor detector (see figure). Here $\tau_\lambda$ is replaced by $\tau_o$, which represents the transmittance of the optics and atmosphere between the monochromator and the beam splitter; $\tau_{bs}$ and $\rho_{bs}$, which represent the transmittance and reflectance of the beamsplitter, respectively; and $\tau_d$ and $\tau_m$, which represent the transmittance of the atmosphere between the beamsplitter and the detectors or the beamsplitter and the monitor, respectively. Thus,

$$\Phi^D{}_\lambda = \tau_o \tau_{bs} \tau_d \Phi_\lambda \qquad (3)$$

is the flux received by the detectors and

$$\Phi^M{}_\lambda = \tau_o \rho_{bs} \tau_m \Phi_\lambda \qquad (4)$$

is the flux received by the monitor. If we arrange the detectors and monitor so the optical path length from the beamsplitter is the same, the transmittance of the atmosphere, $\tau_d$ and $\tau_m$, can be considered equal. We assume the monitor detector and beamsplitter to be stable over the measurement time. The monitor records the source power fluctuations, and the ratio of detector to monitor signals will be free from source instabilities.




The substitution method with monitor photodiodes provides a simple approach to measuring absolute spectral power responsivity of photodetectors.

To calculate responsivity, we simply replace the signal terms, $Y_x$ and $Y_s$, in equation (1) with our signal-to-monitor ratio terms for both the detector and the standard. We see that the signal from the monitor cancels out variations or drifts in the source flux or system transmittance during the time that elapses between measuring the detector and the standard. Also, because of this cancellation, the monitor does not need to be calibrated. To take full advantage of this method, it is necessary to simultaneously measure the detector (or standard) and the monitor (e.g., two amplifiers and digital voltmeters).

The present spectral range for routine photodetector absolute spectral power responsivity measurements is from 200 nm to 1800 nm. Accuracy data is available at the website below. **oe**

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*Reference: 1. T. Larason, S. Bruce, and A. Parr, NIST Spec. Publ. 250-41, p. 13 (1998)*

For more information on NIST Spectroradiometric Detector Measurement Services, visit physics.nist.gov/photodiode.