LINEARITY NOTES FOR CIE TC2-29

A VARIANT ON SUPERPOSITION

An interesting variant on the superposition method was first described by Paul H. Wendland (founder of UDT) in Laser Focus in October 1973. It appeared in the column "Focus on Techniques" and was titled "Characterizing a laser receiver." In the short note, he discusses linearity measurements along with NEP and spectral responsivity.

I have labeled this technique the AC/DC method, and this was picked up by Mike Lind when he was at NBS. The device under test is subjected to two sources. The first is unmodulated and may be adjusted over a wide range of irradiances. The second is modulated, from which the rms irradiance is held at a very low and constant level. The output of the device under test is monitored with an AC-coupled instrument, insensitive to the DC output generated by the unmodulated source. The output is then ΔI (orΔV) when subjected to the modulated irradiance change ΔE, and is thus proportional to responsivity. If this output is constant when the unmodulated irradiance is varied, the device is linear. A decrease in ΔI (or ΔV) at higher levels indicates the onset of saturation. Jon Geist has recently submitted this method to a full mathematical analysis.

This method is very easy to set up and can determine dynamic range very rapidly over many decades. Either source spectral distribution can be set to narrow band (laser, LED, bandpass filter) or broadband. If the AC instrument is a lock-in amplifier synchronized to the modulated source, a dynamic range of at least 6 decades is feasible. We use this method in our teaching labs to demonstrate both the technique and the dynamic range of silicon photodiodes.

I believe that this is functionally the same as the differential spectral responsivity method described by J. Metzdorf in Appl. Opt. 26, 1701 (1987), Metrologia, 28, 247 (1991), and others. By the way, was there ever a sequel to the Applied Optics paper? I first applied a fixed optical bias to the measurement of spectral responsivity of photovoltaic detectors in about 1962, when my colleagues and I stumbled upon the phenomena that Metzdorf calls photoaugmentation. From that time, these measurements have been done in the presence of a white-light bias source, as described in ASTM E1021.

QUICK CHECK

A simple check can be made to determine if a detector or radiometer is saturated. Place a transparent (e.g. glass) plate in front of the device and see if the output is diminished. The drop should be on the order of 8% for a glass plate (e.g., a microscope slide). The transmittance (in the absence of interference effects) of a plane parallel plate, including inter-reflections, is

$$T = \frac{(1-\rho)^2 e^{-\alpha t}}{1-\rho^2 e^{-2\alpha t}}$$

where α is an absorption coefficient, t is the thickness and ρ is the reflectance for a single surface. For a non-absorbing material, the reflectance ρ of a single surface at normal incidence is related to the index of refraction as:

$$\rho = \left[\frac{n-1}{n+1}\right]^2$$

where n is the real part of the refractive index. If α is zero, this reduces to

$$T = \frac{2n}{n^2+1} \quad for\ \alpha = 0$$

For example, if the plate is fabricated from typical borosilicate glass like NATO 517642 (n = 1.517), then the transmittance is 0.919. Note that this technique works only in incoherent beams (not suitable for lasers because of interference effects) and also requires that the surfaces be clean, i.e., free of oils or other materials that may act as anti-reflection (anti-blooming) coatings.

OTHER COMMENTS ON SECOND DRAFT

2.6 It seems to me that r_c is often a function of Z; thus, in general, the equation following note 2 is not valid. I strongly agree with a previous comment that r_c(Z) is appropriate.

3.2.1 & 3.2.2 I believe that Bouguer's law is one form of the exponential absorption law, dealing with different thickness of a substance with a fixed absorption coefficient. It certainly has nothing to do with the inverse square law. Beer's law is another form of the exponential absorption law, dealing with different concentrations of a substance with a fixed thickness.

3.2.1 It should be mentioned how inter-reflections can be avoided. The usual technique is to tilt the filters with respect to each other. A procedure to determine just how much tilt is required would be useful.

3.4 The range of levels that can be covered using the inverse square law can be extended via the insertion of selected ND filters. If sufficient overlap is allowed, the exact density of the filter is not needed. This is a useful way to characterize ND filters as well..

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