OPTRONIC™
LABORATORIES

UNCERTAINTY BUDGET CALCULATIONS USING OPTRONIC LABORATORIES'S STANDARDS

It should be noted that uncertainty is a property of a measurement, not a device or piece of equipment. However, to evaluate uncertainty in measurements you must know the uncertainty contribution from standards and equipment. This short paper is aimed at helping you evaluate those contributions and combine them correctly.

The total uncertainty can be worked out from an uncertainty budget. This includes a list of all uncertainty contributions with their values. If we have values of contributions u_1, u_2, $\ldots u_i$, the total uncertainty in the measurement is calculated by:

$$u_{total} = \sqrt{(u_1)^2 + (u_2)^2 + \ldots + (u_i)^2}$$

To be combined, all uncertainties should be expressed in terms of the result, e.g. irradiance, radiance, etc. To convert uncertainties in distance *(or any other parameter)* into result uncertainties, the sensitivity coefficient needs to be known. The sensitivity coefficient is simply how fast the result changes with the particular parameter[i].

It is also important to combine only uncertainties of the same type. Uncertainties are often expressed in the units of the result or as a percentage of the result. The former is absolute and the latter is relative. ***DO NOT MIX ABSOLUTE AND RELATIVE UNCERTAINTIES WHEN COMBINING***[ii].

Optronic Laboratories provide values of uncertainty for the NIST standard and for transfer from the NIST standard. These are relative uncertainties provided at k=2[iii] and can be combined. Sometimes sensitivity values are also given, e.g. changes in lamp values with current supply or wavelength. Multiply these sensitivity figures by uncertainties appropriate to the actual equipment used to give the uncertainty component to be combined.

There are many sources of uncertainty, e.g. instrument repeatability, that are best determined by performing multiple measurements and calculating standard deviations. It is important to include such sources in the overall uncertainty budget.

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[i] *If there is a fixed formula relationship then it can be calculated. For example, irradiance (E) is related to intensity (I) by* $E = \frac{I}{d^2}$ *hence the differential* $\frac{\partial E}{\partial d} = \frac{-2I}{d^3}$ *is the sensitivity coefficient for the distance (d) component. If the sensitivity coefficient cannot be determined analytically, it is usually obtained experimentally or using numerical methods.*

[ii] *The general rule is: when the result is an addition or subtraction, combine absolute un certainties; when the result is a multiplication or division, combine relative uncertainties.*

[iii] *k is the coverage factor. k=2 is equivalent to 2 standard deviations or 95% confidence interval.*

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