# EXTENSION OF THE NIST TRISTIMULUS COLORIMETER FOR SOLID-STATE LIGHT SOURCE MEASUREMENTS

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The colorimetric calibration of the NIST tristimulus colorimeter is based on the spectral responsivity determination of the colorimeter channels against detector responsivity standards. Since the spectral responsivity of the realized channels is slightly different than the CIE standardized color matching functions, the realized spectral responsivities are to be measured. Low-uncertainty spectral responsivity measurements made it possible to apply spectral mismatch and amplitude corrections to decrease color measurement errors due to the non-perfect channel realizations. The corrections are included in the broad-band channel calibration factors which are the ratios of the CIE tristimulus values to the output currents of the realized channels for a given (reference) source distribution. The corrections are accurate only if the test source distribution is equal (or very similar) to the chosen reference source distribution. It is difficult to achieve this requirement for solid-state light sources where the unknown spectral power distribution can be very different than the reference source distribution used in the calibration equations of the channels.

In order to measure special test sources (like LEDs) with low color measurement uncertainty, the realized spectral-mismatch of the channels (to the CIE standard functions) are corrected using an additional (fifth) channel added to the colorimeter. The spectral responsivity function of this channel is realized such that the missing or excess responsivity components in the original channels (where the spectral match can be poor) can be corrected for different test-source distributions using the matrix transform of the signals of the five channels as instrumental color matching functions. The selectable test source distributions are different temperature tungsten lamps, blue, red, green, and white LEDs, and their mix. Using an A/D converter, the analog output voltages of the channels are converted into digital numbers that can be corrected by a software matrix (that can be switched on and off) and then multiplied by the channel calibration factors. When the matrix is on, the color correction factors in the channel calibration factors are changed to unity and the matrix will perform the spectral mismatch corrections for both the test source(s) and the realized spectral responsivities of the channels.

The chromaticity coordinates of the different test sources obtained by switching the matrix on and off in two consecutive measurements are compared and evaluated. Since the matrix includes the correction of the Y channel as well, the correct illuminance produced by a special test source can also be obtained as the product of the matrix corrected Y-channel output and the Y-channel calibration factor including the unity color-correction-factor. An uncertainty of 0.0004 ($k$=2) can be obtained in the $x$, $y$ chromaticity coordinates when measuring a CIE Illuminant A source (without the matrix correction) if the four channels of the colorimeter were calibrated with a 0.15 % ($k$=2) responsivity uncertainty. The chromaticity uncertainties of blue and red LED tristimulus measurements can be orders of magnitude higher. The described matrix correction combined with the spectral responsivity based tristimulus colorimeter calibration promises an optimum solution for fast and low-uncertainty color measurements of solid-state light sources.