Application Note #11

The effects of a 10 nm bandwidth on data derived from spectrophotometer measurements

1. Introduction

Spectrophotometers are ubiquitous in the printing and color management field. The resolution with which a spectrophotometer provides data is the result of a compromise between accuracy and cost. For many years we have seen reasonably priced instruments capable of providing spectral data in increments of 10 nm (which should, in theory, correspond to the bandwidth of the instrument). While instruments with 5 nm bandwidth have also been available, their cost was always significantly higher, by a factor of at least 5X, and usually more. This cost difference and the small perceived incremental gain in precision are the main reasons why these instruments are not so common.

Yet, many international standards and measurement methods are designed to be performed with 5 nm bandwidth instruments. If you intend to be "in compliance" with a standard, you must follow its procedures with diligence and use only equipment with the prescribed characteristics. However, as just mentioned, this kind of equipment is expensive, even if just renting, and consultants who can come in and do it for you are not cheap either. This is why many of you are looking at doing these measurements with their available equipment, with the hope of being as close as possible to compliance.

In this application note, we look at the **ISO 23603 / CIE S 012** standard used to assess the spectral quality of daylight simulators by computing a Metameric Index (MI) and a Quality Grade, and the **TM-30-15** method, published by the Illuminating Engineering Society (IES, http://www.ies.org/), which was defined to evaluate the color rendition of light source. The ISO 23603 standard is referred to by ISO 3664 which is commonly used to assess the quality of viewing booths. The TM-30-15 method is proposed as a replacement for the venerable but obsolete Color Rendering Index (CRI, CIE 13.3: 1995).

We will specifically evaluate the effect of 10 nm data on the ISO 23603 MI value, which is itself an average of the error of five sample pairs, and on the *Rf* (Fidelity Index) and *Rg* (Gamut Index) of the TM-30-15 method.

The ISO 23603 MI and TM-30-15 indices can be obtained with the Color Translator & Analyzer (CT&A) software. You will find more technical info in the CT&A Help manual which is freely available on the BabelColor Web site (http://www.babelcolor.com).

In CT&A, MI and TM-30-15 computation can be done from i1Pro measurements and from files with spectral data. The TM-30-15 tool accepts files with one or more spectrums, and the files can contain data with 5 nm or 10 nm increments. The MI computation is part of the ISO3664+ tools; these tools can open a file with a single 10 nm spectrum only (as of Version 5.0). In both cases, the 10 nm data in converted to 5 nm with Lagrange interpolation for internal processing.

Please note that we do NOT look at how the precision of the measuring instrument can influence the measurement, but you should always consider your instrument accuracy when using the numbers it provides!

The intent of this document is to give its reader a realistic numerical estimate of the effect of using 10 nm data instead of 5 nm data when measuring the ISO 23603 MI and the TM-30-15 *Rf* and *Rg* indices.

2. Light sources selection and data processing

2.1 Sources selection

We have selected thirty (30) light sources with Correlated Color Temperatures (CCTs) around 5000 K, with CCT values ranging between 4747 K and 5364 K. Twenty-eight (28) of the Spectral Power Density curves came from the spreadsheets used to develop the CQS, CRI2012, and TM-30-15 metrics. They are a mix of commercial, theoretical and experimental sources. The last two are measurements of fluorescent tubes obtained from a customer. The selection is representative of the light sources available nowadays, with some spectrums showing narrow spectral peaks while others being smooth over the complete spectral range.

The same sources were used for the ISO 23603 MI and the TM-30-15 indices.

2.2 Clipping computation to 730 nm

The sources data is defined between 380 nm and 780 nm in 5 nm increments; this is the range prescribed in ISO 23603 for the computation of the visible MI and in the TM-3015 method as well. However, because the i1Pro data is provided only up to 730 nm, we had to check if clipping the computation to 730 nm affected the results. For the TM-30-15 method, clipping the computation to 730 nm for the thirty light sources resulted in a Root-Mean-Square (RMS) error of 0,0066 for *Rf* and 0,0025 for *Rg*, which is insignificant considering that the indices are presented as integers. We have seen similarly negligible effect when computing the error for all the reference sources (over 300) used in the TM-30-15 development.

For the ISO 23603 MI, clipping the computation to 730 nm for the thirty light sources resulted in an even lower RMS error of 0,0015 for the MI value.

2.3 Validating the 5nm CT&A TM-30-15 computation

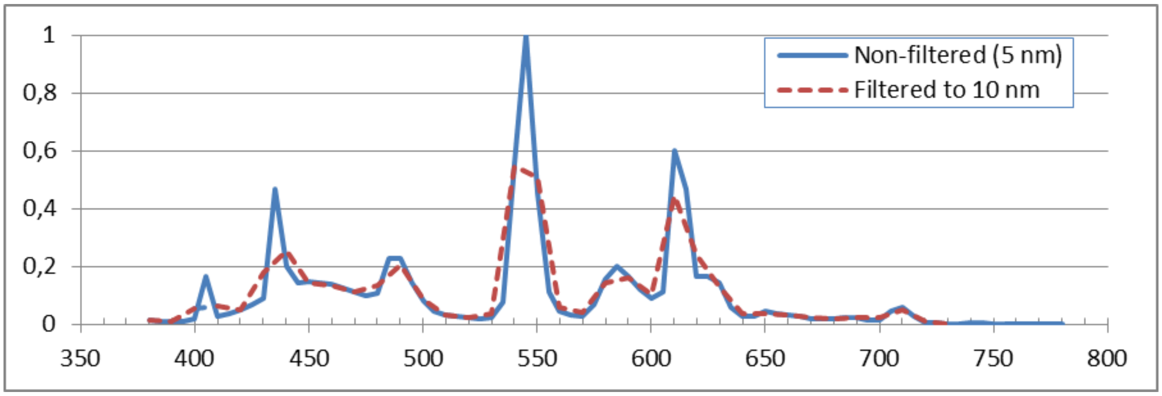
Since the CRI tools in CT&A (see Note below) can accept files with 5 nm bandwidth data, we saw the opportunity to validate the CT&A computation against the TM-30-15 method spreadsheet and thus confirm that we could use either one interchangeably. Since we round the TM-30-15 indices to 1 decimal (Y.Y) when exporting the data in CT&A, which we compare to the non-rounded references (i.e. numbers with multiple decimals, Y.YYYYY) of the TM-30-15 spreadsheet, we expect errors due to rounding around 0.1/2=0.05.

For the thirty light sources, the RMS error is 0,031for *Rf* and 0,046 for *Rg*, just below the expected values. Please note that these errors include the effect of **clipping computation** to 730 nm in CT&A as mentioned in Section 2.2. Again, since these indices are usually presented as integers, the difference is not noticeable.

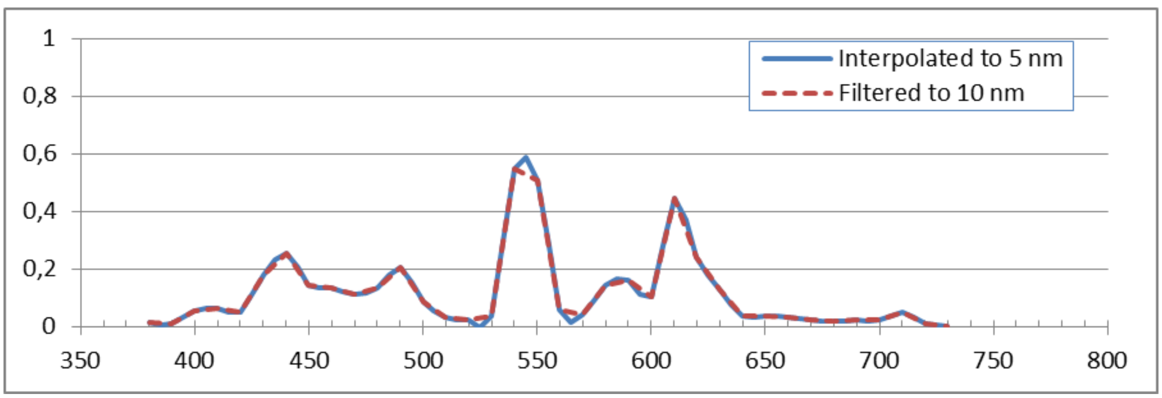
Note: The CT&A CRI tools also support the CQS, the CRI2012, and the original CIE CRI metrics.

2.4 Processing the 5nm reference sources

The purpose of this study is to compare the results obtained with 5 nm bandwidth measurements against 10 nm bandwidth measurements. In order to simulate the 10 nm measurements, we filtered the reference sources with a triangular function. For a description of this filtering method, see Annex "G" of "CGATS.5-2003 Supplement 1 – 2005" which presents procedures for widening the bandwidth of narrow bandpass instruments. Such procedures are usually done to widen very narrow bandwidths, say 1 nm or 2 nm, to larger bandwidths (5, 10, or 20 nm for instance). Here we use the procedures to enlarge the 5 nm bandwidth by a factor of two. The graph below shows how this filtering affects the spectrum of the CIE F10 source. You will also note that we clipped the filtered spectrum at 730 nm.



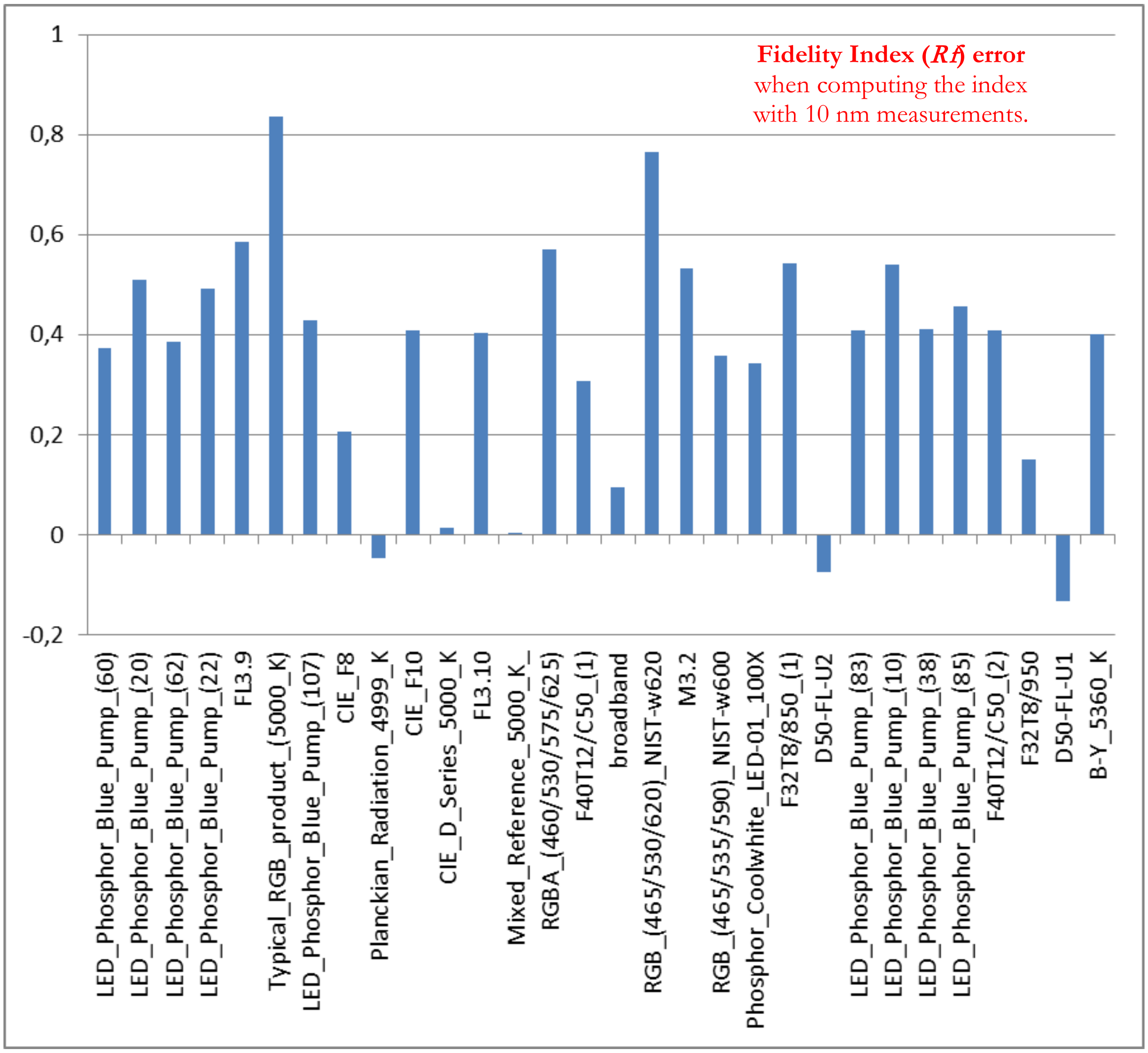
The 10 nm bandwidth filtered data shown above in red represents the measurements from an instrument with a 10 nm bandwidth. When such data is inputted in CT&A, the first processing step is interpolating the data to 5 nm so that it can be processed according to the respective requirements of ISO 23603 and TM-30-15. Unfortunately, filtering a spectrum cannot be done without losing information, whether this is done mathematically or by the physical limitations of an instrument, and no kind of interpolation will ever give us back what we would have measured with a 5 nm bandwidth instrument. The interpolated spectrum is shown below. The improvement may not look impressive but the result is measurably better than if we used linear interpolation.



3. Effect on TM-30-15 measurements

3.1 Fidelity Index (*Rf*)

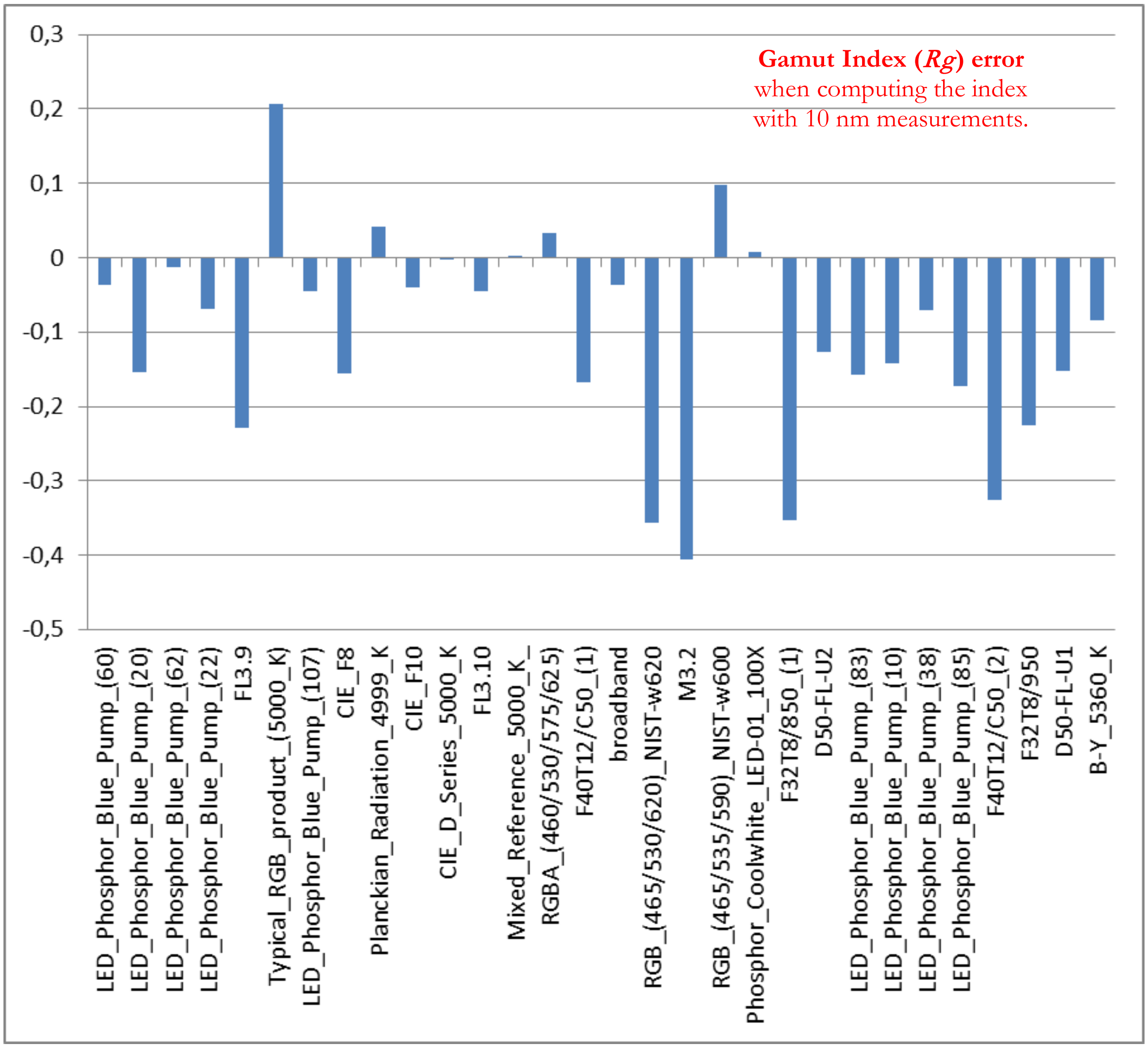
The difference in the *Rf* value obtained with the 5 nm spectrums and the interpolated 10 nm spectrums is shown below for all the sources we tested. We see that using the 10 nm data slightly increases the *Rf* value; the RMS error/increase is 0.43. For example, instead of computing an *Rf* value of 74.1, we would get 74.53. In practice this means that using 10 nm data will sometimes round the Fidelity Index to the next integer, a small effect. When the impact on the index is negative, in three of the cases, our results show an even smaller effect.



Please note that the sources are presented from the lowest CCT, on the left, to the highest CCT, on the right.

3.2 Gamut Index (*Rg*)

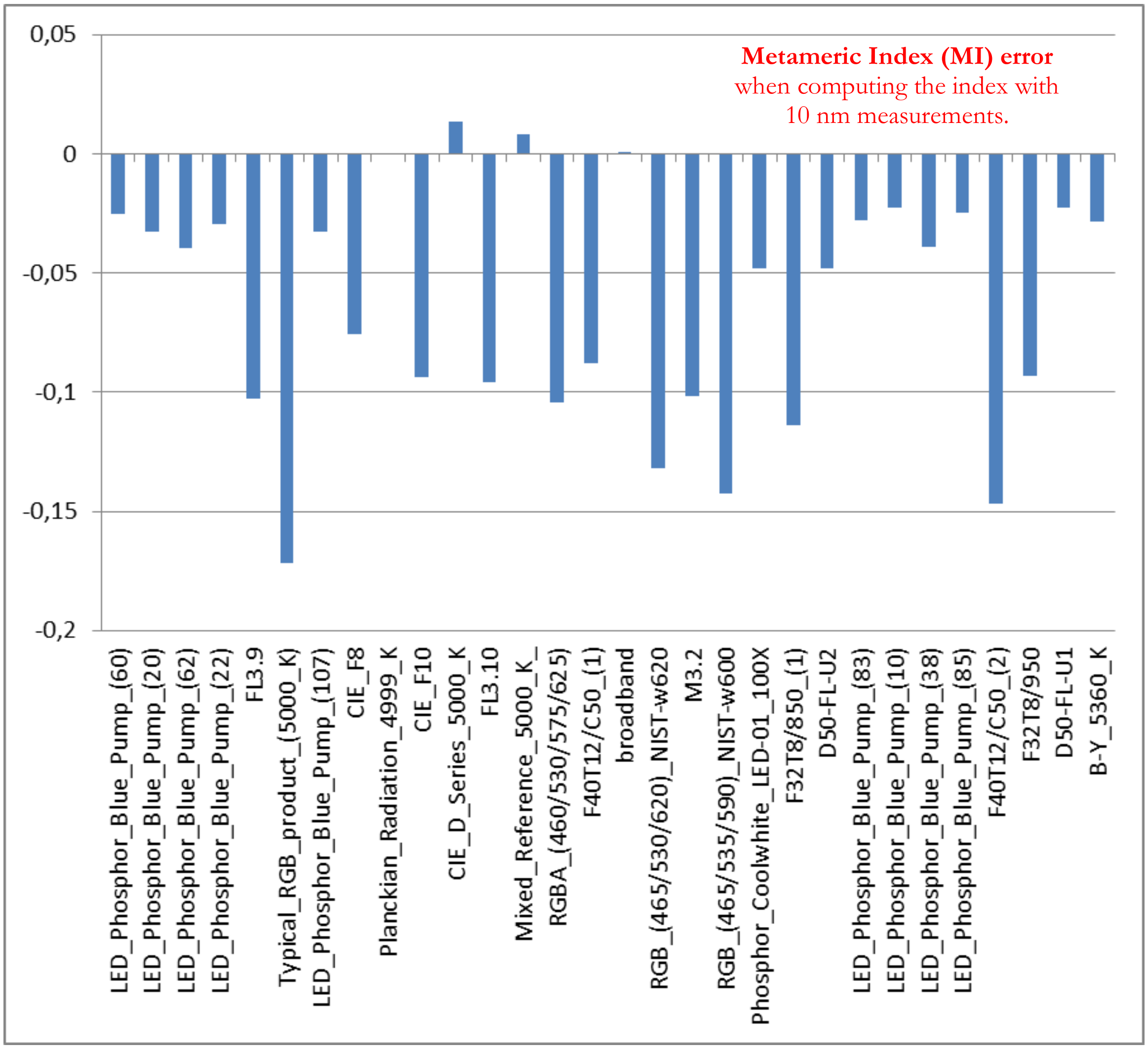
The difference in the *Rg* value obtained with the 5 nm spectrums and the interpolated 10 nm spectrums is shown below for all the sources we tested. We see that using the 10 nm data slightly decreases the *Rg* value on average; the RMS error/decrease is 0.17. When the impact on the index is positive, in six of the cases, our results show a generally smaller effect. Because this index is generally rounded to an integer, the decrease will most often not affect the displayed value.



4. Effect on ISO 23603 MI measurements

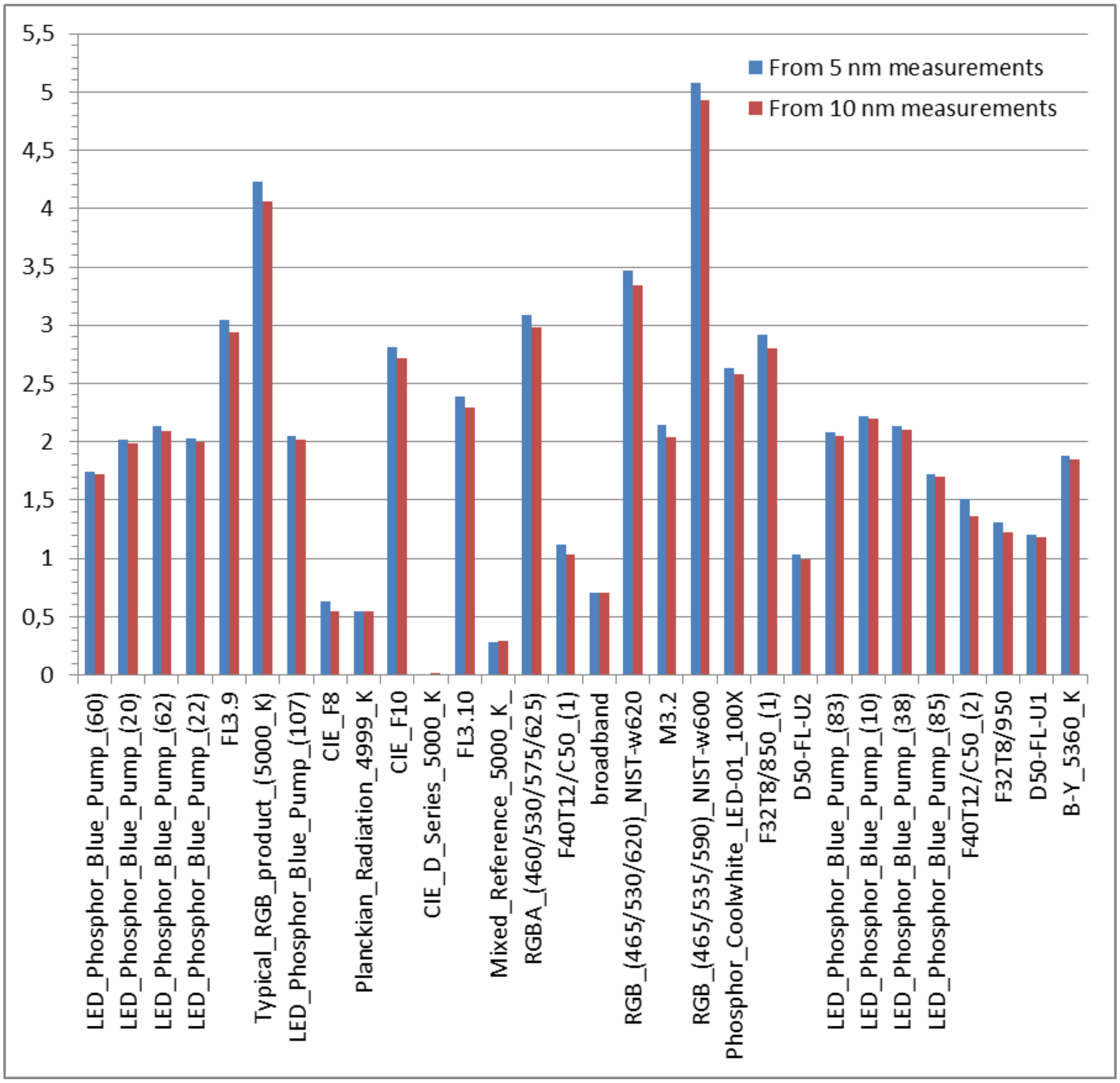
4.1 MI effect

The difference in the MI value obtained with the 5 nm spectrums and the interpolated 10 nm spectrums is shown below for all the sources we tested. We see that using the 10 nm data slightly decreases, and therefore artificially improves, the MI value, which is the average error of five sample pairs, by a small amount. The RMS error, an improvement in most cases, is 0.08 (the simple average error is -0.06). For example, if we obtained 1.02 from 10 nm measurements, one would be tempted to round the result to 1.0 and thus obtain a just-passing "C" grade. However, since, on average, we should add 0.08 to get the "real" 5 nm result (i.e. 1.10), we have in fact a very high quality "D" grade, but not a "C"! This impact on the Quality Grade is better shown on the graph on the next page.



4.2 Quality Grade effect

In the graph below we see, in blue, the actual MI value for each source as obtained with the 5 nm measurements, and the corresponding 10 nm measurements in red. The general decrease in MI, 0.08 on average, is quite clear and we can better assess where we will be faced with judgement calls, that is, where the computed MI is close to a Quality Grade level change (i.e. at MI = 0.25, 0.50, 1.00, and 2.00).



5. Conclusion

The purpose of this short application note is to provide an estimate of the bias introduced by 10 nm measurements in the values computed for the ISO 23603 MI and the TM-30-15 Fidelity and Gamut indices.

We used thirty reference spectrums defined at every 5 nm with CCTs between 4747 K and 5364 K. From these spectrums we derived 10 nm spectrums corresponding to measurements made with a 10 nm bandwidth instrument. We then computed the indices from the 5 nm and 10 nm bandwidths spectrums (It was mentioned that 10 nm measurements are interpolated to 5 nm when being processed). An analysis of the results brings the following observations.

By using 10 nm bandwidth data instead of 5 nm bandwidth data:

- The TM-30-15 Fidelity Index (*Rf*) is, on average (RMS error), overestimated by 0.43.
- The TM-30-15 Gamut Index (Rg) is, on average (RMS error), underestimated by 0.17.
- The ISO 23603 MI average error is, on average (RMS error), underestimated by 0.08.

These observations go against an often heard statement that if you get results which are just over a prescribed threshold with 10 nm instruments, "…your over-the-limit measurement is most likely a consequence of the instrument bandwidth; you should have used a 5 nm bandwidth instrument, and of course this is not a characteristic of the source being measured."

While recommending a 5 nm instrument is a sound advice, you may not obtain "more favorable" results just by using such an instrument. In fact, we have seen that the effect is, on average, just the opposite for these indices, with the 10 nm instruments slightly improving the apparent Fidelity Index (*Rf*) and slightly decreasing the MI, and thus improving the apparent Quality Grade.

And finally, as mentioned before, please use these numbers with caution since they do not convey the complete picture; one must also consider how the instrument accuracy influences a measurement.

The BabelColor Company

Founded in 2003, *The BabelColor Company* is dedicated to the development and sale of specialized color translation software and color tools. It also provides color consulting services for the professional and industrial markets.

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