

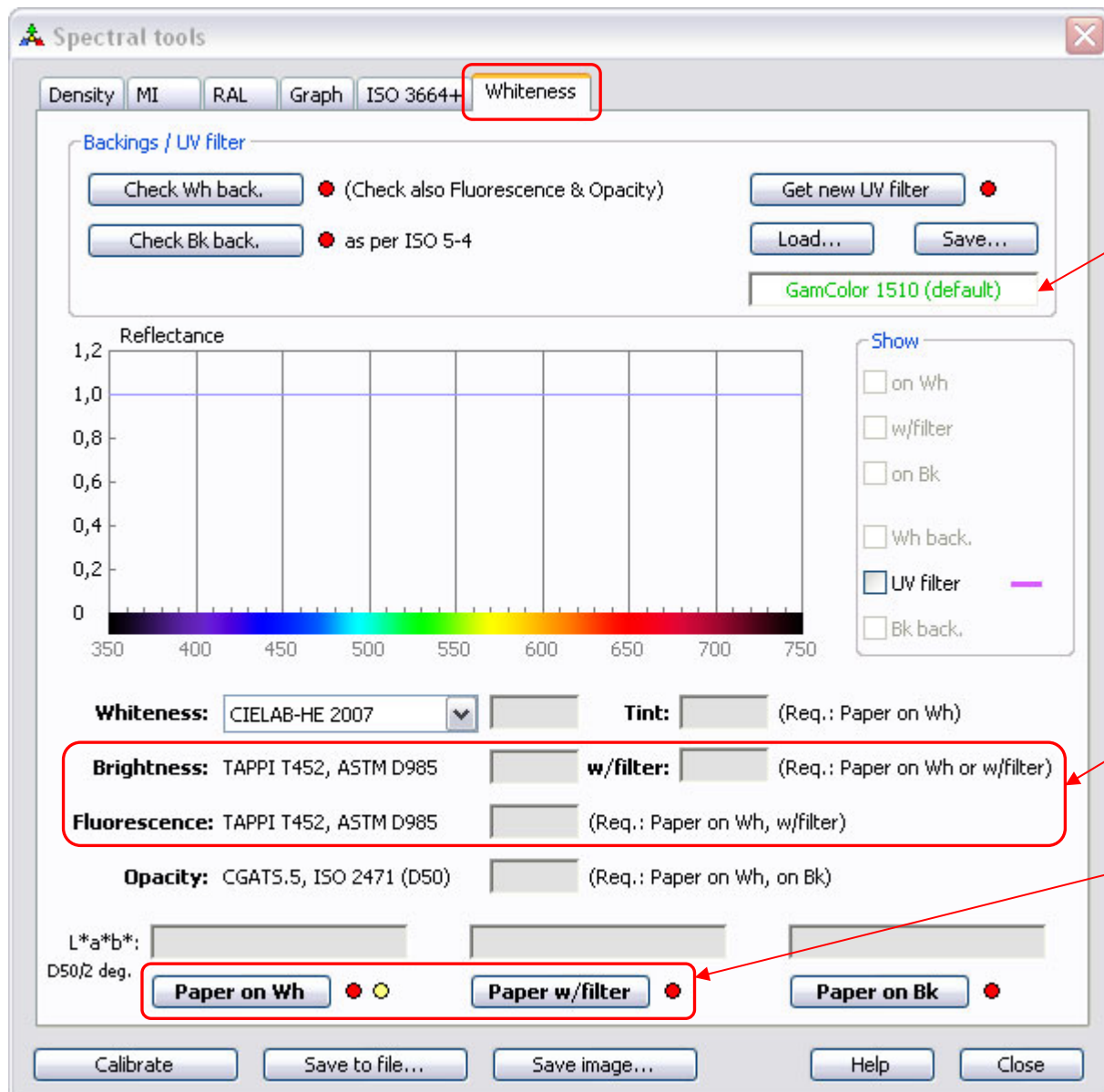


Application Note #8

How to optimize the accuracy of fluorescence measurements with BabelColor CT&A

1. Introduction

The BabelColor[®] CT&A software is dedicated to color translation and color analysis. When used in conjunction with an i1 Pro (Eye-One[®] Pro), a spectrophotometer sold by X-Rite[®], BabelColor CT&A provides a set of specialized tools (densitometer, metamerism analyzer, etc.) which extract the full potential of the spectral data provided by this instrument. The tools regrouped in the “Whiteness” tab are dedicated to the measurement of four characteristics of printing paper: **Whiteness**, **Brightness**, **Fluorescence** and **Opacity**.



CT&A's Spectral tools

Characterize your UV filter for optimal results (i.e. replace the default data).

Measurements associated with fluorescence.

The two operations required to measure fluorescence.

In this application note we discuss the parameters which can influence fluorescence measurements, and we present a step-by-step procedure for optimal results. *Fluorescence* values are obtained by making two *Brightness* measurements. A first measurement is made directly on the paper, which is itself positioned on a reference white backing; the measurement is taken by clicking the “**Paper on Wh**” button, where “on Wh” is shorthand for “on White backing”. A second measurement is made with a UV-blocking filter placed between the paper and the measuring instrument; this time, the measurement is taken by clicking the “**Paper w/filter**” button.

The difference between the two *Brightness* measurements is the *Fluorescence*:

$$Fluorescence = Brightness_{\text{without a filter}} - Brightness_{\text{w/filter}}$$

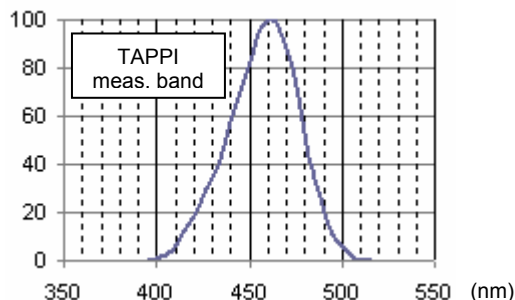
While they look simple at first sight, these measurements should be done with care and a few pitfalls need to be avoided if one is to obtain accurate and reproducible results. In particular, both measurements shall be done on a compliant white backing, where “compliant” means that it must be essentially neutral (i.e. grey), quite reflective but not too much (i.e. not 100% white), and not fluorescent. The backing and other aspects of the measurement are discussed in the next three sections; each of these sections highlights a potential problem and proposes a method to solve or identify the problem. The measurement procedure follows, in the last section.

We suggest you consult the CT&A Help manual for a description of the other Whiteness tools as well as the interface features.

2. Measuring the Brightness

There are many standard methods prescribed for *Brightness* measurements. Two of the most common ones are TAPPI T452 ¹ (or the equivalent ASTM D985 ²), and ISO 2470; these two standards have different requirements, and are not interchangeable. For instance, ISO 2470, dedicated to the measurement of blue reflectance (ISO brightness), requires a Diffuse illumination and a zero degree viewing geometry instrument which is different enough from the 45 degrees illumination and zero degree viewing geometry of the Eye-One, that this standard was not even considered for inclusion as a spectral tool in CT&A. On the other hand, the TAPPI T452/ASTM D985 standard was selected because the Eye-One Pro geometry is close to the TAPPI requirements and the Eye-One Pro lamp source is of the proper type (tungsten).

Another requirement of TAPPI T452 is that the measurement shall be limited to a blue wavelength band centered at about 457 nm, as shown below:



This band is simulated in software when you do a *Brightness* measurement in CT&A's Whiteness tools. Yet another requirement is access to a reference white; this is derived from the standard Eye-One calibration.

In the context of this standard, *Brightness* is thus associated with blue reflectance; this means that there is no direct comparison between this *Brightness* and the *Luminance* (i.e. the "Y" of XYZ) or the *Lightness* (i.e. the "L*" of L*a*b*). This band is also the cause of one of the pitfalls that we can get into. Because we only look at the blue portion of the spectrum, we are particularly sensitive to variations in lamp temperature. We are aware that increasing a lamp filament temperature will increase its *Correlated Color Temperature* (CCT) and shift its output towards the blue end of the spectrum; in other words, this will increase the amount of blue in relation to the other visible wavelengths. Because the Eye-One tungsten lamp has more yellowish content than bluish content by its nature, increasing its temperature will be more noticeable in the blue and UV end of the spectrum than in the red end. In practice, this means that if we make repetitive measurement at short time intervals, we heat the lamp filament and the lamp output shifts toward the blue, slightly increasing the measured *Brightness* each time we make a measurement. Please note that this effect may be more or less important in different versions of the Eye-One Pro.

Pitfall 1 – Making measurements too fast: To minimize the effect of lamp heating, wait at least 20 seconds, preferably 30 seconds, between each measurement.

Important: There are still sufficient differences between an Eye-One and an instrument designed expressly for the requirements of TAPPI T452 or ASTM D985, that you should not expect to match the results obtained with equipment fully qualified for the standard.

¹ TAPPI T452 om-08: "Brightness of pulp, paper, and paperboard (directional reflectance at 457 nm)," available from their Web site: <http://www.tappi.org> .

² ASTM D985-97 (Reapproved 2007): "Standard Test Method for Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm)," available from their Web site: <http://www.astm.org> .

3. The White Backing

Both brightness measurements required to evaluate the fluorescence need to be done with the paper placed on a compliant white backing. According to ISO 13655 ³:

- i- The backing shall be opaque, with a measured opacity of no less than 99%.
- ii- The backing surface shall be diffuse-reflecting, with no perceptible specular reflection when viewed at any angle under typical office room illumination.
- iii- The backing shall not be fluorescent when excited by the instrument source.
- iv- The Chroma (the C^* of $L^*C^*h^*$, D50, 2 degree Observer) shall not be more than 3,0 and should not exceed 2,4.
- v- The reflectance shall be equal or higher than the requirements at these eight (8) specific wavelengths (this corresponds to a CIELAB L^* value greater than 92; however, the CIELAB L^* value shall not exceed 97).

Wavelength	Rmin
400 nm	0,30
410 nm	0,30
420 nm	0,75
450 nm	0,75
460 nm	0,80
670 nm	0,80
680 nm	0,75
700 nm	0,75

These requirements are quite difficult to meet. This is why there is a dedicated tool to check the white backing compliance in CT&A's Whiteness tab. Of course, some of the requirements are more important than others, and their importance is modulated by the type of measurement we use the backing for. You should not be surprised if we mention that the lack of fluorescence for the backing is crucial if we want to do fluorescence measurements! Backing fluorescence affects us in two different ways when we measure the fluorescence of a paper:

- Because most papers are not totally opaque, a fluorescent backing will add its fluorescence to the paper fluorescence; a non-fluorescent paper may thus appear to contain Optical Brightening Agents (OBAs).
- Because a non-fluorescent backing is assumed when measuring the transmission characteristics of a UV filter (with the "Get new UV filter" button), the resulting UV filter characteristics will be wrong and all subsequent measurements derived from it will be inaccurate if the backing is fluorescent.

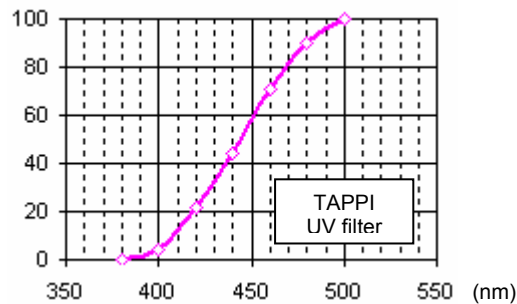
Pitfall 2 – Using a fluorescent backing: While it may seem impossible to be sure that a backing is not fluorescent using only the Eye-One and a UV-filter, there is an indirect way of checking this: Whenever you characterize your own filter **and** you obtain NEGATIVE fluorescent values, you can almost be certain that the backing used for characterizing the UV filter was fluorescent.

Important: You may be tempted to use a UV lamp to assess a paper's fluorescence. While this method is acceptable to judge if a paper has OBAs or not, it is not appropriate for evaluating the relative OBA's content between papers. The first reason is that the UV content of those lamps can be much higher than the UV content of most illumination conditions; you thus see a fluorescence effect which amplifies what would happen in real life. The second reason is that not all OBAs are created equal; the UV absorption may vary from one compound to the other. The third reason is that the UV content of a lamp may vary between brands, with different lamps of the same power exciting more or less a given OBA (i.e. converting more or less UV into visible light). Finally, the fluorescence measured according to TAPI T452 is based on the UV content of a tungsten lamp, which is representative of indoor illumination, and the results are applicable to this viewing context.

³ ISO 13655:2009: "Graphic technology — Spectral measurement and colorimetric computation for graphic arts images," available from their Web site: <http://www.iso.org> .

4. Characterizing the UV-blocking filter

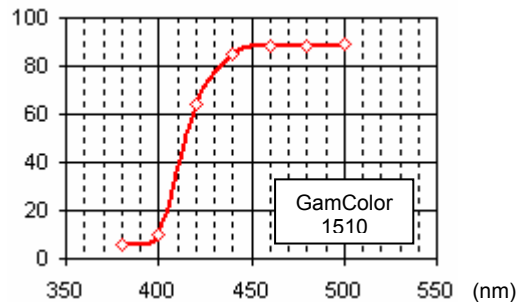
We saw in the preceding section that a non-fluorescent backing is crucial to proper characterization of the UV blocking filter; now, let's look at the filter characteristics. The idealized UV filter derived from TAPPI T452 is shown below:



This filter's curve was obtained by dividing the specified relative spectral energy distribution of the light incident on the paper with the UV filter present, by the specified relative spectral energy distribution without the filter. Please consult the CT&A Help manual for more information on the energy distributions values with and without the filter.

To our knowledge, a thin TAPPI T452 UV filter suitable for use under an Eye-One Pro cannot be found off-the-shelf. On the other hand, the two filters we recommend are readily available, and are equivalent to the **Wratten 2B** and the **FujiFilm SC-41** suggested in the ISO 13655 standard (see Ref. on previous page) for UV-cut and fluorescence measurements:

- **GamColor 1510** (<http://www.gamcolor.com>)
- **Rosco 3114** (<http://www.rosco.com>)



The GamColor 1510 and Rosco 3114 filters are flexible coated plastic sheets designed to remove UV emissions from lamps (fluorescent tube lamps in particular). The default values used in CT&A are those of the GamColor 1510. Data files for these filters as well as for the Wratten and FujiFilm filters can be found in the "UV-filters" folder located in the main CT&A application folder (In Windows, use the "Start menu/BabelColor/UV-filters file" shortcut). Still, we strongly recommend that you measure your own filter characteristics even if it is of the same brand (You will understand why below!). For purchasing information, please consult the companies' Web sites.

The four filters we just mentioned have a sharper cut-off slope than the filter required by the TAPPI T452 standard, and their 50% transmission point is at lower wavelengths, i.e. more towards the violet. However their sharp cut-off blocks the UV as efficiently.

While these filters effectively prevent UV radiation from reaching the paper, they are not “perfect”; they also attenuate the light across the spectrum, with a maximum transmission of about 90% in the case of the GamColor 1510, as we see on the previous page. We thus need to compensate for the filter’s presence between the paper and the Eye-One. We particularly need to compensate for the visible radiation which is blocked below 450 nm and which is not due to fluorescence. Expressed otherwise, we need to remove the UV that generates fluorescence without affecting the Eye-One response in the blue part of the spectrum where the fluorescent light is added to the normal paper reflectance! This is done automatically by the program for all measurements done with the **"Paper w/filter"** button (Note: This also means that a similar measurement done elsewhere, for example in the “Graph” tool, will NOT be compensated).

Important: Because the suggested UV filters have transmission characteristics which are not those specifically required by the standards, you should not expect to reproduce the results obtained with the prescribed filter. However, you will be able to reliably detect papers which are fluorescent and be able to grade their susceptibility to fluorescence.

While the recommended filters have suitable transmission characteristics for fluorescence measurements, we have found that they often exhibit non-uniform UV-blocking characteristics across their surface, even at locations just a few cm apart. The differences may not be obvious when visually comparing two UV curves but it does not take a large shift in the cut-off wavelength to have an impact on the fluorescence measurements. To be fair, these filter sheets were not all designed for scientific applications and are perfectly adequate for their intended use. However, by understanding and controlling their particularities, we can perform more accurate measurements.

Pitfall 3 – UV filter uniformity: Unless you verified that your UV filter has a uniform response across its surface, we recommend that you use a black permanent felt pen to draw the outline of a small zone, of about 10 mm in diameter (1/2 inch), on the filter’s surface. This zone shall be used to get the UV filter curve **and** make fluorescence measurements thereafter.



With a black felt pen, draw the outline of a zone of approximately 10 mm in diameter (1/2 inch) on the filter. Use this zone to characterize the filter and make measurements.

Important: In certain cases, negative fluorescence can be obtained if the current filter data does not correspond to the filter used for measurements. It is thus strongly recommended to characterize you filters and identify them for future use.

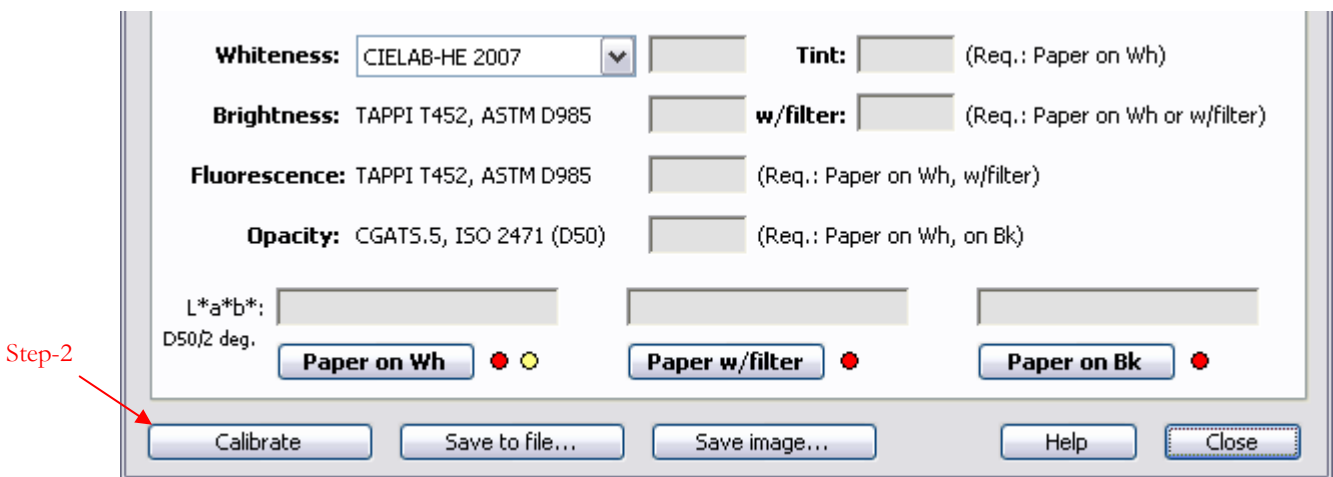
5. A Step-by-Step procedure for fluorescence measurements

Now that we have identified the pitfalls, we can do our fluorescence measurements without falling into them. To put all chances on your side, we recommend that you use the small plastic positioning guide provided with the Eye-One Pro, shown at right, to perform your measurements. Not only does it help in aligning the instrument on the zone we identified on the UV filter, but it also places the instrument at the optimum distance relative to the paper being measured (i.e. not in direct contact!).

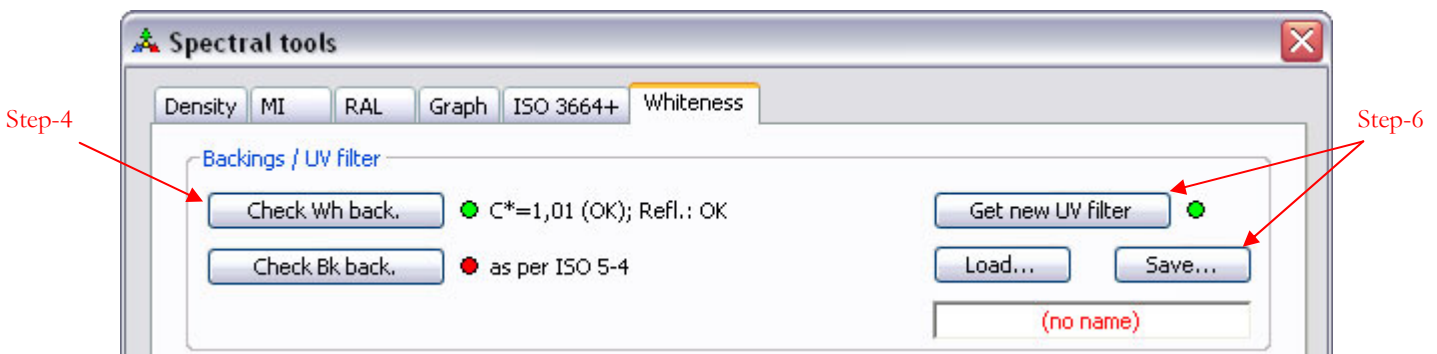


Steps 1 to 6 describe how to measure the UV filter characteristics. The fluorescence is measured in **Steps 7 to 11**.

- 1- Make a few measurements with the Eye-One, and then **wait 30 seconds** before doing the next step.
- 2- Make sure the “Whiteness” tab is selected in the “Spectral tools” window. Place the Eye-One on its base and calibrate it using the “**Calibrate**” button located in the bottom of the window.



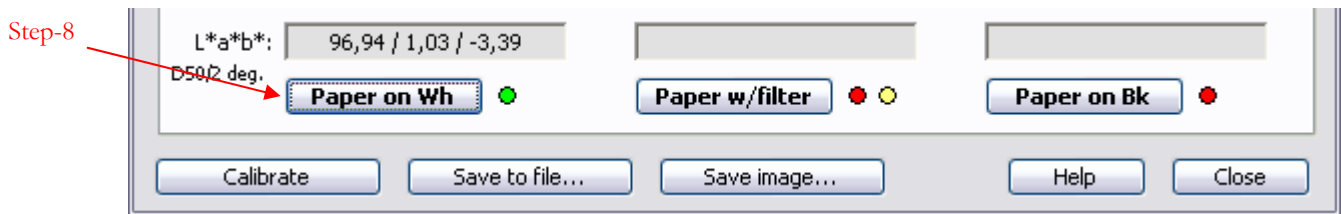
- 3- Wait 30 seconds.
- 4- Measure the white backing, with no filter or paper, using the “**Check Wh back**” button. This is always required **before** measuring the UV filter (in **Step-6**).



- 5- Wait 30 seconds.
- 6- Place the UV filter on the white backing and measure the UV filter using the “**Get new UV filter**” button. Make sure you position the Eye-One within the zone identified by a felt pen on the filter. You may want to save the filter using the “**Save...**” button.

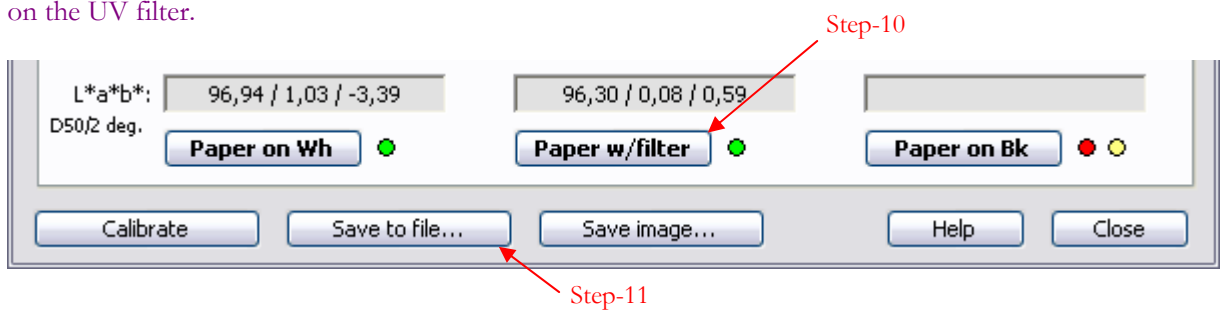
7- Wait 30 seconds.

8- Place the paper on the white backing and measure the brightness, without the filter, using the “**Paper on Wh**” button. You should circle the area on the paper where you made your measurement with a lead pencil, in order to use the same location in **Step-10**.



9- Wait 30 seconds.

10- Place the UV filter between the paper and the Eye-One and measure the brightness with the filter using the “**Paper w/filter**” button. Make sure you do your measurement within the 10 mm zone you delimited on the UV filter.



11- Save the results using the “**Save to file...**” button.

12- Redo **Step-2 to Step-11** two other times (or more) and compute the average of all fluorescence measurements (Note: Making the average of multiple measurements will improve your result’s accuracy).

An alternate procedure is to characterize the UV filter once and for all (at least for the 10 mm zone delimited with a felt pen). To do so, again for better accuracy, we suggest making the average of multiple filter measurements; however, you may find that one measurement is accurate enough:

- i- First do **Step-1 to Step-6** three or four times, each time saving the filter under a different file name.
- ii- Using PatchTool, open each filter file and make an average using PatchTool’s Average tool (Note: A PatchTool license is required to access this tool). Export only the spectral data of the averaged file.
- iii- Load the averaged file in CT&A’s Whiteness tool using the “**Load...**” button.
- iv- From here, you can just do **Step-7 to Step-11** and repeat them as required.

And finally, when you compare your results with others, do not forget that:

- Average inter-instrument agreement for the Eye-One is 0,4 CIEDE94, with a maximum of 1,0 CIEDE94 (you can double these values if working with the CIELAB color difference formula).
- You should expect an accuracy of about $\pm 0,5$ Fluorescence units in your own measurements.
- Different batches of the same paper may exhibit different characteristics.
- Paper fluorescence will be affected more or less by exposure to light, depending on its intensity and duration, and by chemicals in the environment.

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.

info@BabelColor.com

<http://www.BabelColor.com>

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