Flourescent Database

Introduction

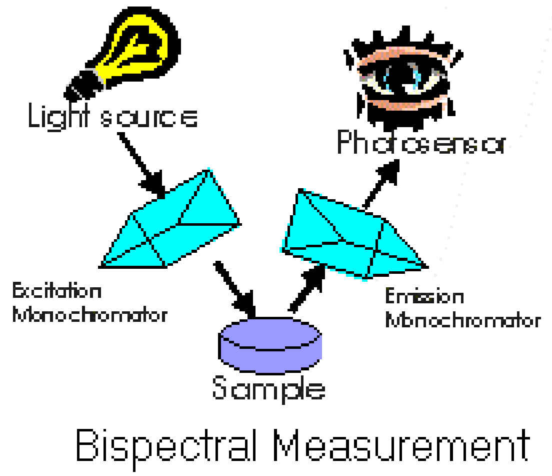
This page was design with the purpose of making available bispectral measurements for anyone who wants to analyze them. The database is made up of sampling different printing processes under normal reproduction conditions of solid colors and a variety of fluorescent materials. Throughout the experiment a bispectral spectrophotometer (BFC-450) manufactured by Labsphere was used to measure the samples. All of the data files can be downloaded here. This is a **6.5MB** zipped file. The thesis on which this page is based can also be downloaded: SergioThesis.pdf

The Data

Below there is brief discription of bispectral measurement and how to obtain colorimetric values out of the files.

BISPECTRAL METHOD

Bispectral spectrophotometric instruments can make colorimetric measurements by taking into account the contribution of both the fluorescent and the reflected component to the total radiance of a sample. For the bispectral method one monochromator is located between the instrument light source and the sample to be measured. The function of the monochromator is to separate the radiation from the instrument's light source into its spectral components before it reaches the sample. The second monochromator is located between the sample and the photodetector, which separates the radiation leaving the sample surface into its spectral components.



This section is devoted to describing the process in which colorimetric values are obtained (CIELAB) from the spectral radiance factor of a fluorescent sample. Two arbitrary samples were chosen to exemplify how the values are calculated. The samples chosen were a fluorescent orange golf ball and a green fluorescent plastic sample.

The work in this investigation was done in a bispectral spectrophotometer (which gives data of complete spectrum of light emitted by the sample at each wavelength of irradiation). The procedure will have as starting point the output data from bispectral measurements.

The instrument output is a matrix with wavelength by wavelength contribution of light excitation and emission. The columns in *Figure 5* correspond to the excitation while the rows correspond to the emission wavelengths, the values within the diagonal correspond to the reflected component while the values off-diagonal correspond to the fluorescent contribution. *Figure 6* shows the graphical representation of the matrix form. The xy plane corresponds to the excitation and emission wavelengths while the z-axis represents the radiance factor.

300~	430	440	450	460	470	480	490	500	510~~780
440		0.046475							
450			0.046363						
460				0.047336					
470					0.047867				
480	0.003761	0.00446	0.005088	0.004754	0.001302	0.058661			
490	0.011325	0.013698	0.015199	0.014556	0.012131	0.005584	0.09798		
500	0.024563	0.027368	0.02929	0.029882	0.028557	0.026865	0.012881	0.183529	
510	0.039665	0.043669	0.044939	0.046761	0.046878	0.04396	0.038887	0.012886	0.291216
520	0.036722	0.040335	0.04196	0.042792	0.041618	0.04063	0.03723	0.026923	0.002903
530	0.02523	0.027876	0.030193	0.030422	0.028911	0.028284	0.026957	0.019357	0.008819
540	0.019142	0.021393	0.023585	0.023488	0.021749	0.020803	0.020318	0.014466	0.006898
550	0.01116	0.013939	0.01432	0.015269	0.012544	0.012127	0.012329	0.009582	0.004307
560	0.007446	0.009776	0.009541	0.010181	0.008627	0.007398	0.0081	0.006342	
570	0.003724	0.005074	0.006	0.007116	0.00506	0.003825	0.004411	0.002882	
580	0.001602	0.002742	0.003835	0.004281	0.00234	0.001341	0.003135	0.001463	
590~~780		0.00132	0.003033	0.003063					

Figure 5 Part of Matrix of a bispectral measurement from a green fluorescent sample

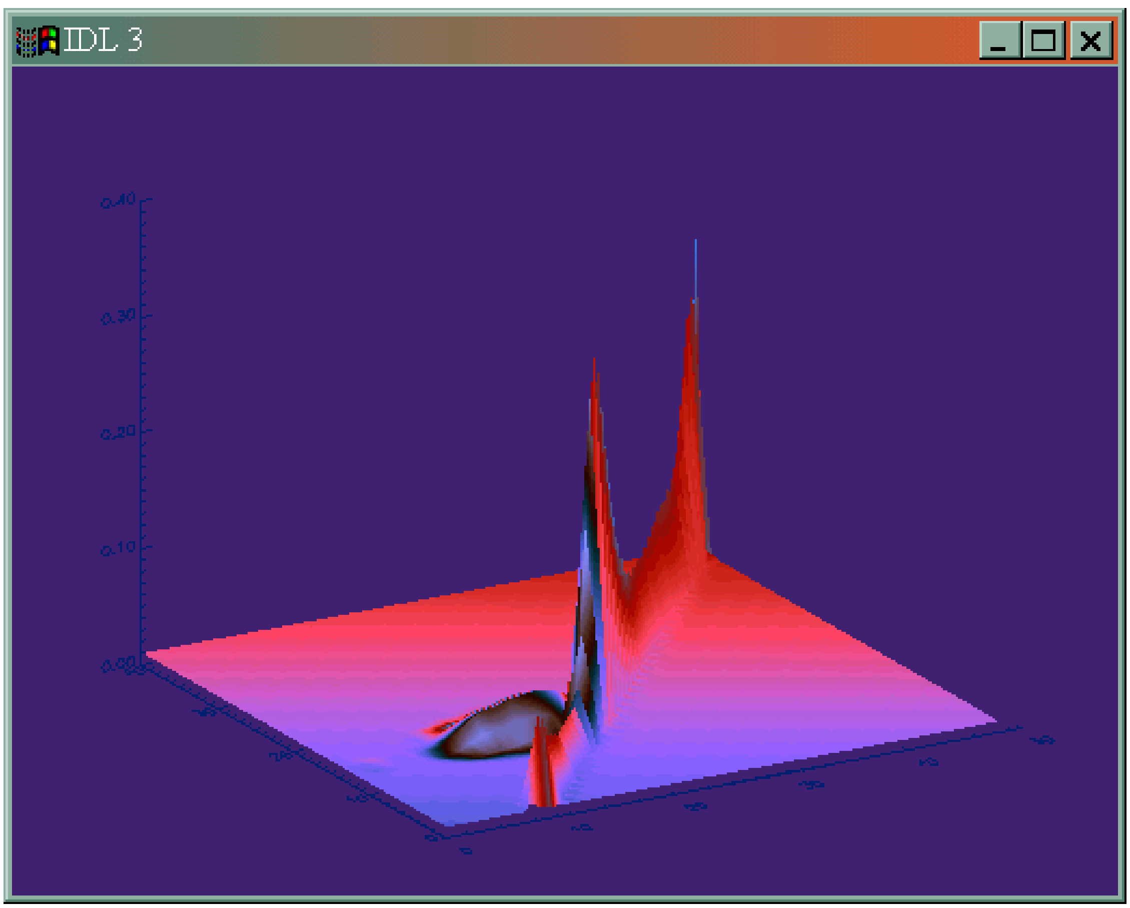


Figure 6. 3D representation of a bispectral measurement from a green fluorescent sample.

After having the matrix representation of a fluorescent sample *Equation 1* can be rewritten into *Equation 2*, where the total radiance factor is in terms of both the emission wavelengths (irradiating light) and the excitation wavelengths (light coming out of the sample) as well as the reflected radiance factor and fluorescent radiance factors. Now the total radiance will be describe with the symbol "β" instead of the "I", previously used because the total radiance now is a function depending on two variables.

$$\beta_T(\mu,\omega) = \beta_S(\mu,\omega) + \beta_F(\mu,\omega)$$

The calculation of the tristimulus values starts with the bispectral radiance factor ($\beta_T(\mu,\omega)$ matrix form) which is expressed in function of the excitation (μ) and the emission (ω) wavelengths.

The $\beta_T(\mu,\omega)$ is multiplied by the specified light source ($\Phi^I_\lambda(\mu)$) for colorimetric calculations as shown in *Equation 6*. Then the resultant matrix is summed over the excitation wavelength to obtain an array, which becomes emission wavelength dependent.

$$\tau_F(\omega) = \sum_\mu \Phi^I_\lambda(\mu)\beta_F(\mu,\omega)$$

$$\tau_S(\omega) = \sum_\mu \Phi^I_\lambda(\mu)\beta_S(\mu,\omega)$$

$$\tau_T(\omega) = \sum_\mu \Phi^I_\lambda(\mu)\beta_T(\mu,\omega)$$

$$k = \frac{100}{\sum_\omega \Phi^I_\lambda(\omega)\,\bar{y}(\omega)} \qquad \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} k\sum_\omega \tau(\omega)\bar{x}(\omega) \\ k\sum_\omega \tau(\omega)\bar{y}(\omega) \\ k\sum_\omega \tau(\omega)\bar{z}(\omega) \end{bmatrix}$$

Once obtaining $\tau_T(\omega)$, which can be called the stimulus function, the XYZ can be obtained with traditional matrix colorimetric approach as shown in *Equation 7*. In the present work, the CIE 1931 standard colorimetric observer (2°) color matching functions were employed.

Also by using equations 4 and 5 the stimulus function for the reflected and the fluorescent components can be obtained separately. Then by solving *Equation 7* the tristimulus values of any stimulus function can be derived. The sum of each tristimulus value from the reflected component with the fluorescent component must equal each tristumulus value of the total radiance factor (example $X_F+X_S=X_T$).

For a better understanding how the math works an analogy for non-fluorescent samples can be made using bispectral nomenclature. *Equation 9* shows the stimulus function for a non-fluorescent sample. In this case, the sum symbol is replaced with the integral symbol because a continuous function replaces the discrete function of the fluorescent sample. Both equations have the same function to sum over the excitation wavelengths. Since there is no fluorescent component the equation is simplified because there is no excitation dependency. Then by applying *Equation 7* the XYZs can be derived.

$$\int \Phi_{\lambda}^{I}(\mu)\beta_{T}(\mu,\omega)d\mu = \Phi_{\lambda}^{I}(\omega)\beta_{T}(\omega) = \Phi_{\lambda}^{I}(\omega)\beta_{S}(\omega)$$

Equation 9. Approach using bispectral terminology for non-fluorescent materials

CIELAB VALUES

Once the XYZ values are calculated, the CIELAB colorimetric values are obtained using the traditional approach *Equations 10* through *12* (for most of the work a D50s light source was employed). In *Equations* 10 through 12 the subscript *n* refers to the tristimulus values of a perfectly diffuse reflector.

$$L^* = 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16$$

$$a^* = 500\left[\left(\frac{X}{X_n}\right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n}\right)^{\frac{1}{3}}\right]$$

$$b^* = 200\left[\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n}\right)^{\frac{1}{3}}\right]$$

DIFFERENCE BETWEEN BISPECTRAL MEASUREMENTS AND CONVENTIONAL INSTRUMENTAL METHOD

The main difference of the bispectral instruments from the conventional spectrophotometers is the incorporation of two monochromators into the instrument. This way the measurement becomes light-source independent and the full bispectral radiance factor can be obtained in a matrix form as a function of the excited and emitted wavelengths.

THE TYPES & QUANTITY OF SAMPLES

On the first stage the analysis was based on: seven prints (paper with color patches of 100% CMYK and 50 % CMYK), one print (paper with patches of 100% CMYK and 40 % CMYK), and one print (paper with patches of 100% CMYK). In total they were 76 measurements. They were measured with the intention to analyze the effect of fluorescent component in color determination.

Among the different printing process used to generate the samples were: two color proofers (3M & Epson), two thermal printers (Kodak XLT 7720 & Fujix Pictography), two RIT Lithographic presses, and a combination of inkjet printers with different quality papers. *Table 1* shows the complete list of printed samples used on the first stage of measurements.

Table 1 Sample list for the first stage

KodakXLT_100%_Cyan	3m-conventional film proof 100% Cyan
KodakXLT_100%_Black	3m-conventional film proof 100% Black
KodakXLT_100%_Magenta	3m-conventional film proof 100% Magenta

KodakXLT_100%_Yellow	3m-conventional film proof 100% Yellow
KodakXLT_50%_Cyan	3m-conventional film proof 50% Cyan
KodakXLT_50%_Black	3m-conventional film proof 50% Black
KodakXLT_50%_Magenta	3m-conventional film proof 50% Magenta
KodakXLT_50%_Yellow	3m-conventional film proof 50% Yellow
KodakXLT_White-Paper	3m-conventional film proof white film
Printed Litho Web feed 100% Cyan	Printed Epson digital proof 100% Cyan
Printed Litho Web feed 100% Black	Printed Epson digital proof 100% Black
Printed Litho Web feed 100% Magenta	Printed Epson digital proof 100% Magenta
Printed Litho Web feed 100% Yellow	Printed Epson digital proof 100% Yellow
Printed Litho Web feed 40% Cyan	Printed Epson digital proof White
Printed Litho Web feed 40% Black	Fuji_Pict._100%_Cyan
Printed Litho Web feed 40% Magenta	Fuji_Pict._100%_Black
Printed Litho Web feed 40% Yellow	Fuji_Pict._100%_Magenta
Printed white paper web offset Litho	Fuji_Pict._100%_Yellow

Litho sheet feed 100% Cyan	Fuji_Pict._50%_Cyan
Litho sheet feed 100% Black	Fuji_Pict._50%_Black
Litho sheet feed 100% Magenta	Fuji_Pict._50%_Magenta
Litho sheet feed 100% Yellow	Fuji_Pict._50%_Yellow
Litho sheet feed 50% Cyan	Fuji_Pict._White_paper
Litho sheet feed 50% Black	Hp870cxi_100%_Cyan_hp_paper
Litho sheet feed 50% Magenta	Hp870cxi_100%_Black_hp_paper
Litho sheet feed 50% Yellow	Hp870cxi_100%_Magenta_hp_paper
Litho sheet feed white paper	Hp870cxi_100%_Yellow_hp_paper
Xeror-Cyan-100%-riverside paper	Hp870cxi_50%_Cyan_hp_paper
Xeror-Cyan-50%-riverside paper	Hp870cxi_50%_Black_hp_paper
Xeror-Black-100%-riverside paper	Hp870cxi_50%_Magenta_hp_paper
Xeror-Black-50%-riverside paper	Hp870cxi_50%_Yellow_hp_paper
Xeror-Magenta-100%-riverside paper	Hp870cxi_white_hp_paper
Xeror-Magenta-50%-riverside paper	Hp870cxi_100%_Cyan_riverPaper
Xeror-White-paper-riverside paper	Hp870cxi_100%_Black_riverPaper
Xeror-Yellow-100%-riverside paper	Hp870cxi_100%_Magenta_riverPaper

Xeror-Yellow-50%-riverside paper	Hp870cxi_100%_Yellow_riverPaper
	Hp870cxi_50%_Cyan_riverPaper
	Hp870cxi_50%_Black_riverPaper
	Hp870cxi_50%_Magenta_riverPaper
	Hp870cxi_50%_Yellow_riverPaper
	Hp870cxi_white_riverPaper

In the second stage 60 samples were measured, which were considered to have fluorescent properties under normal conditions seen by an average person as well as under black light. The list of samples is shown in *Table 2*. The origin of the samples is broad, it ranges from textiles, plastics, crayons, highlighters to color catalogs, etc. The main purpose of this second stage is to build a small database of fluorescent materials for future study and research.

Table 2 Sample list for the second stage non-printed material

Riverside Array Hyper laser & inkejet multipurpose paper	**Textiles**
Red	Magenta
Orange	Light Blue
Yellow	Orange
Green	Yellow
Magenta	Magenta un cut

Paint sample (oxfrod index card)	**Plastic film**
Colorations paint Red	Orange
Colorations paint Orange	Green
Colorations paint Yellow	White
Colorations paint Green	**White plastic (ciba white scale)**
Colorations paint Blue	Num 8
Alex poster paint Magenta	Num 9
Alex poster paint Green	Num 10
Sanford highlighter (oxford index cards)	Num 11
Sample	Num 12
Crayola markers (oxford index cards)	**Baked Scupley III polymer clay**
Hot pink	Red
Infra Red	Orange
Laser Lemon	Yellow
Hot Magenta	Green
Outrageous Orange	Blue

Unmellow Yellow	Purple
Atomic Tangerine	**Radiant color Pigments (hercules)**
Electric Lime	Orange
Blizarrd Blue	Pink
Shocking Pink	Blue
Purple Pizzazz	Red
Magic Mint	Chartreuse
Index Card	Magenta
Sample	Orange Yellow
Golf Ball	Orange Red
White	Green
Yellow	Cerise
Orange	**3M Scotchlite Retroreflective Sheeting**
Macbetch color checker	Orange uniform
Moderate red	Orange grided

Extracted from the thesis:

Gonzalez,Sergio "*Evaluation of Bispectral Spectrophotometry for Accurate Colorimetry of Printing Materials" ,RIT, Jun 2000, pp 14-23 Any comments or Questions at* sgcheco@usa.net