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DECADES OF COLOR MEASUREMENT IN PRINTING EDUCATION

Ákos Borbély, Péter Schulz

Institute of Media Technology

Faculty of Light Industry and Environmental Engineering

Óbuda University

HUNGARY

Introduction

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- 1972 Technical College of Light Industry
- 2000 Budapest Tech, Faculty of Light Industry and Environmental Engineering
- 2010 Óbuda University

Home of color measurement:

- 1972 – 2006 Departement of Print Industry
- 2000 Institute of Media Technology
- 2009 Institute of Media Technology and Light Industry

Color measurement in Hungarian print industry

- Transmission and reflection densitometers
- Color measurement : reproduction of color
- ‘70s: monochromators, spectrophotometers for research
- ’80s: experimental use of tristimulus colorimeters
- late 90’s: device for quality control, first in packaging industy
- Industry-ready device: MOMCOLOR
- DTP -> closed systems open up
- Color management problems:
  - Device color calibration, gamut mapping, etc.
- ICC standard

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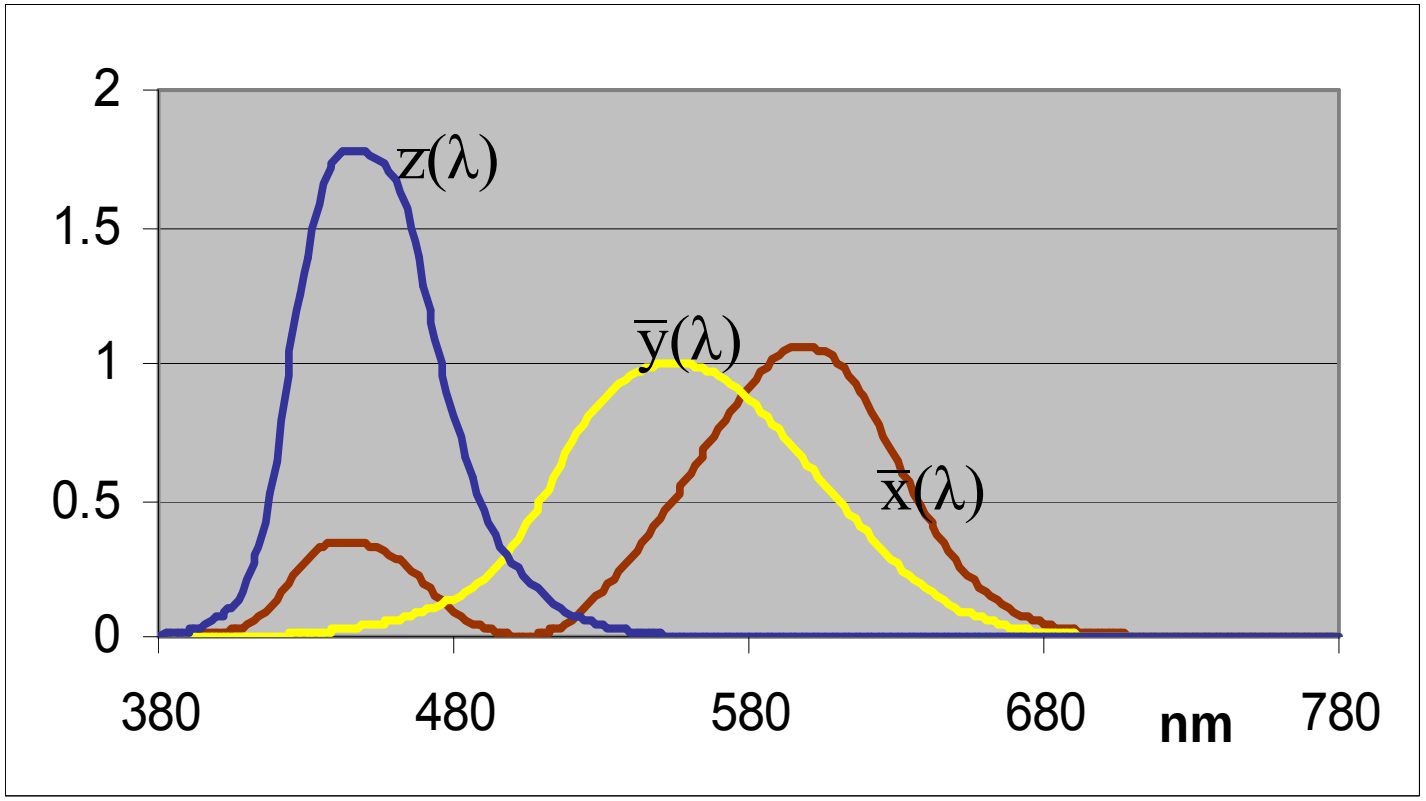
CIE 1931 (2°) standard colorimetric observer



$$X = k\int_{380}^{780} S_\lambda \bar{x}(\lambda)d\lambda; \quad Y = k\int_{380}^{780} S_\lambda \bar{y}(\lambda)d\lambda; \quad Z = k\int_{380}^{780} S_\lambda \bar{z}(\lambda)d\lambda$$

X, Y, Z are *tri-stimulus values*

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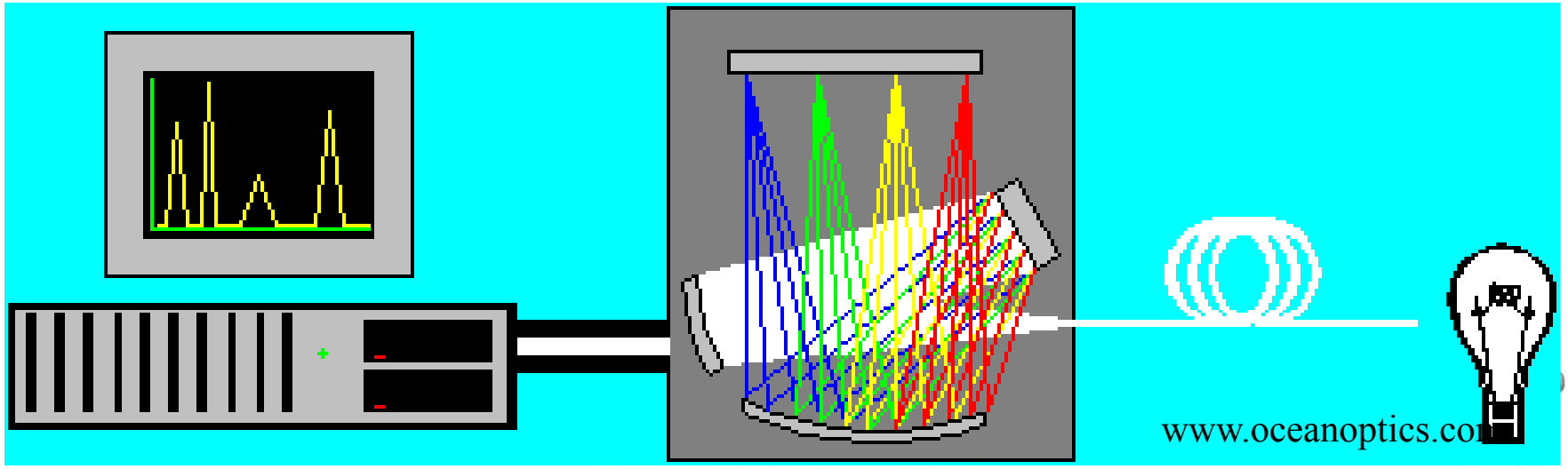
Color measurement devices

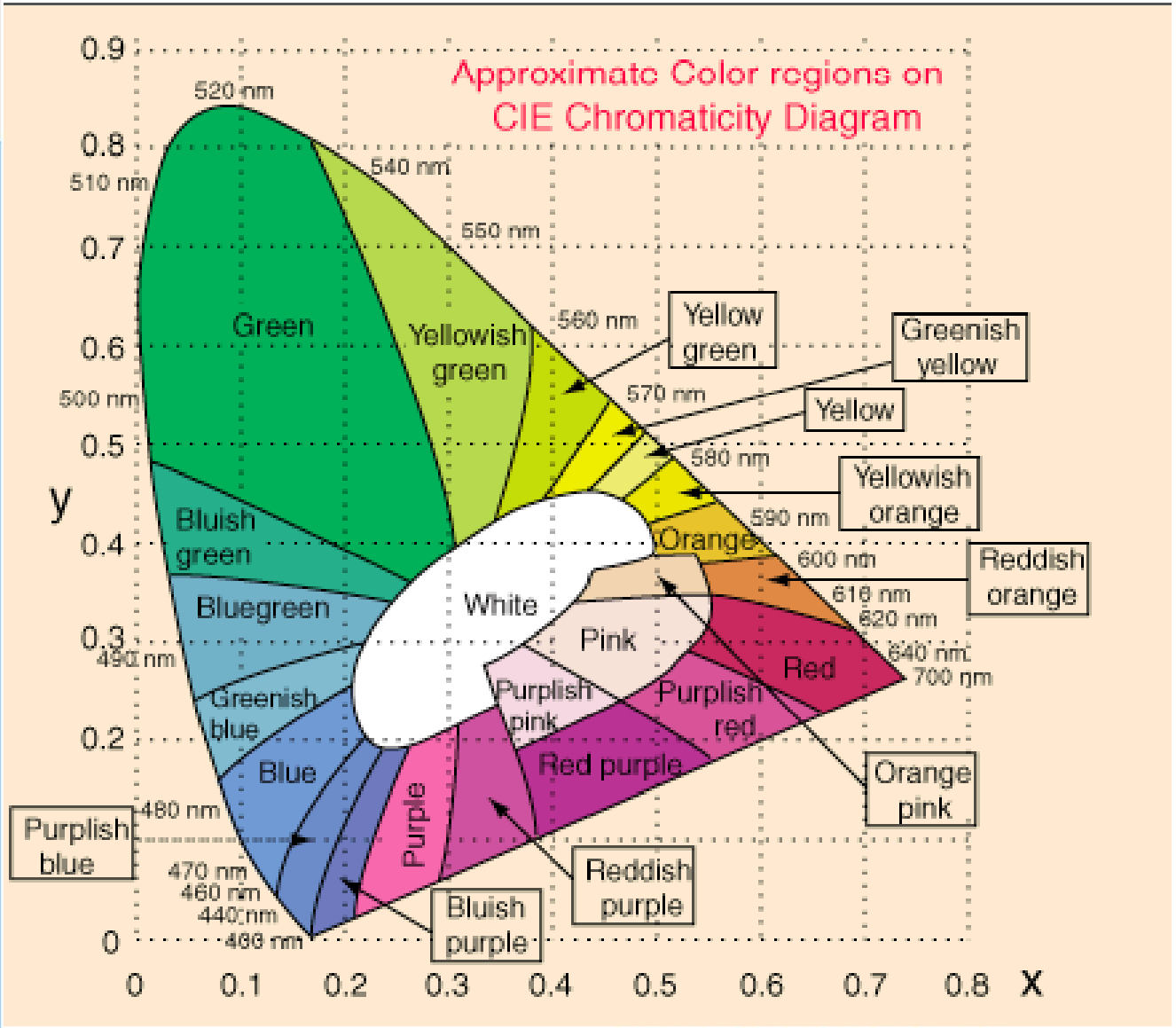
Tri-stimulus colorimeters

The CIE $\bar{x}(\lambda)$ (*actually* $(\bar{x}_1(\lambda) + \bar{x}_2(\lambda))$), $\bar{y}(\lambda)$, $\bar{z}(\lambda)$ color matching functions are implemented as spectral transmission functions of optical filter packages.

Spectro-photometers (e.g. with CCD detector array)



CIE 1931 x,y chromaticity diagram



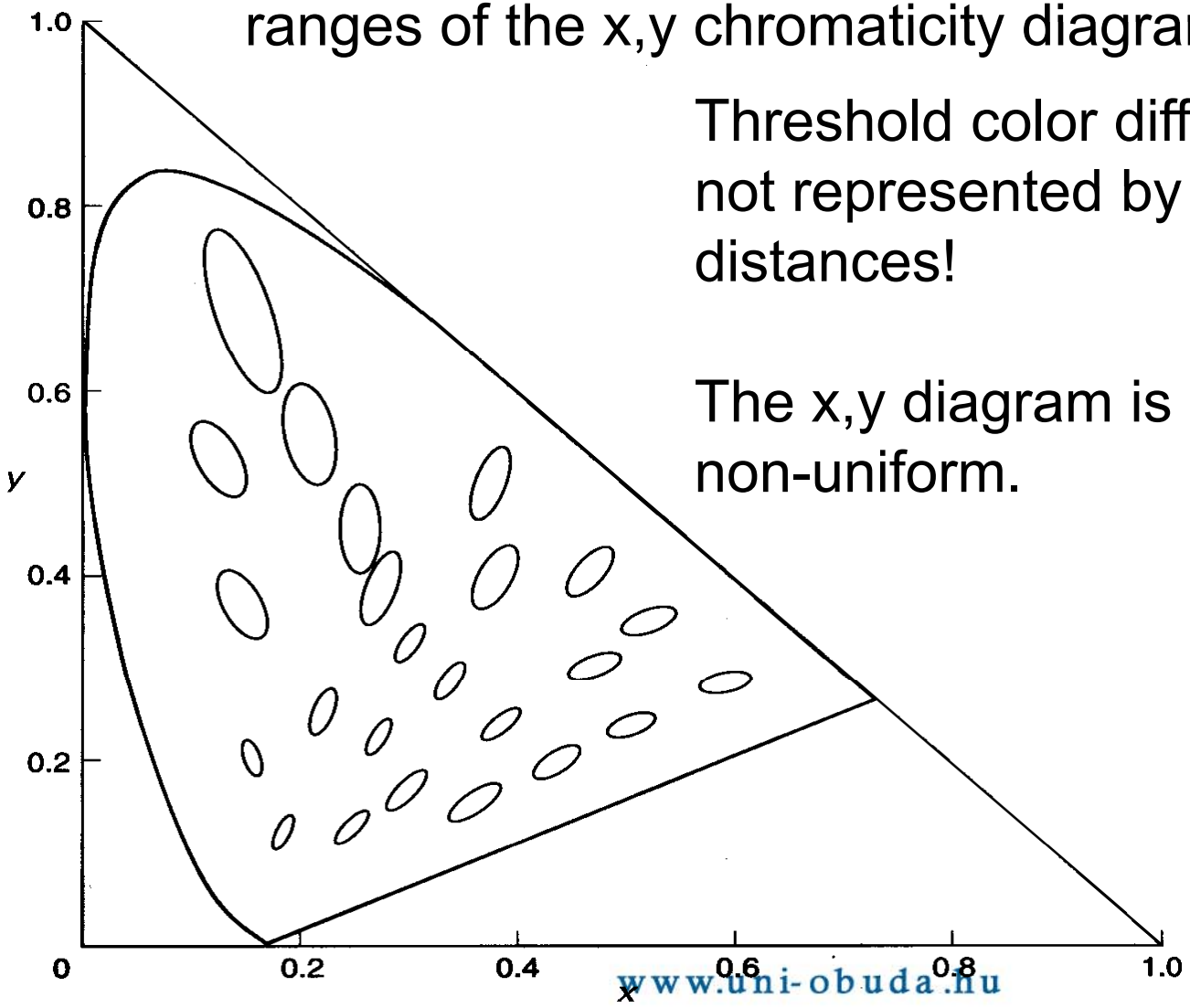
$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

$$z = \frac{Z}{X+Y+Z}$$

MacAdam ellipses

Threshold color differences plotted in different ranges of the x,y chromaticity diagram



Threshold color differences are not represented by constant distances!

The x,y diagram is perceptually non-uniform.

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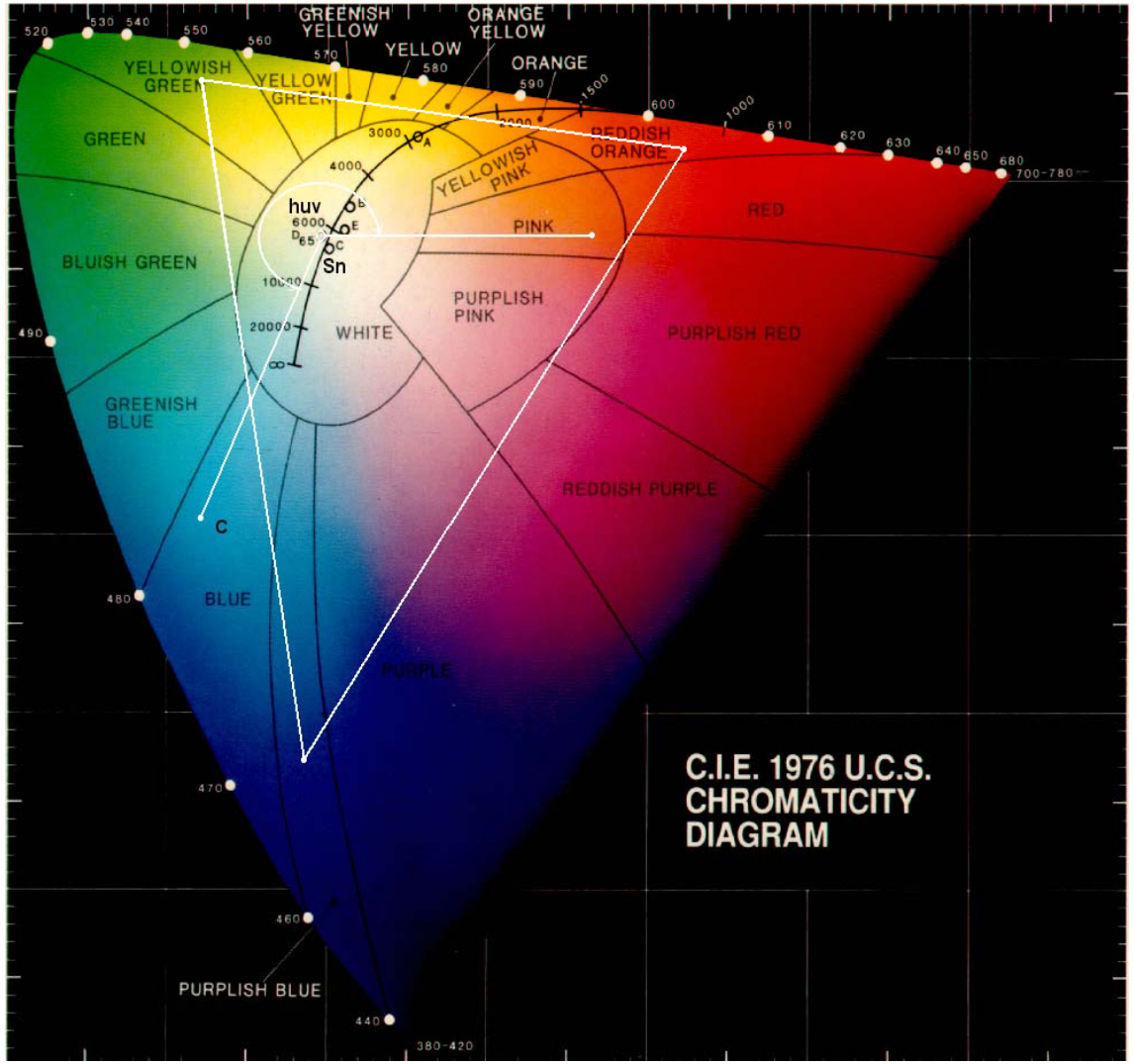
CIE 1976 u',v' uniform chromaticity diag.

$$u' = \frac{4x}{-2x+12y+3}$$

$$v' = \frac{9y}{-2x+12y+3}$$

$$y = \frac{2v'}{3u'-8v'+6}$$

$$x = \frac{9u'}{4yv'}$$



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CIE 1976 L*a*b* color space

$$L^* = 116(Y/Y_n)^{1/3} - 16$$

$$a^* = 500\,(\,(X/X_n)^{1/3} - (Y/Y_n)^{1/3}\,)$$

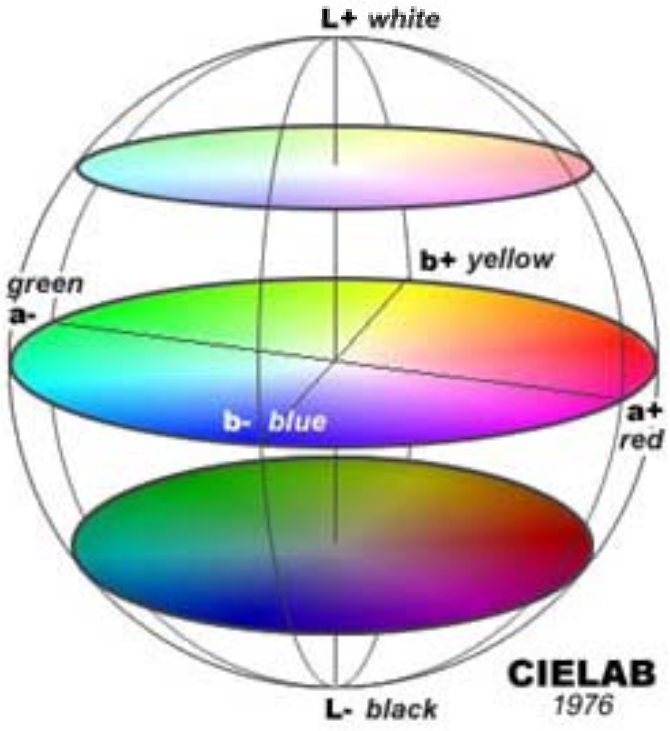
$$b^* = 200\,(\,(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}\,)$$

if $X/X_n > 0{,}008856$

$Y/Y_n > 0{,}008856$

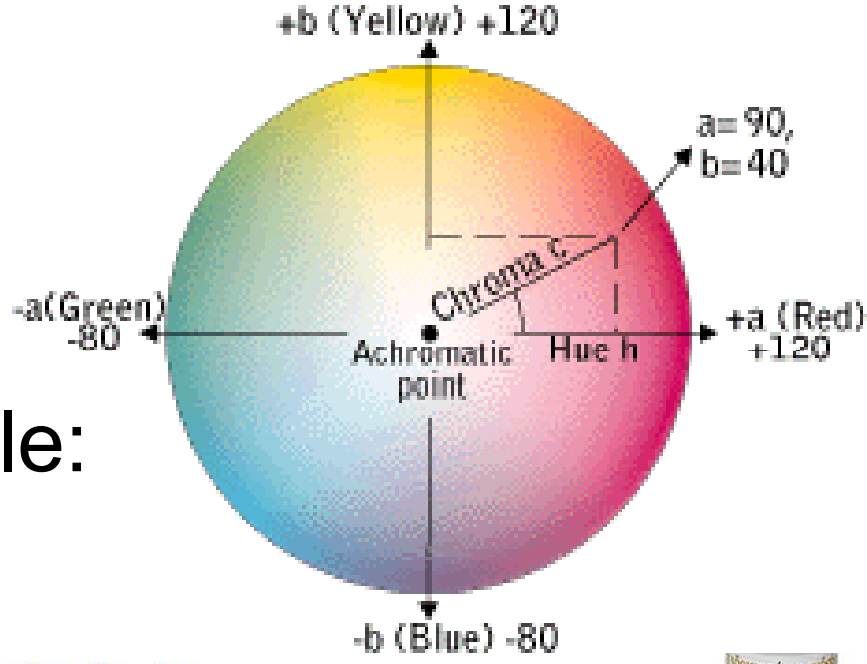
$Z/Z_n > 0{,}008856$

which is true in most cases…

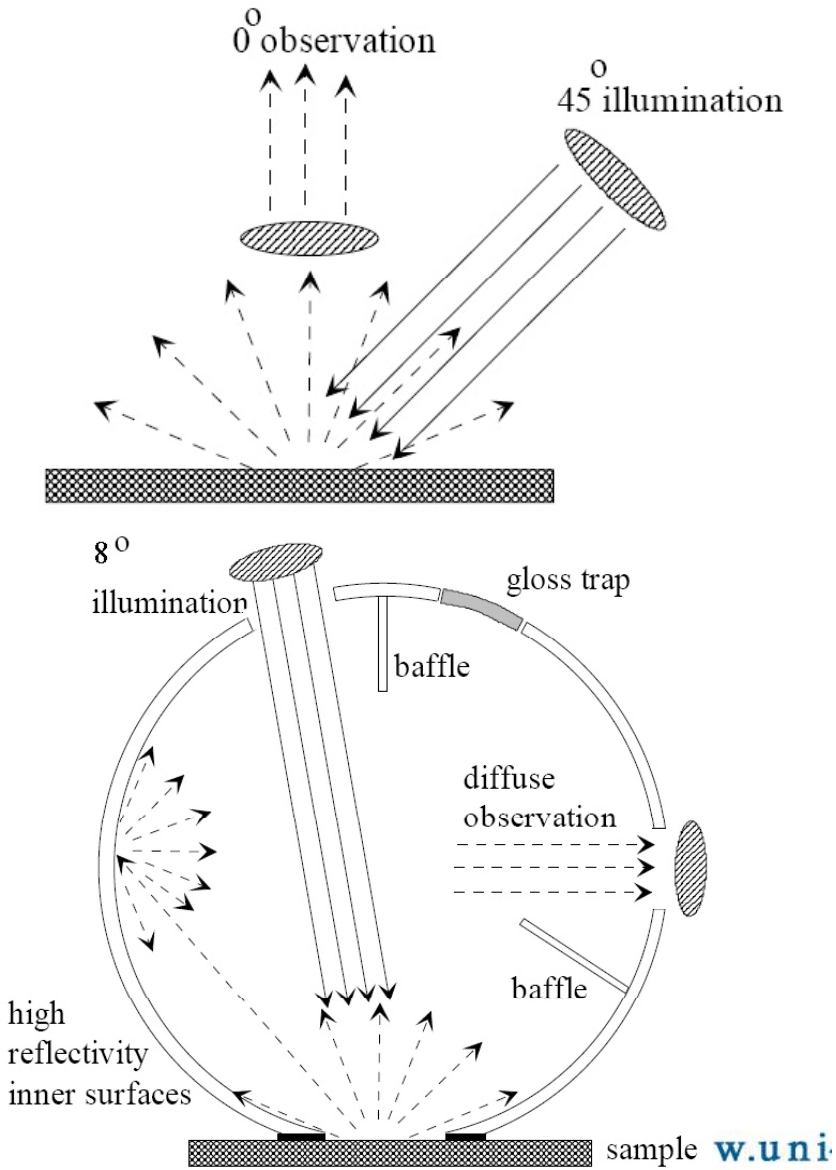


CIE 1976 L*a*b* color space

- Color difference formulas:
  - $\Delta E^*_{ab} = [\ (\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta\ b^*)^2]^{1/2}$
- CIE1976 a,b chroma:
  - $C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$
- CIE 1976 a,b hue angle:
  - $h_{ab} = \arctan (b^*/a^*)$



Measurement geometries



45º directional geometry
Reflected radiation is collected at 0º
CIE notation 45º:0º or 0º:45º
Annular illumination: 45ºa:0º

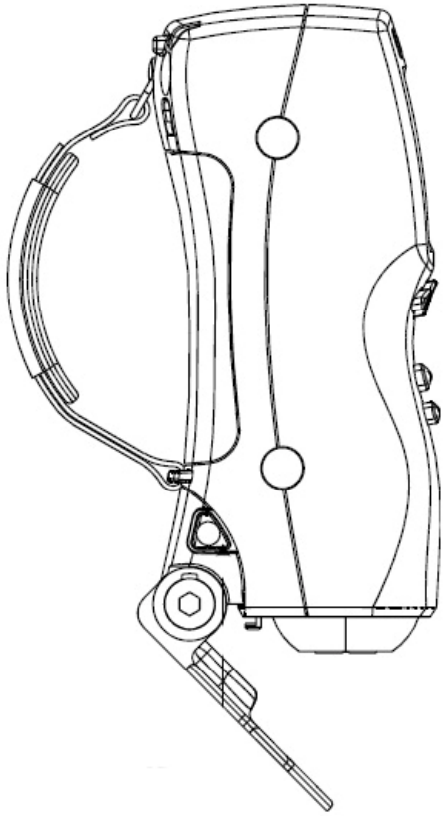
8º diffuse geometry
Diffuse observation
CIE notation 8º:di and 8º:de or
di:8º and de:8º
Specular component incl. mode: 8º:di
Specular component excl. mode: 8º:de

Reflectance spectrophotometers

- 45°a:0° measurement geometry
- Spectral range: 380 nm – 730 nm
- Illumination: A, D50, D65
- Repeatability: 0,1 ΔE^*_{94} (D50, 2º)
- Computer control
- ICC profiling & other tools

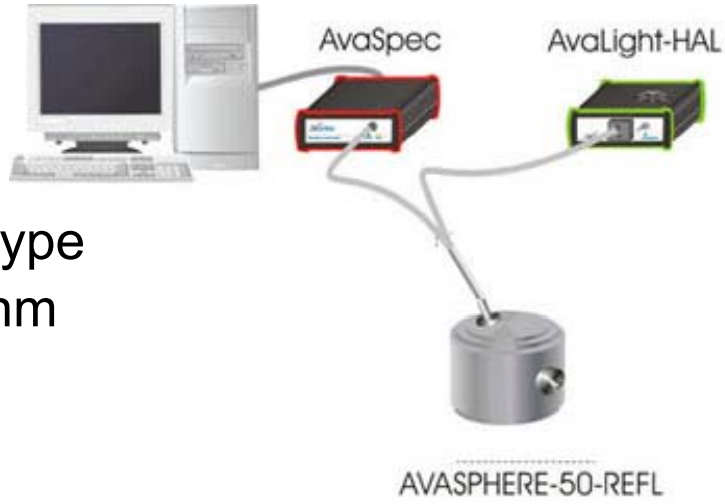
Industry standard spectrophotometer

- Spectral range: 360 – 750nm
- Wavelength interval: 10nm
- Geometry: di:8º
- Aperture: 10mm circular diameter
- Integrating sphere diameter: 38mm
- Illumination: short-arc, high pressure xenon gas discharge lamp



Modular fibre optic spectrophotometer

AVANTES Avaspec3648



- Detector: CCD, 3648 pixels
- AD converter: 16 bit
- Monochromator: Czerny-Turner type
- Wavelength interval: 360 – 1100nm
- Typical integration time: 1500ms

Illumination:

- Avalight-HAL tungsten halogen light source
- Current stabilized, fan cooled

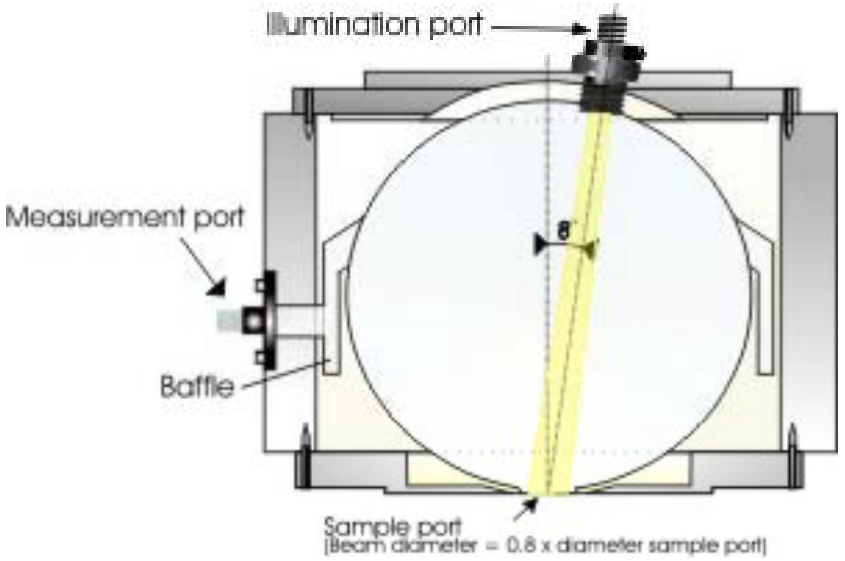
White calibration target for both instruments:

- WS-2 diffuse PTFE (~ 98% reflectance)

Modular fibre optic spectrophotometer

Integrating sphere
- Geometry: 8º:di
- Aperture: 10mm circular diameter
- Sphere diameter: 50mm

Fibres:
- 600 µm for illumination
- 400 µm to spectrophotometer



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Color related research at the Institute of Media Technology

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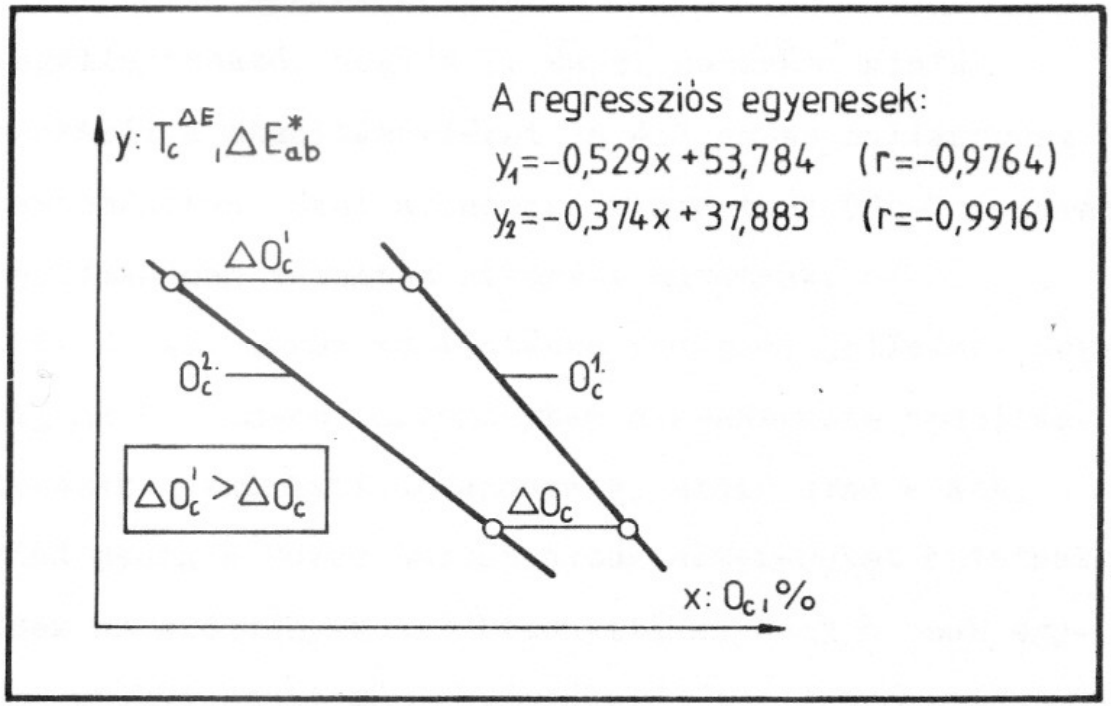
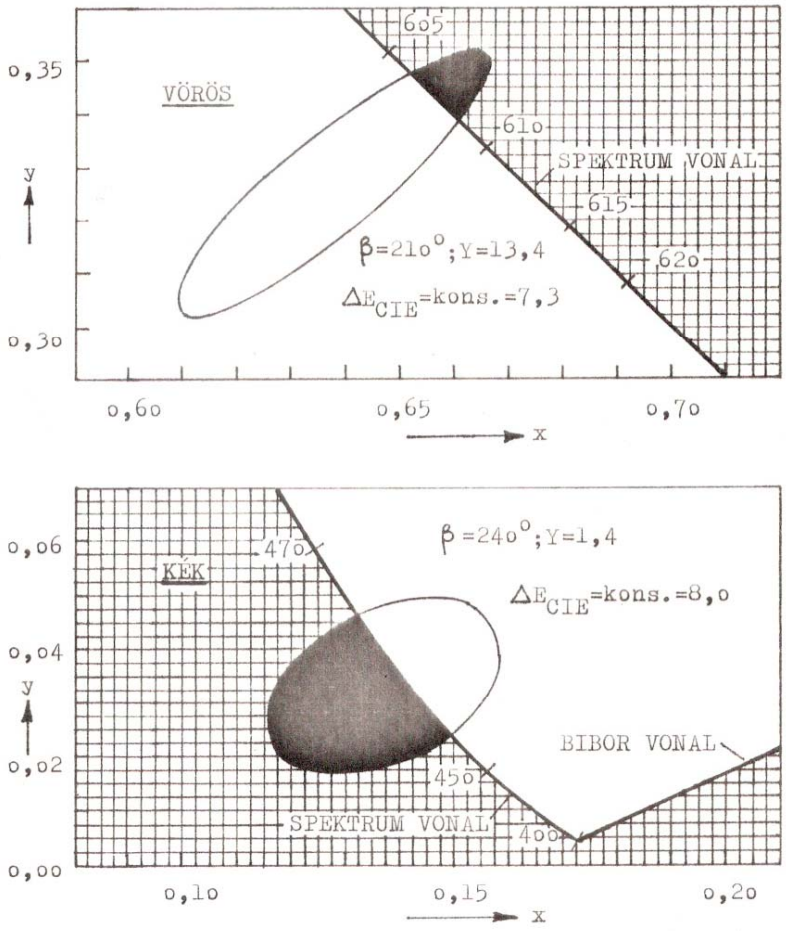
Contrast transparency: a new correlate of opacity based on colorimetric values



A kontraszt transzparencia /$T_c^{\Delta E}$/ és a kontraszt opacitás /O_c/ összefüggése. O_c^1 : MSZ 5645, O_c^2: DIN 53146 szerinti opacitás

Schulz, P. – Gara, M.: *A Kontraszt transzparencia: a kontraszt opacitás új mérőszáma*. Mérés és Autom., 5., 178–183., 1984

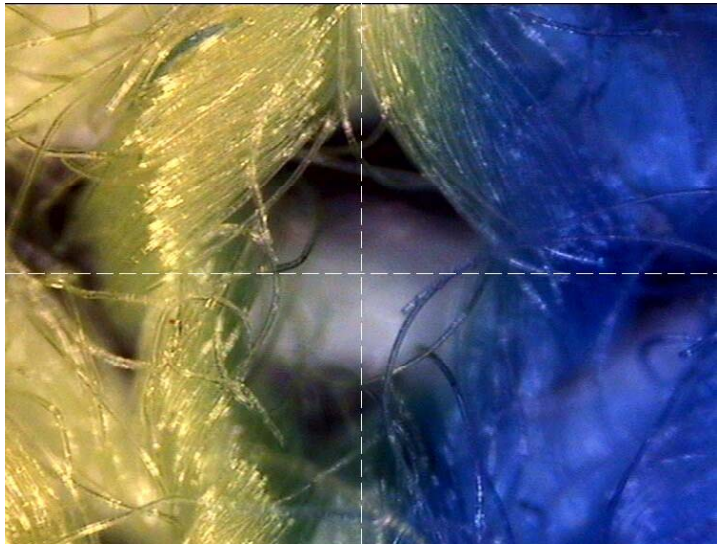
Anomalies of tolerances of secondary colors

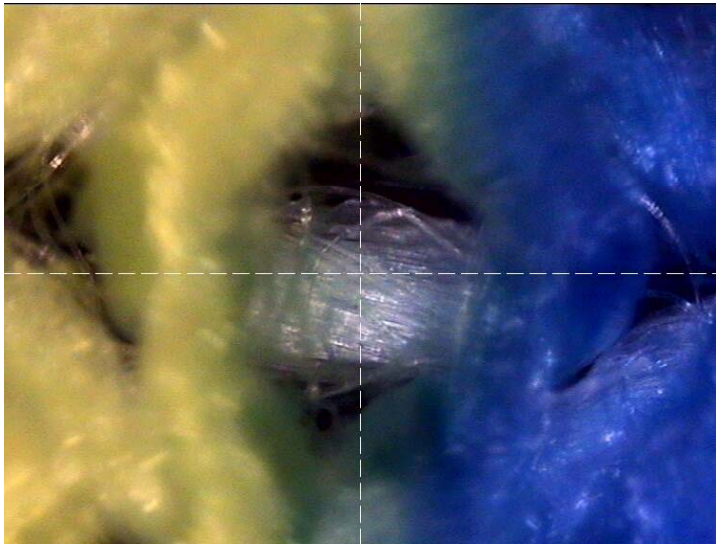


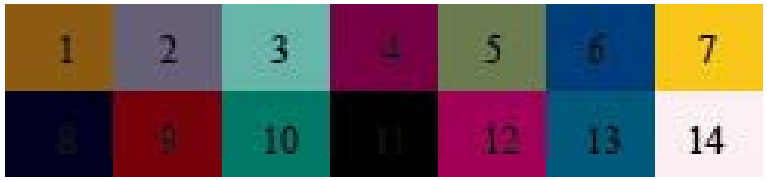
A DIN 16539 Europa-szinskála vörös és kék másodlagos szineire megadott toleranciák határai CIE 1931, x,y sziningerháromszögben /β=konstans,

Schulz, P. – Lukács, Gy.: *Az Európa nyomdafesték-színskála másodlagos színeinek tűrései*. Mérés és Autom., 5., 161–166., 1986 DIN 16539

Color measurement of transfer printed textiles







Background	Mean ΔE^*_{ab}	Std. Dev
White<>black	8.1	2.5
White<>chromatic	6.0	1.7

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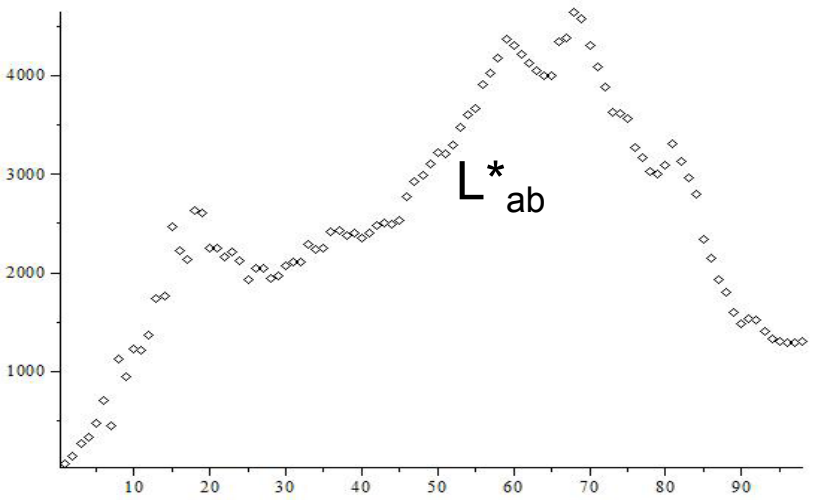
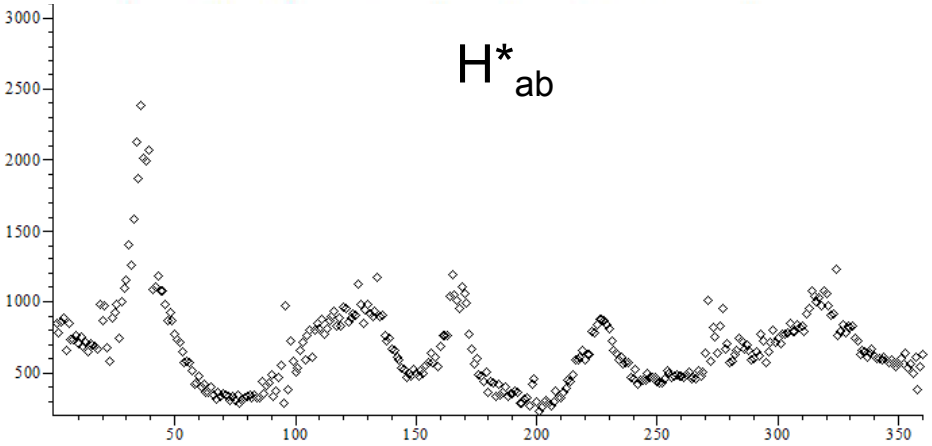
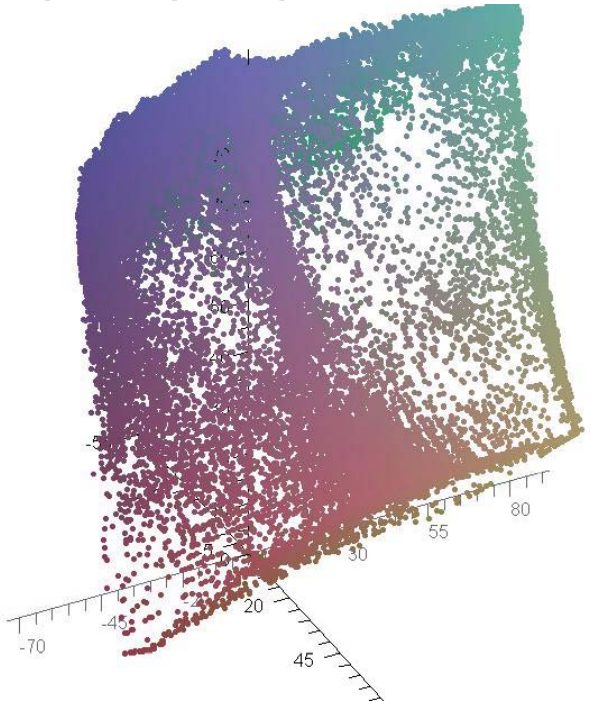
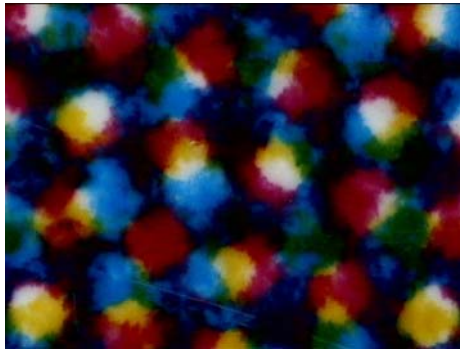
Determination of halftone dot area by color space segmentation









CMY 70%

Offset printability of recycled paperboard

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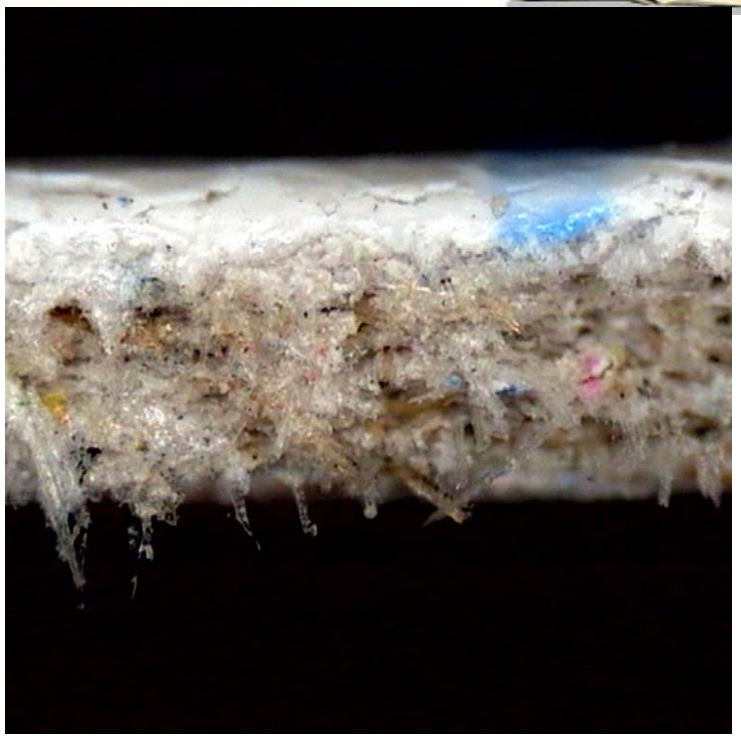
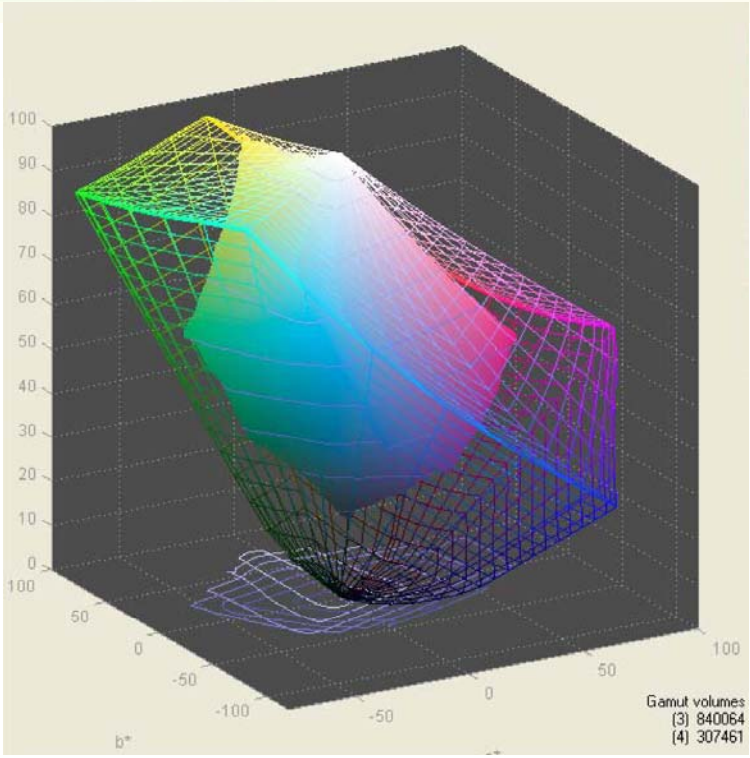
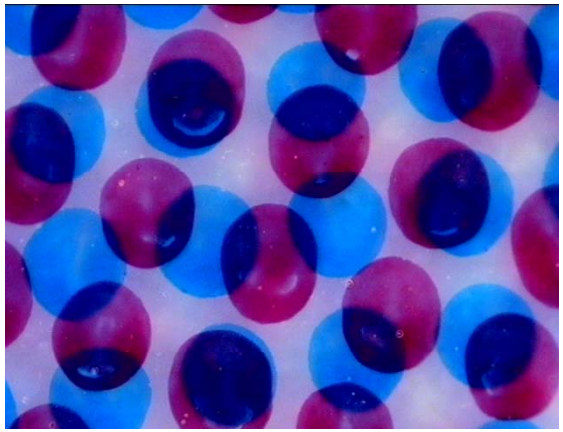


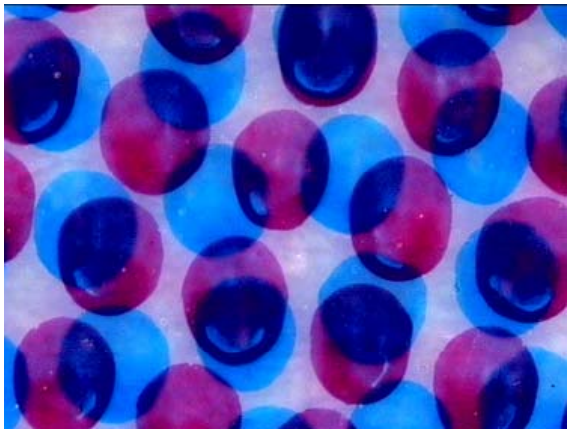


	T1	T2	R1	R2
Test chart gamut (sRGB gamut = 100%)	35.88%	34.62%	36.60%	36.48%
Relative to largest	98.03%	94.59%	100%	99.67%

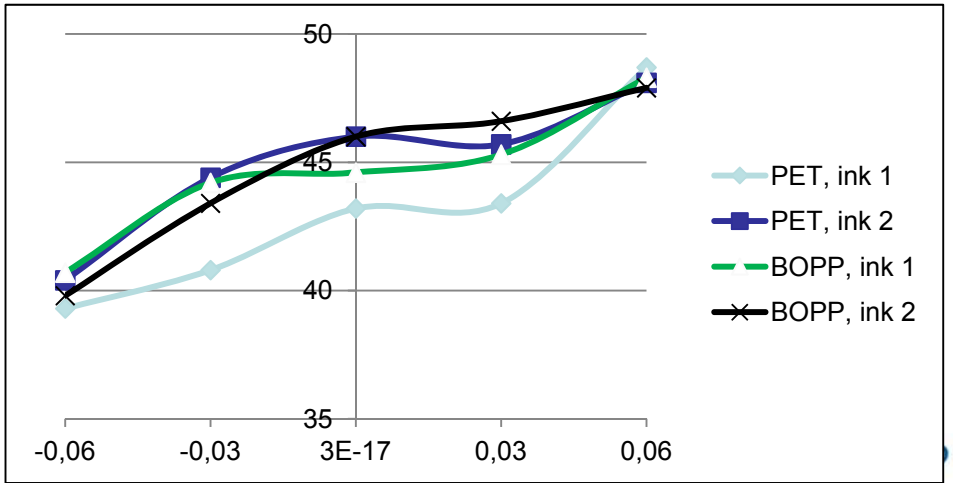
The effect of printing pressure on flexo dot on non-absporbing substrates

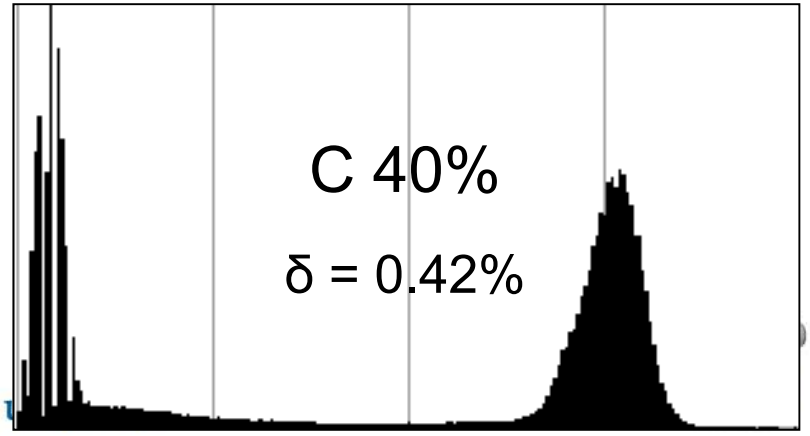


Normal pressure



Increased pressure





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MOMCOLOR – tristimulus colorimeter

- MOM – Hungarian Optical Works
- Chief constructor: dr. Gyula Lukács
- Years of development: 1968 – 1991
- Technical parameters:
- Geometry: 0°:45°, specular component excluded
- Illuminants: CIE A, C
- Apertures: 5 mm, 10 mm, 15 mm
- Accuracy: $\Delta x, \Delta y < 0{,}005$ if $Y > 10$ and Munsell Chroma > 10
- Diff. Accuracy: $\Delta x, \Delta y < 0{,}001$ if $Y > 10$ and Munsell Chroma > 10

MOMCOLOR – tristimulus colorimeter

MOMCOLOR	MOMCOLOR D
1969-1976	1974-1985
230	538

MOMCOLOR 100	MOMCOLOR 1000
1986-1990	1991-1994
115	19

Export: 549

Inland: 353

Closing remarks

- The theory and measurement of color has a fundamental role in the education of printing and graphic arts related academic training programs.
- To understand complex standard color management workflows it is necessary to review the building blocks in detail.
- The future path of printing and media may be uncertain, but the education of color science and technology provides solid foundations for the next generations.

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THANK YOU FOR YOUR KIND ATTENTION!

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