University of the Arts London
London College of Communication

Research Degree Student Project:

ICC based Colour Management on non-paper based substrates

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ICC | GRAPHIC ARTS SPECIAL INTEREST WORKING GROUP meeting Barcelona | June 2011

Professional Color Management Solutions

x-rite

What's the relationship between George Clooney...

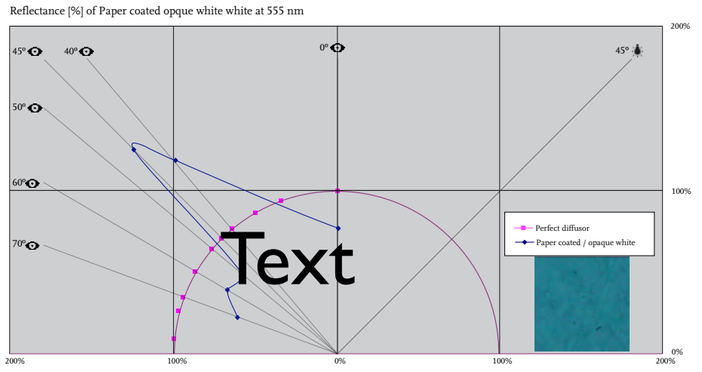
George’s coffee and the Terrier’s dog food come both in FLEXALPEEL® package... which will give everybody a headache who tries to apply ICC-based colour management on this substrate.

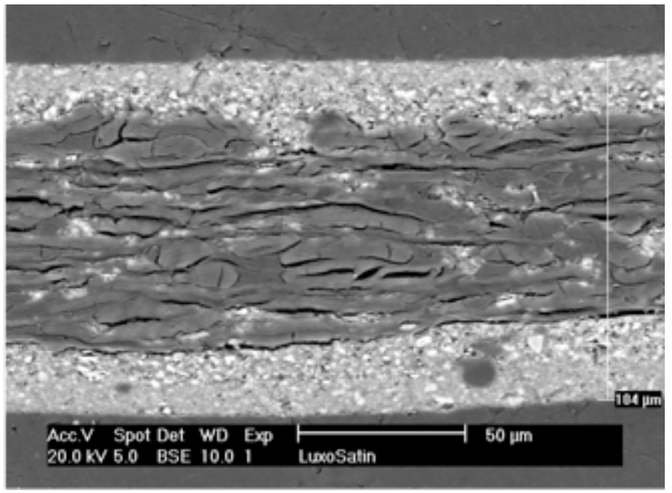
FLEXALPEEL® is a trademark of Amcor Flexibles Singen GmbH

What's the problem with ICC based colour management on such substrates?

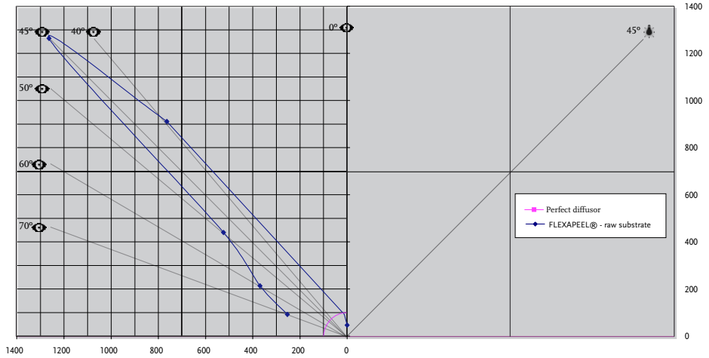
ICC colour management on substrates with rather diffuse reflection characteristics (BRDF, BTF, BSSRDF) works well but tends to break on substrates with complex reflection characteristics like metallic printing substrates (e.g. Flexalpeel®)

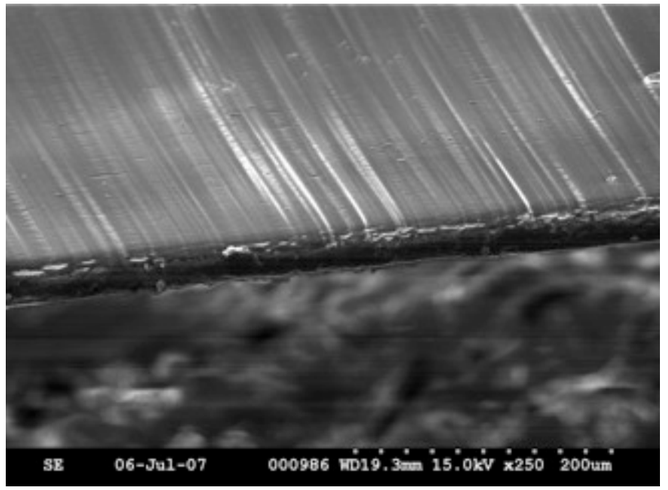
Coated Paper





Flexalpeel®



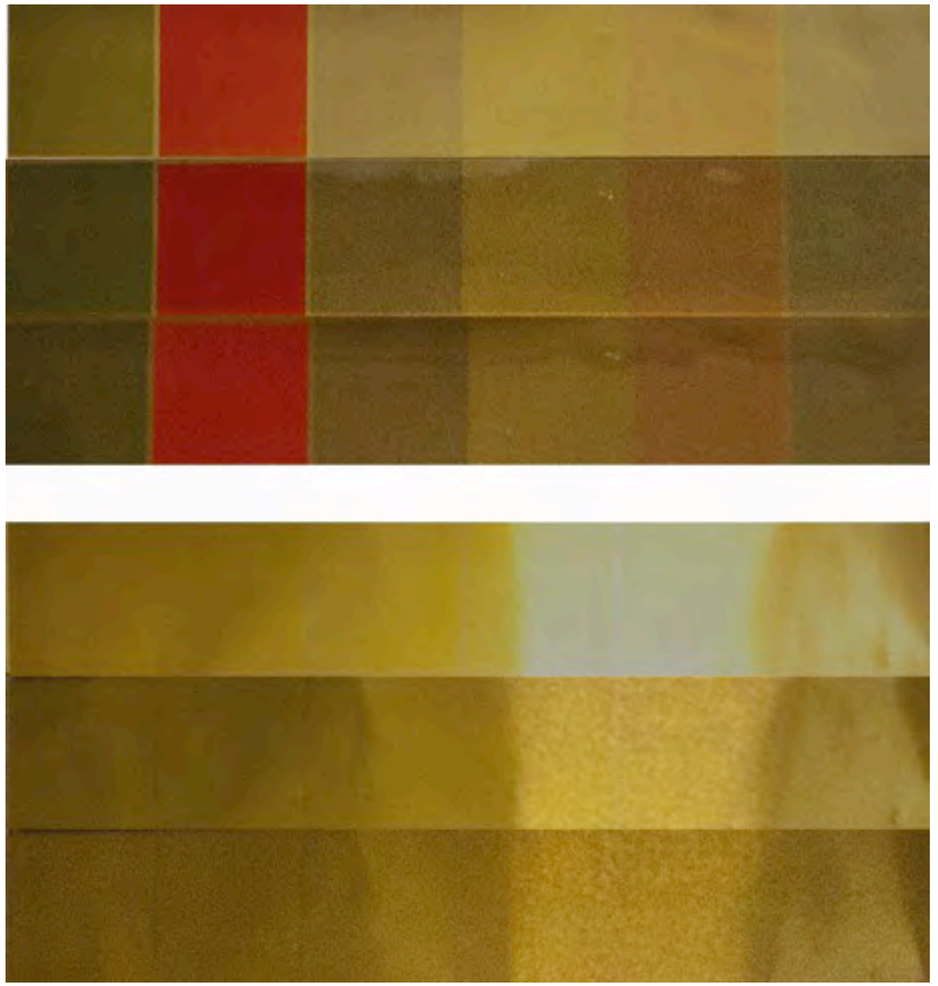


What's the problem with ICC based colour management on such substrates?

Substrates with rather diffuse reflection characteristics show only a moderate change if the viewing or illumination geometries are changed.

Substrates with complex reflection characteristics may show dramatic colour changes if the viewing or illumination geometries are changed... also rotating the sample may result is a completely different behavior for the geometric colour changes.

Flexalpeel®



Let's take a look at our colour management process and how it is specified today:

	paper	none-paper based substrates
ICC architecture		
ISO 15076-1:2005 Image technology colour management -- Architecture, profile format and data structure -- Part 1: Based on ICC.1:2010		
Measurement conditions		
ISO 13655:2009 Graphic technology -- Spectral measurement and colorimetric computation for graphic arts images ISO 5-4:2009 Photography and graphic technology -- Density measurements -- Part 4: Geometric conditions for reflection density		
Viewing conditions		
ISO 3664:2009 Graphic technology and photography -- Viewing conditions		

Bottleneck No. 1: The current ICC architecture

ICC architecture

The current ICC architecture is only capable to transport a single colour which is defining an object through our colour management process:

This is usually enough to define a print on paper as the reflection characteristics are rather diffuse.

For substrates with rather complex reflection characteristics this is not enough!

The problem is known and will be addressed in the future.

Bottleneck No. 2: Measurement technology used today in the GA industry

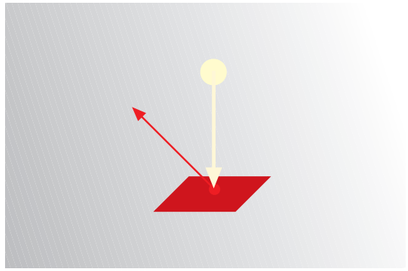
Measurement conditions

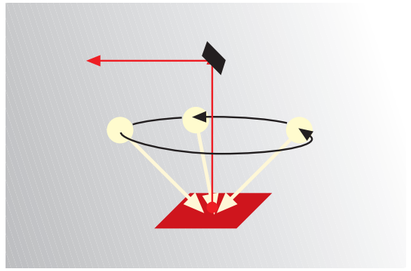
In the graphic arts industry we usually use today measurement instruments with a 45º/0º or 0º/45º geometry.

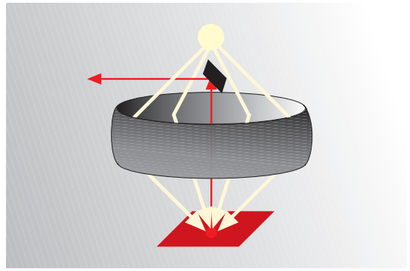
Instruments either illuminate the sample from one angle, three angles or circumferential.

For diffuse reflecting samples the different geometric designs of the instruments make only little difference in the results...

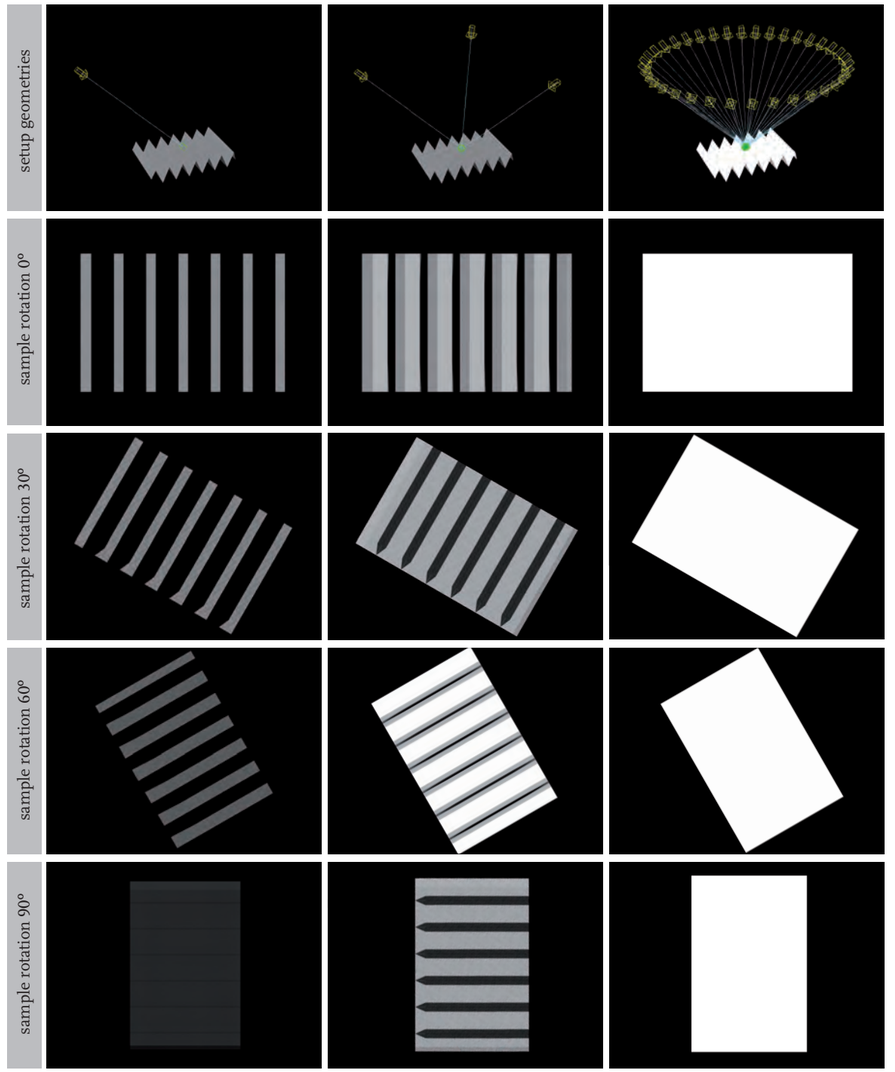
... for samples with complex reflection characteristics the different geometric designs may make a big difference.



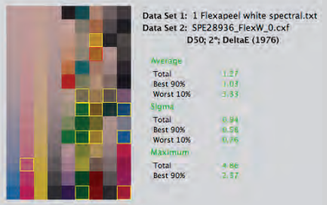
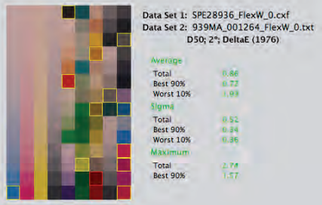
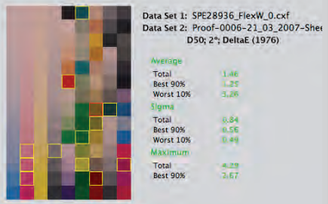
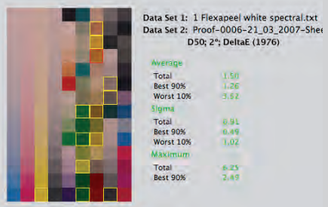
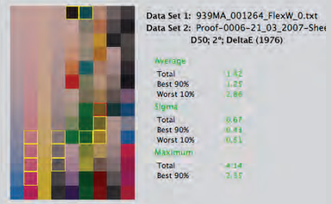
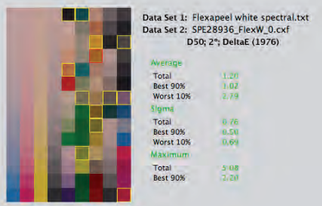
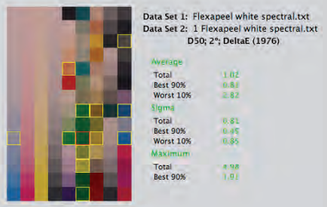
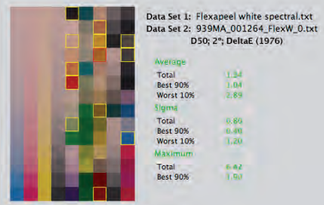
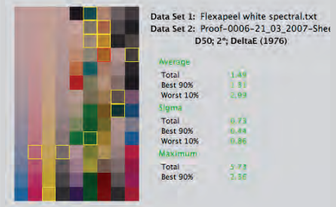




Simplified simulation of different 45º/0º measurement instruments on Flexalpeel®



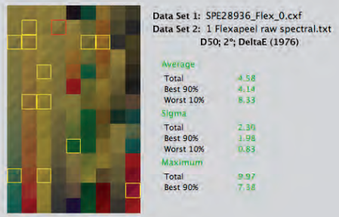
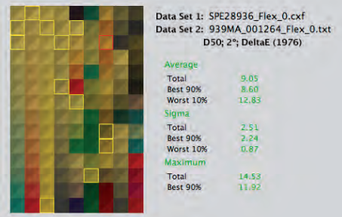
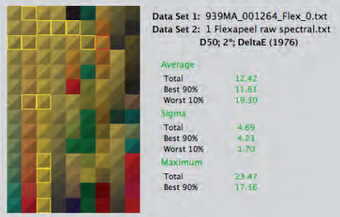
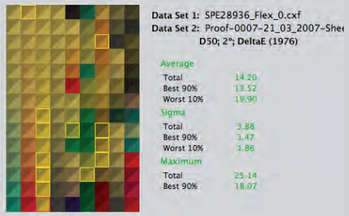
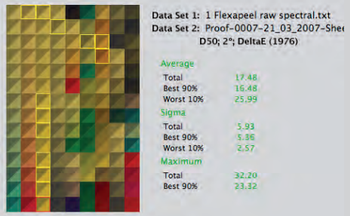
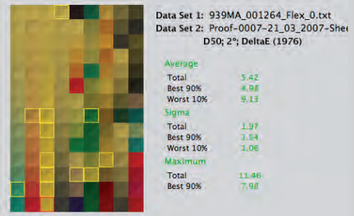
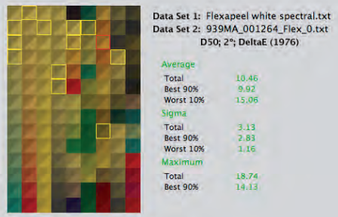
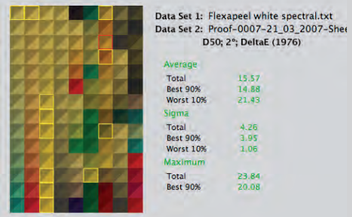
Bottleneck No. 2: Measurement technology used today in the GA industry

Flexalpeel® Opaque White Orientation 0º	X-Rite SpectroEye SN: 28936	X-Rite 530 SN: 5195	X-Rite 939 SN: 001264	Heidelberg ImageControl 1
X-Rite 530 SN: 5195				
X-Rite 939 SN: 001264				
Heidelberg ImageControl 1				
GretagMacbeth Spectrolino SN: 16655				

IMA
on white coated
FELXALPEEL
Max deltaE
best 90%

1.08 -2.76

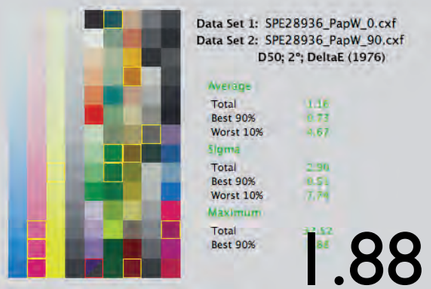
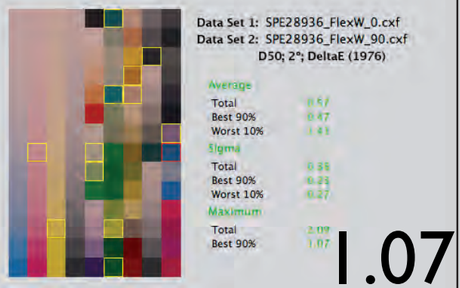
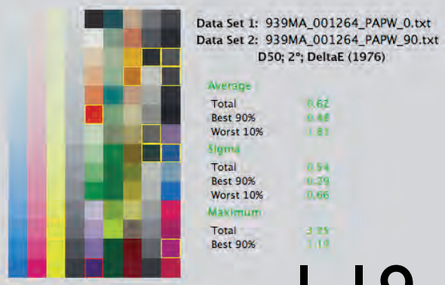
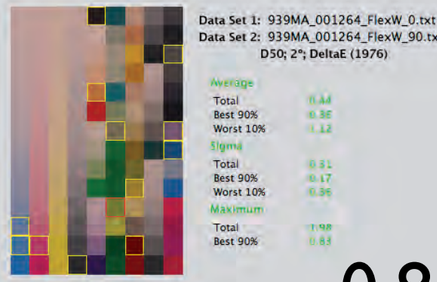
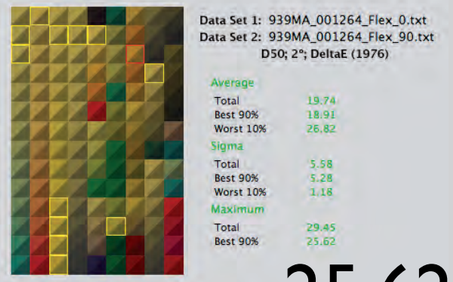
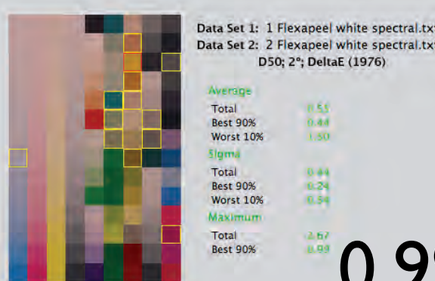
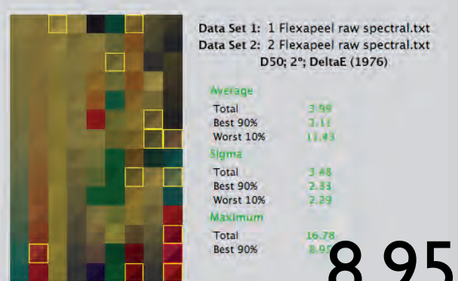
Bottleneck No. 2: Measurement technology used today in the GA industry

Flexalpeel® Orientation 0°	X-Rite SpectroEye SN: 28936	X-Rite 530 SN: 5195	X-Rite 939 SN: 001264	Heidelberg ImageControl 1
X-Rite 530 SN: 5195	 Data Set 1: SPE28936_Flex_0.cxf Data Set 2: 1 Flexapeel raw spectral.txt D50; 2°; DeltaE (1976) Average Total 4.58 Best 90% 4.14 Worst 10% 8.33 Sigma Total 2.30 Best 90% 1.98 Worst 10% 0.83 Maximum Total 9.97 Best 90% 7.18			
X-Rite 939 SN: 001264	 Data Set 1: SPE28936_Flex_0.cxf Data Set 2: 939MA_001264_Flex_0.txt D50; 2°; DeltaE (1976) Average Total 9.05 Best 90% 8.60 Worst 10% 12.83 Sigma Total 2.51 Best 90% 2.24 Worst 10% 0.87 Maximum Total 14.53 Best 90% 11.92	 Data Set 1: 939MA_001264_Flex_0.txt Data Set 2: 1 Flexapeel raw spectral.txt D50; 2°; DeltaE (1976) Average Total 12.42 Best 90% 11.81 Worst 10% 19.30 Sigma Total 4.69 Best 90% 4.23 Worst 10% 1.70 Maximum Total 23.47 Best 90% 17.46		
Heidelberg ImageControl 1	 Data Set 1: SPE28936_Flex_0.cxf Data Set 2: Proof-0007-21_03_2007-She D50; 2°; DeltaE (1976) Average Total 14.20 Best 90% 13.52 Worst 10% 19.90 Sigma Total 3.88 Best 90% 3.47 Worst 10% 1.86 Maximum Total 25.14 Best 90% 18.07	 Data Set 1: 1 Flexapeel raw spectral.txt Data Set 2: Proof-0007-21_03_2007-She D50; 2°; DeltaE (1976) Average Total 17.48 Best 90% 16.48 Worst 10% 25.99 Sigma Total 5.93 Best 90% 5.36 Worst 10% 2.57 Maximum Total 32.20 Best 90% 23.32	 Data Set 1: 939MA_001264_Flex_0.txt Data Set 2: Proof-0007-21_03_2007-She D50; 2°; DeltaE (1976) Average Total 5.42 Best 90% 4.98 Worst 10% 9.13 Sigma Total 1.97 Best 90% 1.54 Worst 10% 1.06 Maximum Total 11.46 Best 90% 7.98	
GretagMacbeth Spectrolino SN: 16655	 Data Set 1: Flexapeel white spectral.txt Data Set 2: SPE28936_Flex_0.cxf D50; 2°; DeltaE (1976) Average Total 2.07 Best 90% 1.85 Worst 10% 3.94 Sigma Total 1.11 Best 90% 0.95 Worst 10% 0.32 Maximum Total 4.56 Best 90% 3.54	 Data Set 1: Flexapeel white spectral.txt Data Set 2: 1 Flexapeel raw spectral.txt D50; 2°; DeltaE (1976) Average Total 3.43 Best 90% 3.00 Worst 10% 7.07 Sigma Total 1.86 Best 90% 1.36 Worst 10% 1.28 Maximum Total 8.89 Best 90% 5.34	 Data Set 1: Flexapeel white spectral.txt Data Set 2: 939MA_001264_Flex_0.txt D50; 2°; DeltaE (1976) Average Total 10.46 Best 90% 9.92 Worst 10% 15.06 Sigma Total 3.13 Best 90% 2.83 Worst 10% 1.16 Maximum Total 18.74 Best 90% 14.13	 Data Set 1: Flexapeel white spectral.txt Data Set 2: Proof-0007-21_03_2007-She D50; 2°; DeltaE (1976) Average Total 15.57 Best 90% 14.88 Worst 10% 21.43 Sigma Total 4.26 Best 90% 3.95 Worst 10% 1.06 Maximum Total 23.84 Best 90% 20.08

IMA
on
FELXALPEEL
Max deltaE
best 90%

7.20 -23.38

Bottleneck No. 2: Measurement technology used today in the GA industry

	Coated Paper Opaque White 0° vs. 90° orientation	Flexalpeel® Opaque White 0° vs. 90° orientation	Flexalpeel® 0° vs. 90° orientation
X-Rite SpectroEye SN: 28936	 1.88	 1.07	 2.19
X-Rite 939 SN: 001264	 1.19	 0.83	 25.62
X-Rite 530 SN:5195		 0.99	 8.95

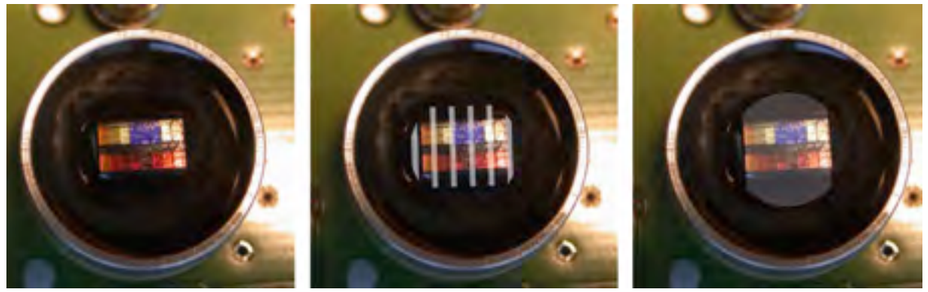
90° sample rotation
Max deltaE best 90%

Bottleneck No. 2: Measurement technology used today in the GA industry

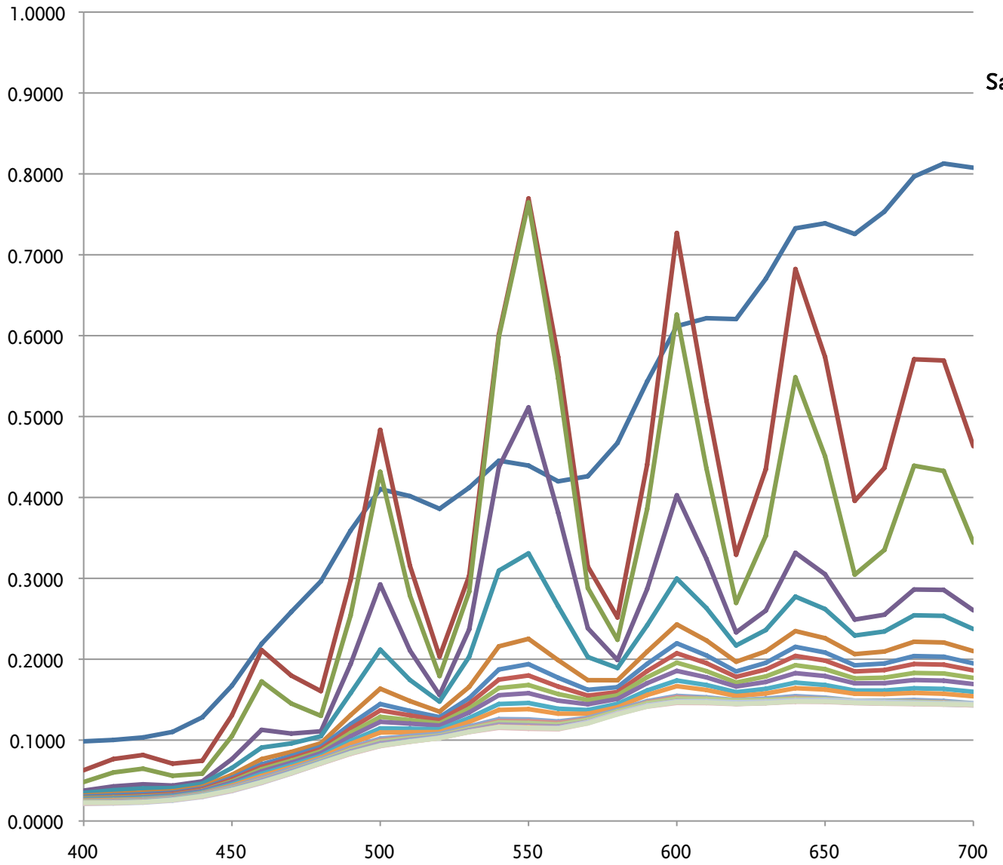
Measurement conditions

...but complex reflection characteristics of a sample can cause even worse effects:

This sample shows interference effects between the spectral sensor of a 0º/45º instrument and the micro structure of the sample.



Results from a 0º/45ºa measurement instrument on Flexalpeel® (sample rotates 5º every measurement)



Sample ID:	Orientation:	L*	a*	b*
1	0º	74.34	9.73	36.84
2	5º	73.01	-4.36	44.33
3	9º	70.41	-10.32	46.6
4	14º	61.88	-10.32	41.86
5	18º	55.63	-5.19	35.91
6	23º	50.58	-0.85	31.35
7	27º	48.49	0.17	29.73
8	32º	47.38	0.44	28.92
9	36º	46.35	0.53	28.25
10	41º	45.45	0.63	27.59
11	45º	44.27	0.83	26.75
12	50º	43.47	1.04	26.35
13	54º	42.36	1.32	25.33
14	59º	42.05	1.46	25.45
15	63º	41.93	1.69	25.46
16	68º	41.53	1.59	25.25
17	72º	41.29	1.97	25.36
18	77º	41.35	2.16	25.9
19	81º	41.34	2.24	26.21
20	86º	41.16	2.07	25.73
21	90º	41.24	2.06	25.56

Bottleneck No. 2: Measurement technology used today in the GA industry

Measurement conditions

Wouldn’t instruments with a d/8º geometry solve the problem?

For process control yes!

For colour management unfortunately not, unless your viewing condition is on a ski lift on a foggy winter day.

Bottleneck No. 2: Measurement technology used today in the GA industry

Measurement conditions

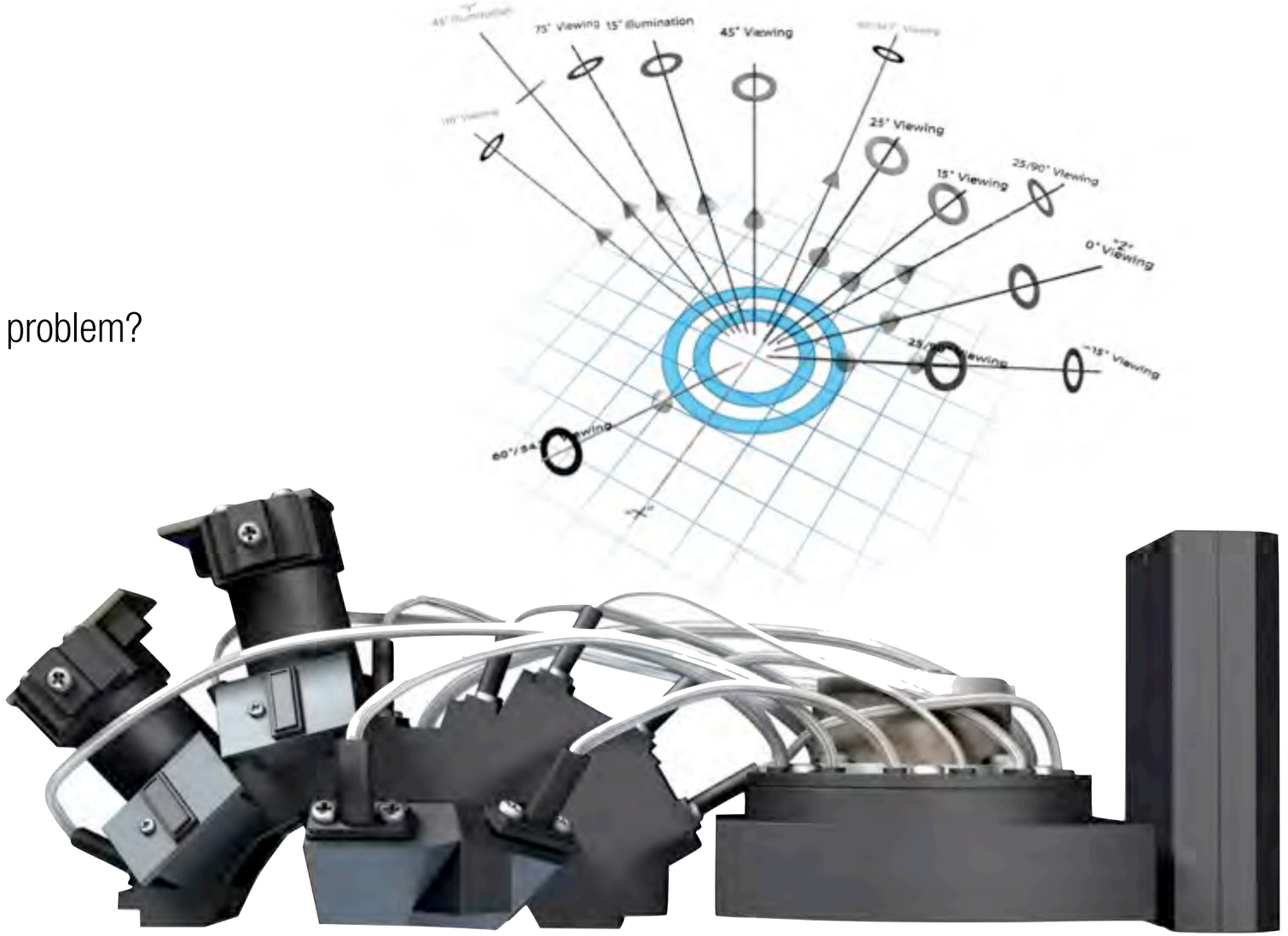
Could multi-angle instruments solve the problem?

Yes, but...

keep in mind that current ICC is not ready to process multiple angle colour information yet

multi-angle instruments are developed for different industries with different requirements (e.g. spot size)

Compared to 45º/0º instruments multi-angle instruments are rather pricy



© Images: X-Rite, Inc.

Bottleneck No. 3: Viewing conditions

Viewing conditions

Real world viewing conditions are rather complex:

- illuminants with different spectral power distributions

- a variation of diffuse and spot illumination

- multiple illumination angles and usually observers who tend not to look at the package from just one angle.

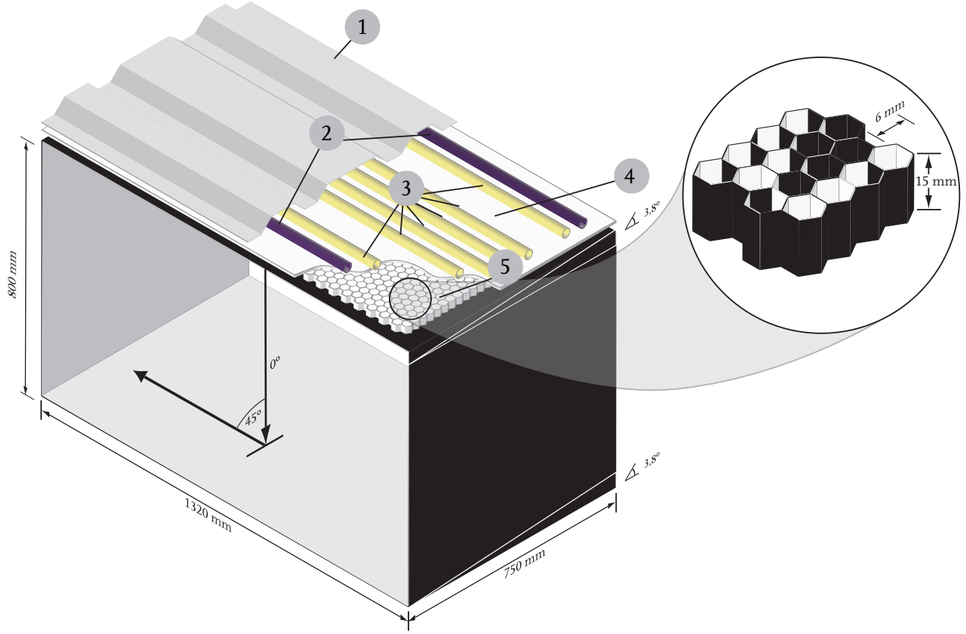
Bottleneck No. 3: Viewing conditions

Viewing conditions

To make ICC colour management work we are already used to restrict ourselves to a light box with a spectral power distribution close to D50 daylight.

© Image: X-Rite, Inc.

To make colour management work for substrates with rather complex reflection characteristics the viewing conditions for observation must match those illumination and pickup conditions in the measurement instrument.

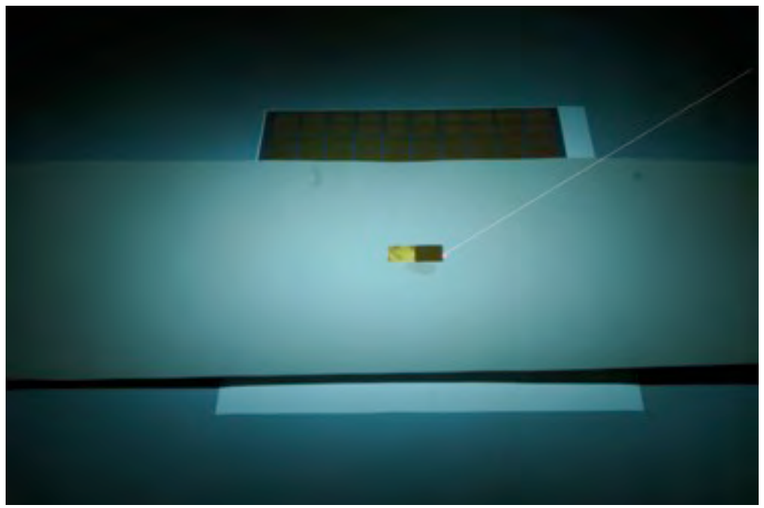


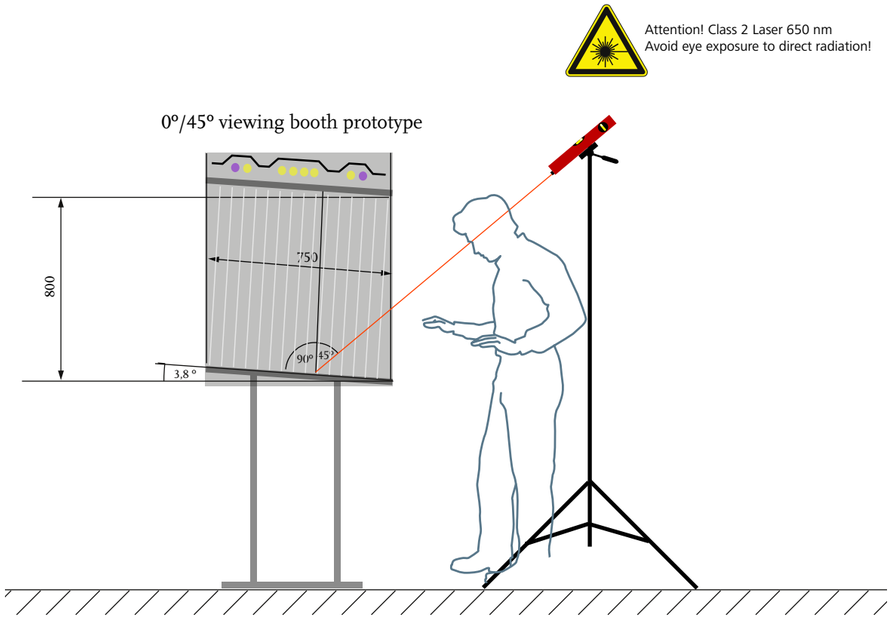
Conclusion from the psychophysical study

ICC colour management on non-paperbased substrates can be enabled within the current ICC architecture if:

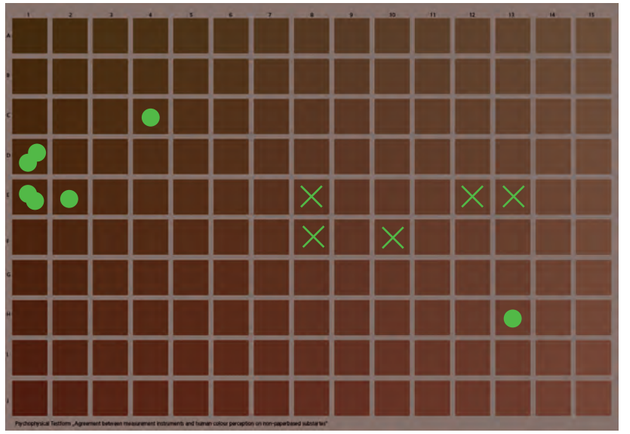
- geometric design of 45º/0º or 0º/45º is used but instrument optics design is carefully chosen

- geometries for the viewing conditions for observation match those of the measurement instrument





Conventional viewing booth



0º/45º viewing booth