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BRDF measurement and color appearance simulation based on iccMAX framework

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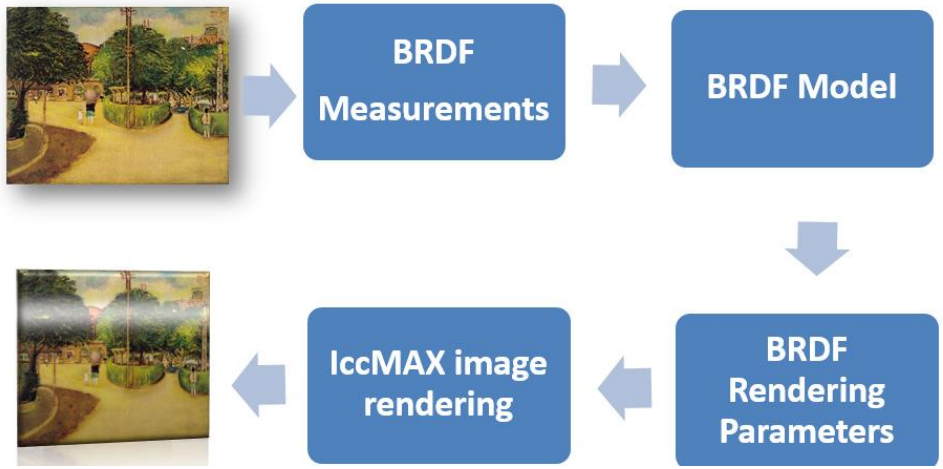
Motivation

- ICC profiles have been widely used in digital archives to preserve the color information of the relics. However, their surface properties such as glossiness and texture have not yet been recorded using the conventional ICC system.
- ICC is currently working on iccMAX. The new ICC system can be used to simulate material appearance with BRDF parameters.
- The study aims to optimize BRDF measurement and color appearance simulation based on the iccMAX and providing real-world examples for evaluation.

Contents

- BRDF measurement of real-world samples
- Evolution of BRDF parameters
  - Blinn-Phong model as an example
- Color appearance simulation based on the iccMAX framework



1

BRDF measurement of real-world samples

BRDF Measurements

Samples:

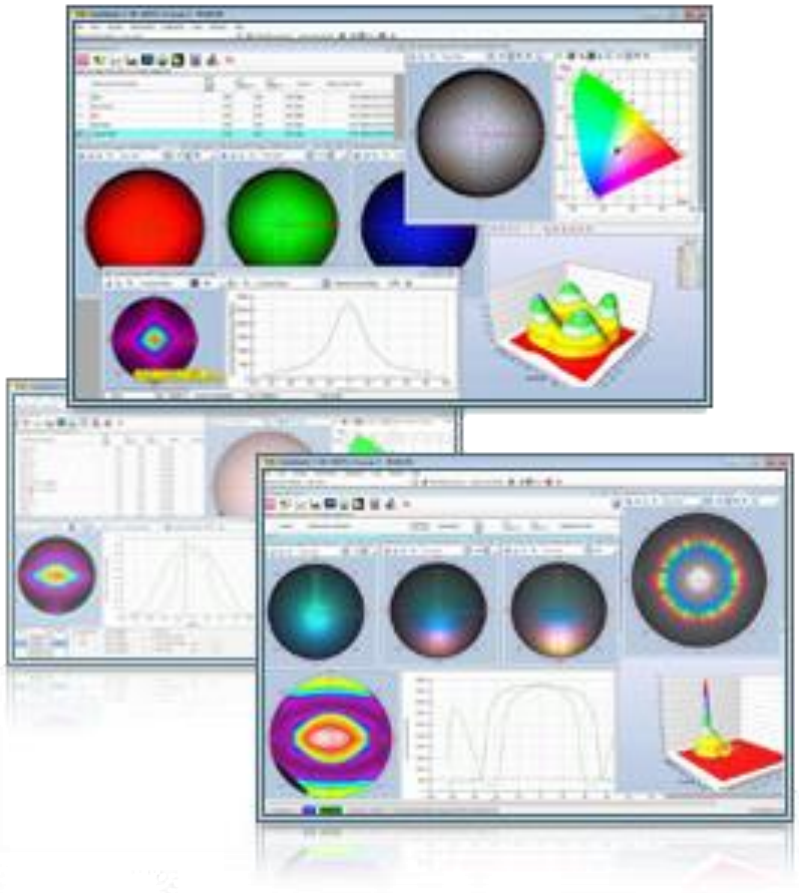
PANTONE®

- PANTONE coated/uncoated/metallic/ cotton
- R/G/B/W/K/GY

BRDF Measurements

Apparatus: IS-SA BRDF Scatterometer

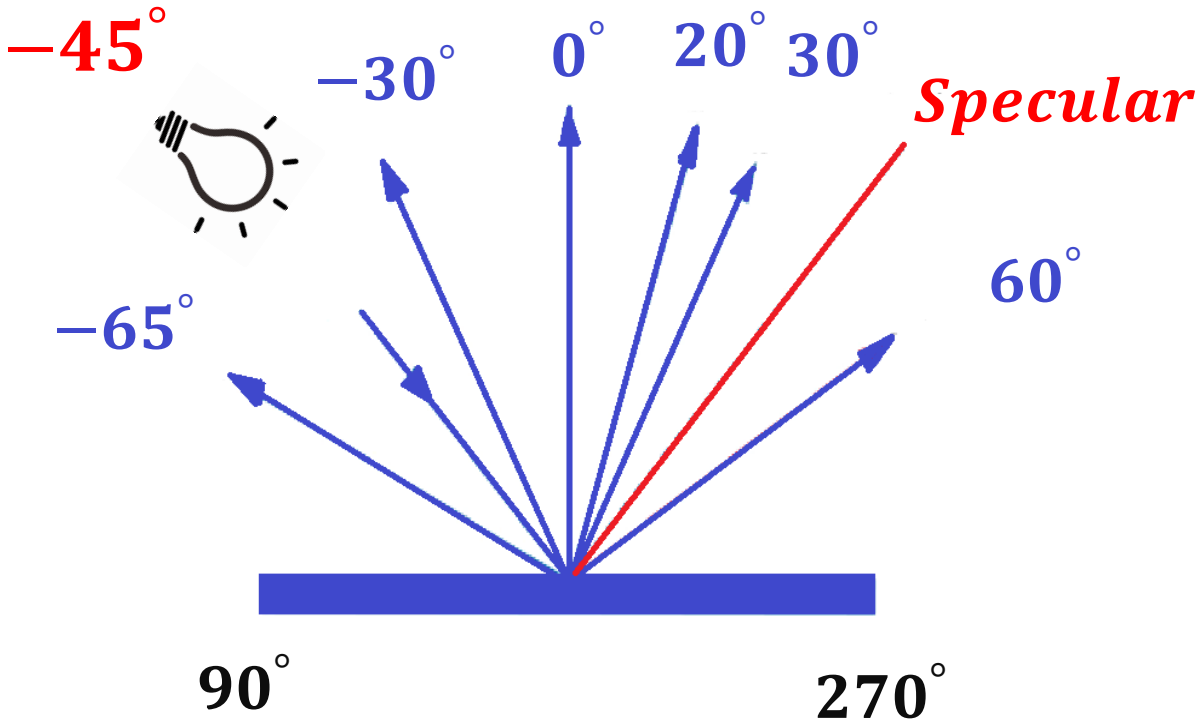
A hemisphere scatter imager



BRDF Measurements

Apparatus:

BYK-mac



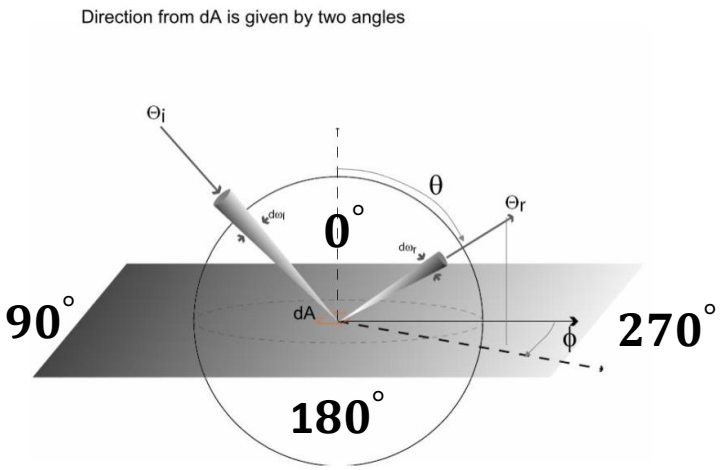
BRDF Measurements

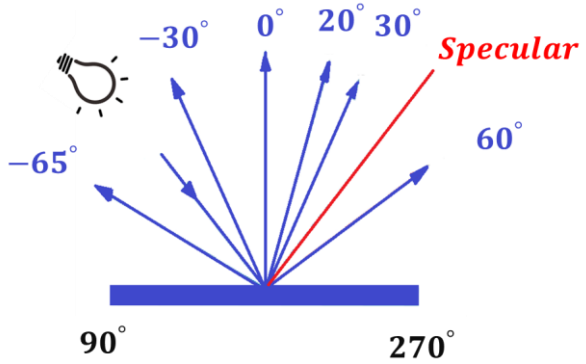
Measurement Geometries :

	IS-SA	BYK-Mac		IS-SA	BYK-Mac
Incident Angles	**d=ϕ=90°**	**d=ϕ=90°**	**data**	**X Y Z**	**L*a*b***
Θ_i	$10^\circ to\ 80^\circ$	-45°			
Reflection Angles	**d=ϕ=0° to 359°**	**d=ϕ=90° / 270°**			
Θ_r	0° to 80°	$0^\circ, 20^\circ, 30^\circ, 60^\circ, -30^\circ, -65^\circ,$			

d= azimuth angle,
Θ_i= illumination angle
Θ_r = viewing angle

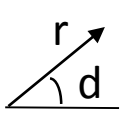
five aspecular angles



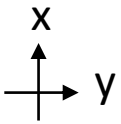


BRDF data coordinate transform

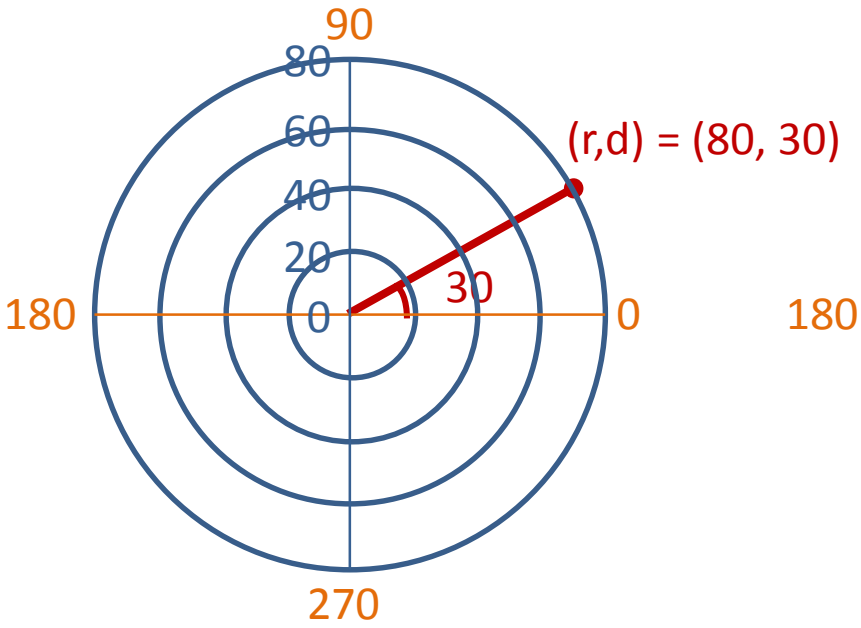
range
r =[0 90]
d=[0 360]

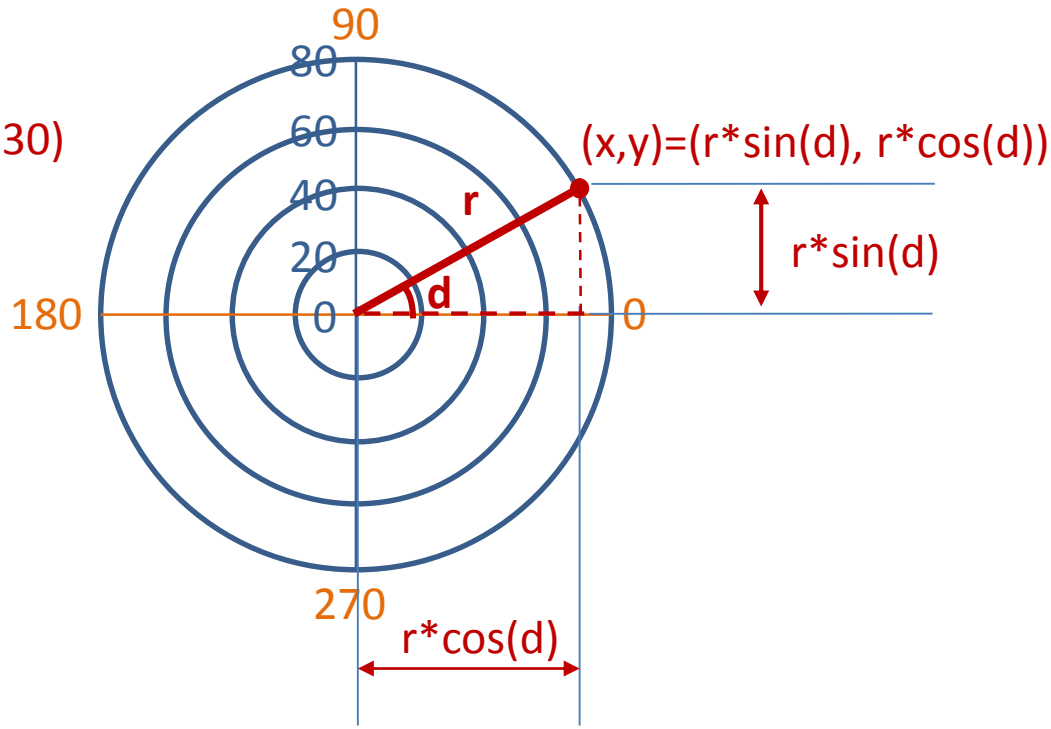


Raw Data (polar coordinates)



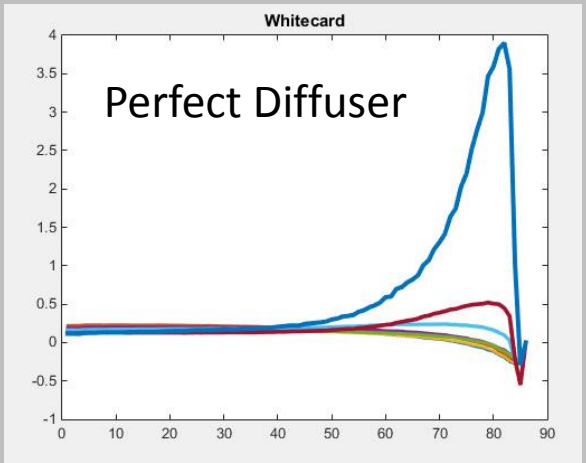
Raw Data (Cartesian coordinates)



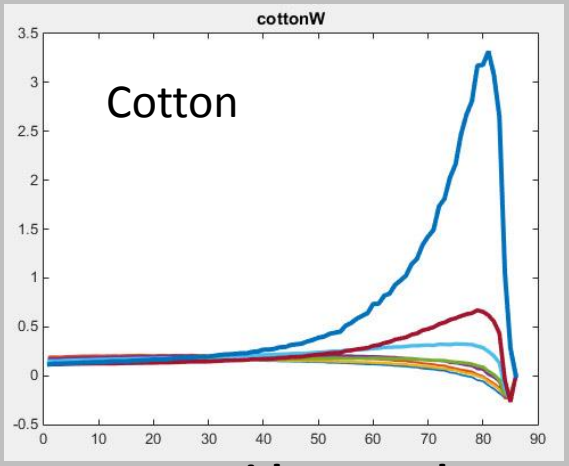


White samples with different glossiness

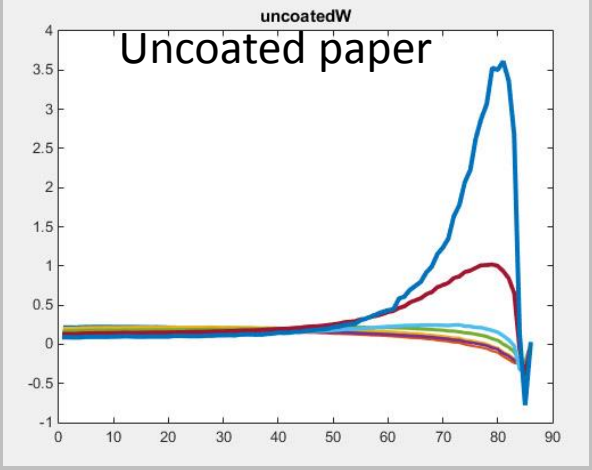
Y stimulus



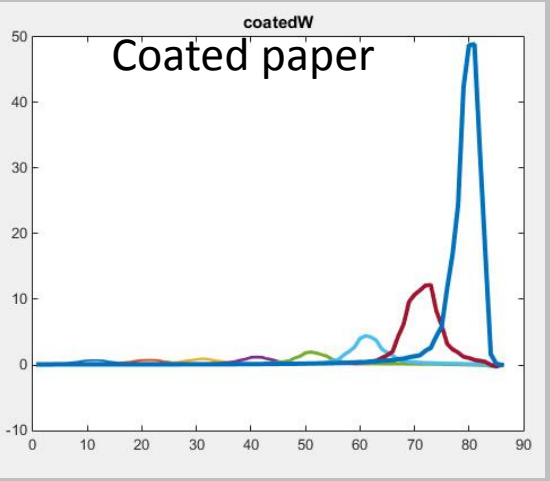
Incident Angles



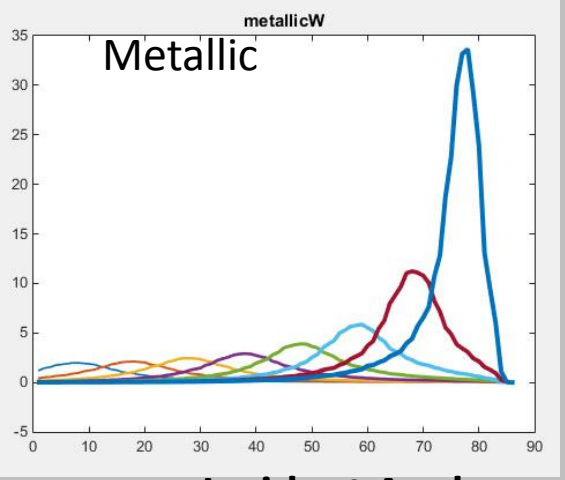
Incident Angles



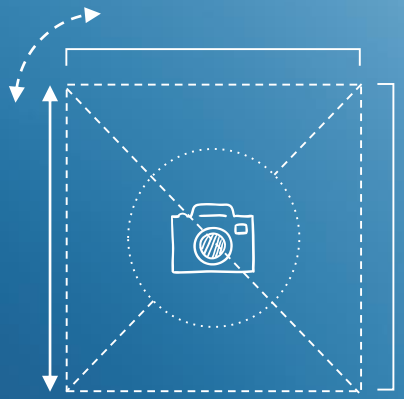
Incident Angles



Incident Angles



Incident Angles



2

Evolution of BRDF parameters

Blinn-Phong model as an example

BRDF Model

The following are the Blinn-Phong parameters that specify the material:

K_d is the diffuse reflection constant for the material
K_s is the specular reflection constant for the material.
n is the shininess constant for the material.

For the full colour Blinn-Phong function the three parameters shall be K_d , K_s, and n .
The order of the parameters in the transform shall be: K_d , K_s, and n

The monochrome function combines the output of the absolute transform with three parameters to compute the Blinn-Phong parameters

$K_d = I_d B$
$K_s = I_s B + I_{gs}$

XYZ tristimulus value in x/0 viewing

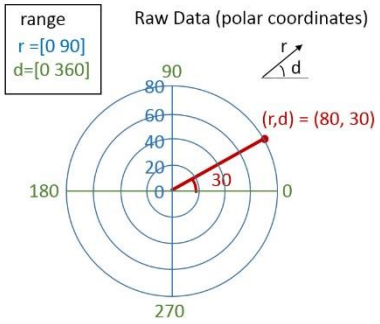
Where B is the output of the absolute transform, I_d is the diffuse scaling factor, I_s is the specular scaling factor, and I_{gs} is a global specular component.

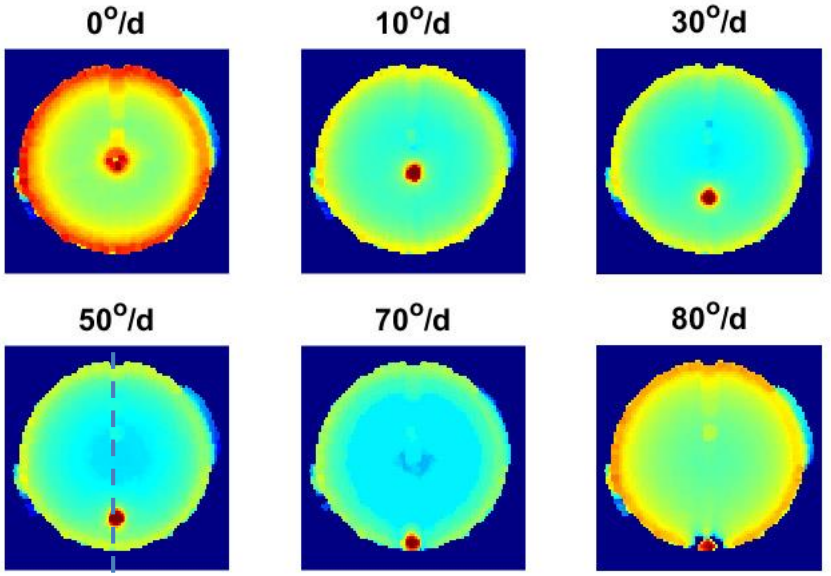
I_s are normally very small. We ignore them.

BRDF Rendering Parameters

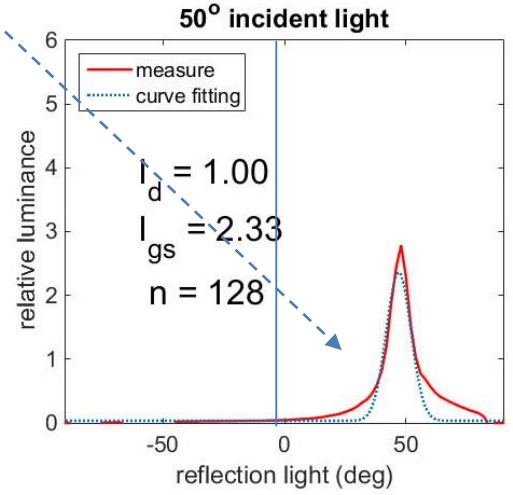
BRDF parameter fitting:

- Convert IS-SA raw data to images





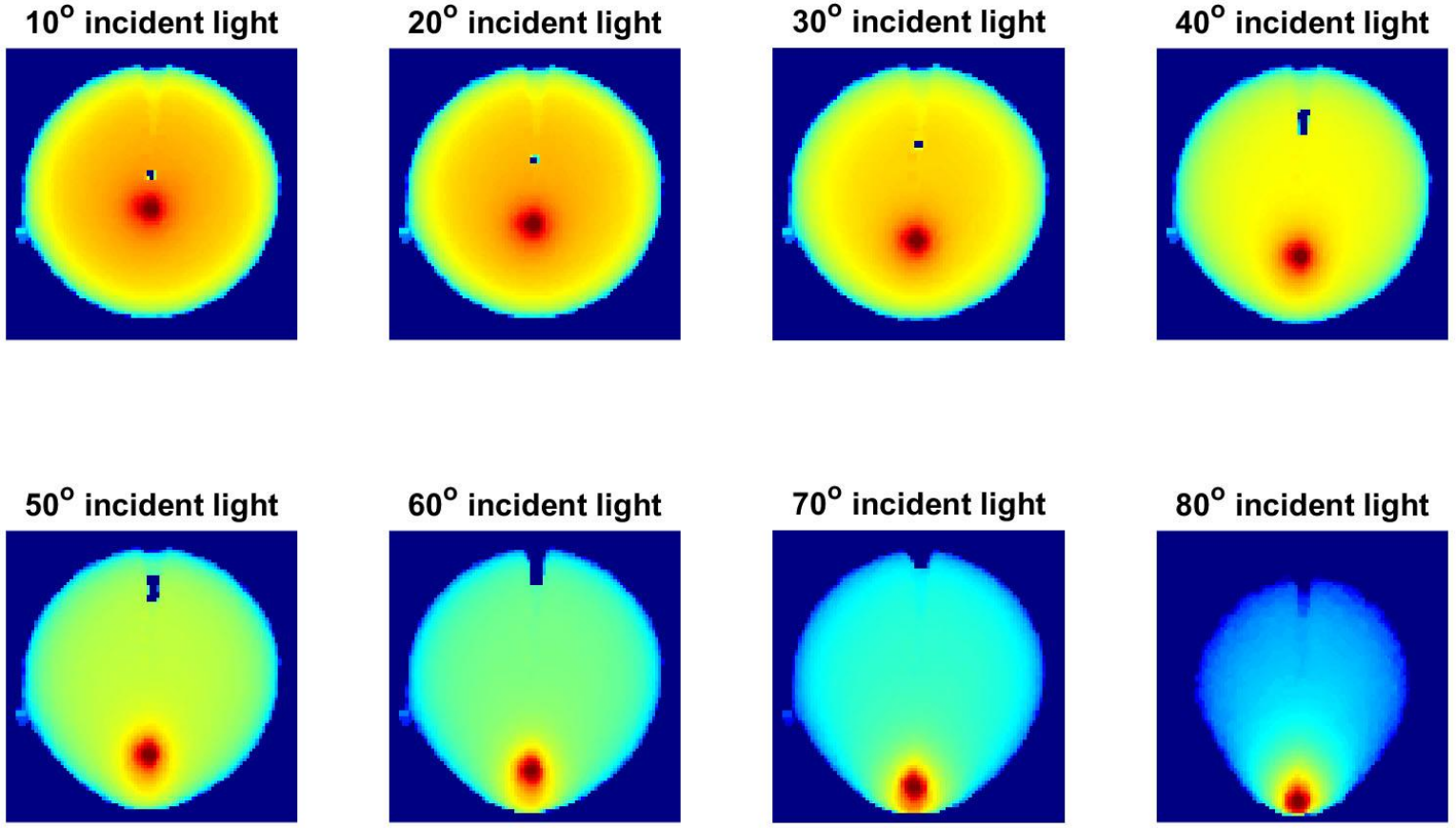
cross section



- Least-squared curve fitting for Blinn-Phong Reflection model

Coated Paper - Red

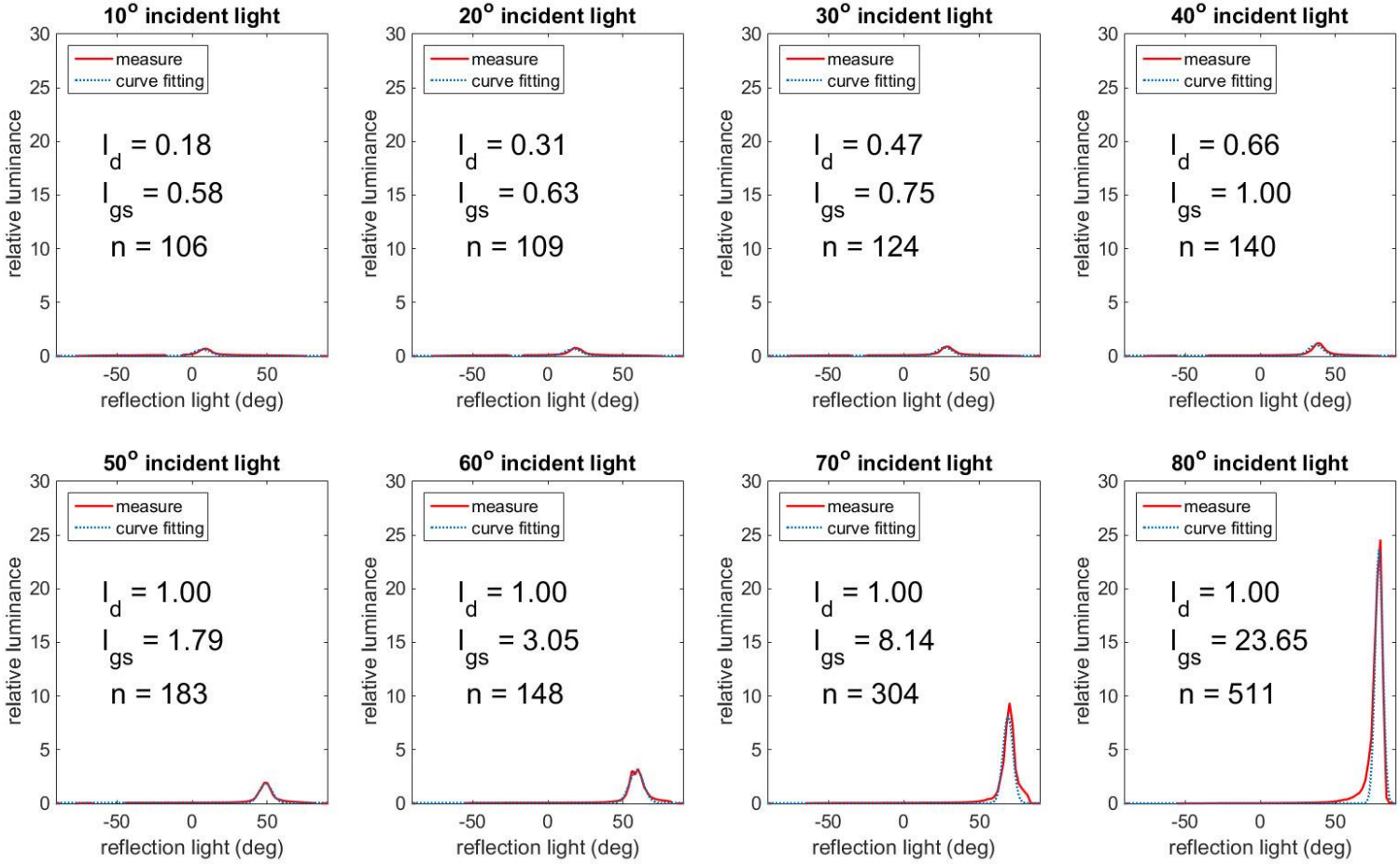
X stimulus



Normalized X stimuli with pseudo-colors

Coated Paper - Red

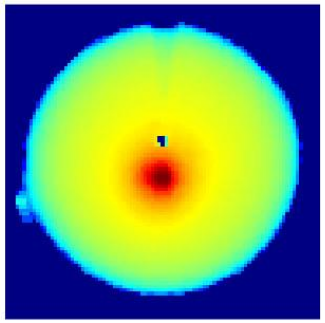
X stimulus



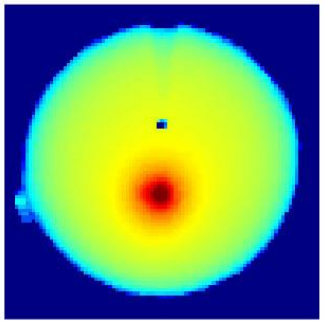
Coated Paper - Red

Y stimulus

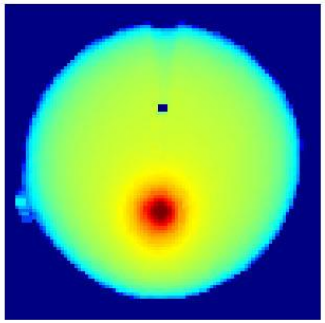
10° incident light



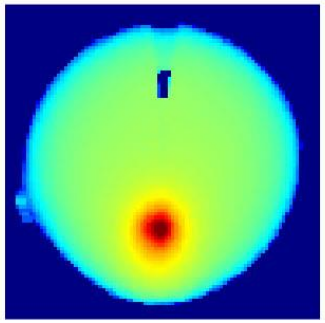
20° incident light



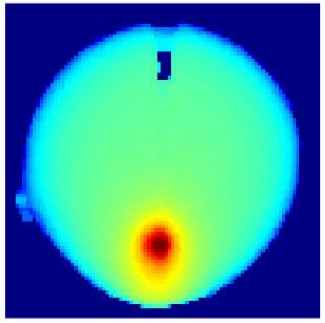
30° incident light



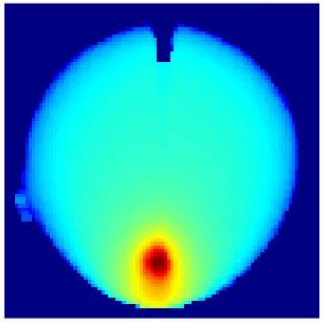
40° incident light



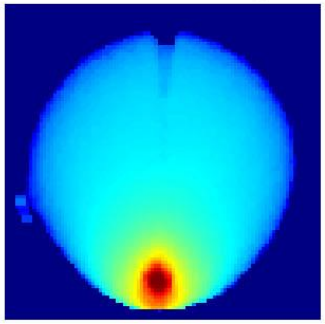
50° incident light



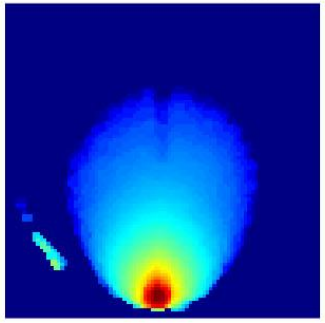
60° incident light



70° incident light



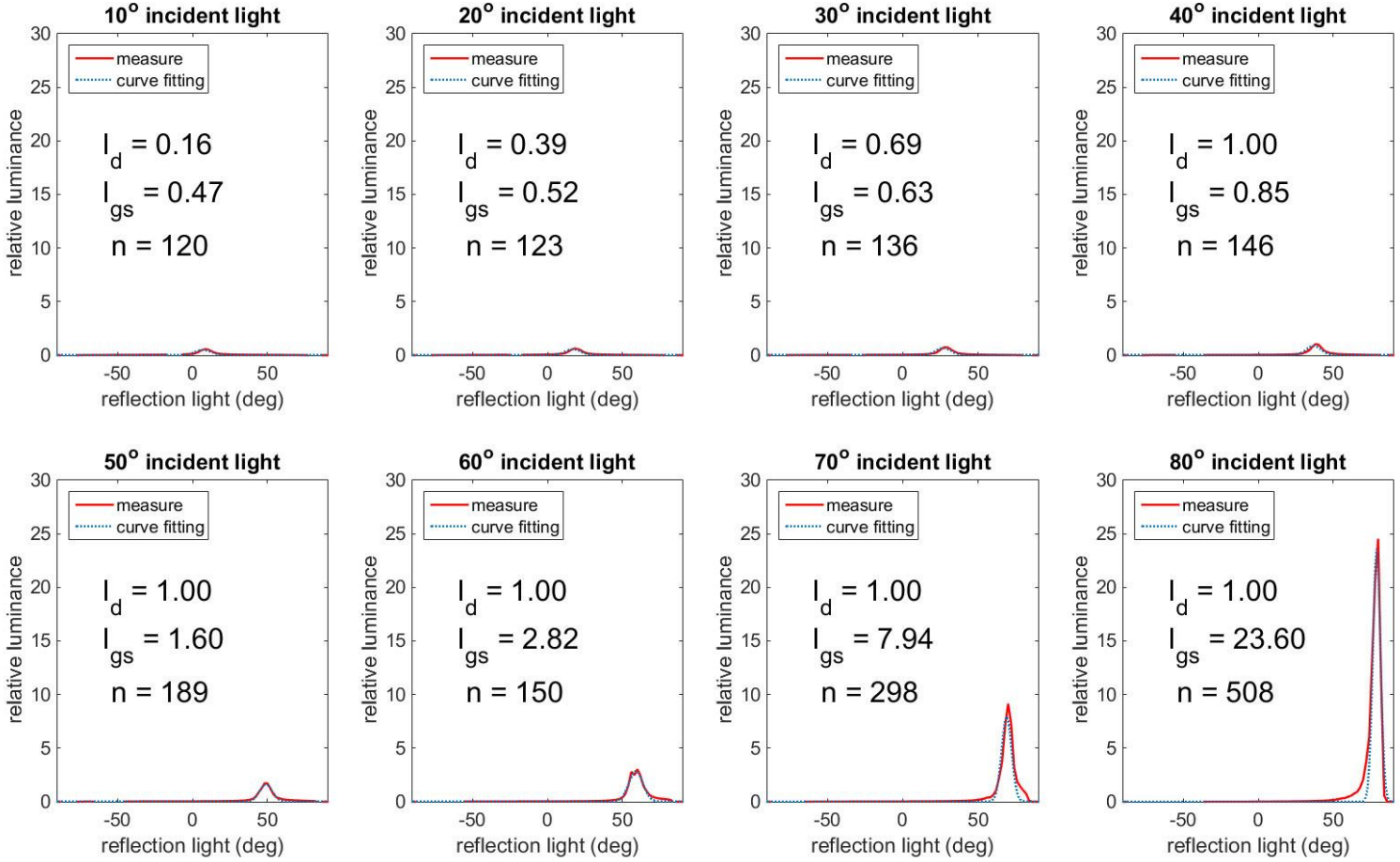
80° incident light



Normalized Y stimuli with pseudo-colors

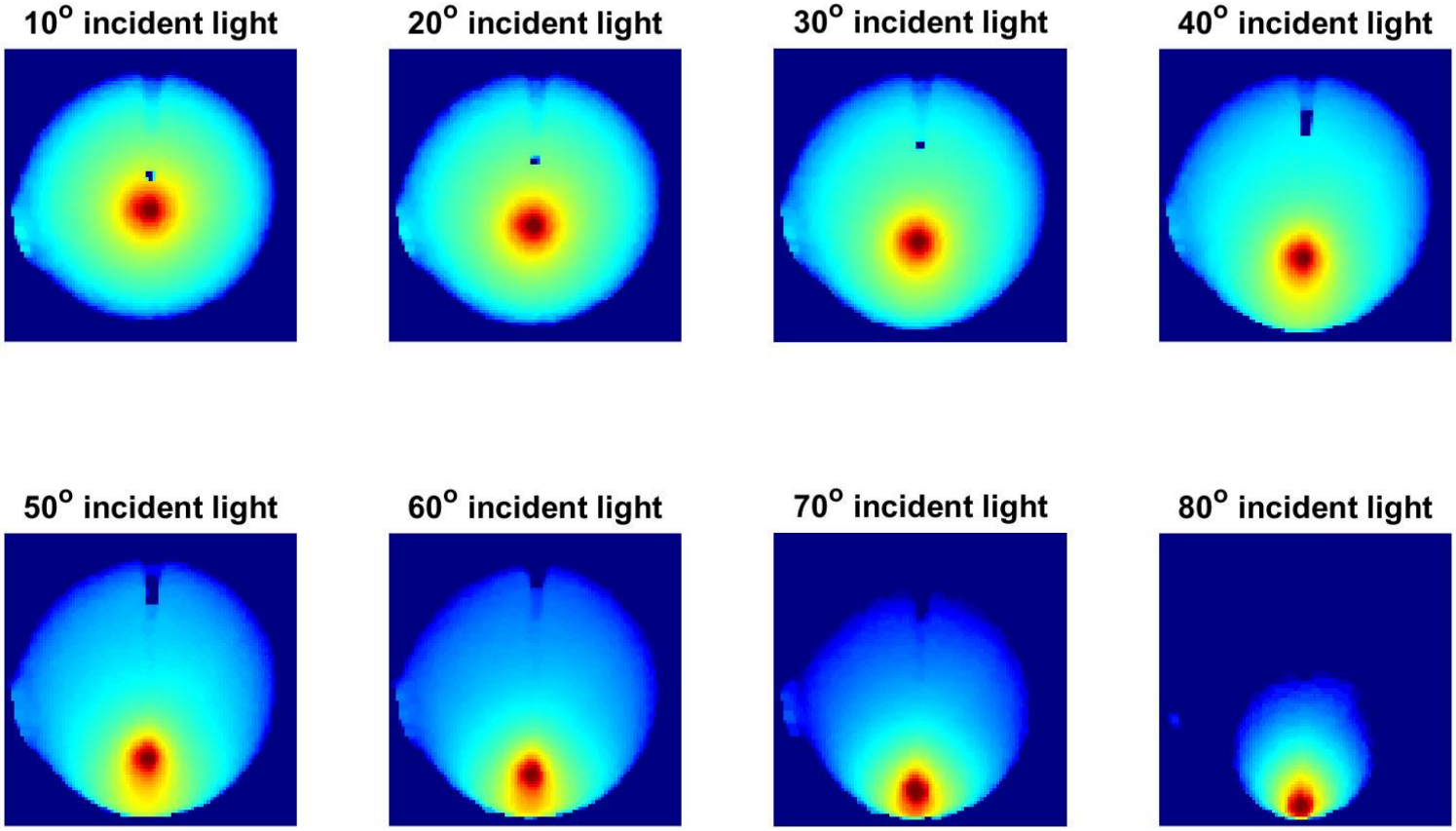
Coated Paper - Red

Y stimulus



Coated Paper - Red

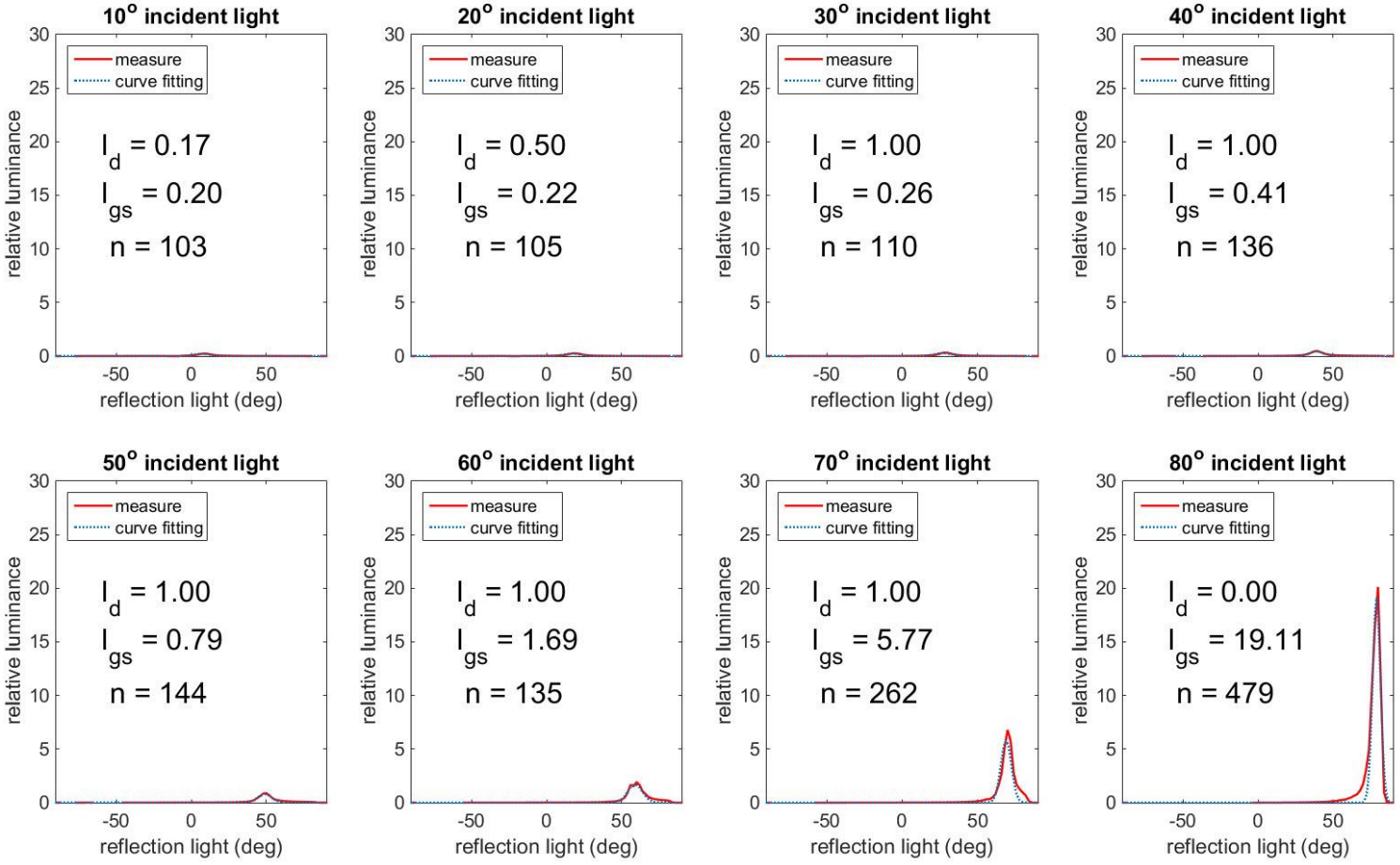
Z stimulus



Normalized Z stimuli with pseudo-colors

Coated Paper - Red

Z stimulus

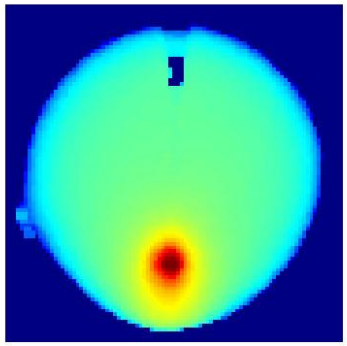


Summary

- Monochrome BRDF parameters across X, Y and Z channels are very similar.
- l_s are normally very small. We ignore them.
- Limit upper boundary of l_d to 1 could improve the fitting.

Coated Paper

R



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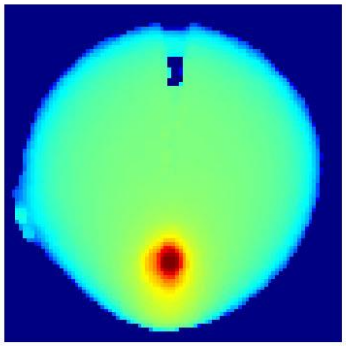

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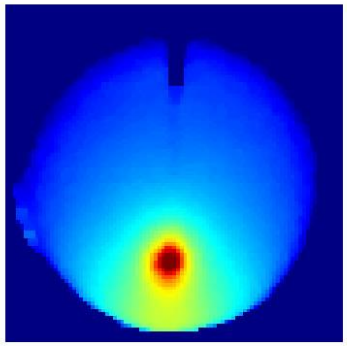

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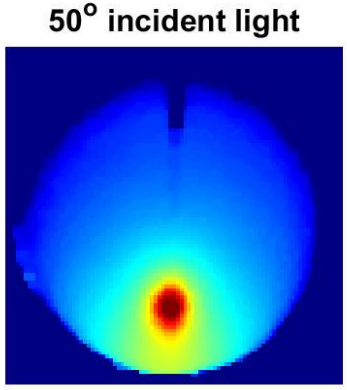

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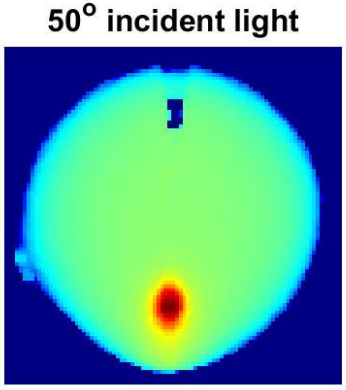

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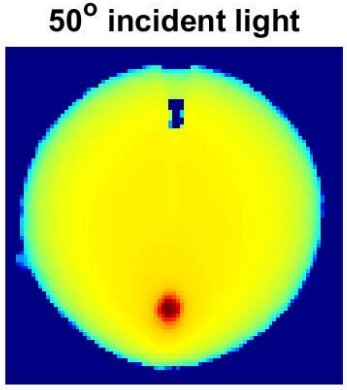
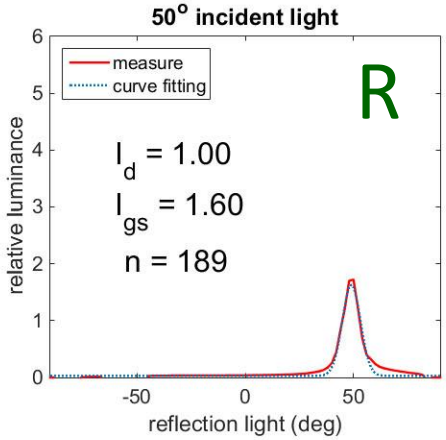
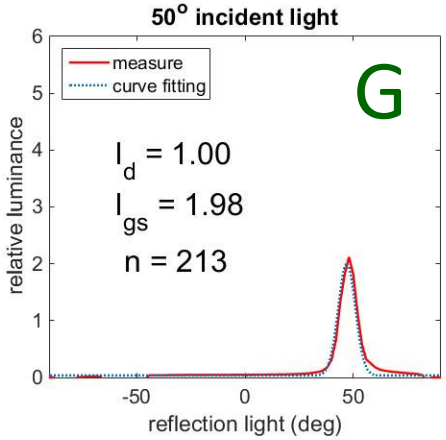


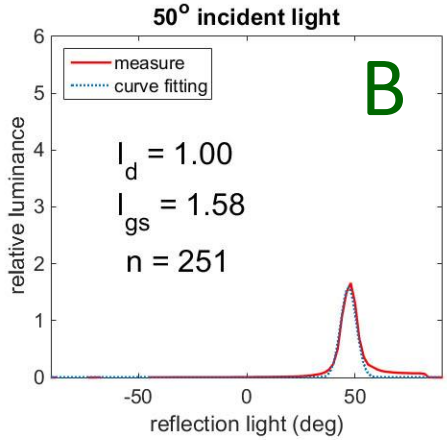
Normalized Y stimuli with pseudo-colors

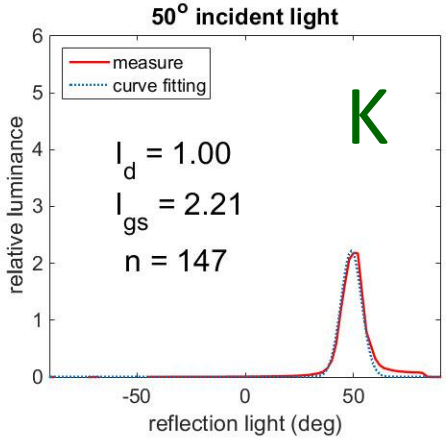
Coated Paper

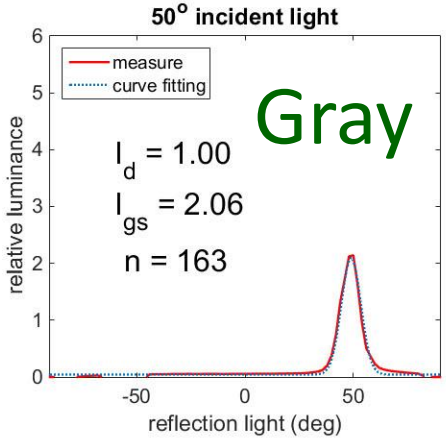
Y stimulus

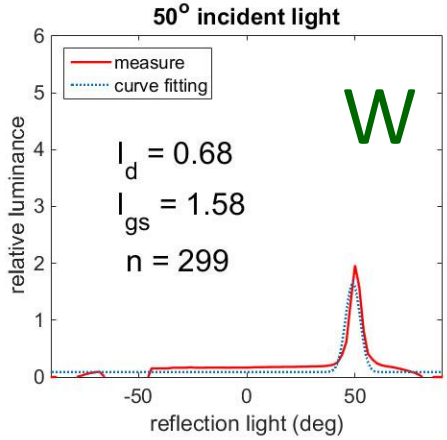






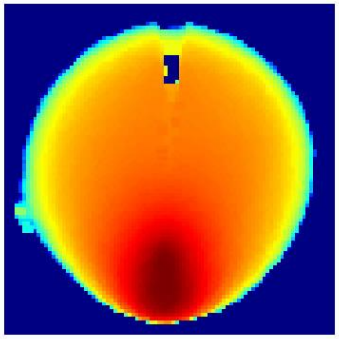






Uncoated Paper

R



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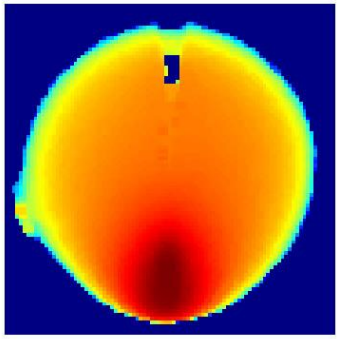

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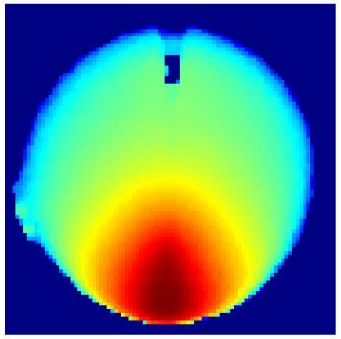

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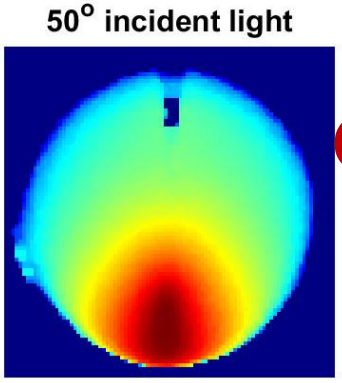

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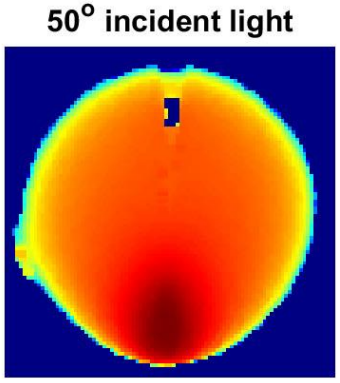

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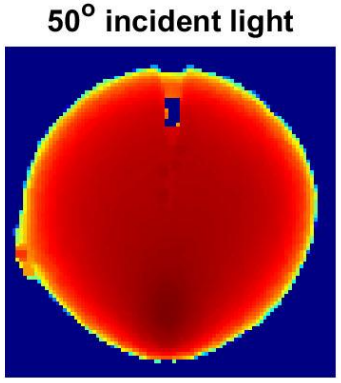
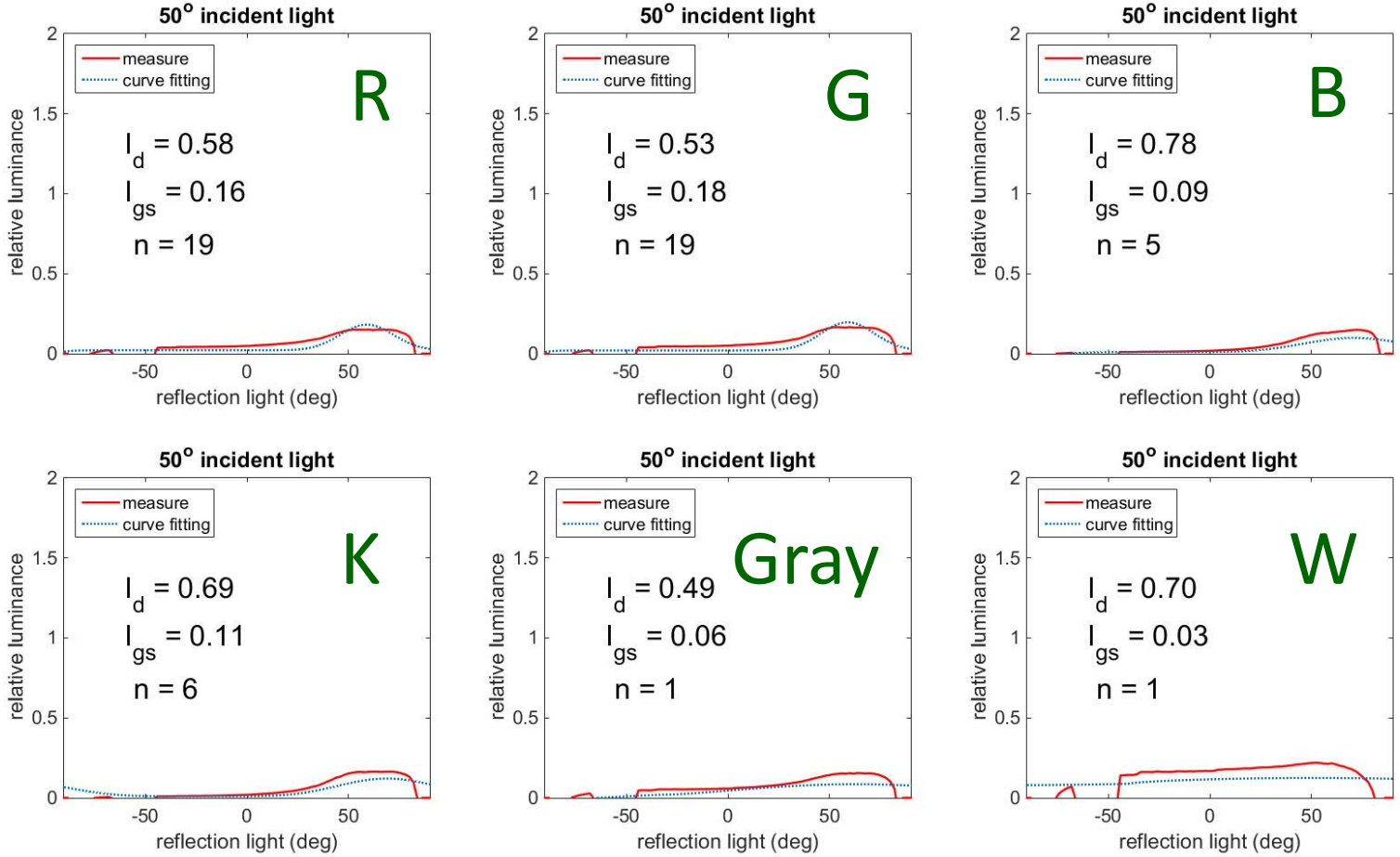


Normalized Y stimuli with pseudo-colors

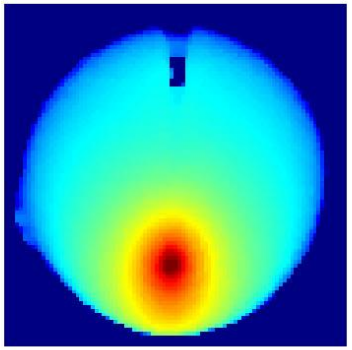
Uncoated Paper

Y stimulus



Metallic coated paper

R



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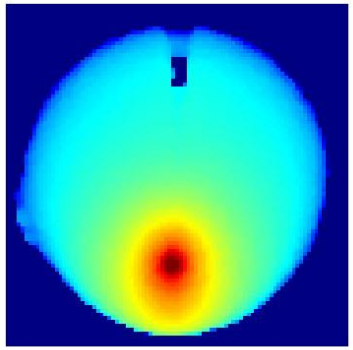

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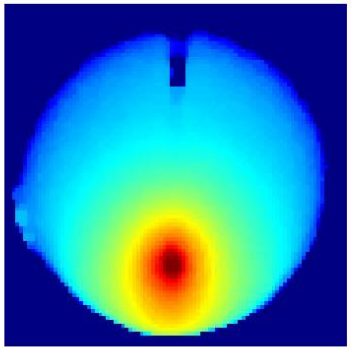

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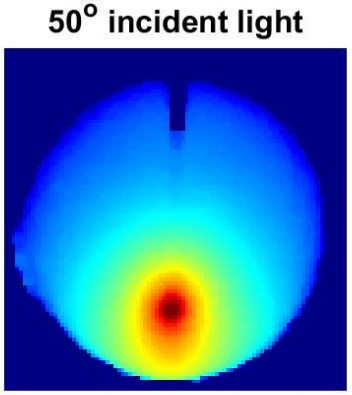
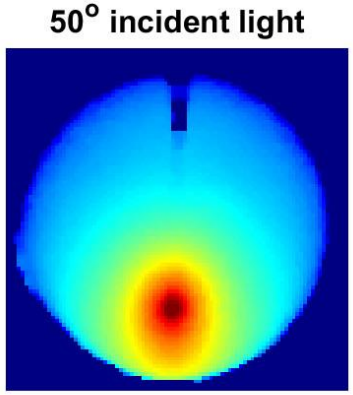
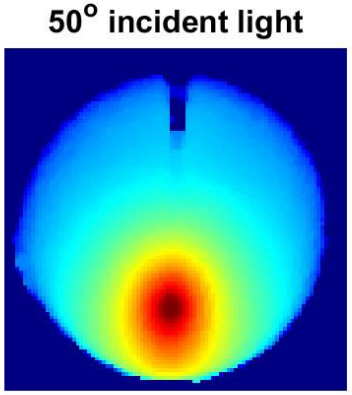


Gray



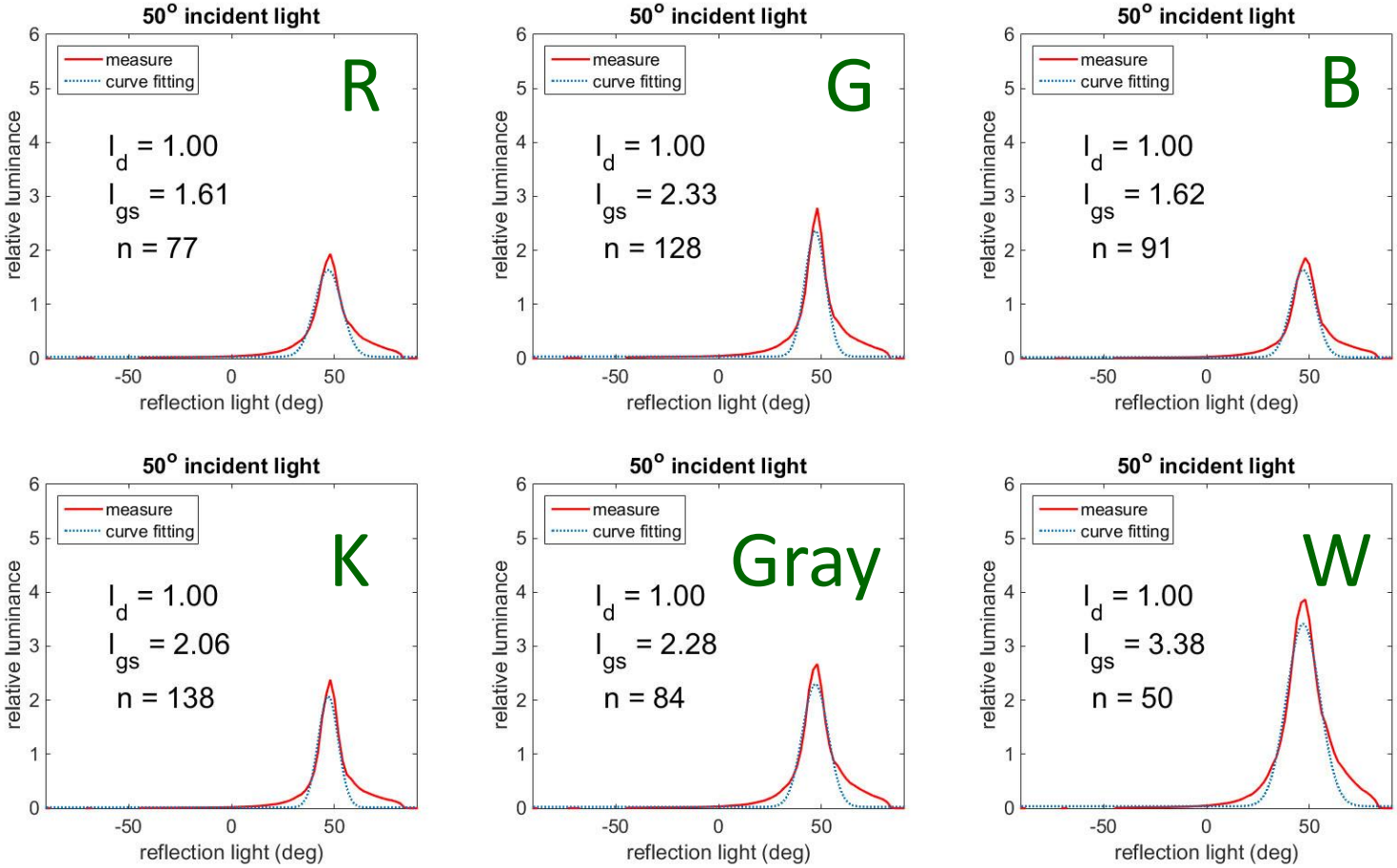
W



Normalized Y stimuli with pseudo-colors

Metallic coated paper

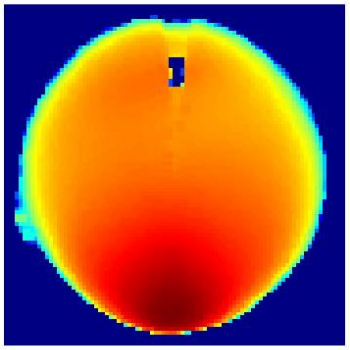
Y stimulus



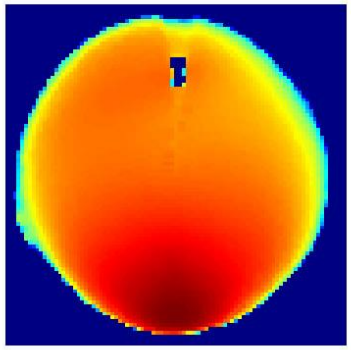
Cotton

Y stimulus

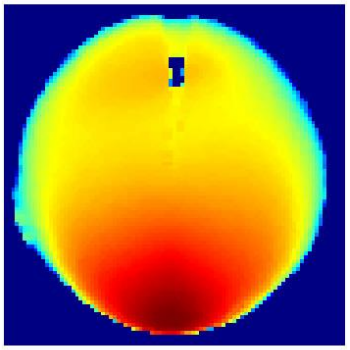
R



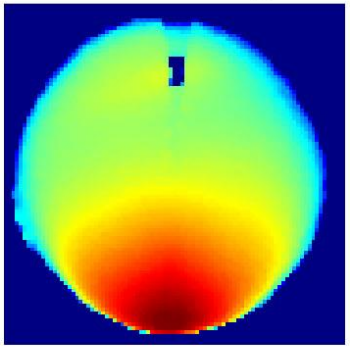
G



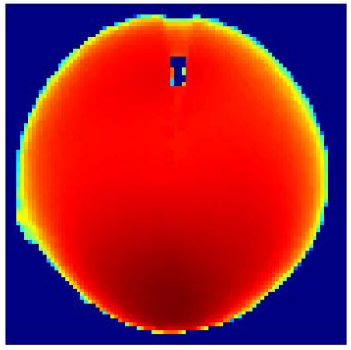
B



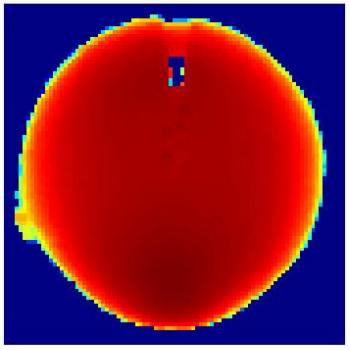
K



Gray



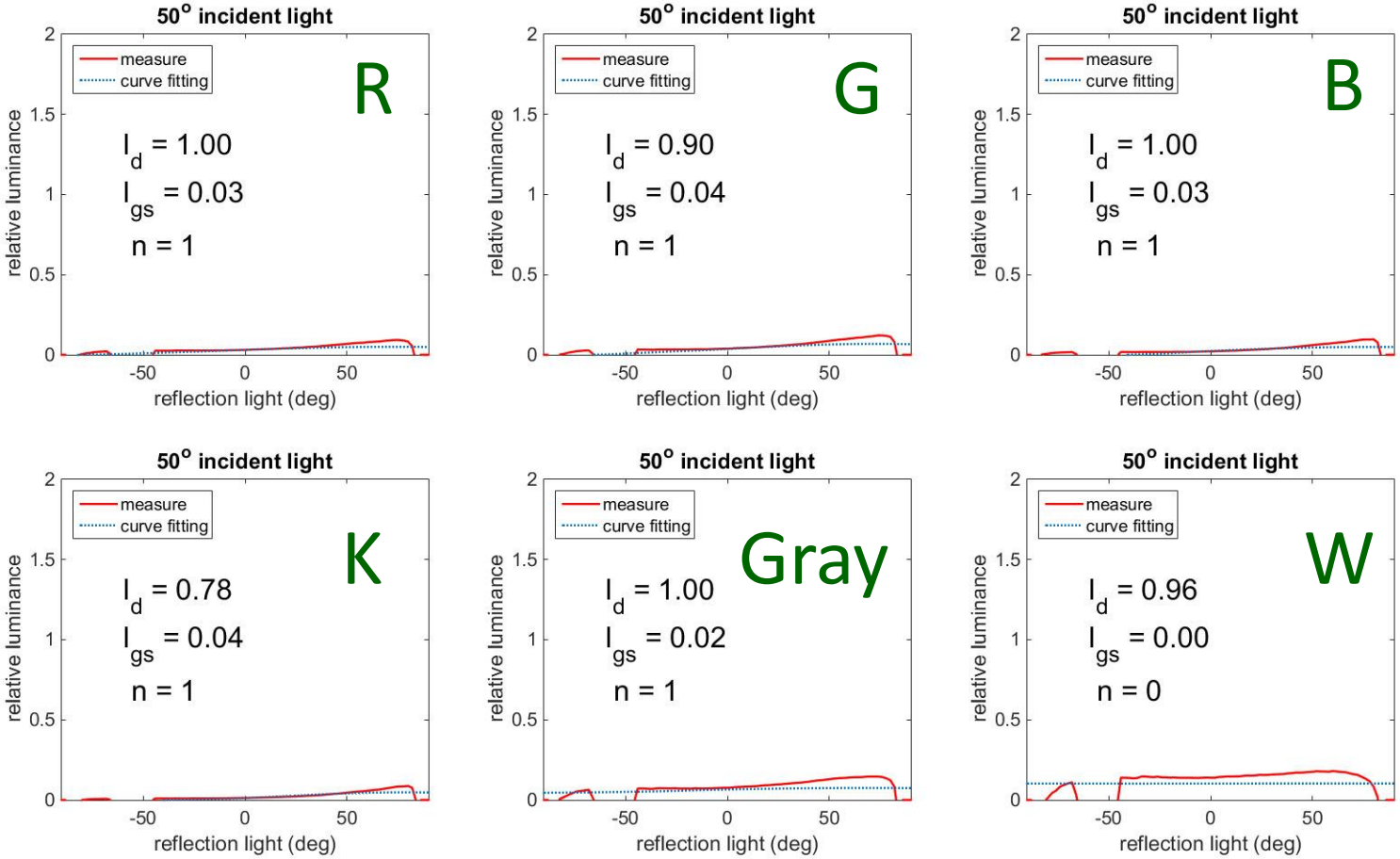
W

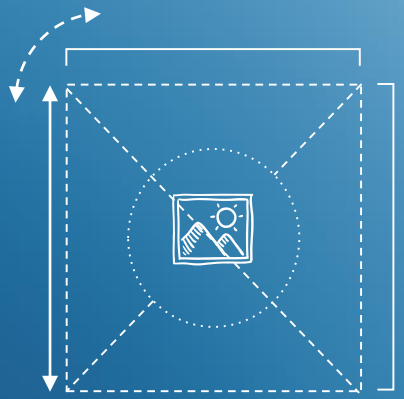


Normalized Y stimuli with pseudo-colors

Cotton

Y stimulus



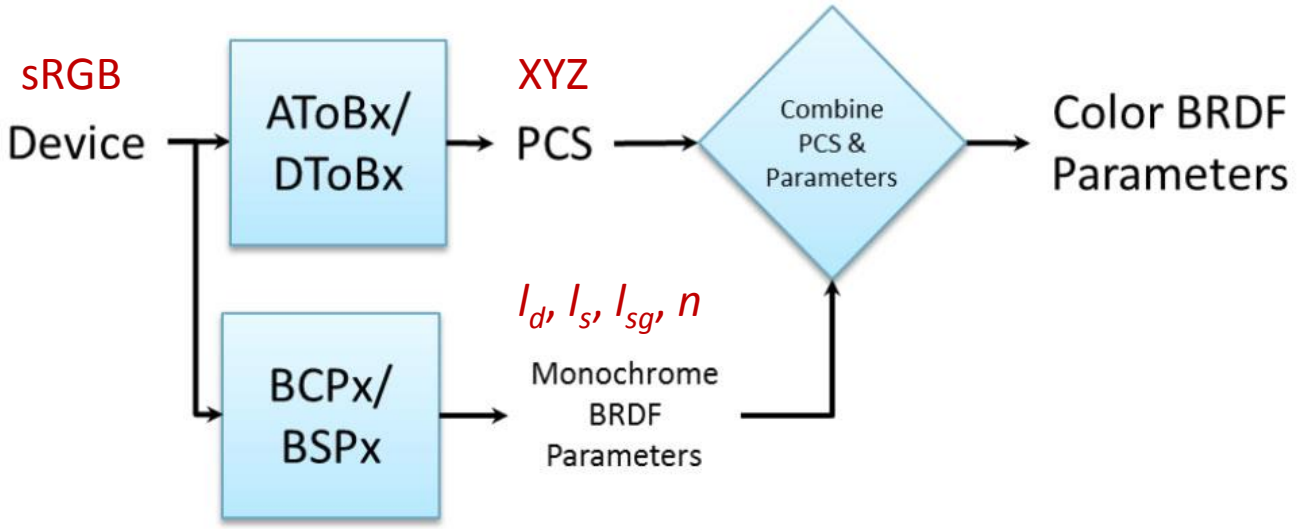


3

Color appearance simulation based on the iccMAX framework

iccMAX application

1. Device signals to PCS conversion using an A2Bx profile.
2. Apply a monochrome BRDF profile for the material. It contains l_d, l_s, l_{sg} and n parameters for each of XYZ channel.

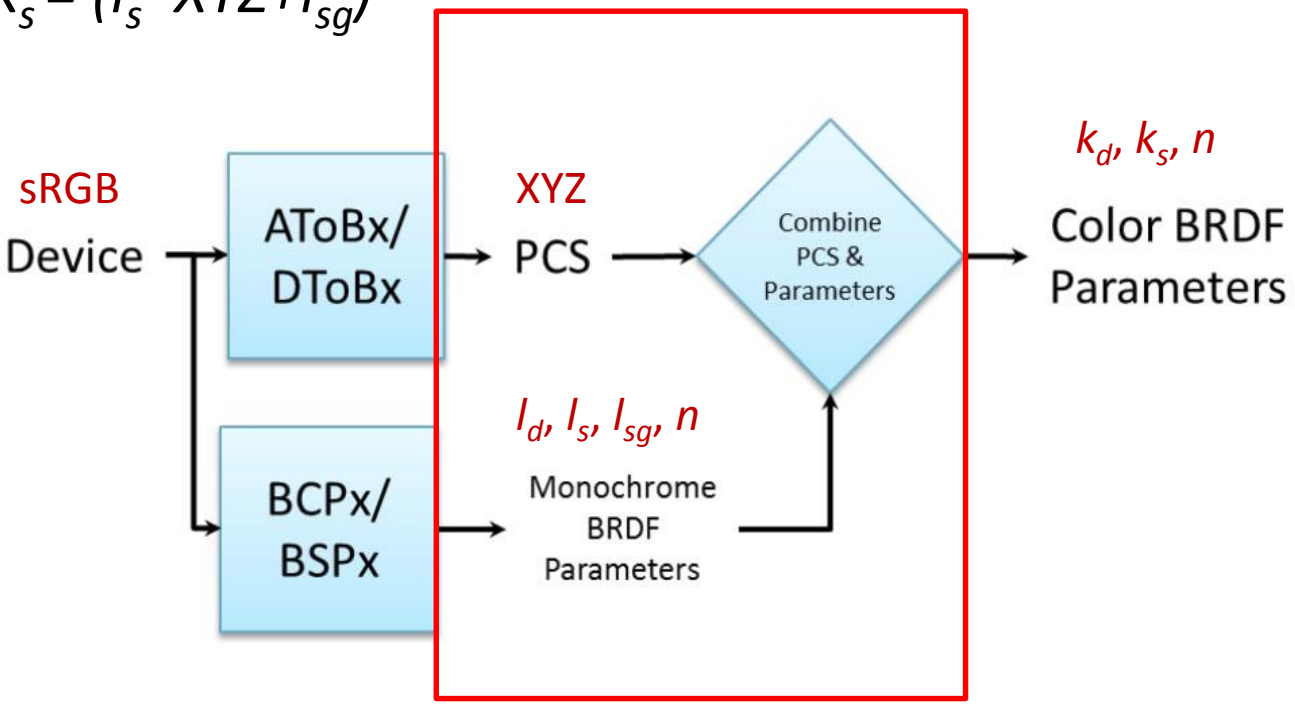


iccMAX application

3. Calculate color BRDF parameters.

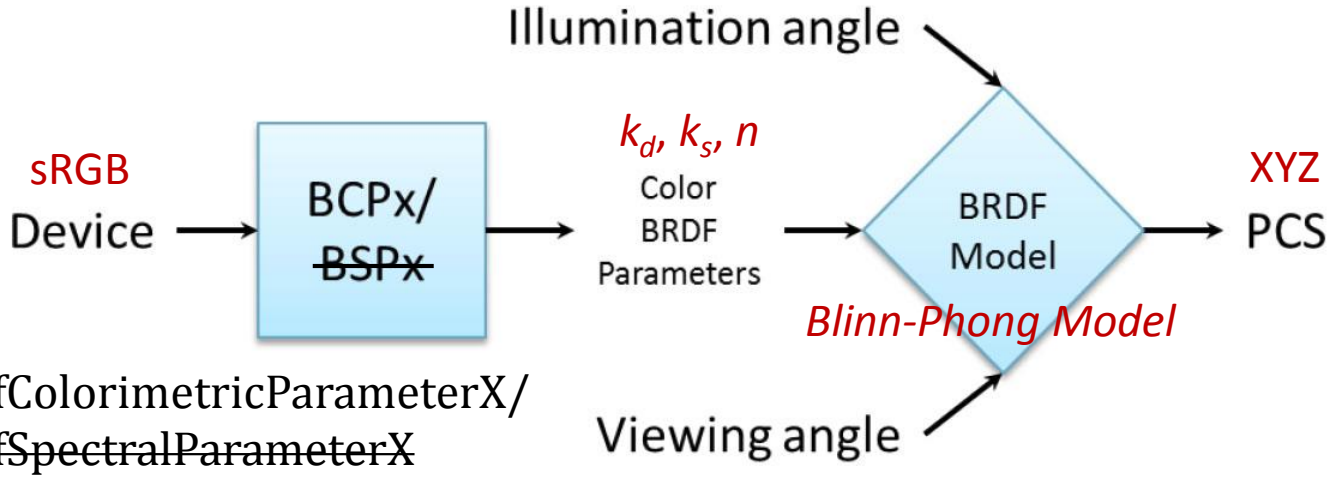
$K_d = I_d * XYZ$

$K_s = (I_s * XYZ + I_{sg})$



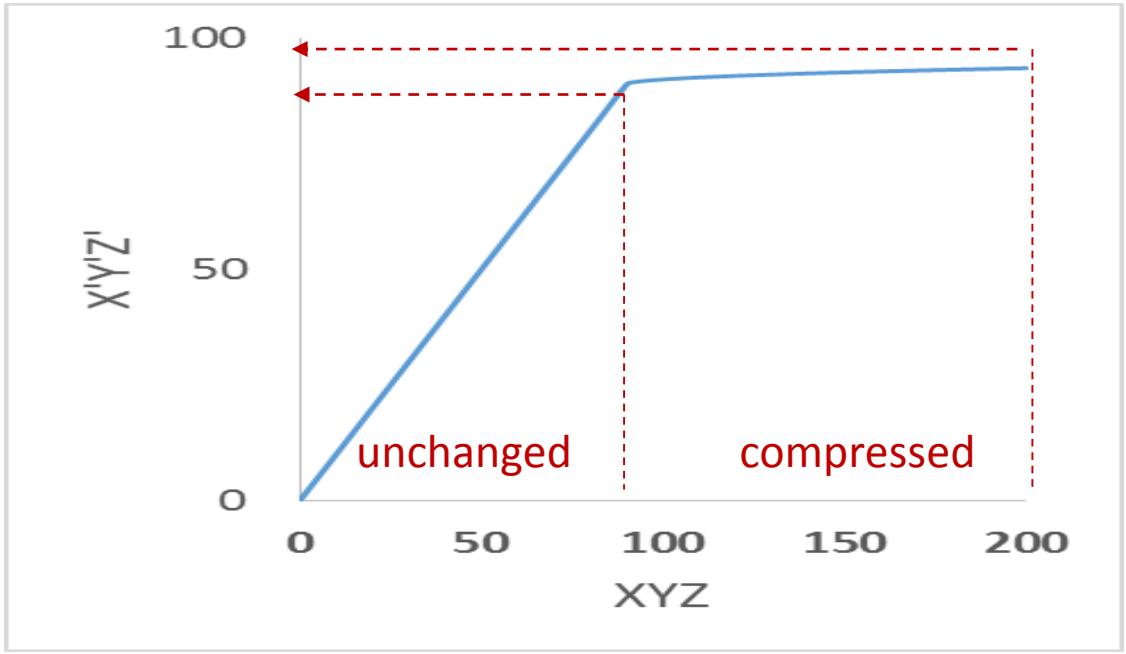
iccMAX application

4. Color rendering based on given illumination angle, viewing angle and the BRDF model.
   - We have implemented *Blinn-Phong* and *Cook-Torrance* models.



iccMAX application

5. Highlight compression in XYZ space.
   - Non-linear tone mapping is needed to avoid highlight clipping of shiny objects.

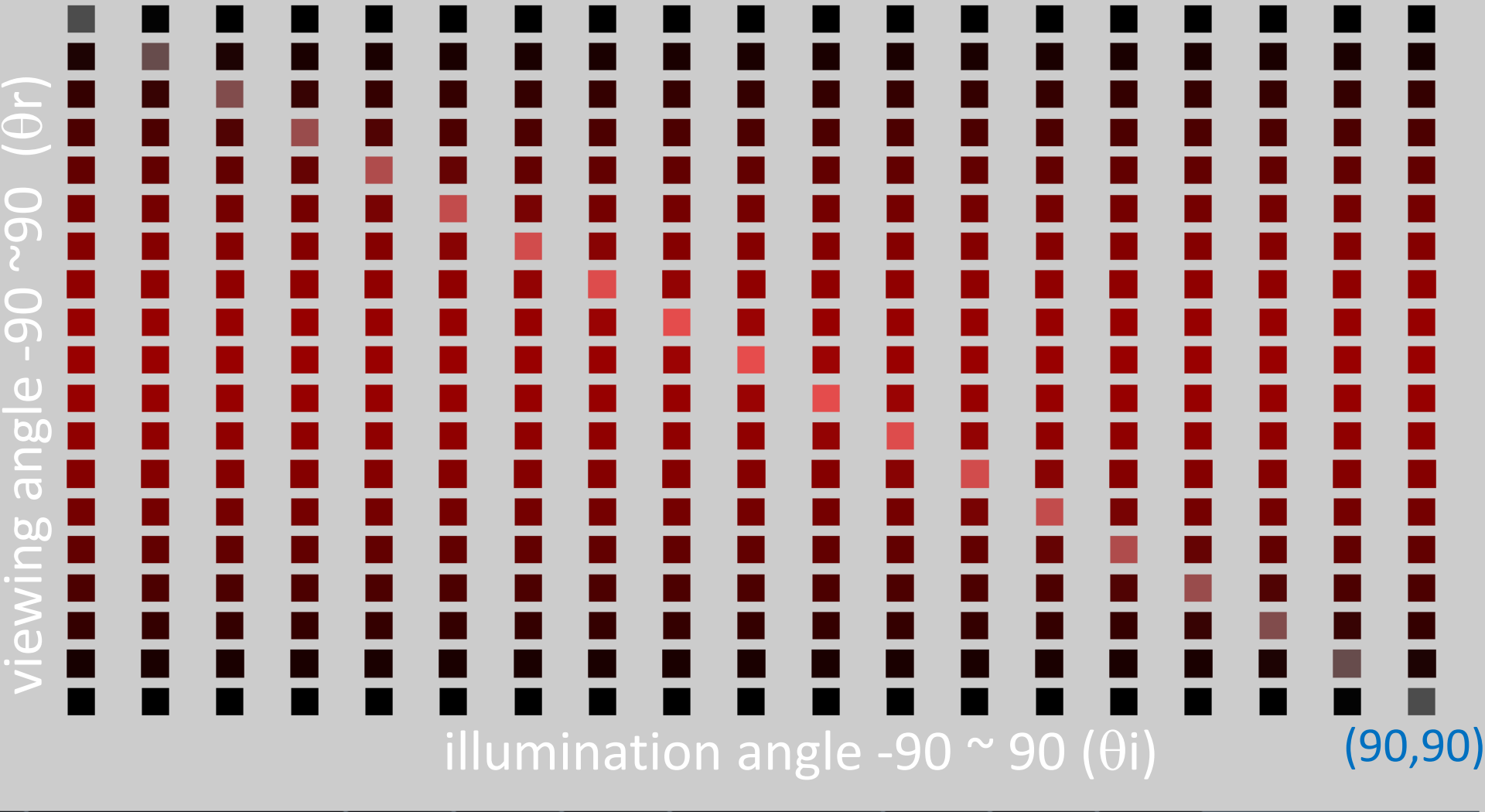


iccMAX application

6. PCS to Device conversion using a B2Ax profile.
   - In our case, use a sRGB profile for LCD simulation.

Multi-Angle

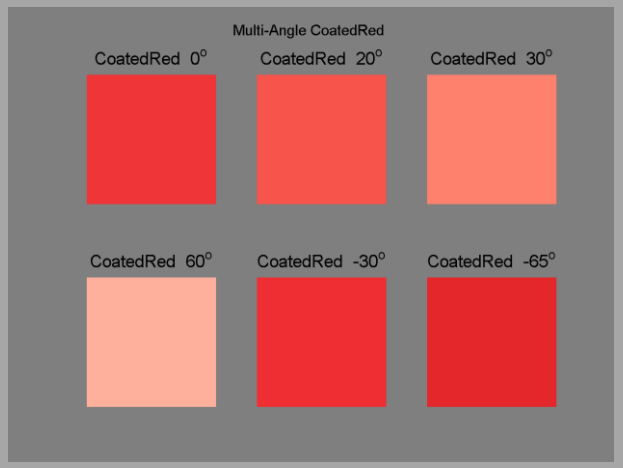
A Red coated paper - l_d: 1, l_s:1.6, n:189

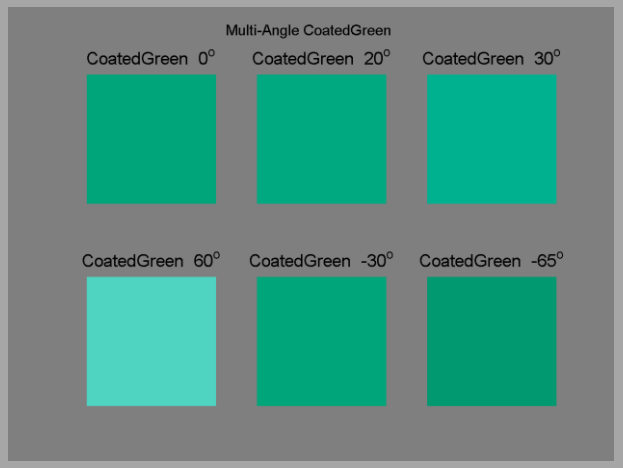


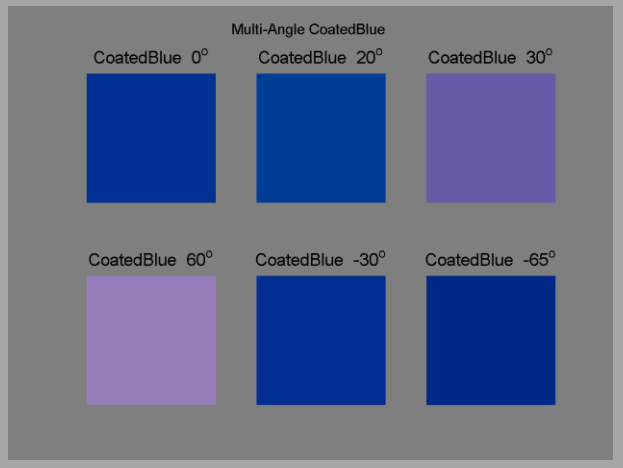
Correct the input values

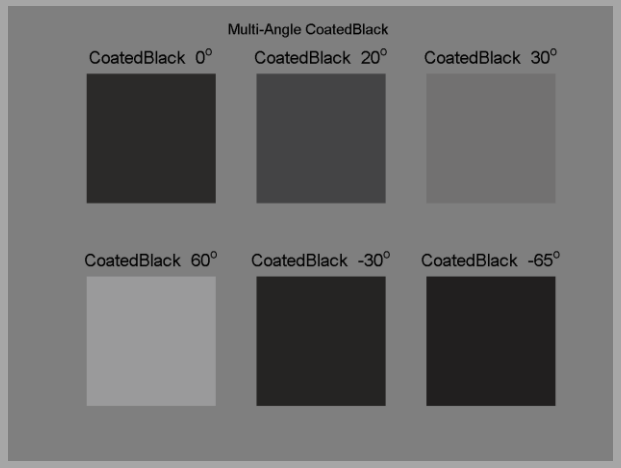
BYK-mac

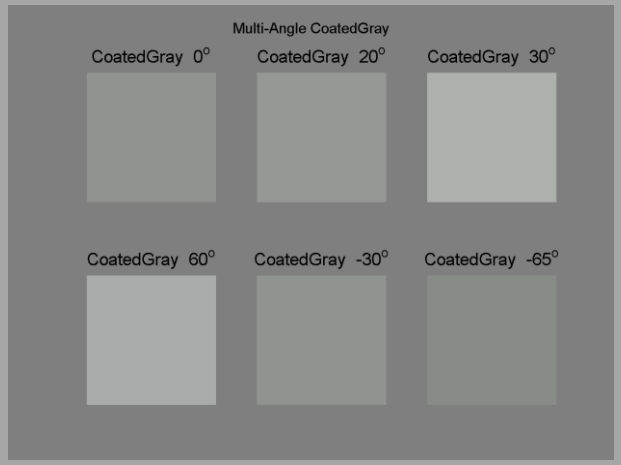
coated

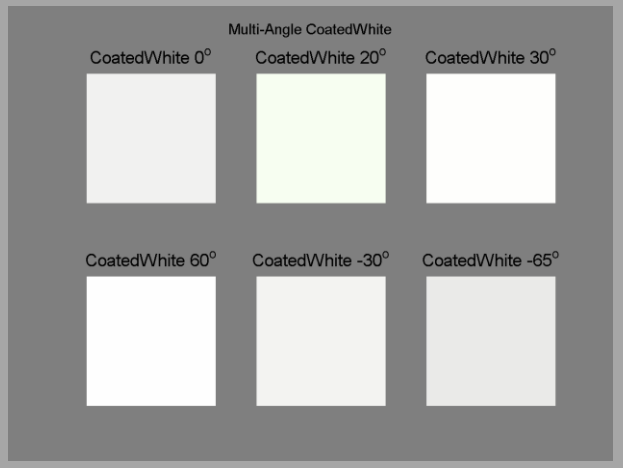








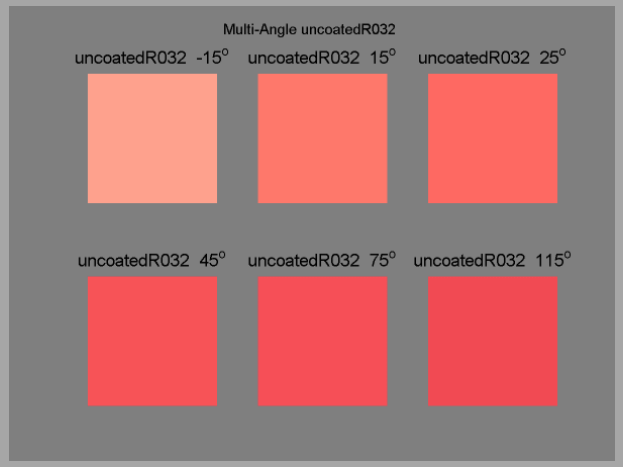


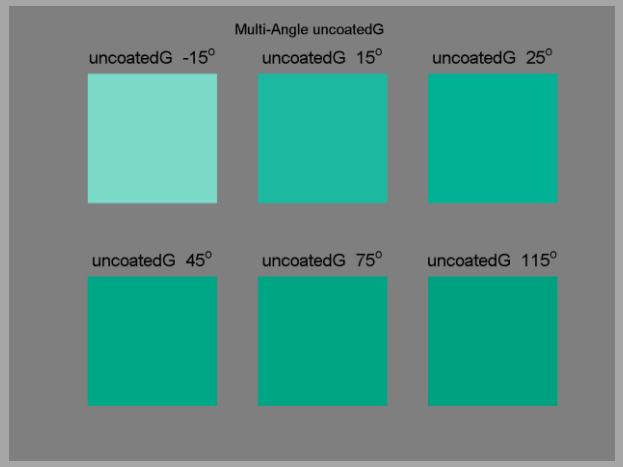


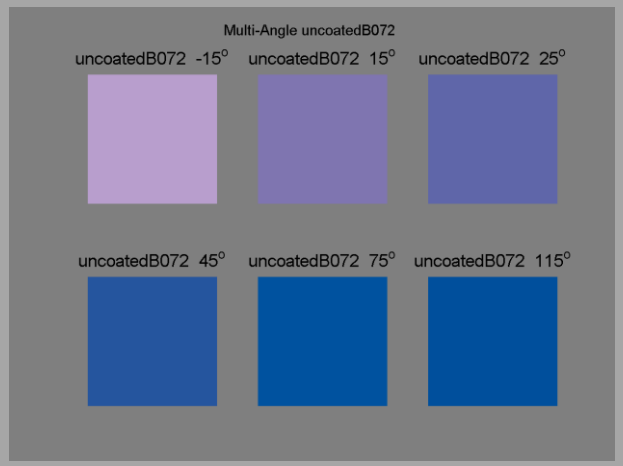
Correct the input values

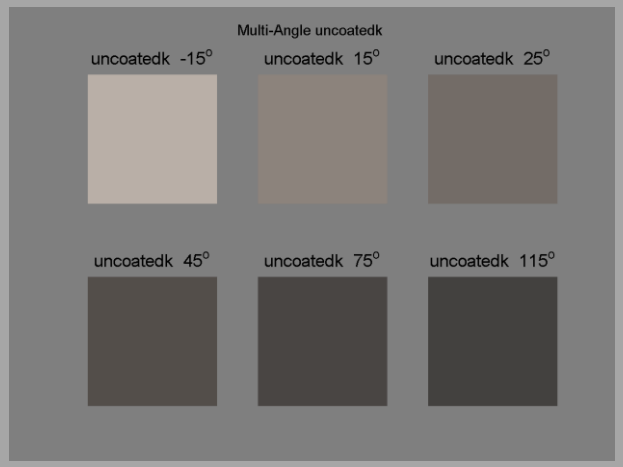
BYK-mac

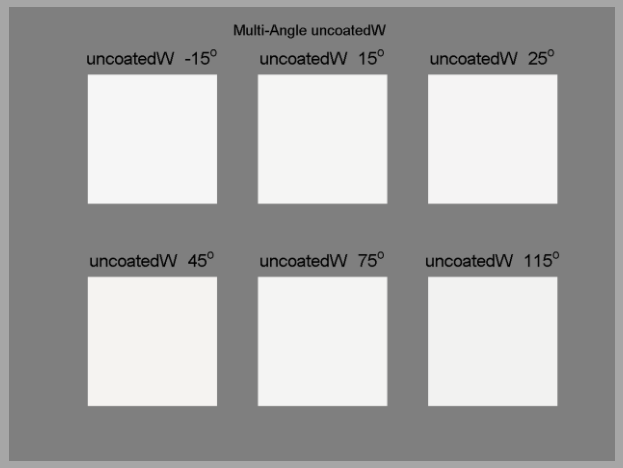
uncoated







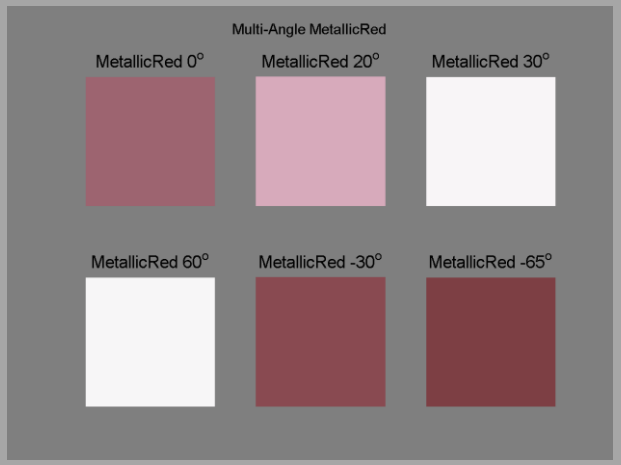


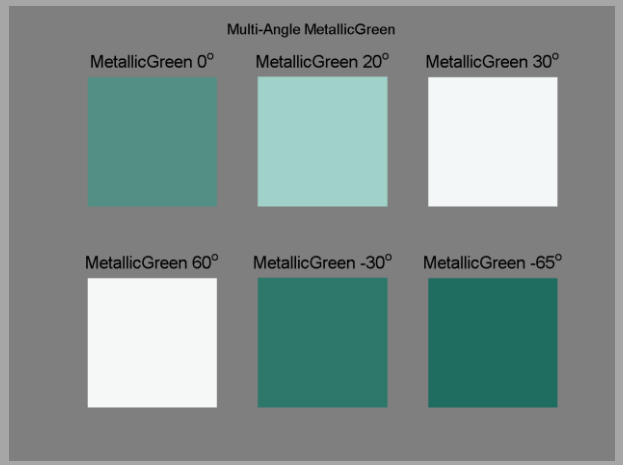


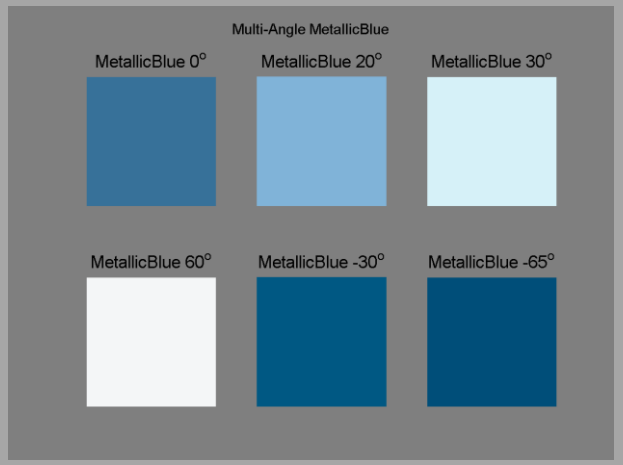
Correct the input values

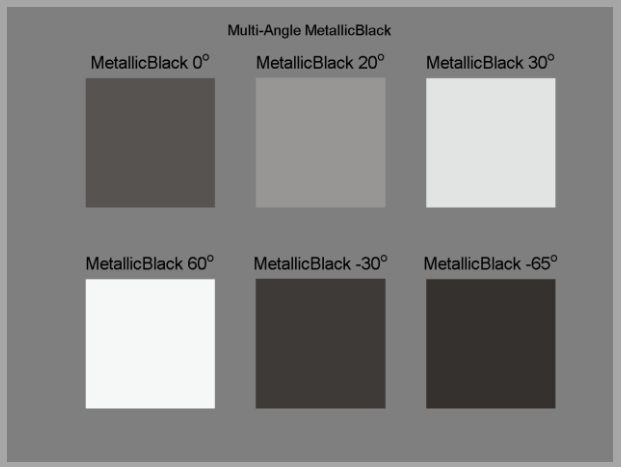
BYK-mac

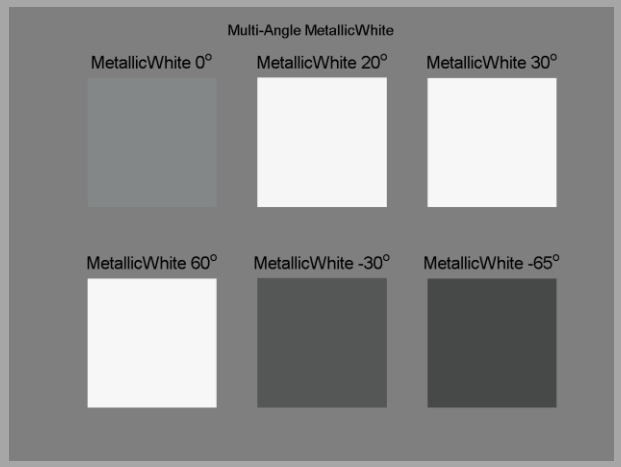
Metallic







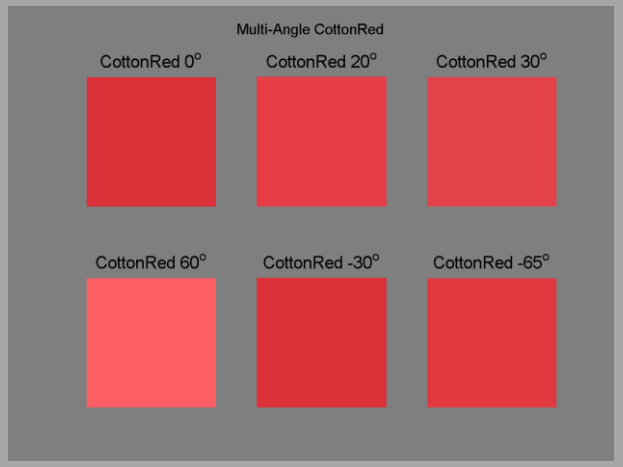


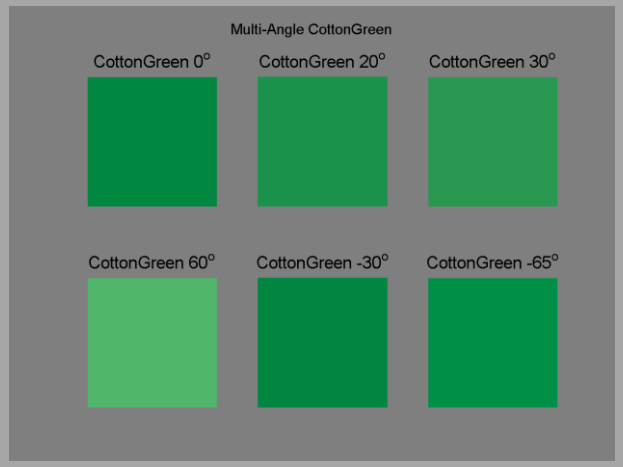


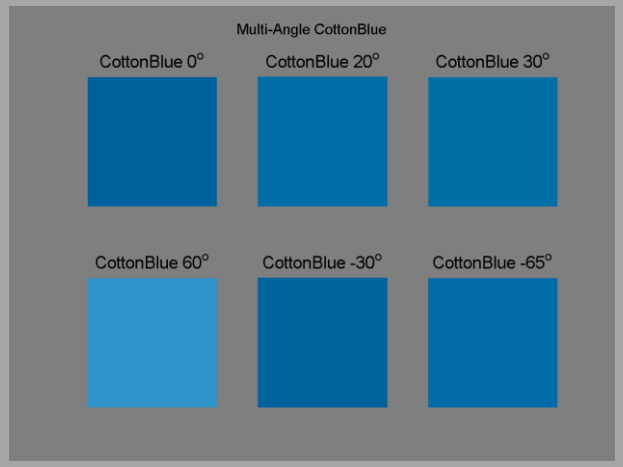
Correct the input values

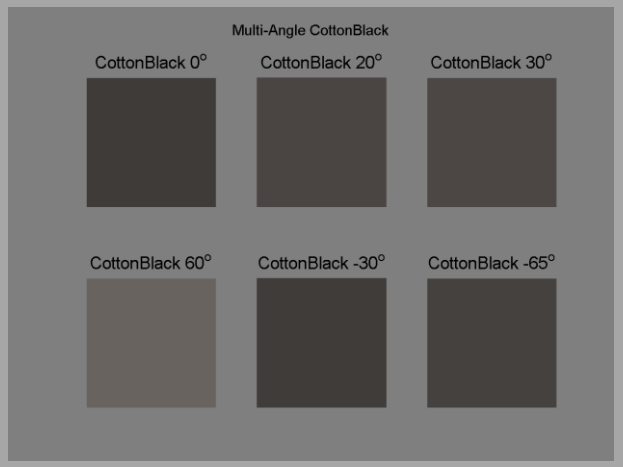
BYK-mac

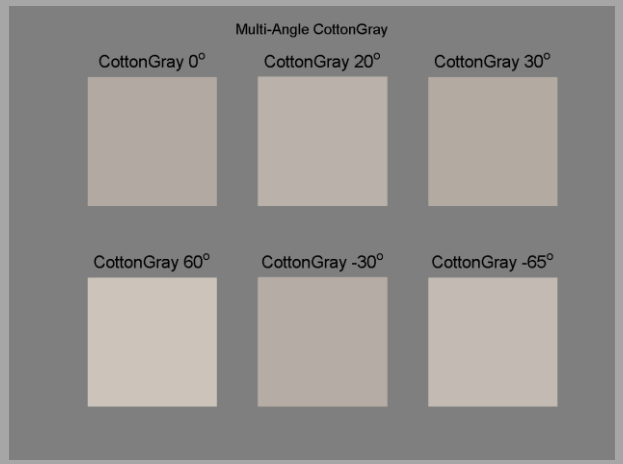
Cotton

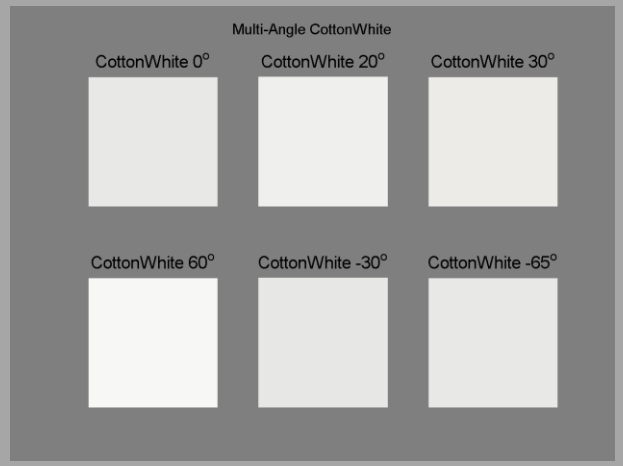










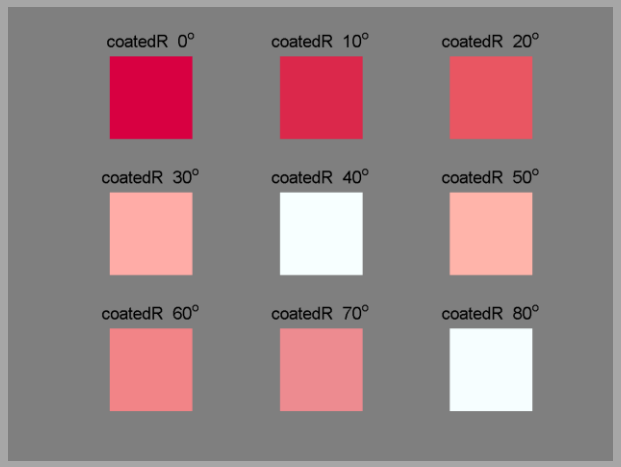


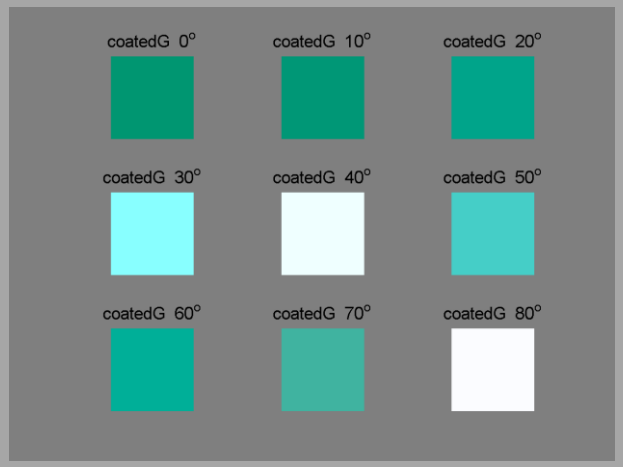
Correct the input values

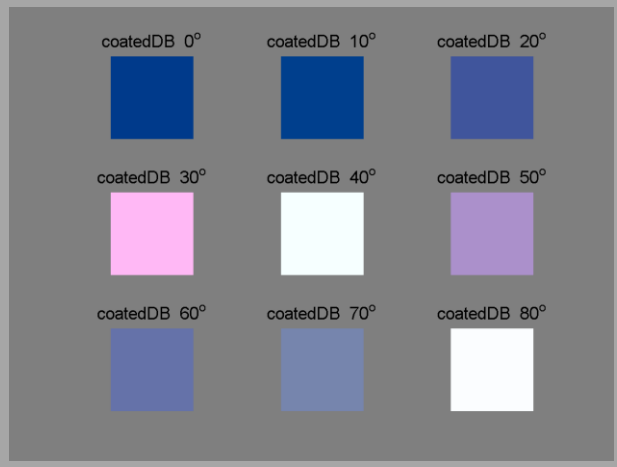
IS-SA BRDF Scatterometer

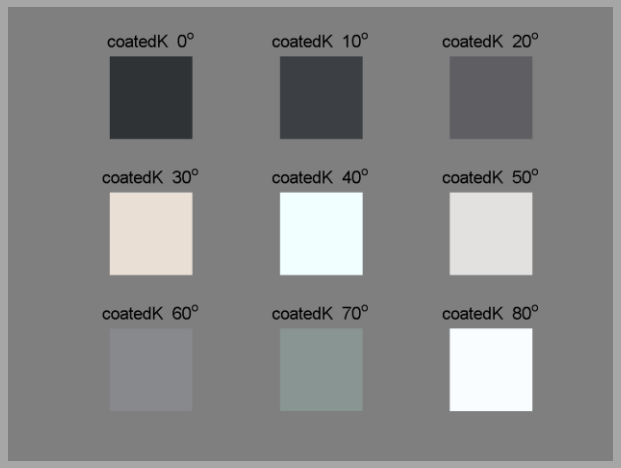
Incident Angles50^°

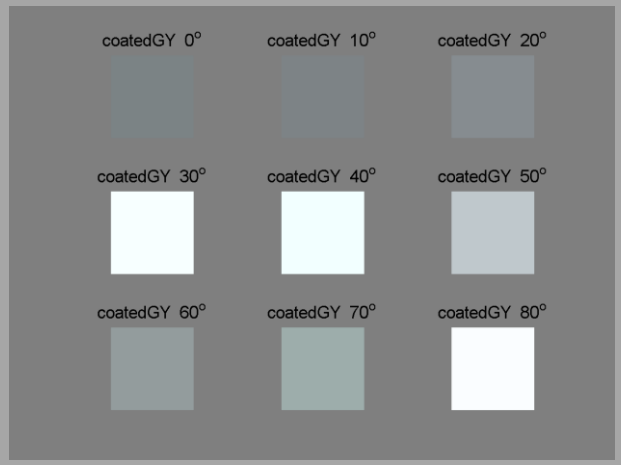
coated

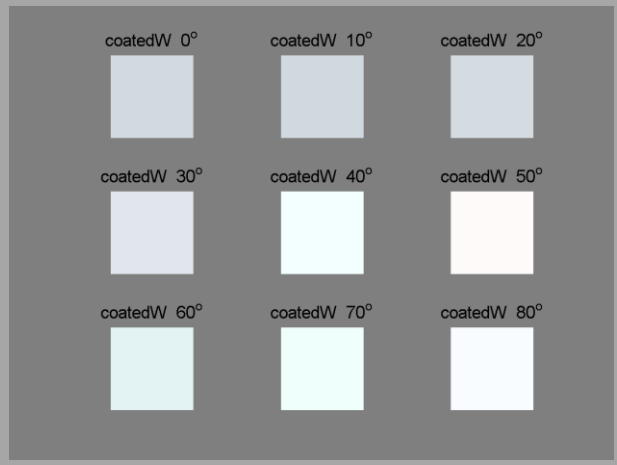








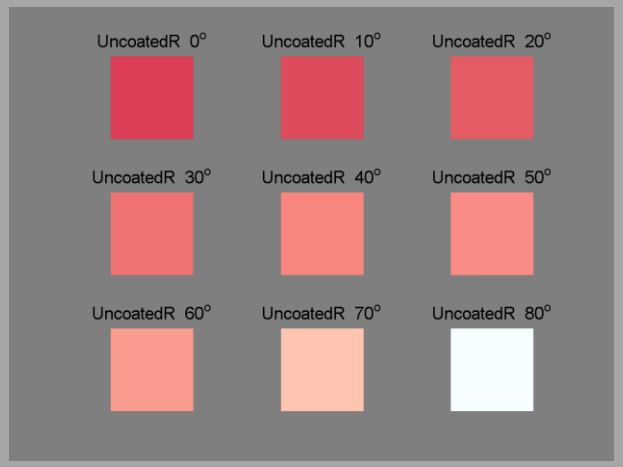


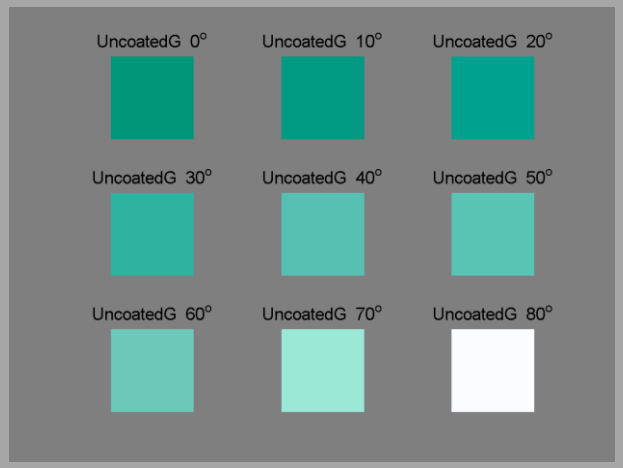


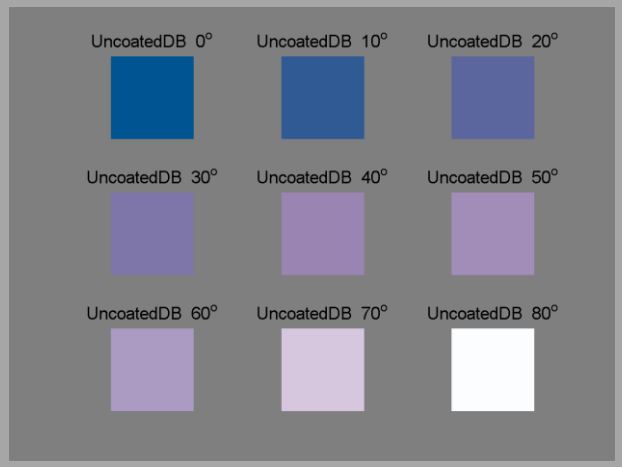
Correct the input values

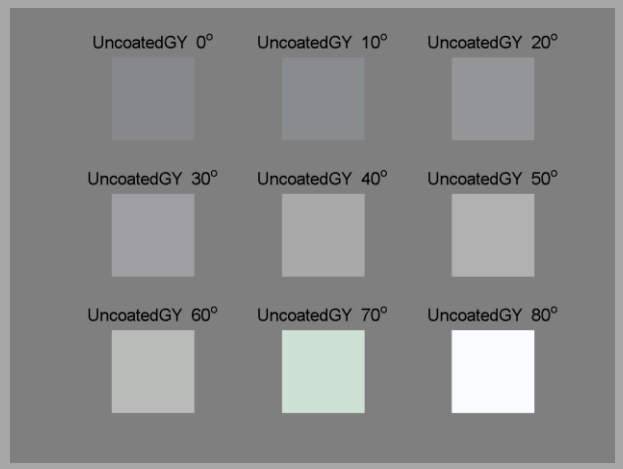
IS-SA BRDF Scatterometer

uncoated





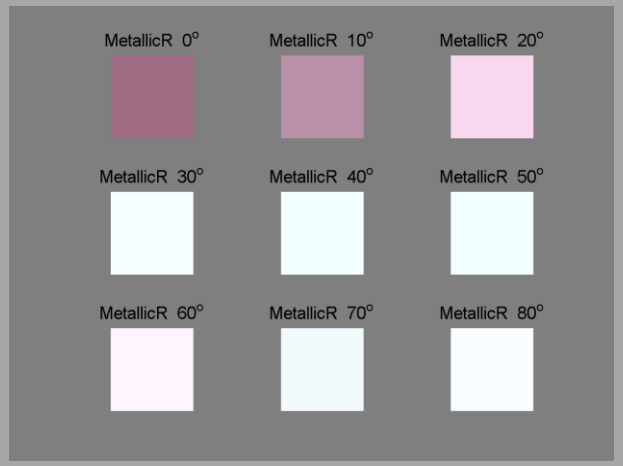


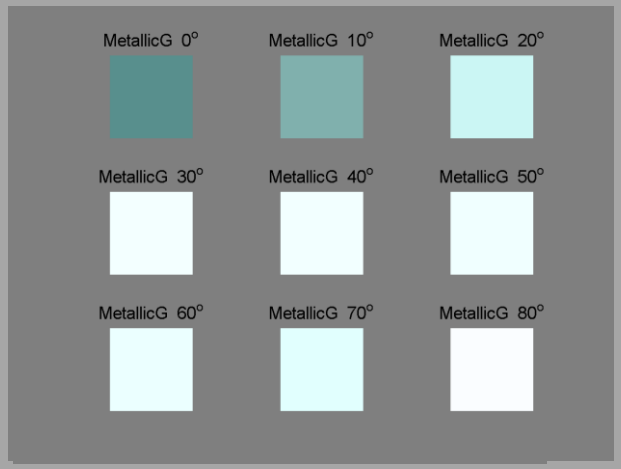


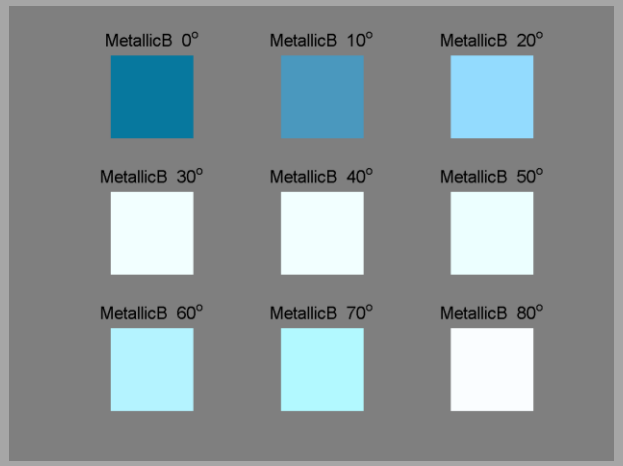
Correct the input values

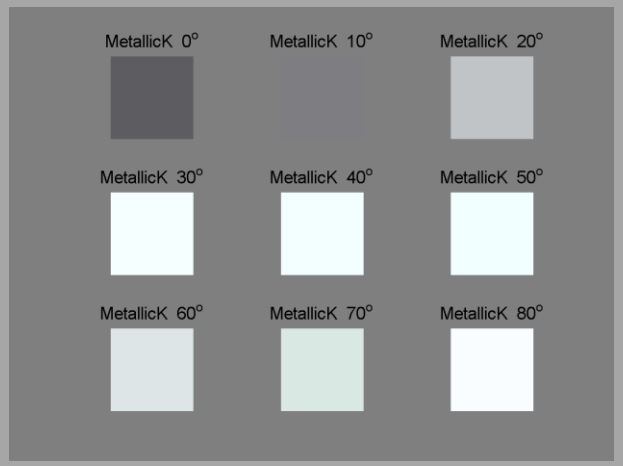
IS-SA BRDF Scatterometer

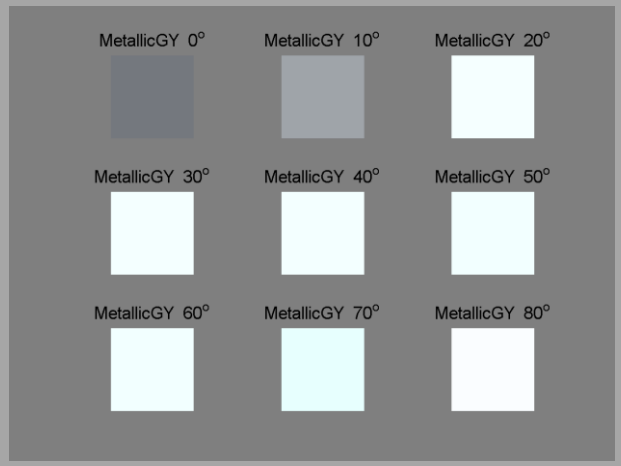
Metallic

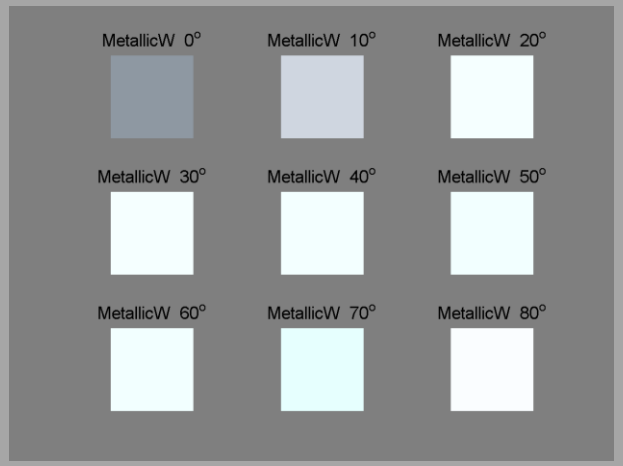








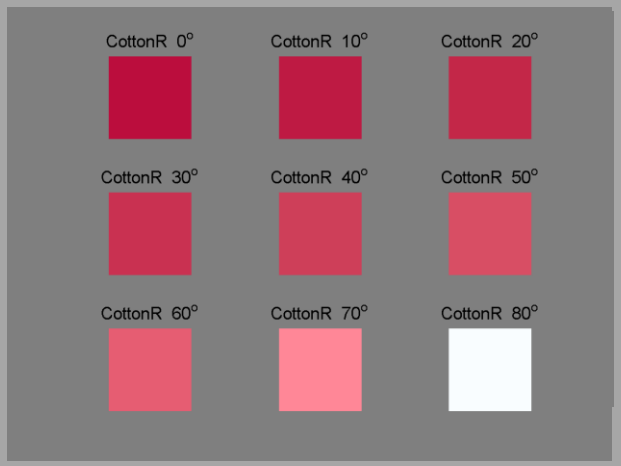


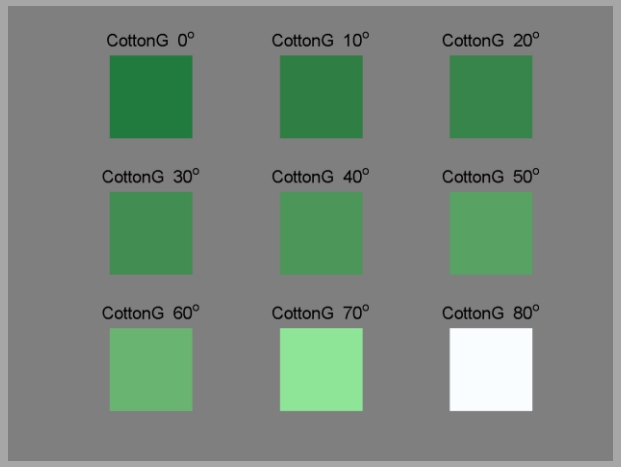


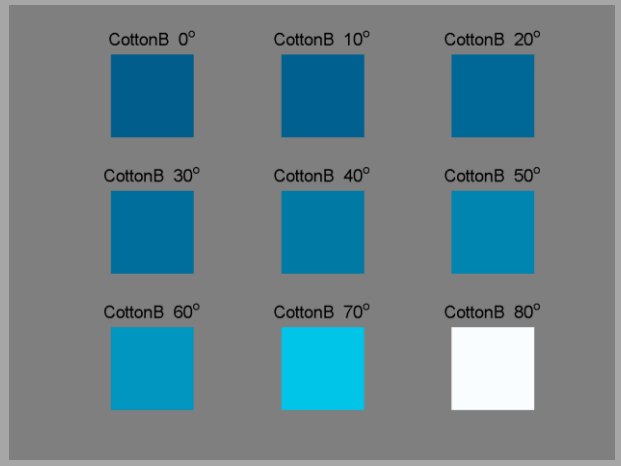
Correct the input values

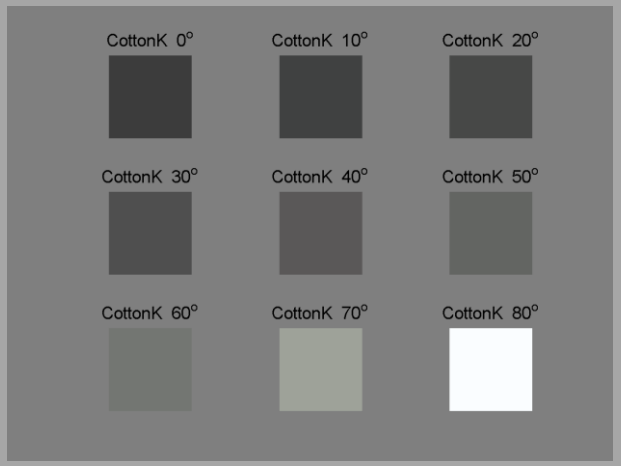
IS-SA BRDF Scatterometer

Cotton









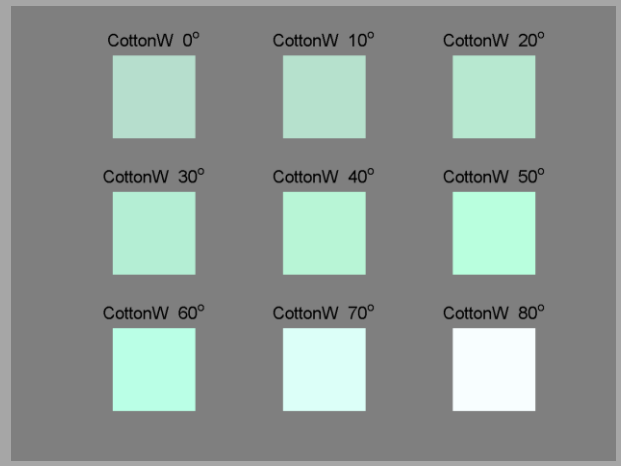
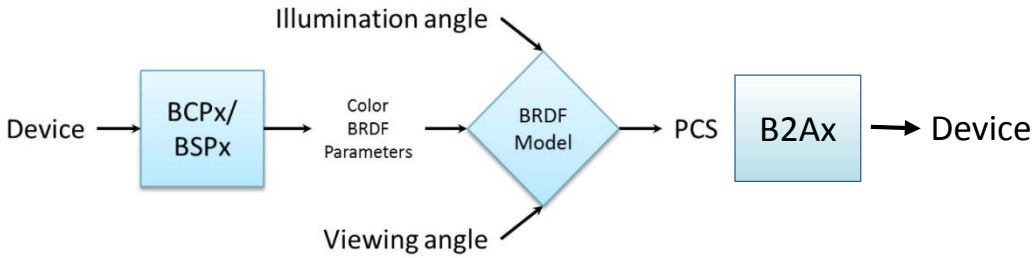
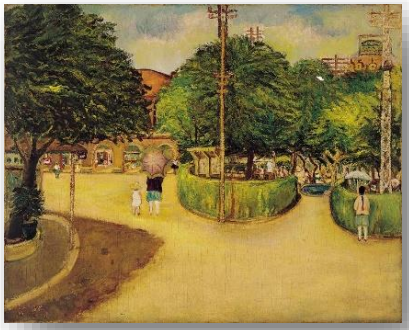
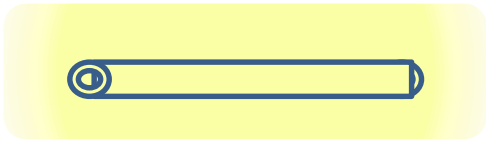


Image simulation





iccMAX approach



Simulate a light tube above the painting

Conclusions

- We have done BRDF measurement of many real-world samples.
- We also proposed a method for evaluating BRDF parameters of Blinn-Phong model.
- Tone compression is needed to avoid highlight clipping.
- The BRDF parameters can be used to simulate color appearance of a material based on the the iccMAX framework.

Thanks!

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