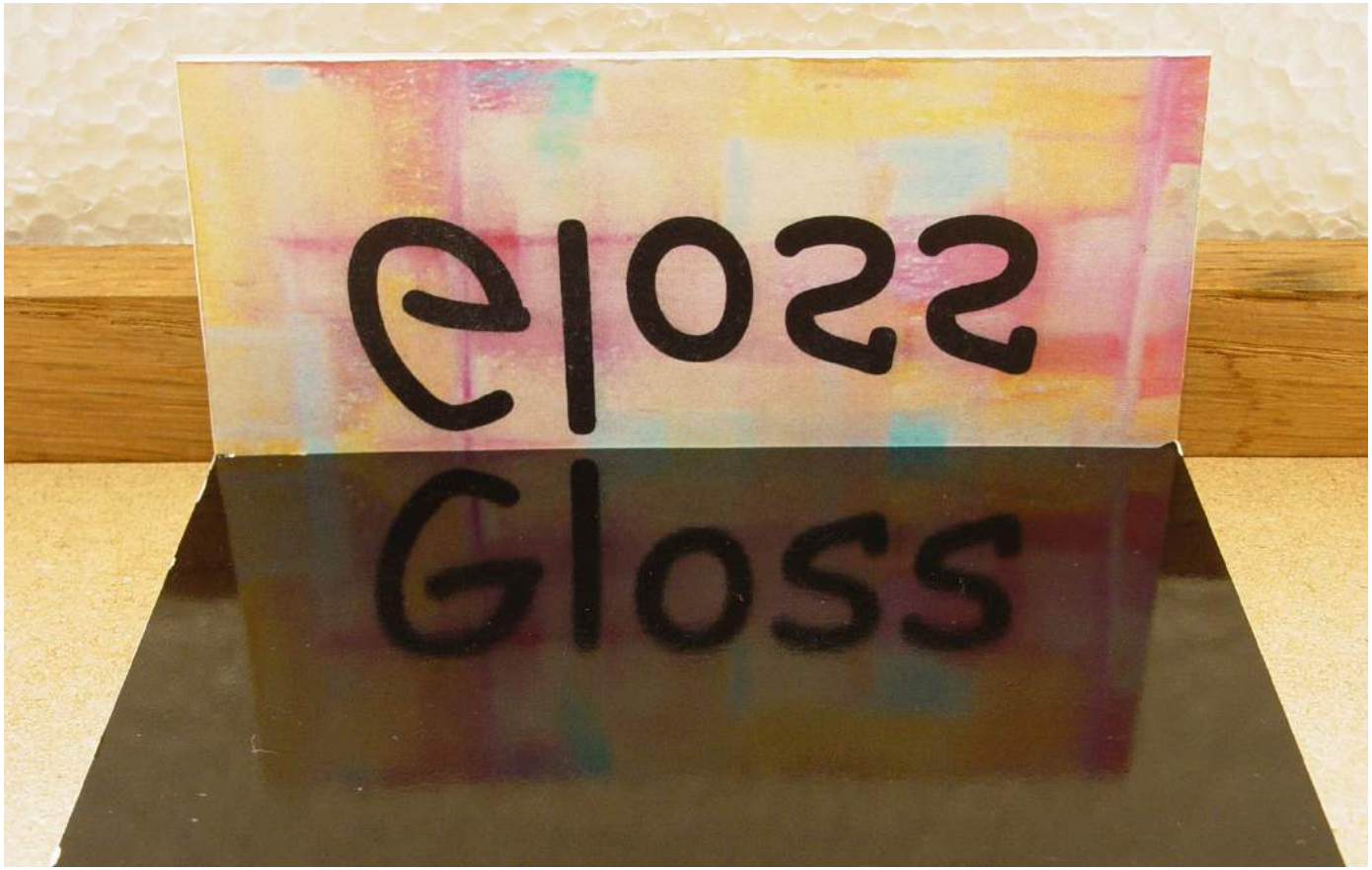

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Outline

- What is gloss ?
- The measurement of gloss
  - Empirical Approach
  - Optical approach
  - Glossmeter
- Gloss as a multivariable quantity
  - Visual approach
  - Existing instrumentation
  - Correlation with the visual sensation
- Future chanllenges
- Discussion

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What is gloss ?

17-500 gloss (of a surface)
mode of appearance by which reflected highlights of objects are perceived as superimposed on the surface due to the directionally selective properties of that surface
(CIE e-ILV)

Gloss is present in our daylife

Put here a classical sceene of every day life, with arrows pointing at gloss highlights

Gloss is highly implicated in our cognitive processes

Gloss is implicated in our cognitive processes

Stilleven met vergulde bierkan, Willem Claesz. Heda, 1634

Van Assen & al, JOV 2016

It provides us informations on the shape, the position, and the spectrum of the lighting

Gloss is implicated in our cognitive processes

Peter Maier, « Auld Lang Syne », 48''x70'', 1998

Gloss allows detecting curvatures and shapes

Gloss is implicated in our cognitive processes

Gloss is implicated in the identification of materials

Gloss is implicated in our cognitive processes

Gloss is strongly connected to the sensation of quality

Its control is essential for industry

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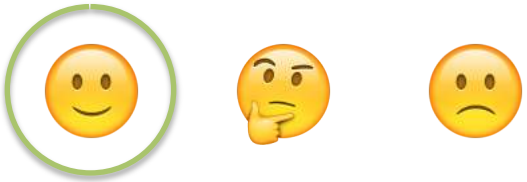
Empirical Approach

Look at the five black samples you have in front of you.

Do you think you can rank these samples from the matiest to the glossiest?



Empirical Approach

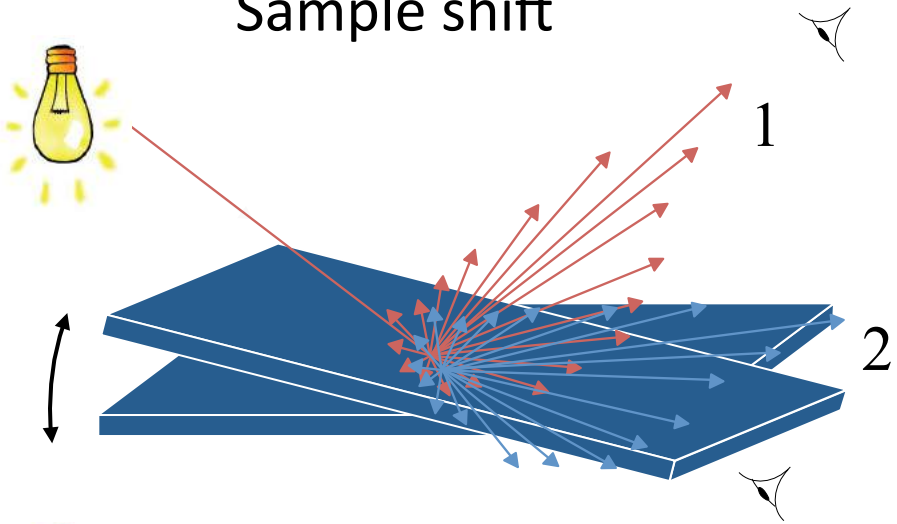
- If gloss can be ranked, we can measure it
  - How?
    - We'll try to mimic the observer

Empirical Approach

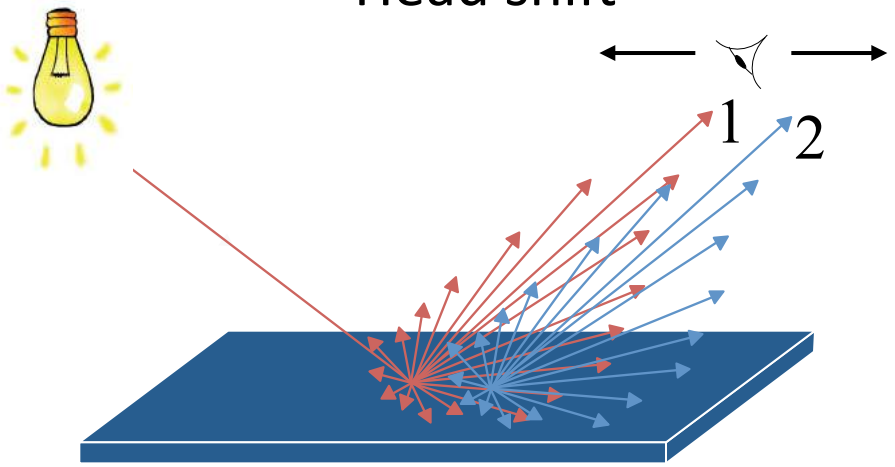
Ranking of 7 grey samples from NCS gloss scale

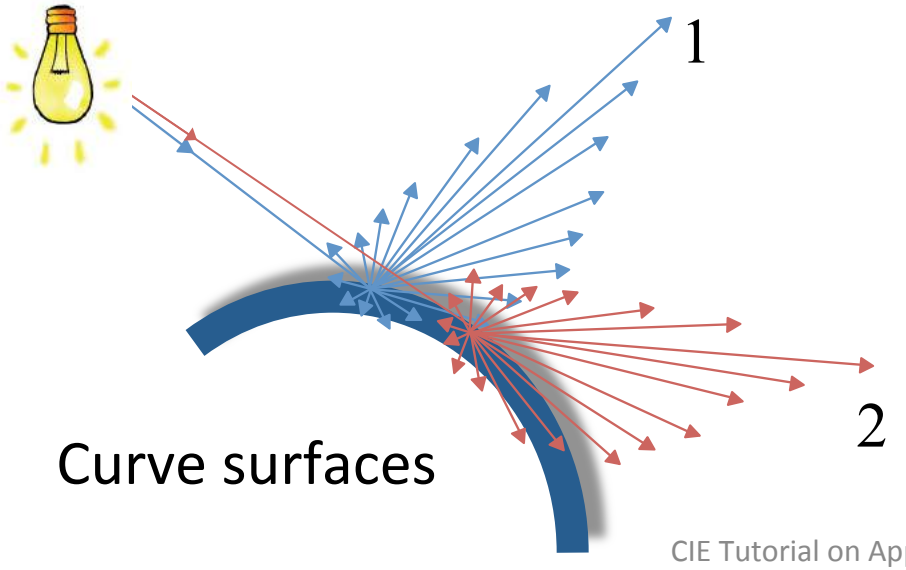
Observer's comportment to evaluate gloss

Sample shift



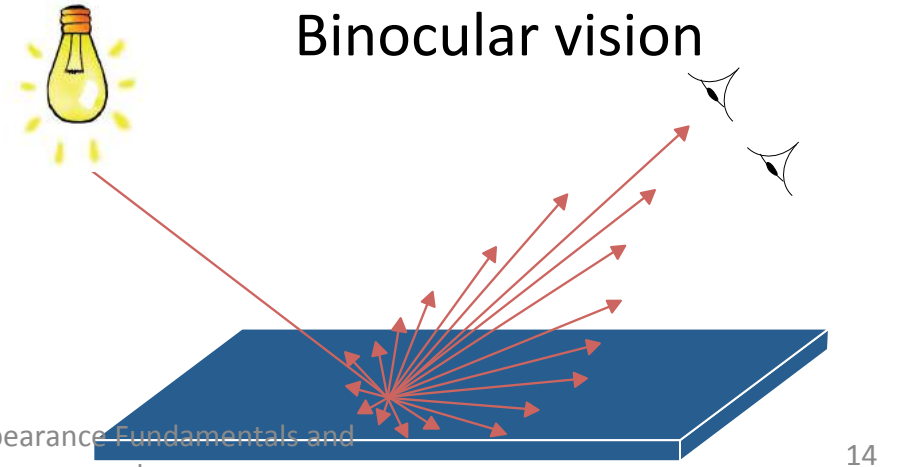
Head shift





Curve surfaces

Binocular vision



Empirical Approach

Conclusion

- Gloss can be ranked
- Gloss can be measured
- Gloss is in and around the specular direction

Outline

- What is gloss ?
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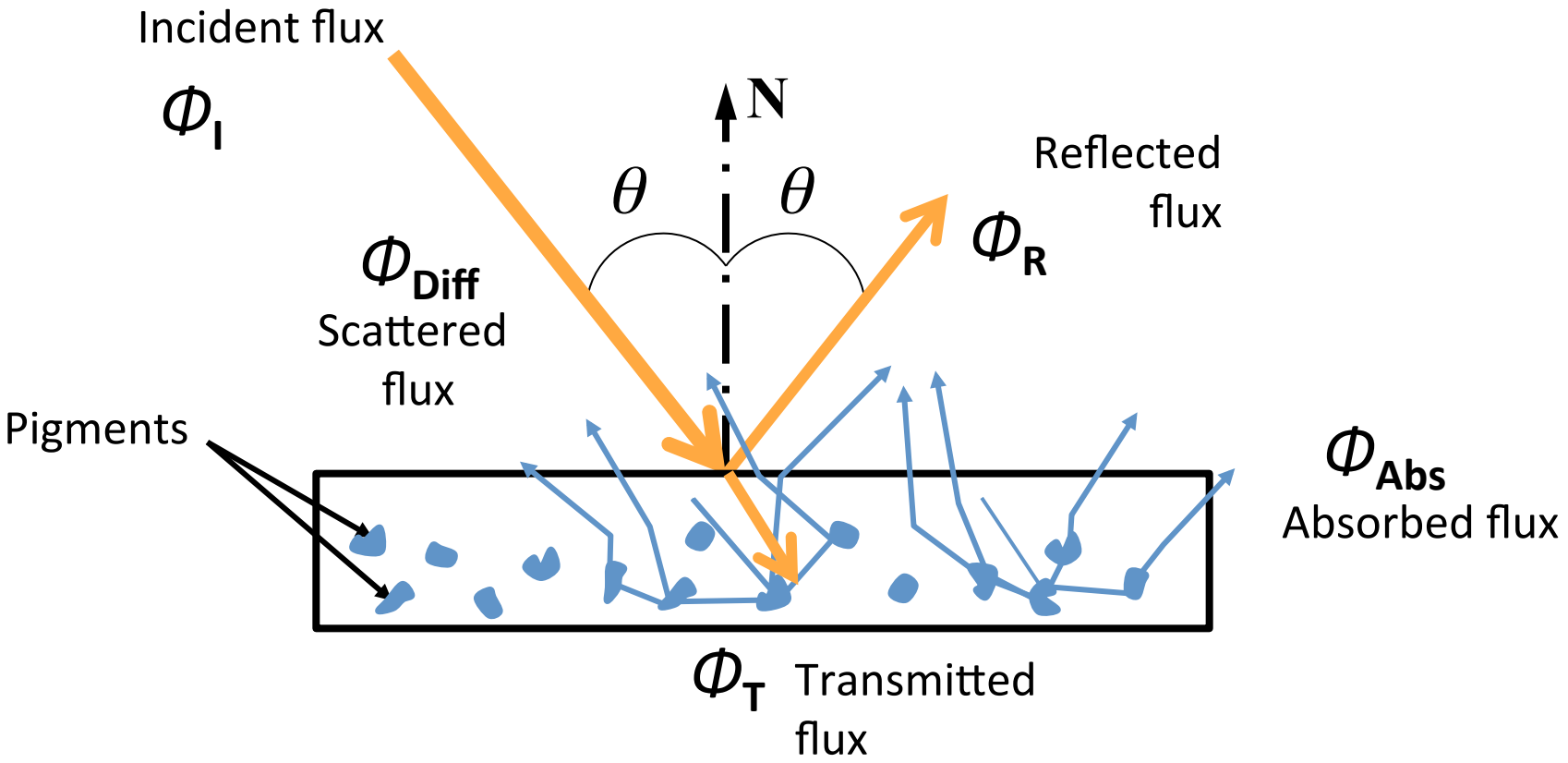
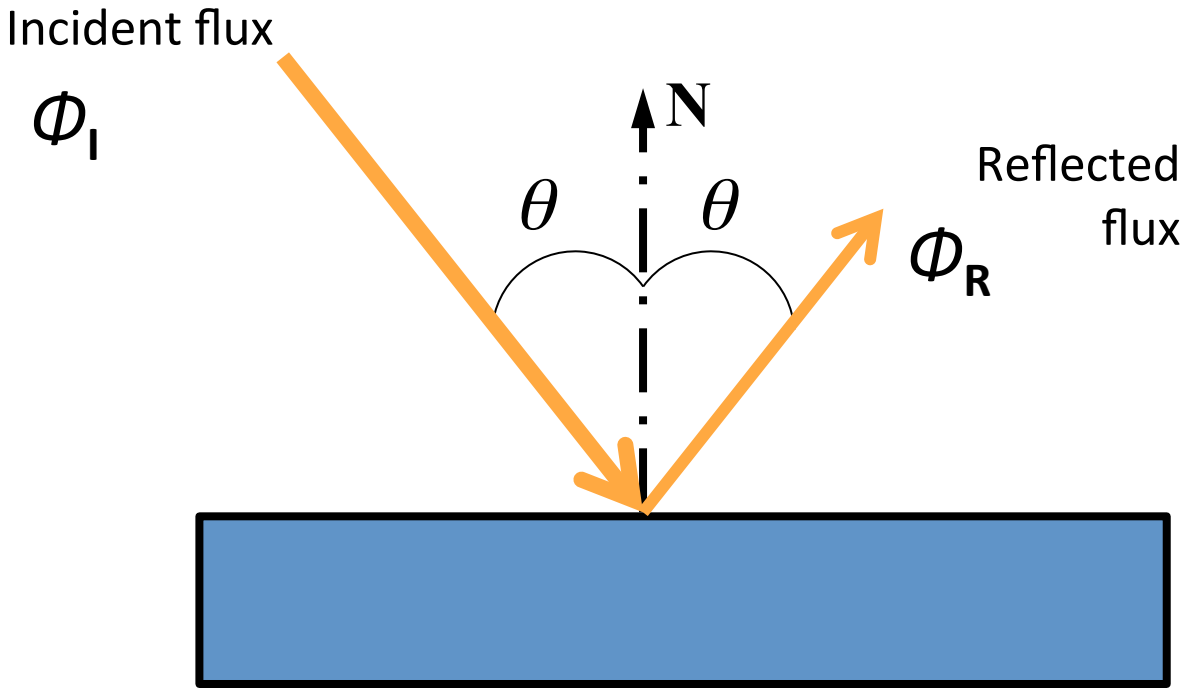
Surface reflexion



$$\Phi_I = \Phi_R + \Phi_{diff} + \Phi_T + \Phi_{abs}$$

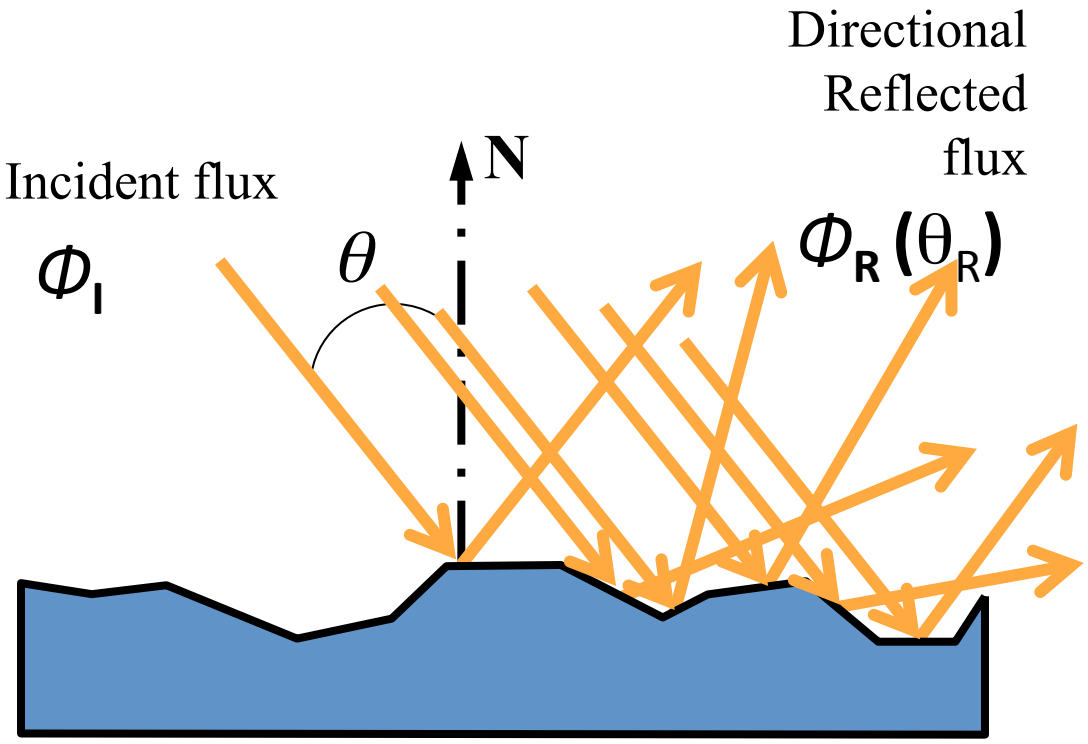
Perfectly polished Surface



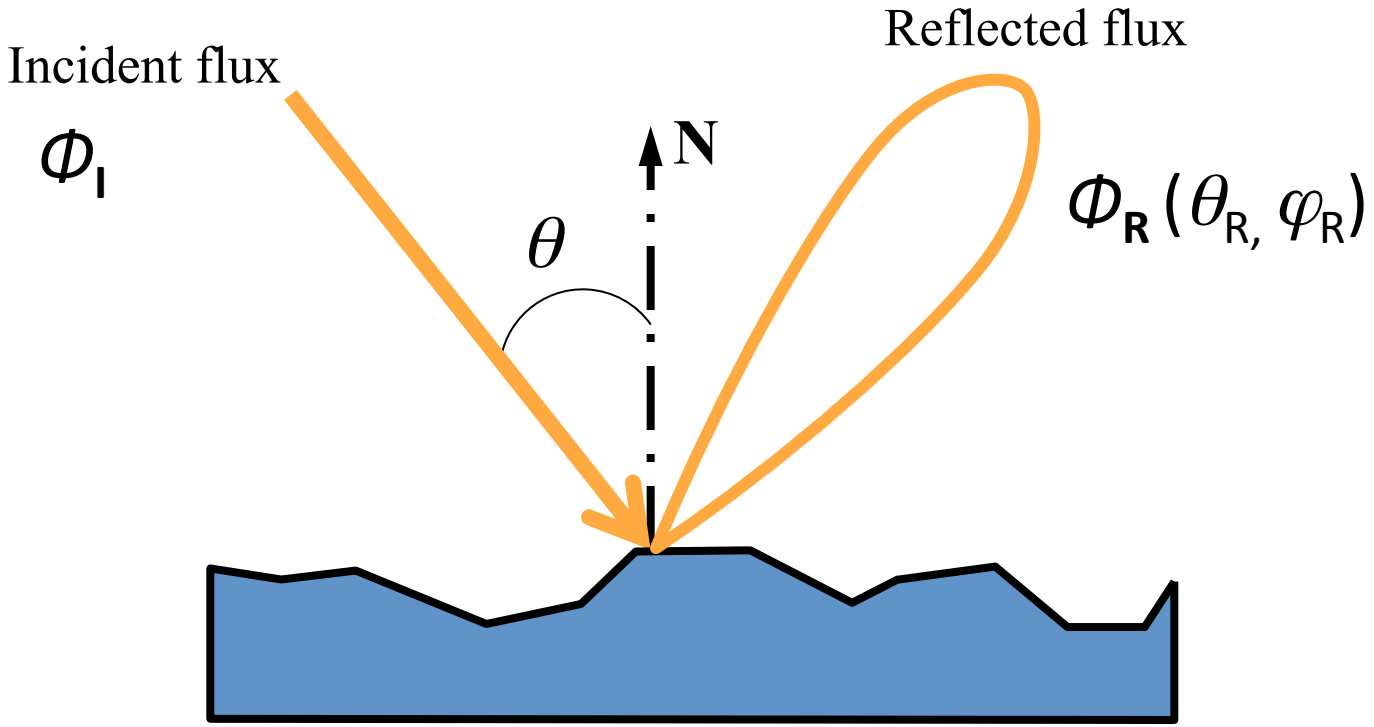
F, reflectance
θ, angle of incidence
n, refractive index

$$F = \frac{\Phi_R}{\Phi_I} = \frac{1}{2}\left[\left(\frac{\cos\psi - \sqrt{n^2 - \sin^2\psi}}{\cos\psi + \sqrt{n^2 - \sin^2\psi}}\right)^2 + \left(\frac{n^2\cos\psi - \sqrt{n^2 - \sin^2\psi}}{n^2\cos\psi + \sqrt{n^2 - \sin^2\psi}}\right)^2\right]$$

Real surface



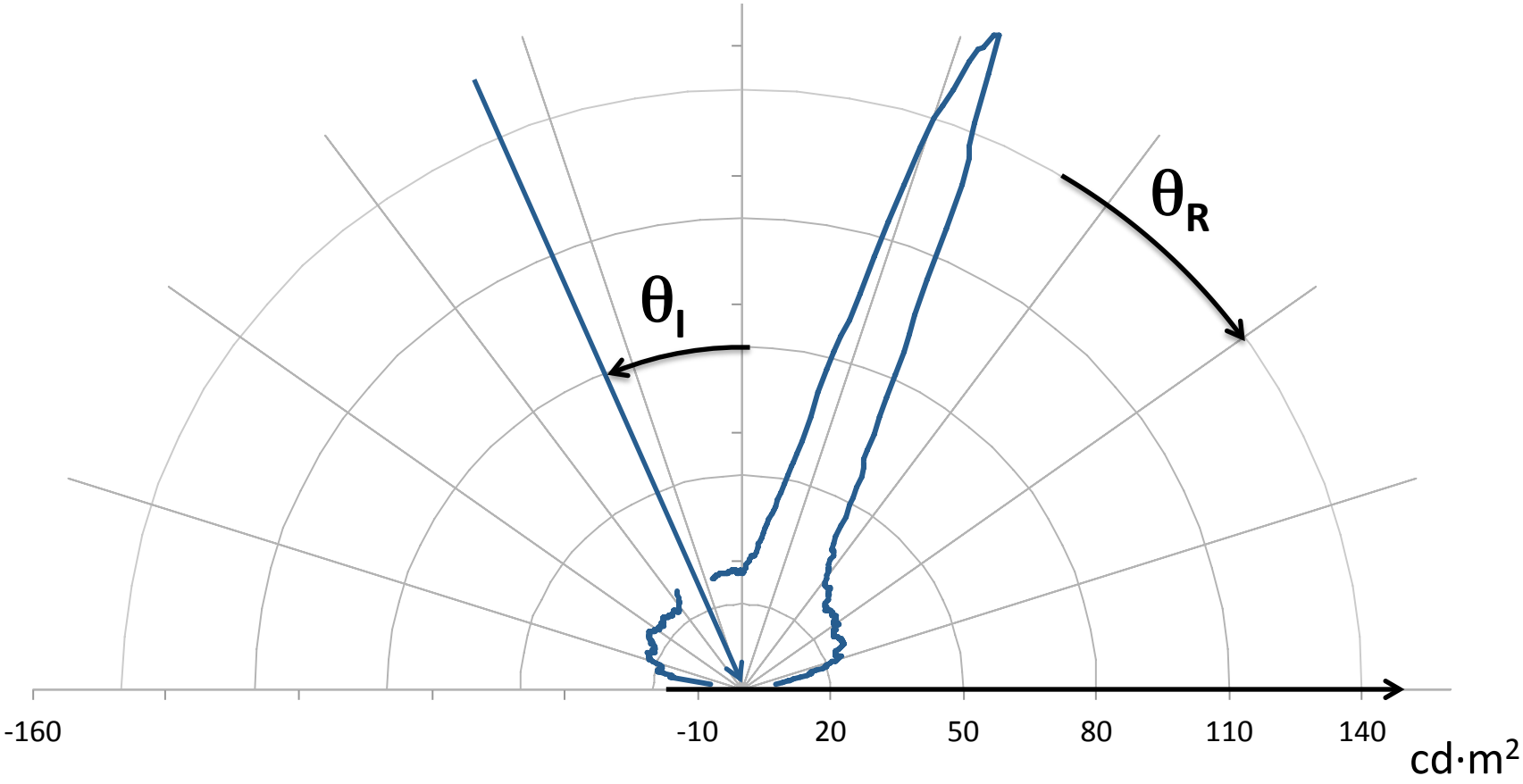
Real surface



The reflected flux can be described by function of the zenital and azimutal angles. It gives a peak, called **the specular peak**

Specular peak

Mid-glossy grey sample, $\theta_I = 21°$

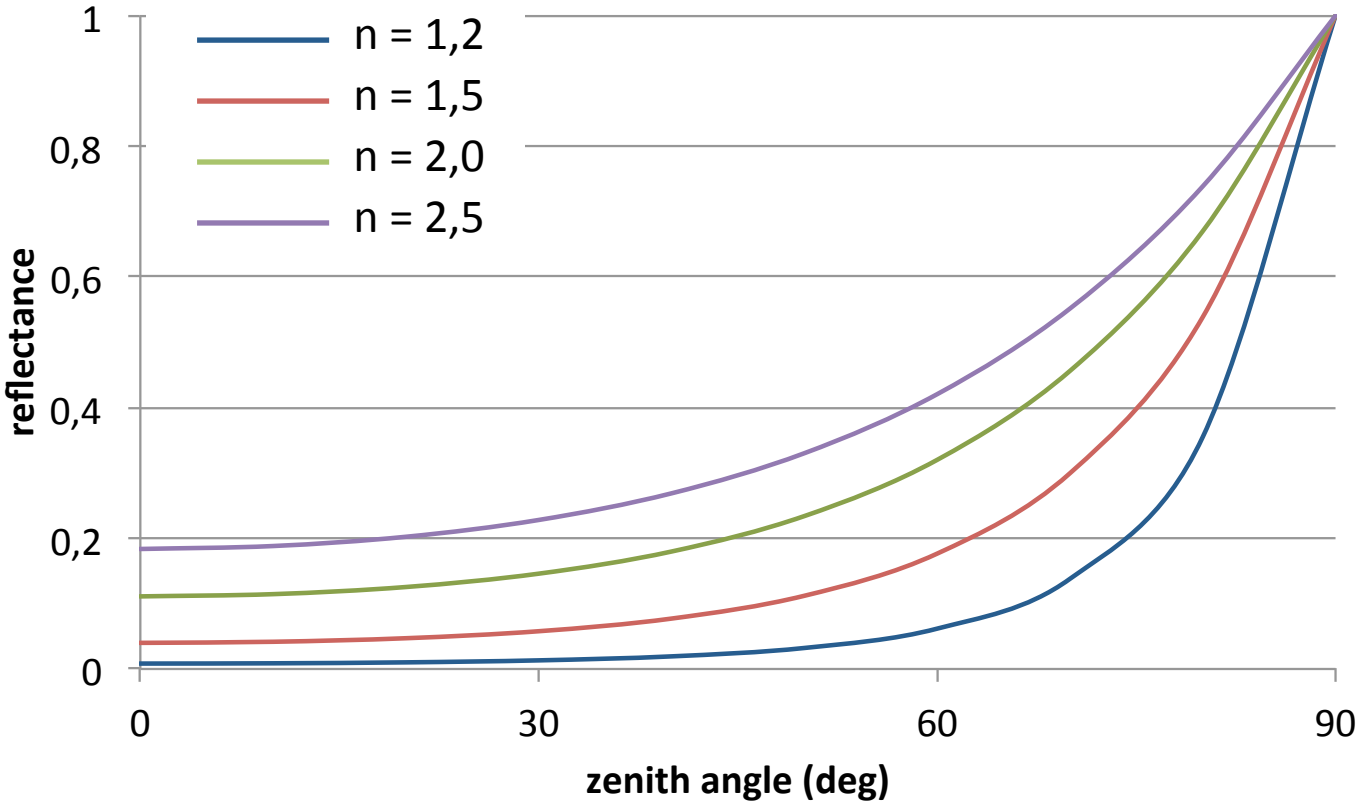


Few things to know about the pecular peak

The specular peak has the spectrum of the lighting (for non-metallic surfaces)

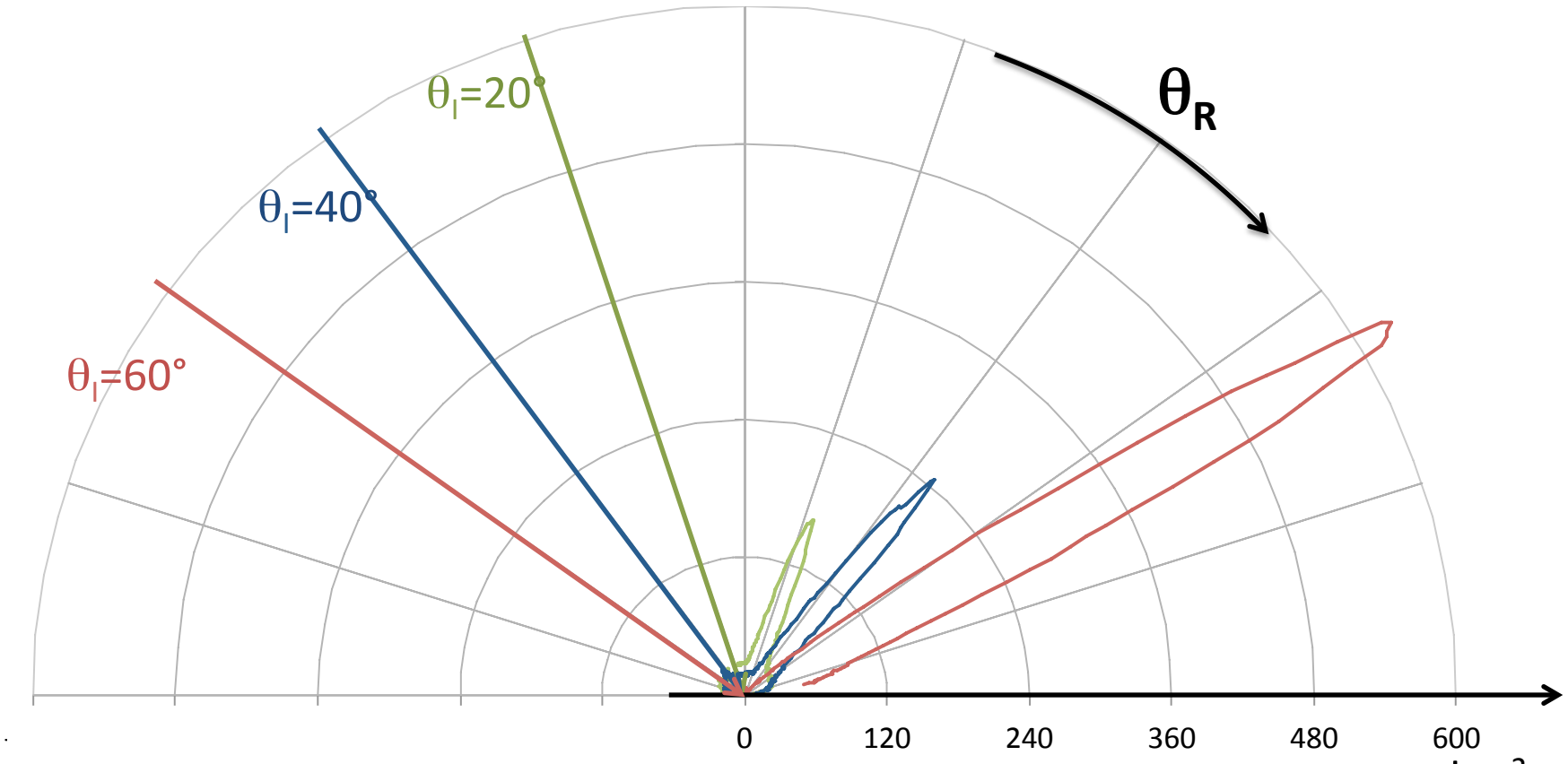
Few things to know about the pecular peak

The size of the peak increases with the refractive index of the material



Few things to know about the pecular peak

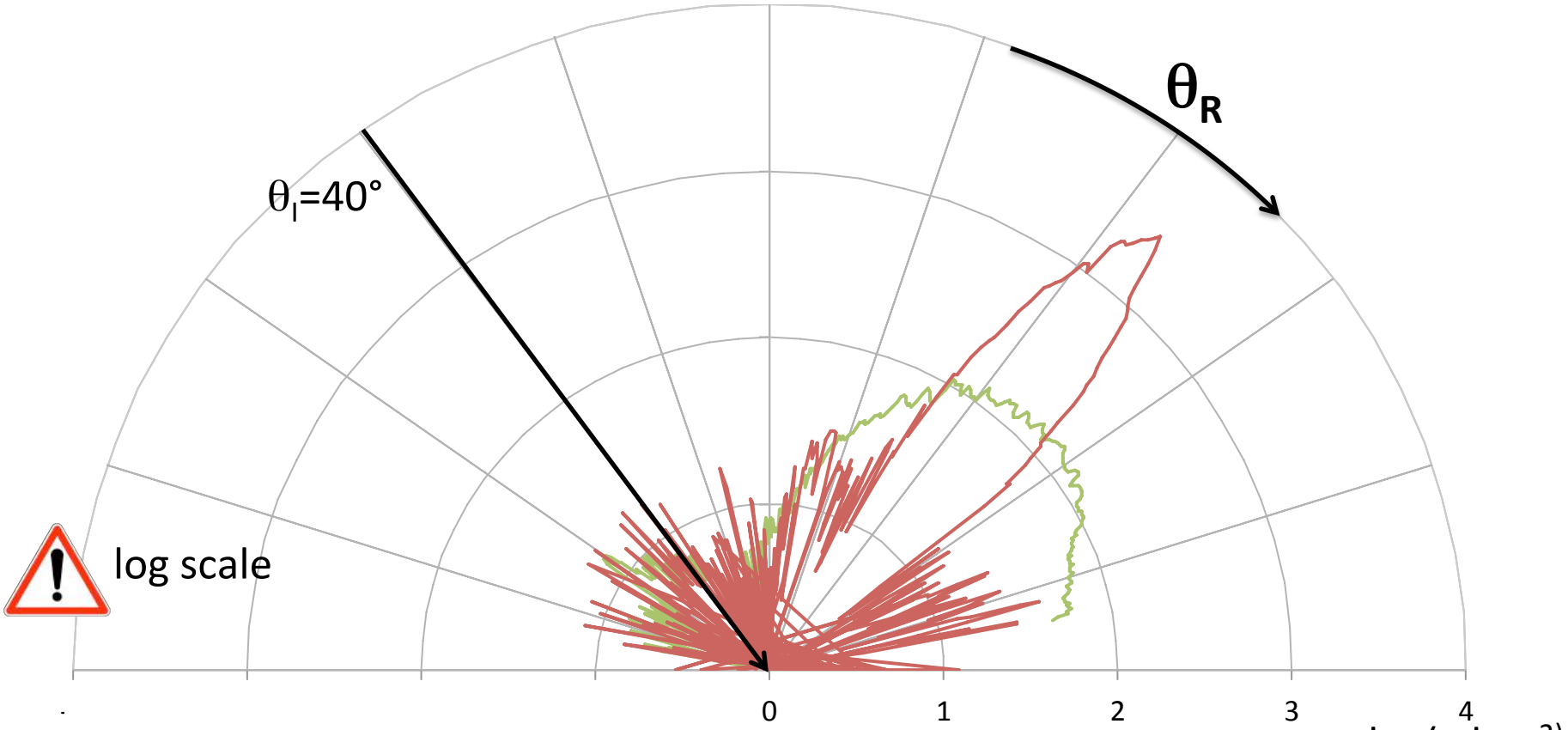
The size of the peak increases with the zenith of incidence



Mid-glossy grey sample, $\theta_I = 20°$, $\theta_I = 40°$,$\theta_I = 40°$

Few things to know about the pecular peak

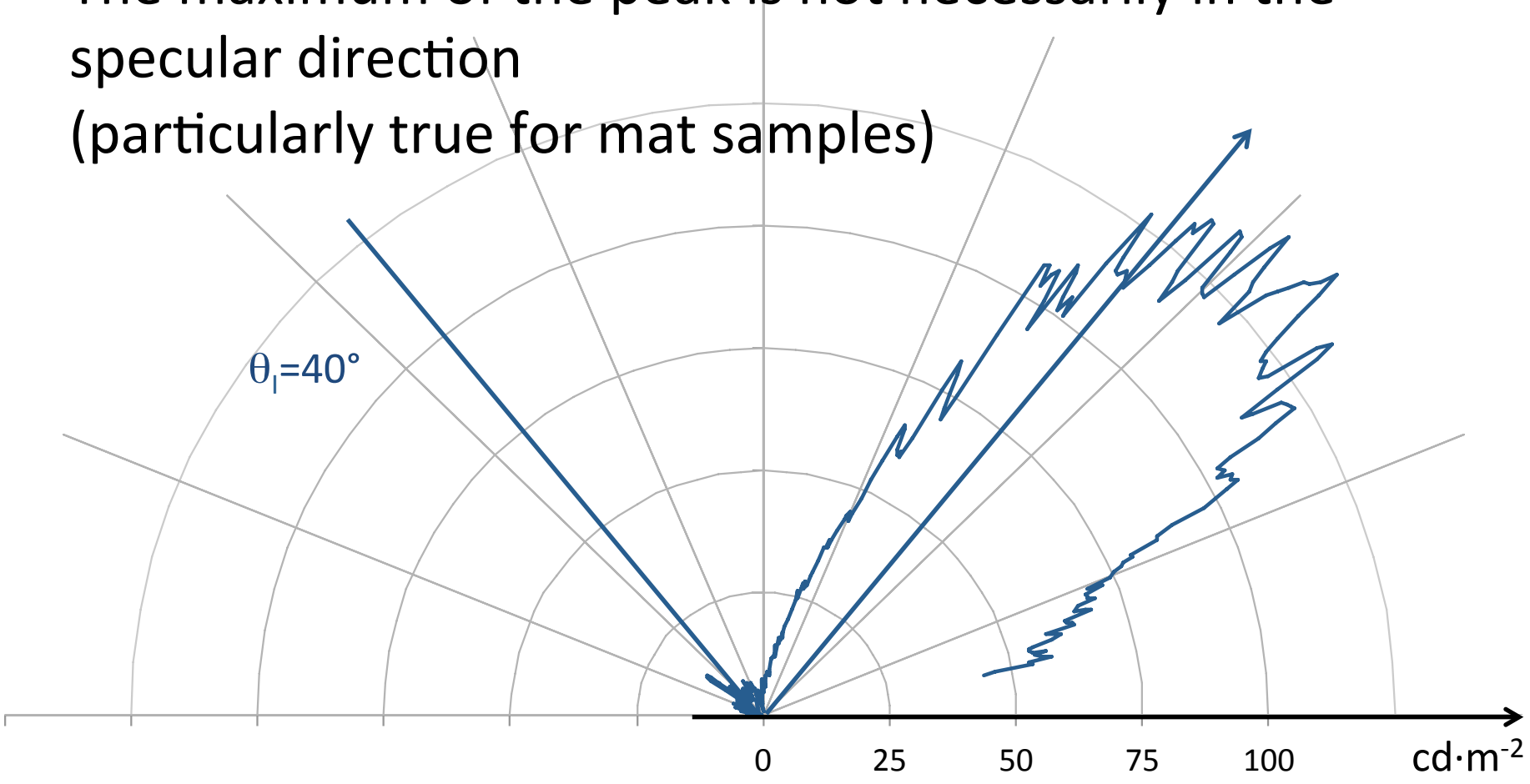
The width of the peak increases with the roughness



Black glass with 2 levels of roughness $\theta_I = 40°$

Few things to know about the pecular peak

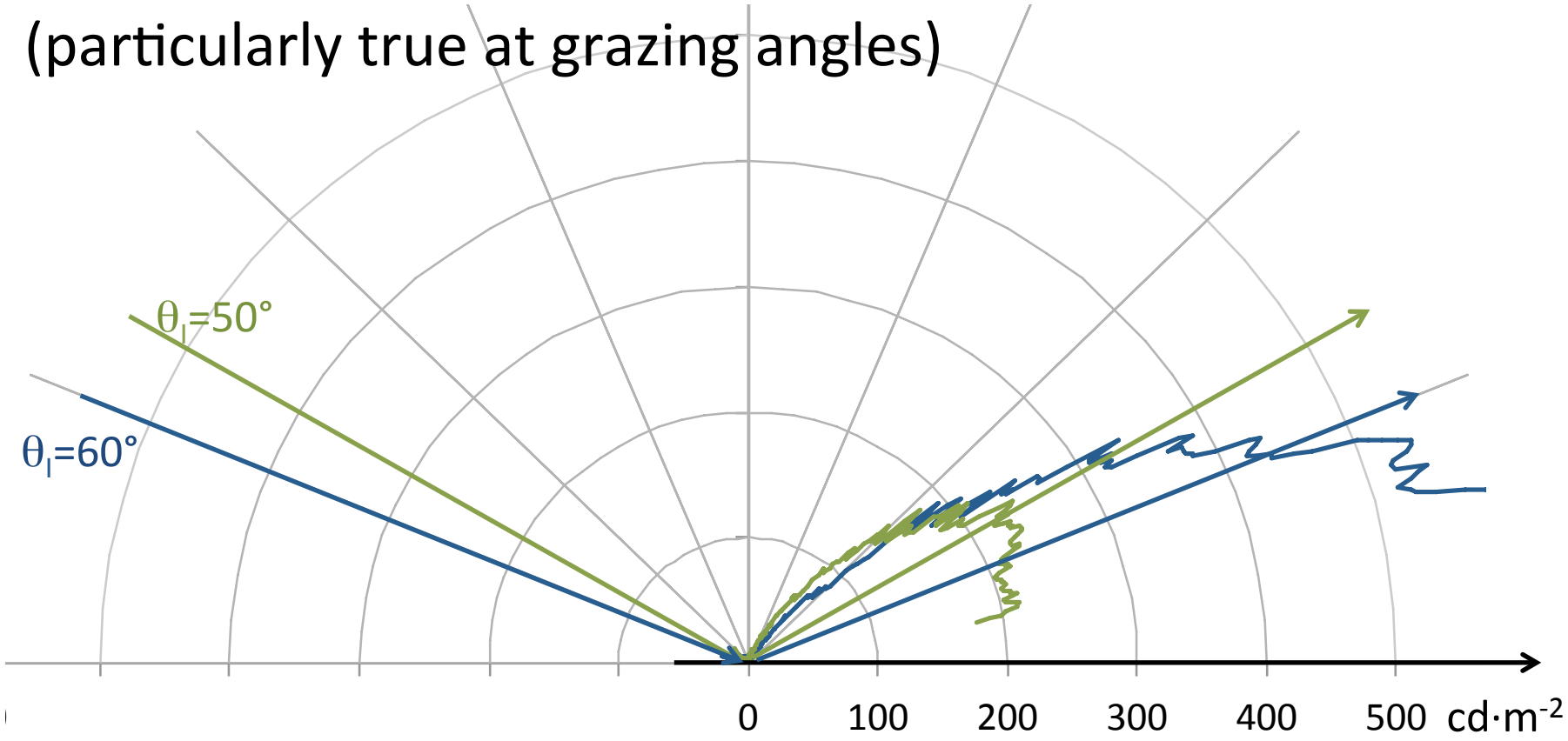
The maximum of the peak is not necessarily in the specular direction
(particularly true for mat samples)



Sanded black glass, $\theta_l = 40°$

Few things to know about the pecular peak

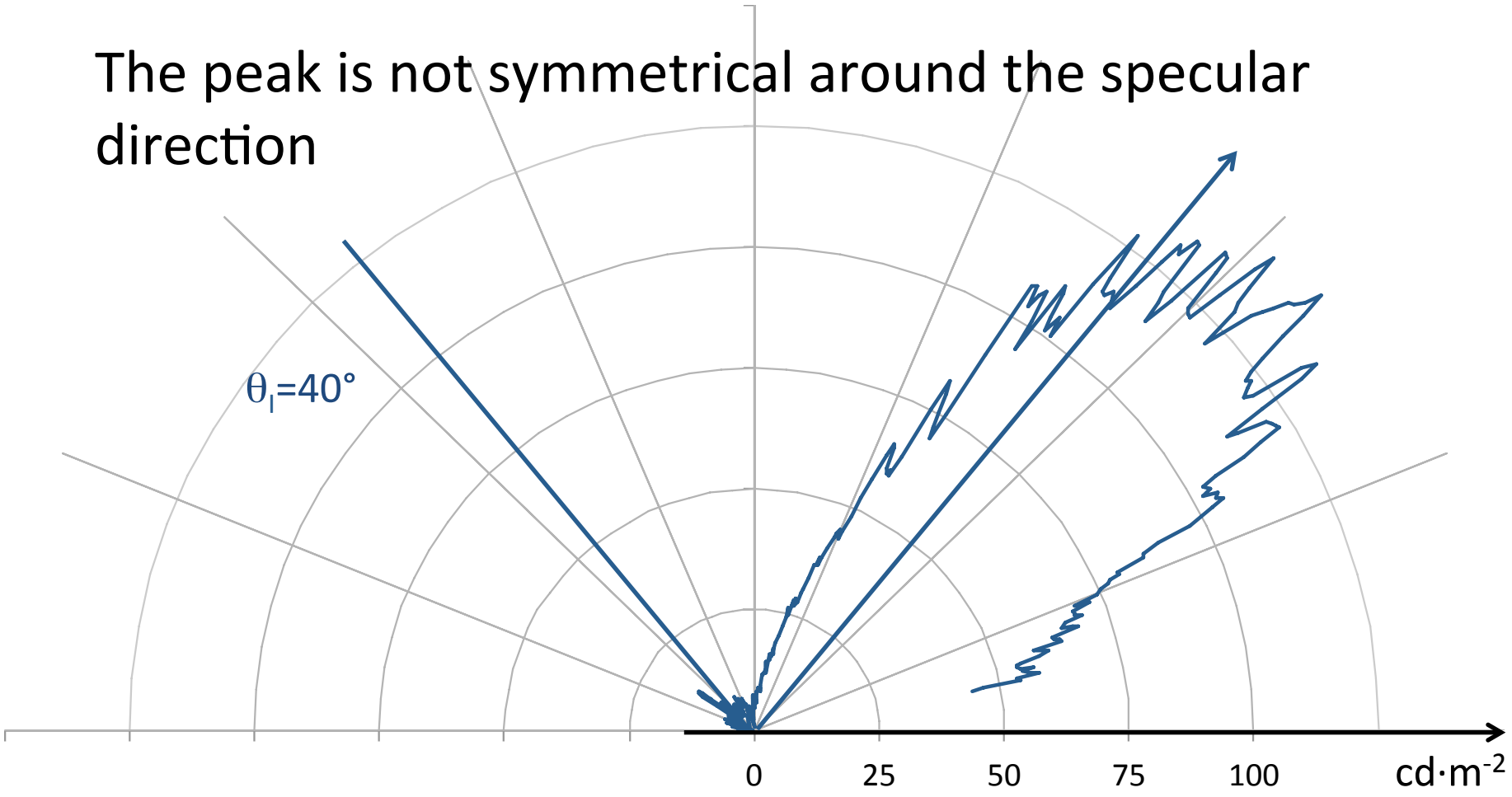
The maximum of the peak is not necessarily in the specular direction
(particularly true at grazing angles)



Sanded black glass, $\theta_I = 50°$, $\theta_I = 60°$

Few things to know about the pecular peak

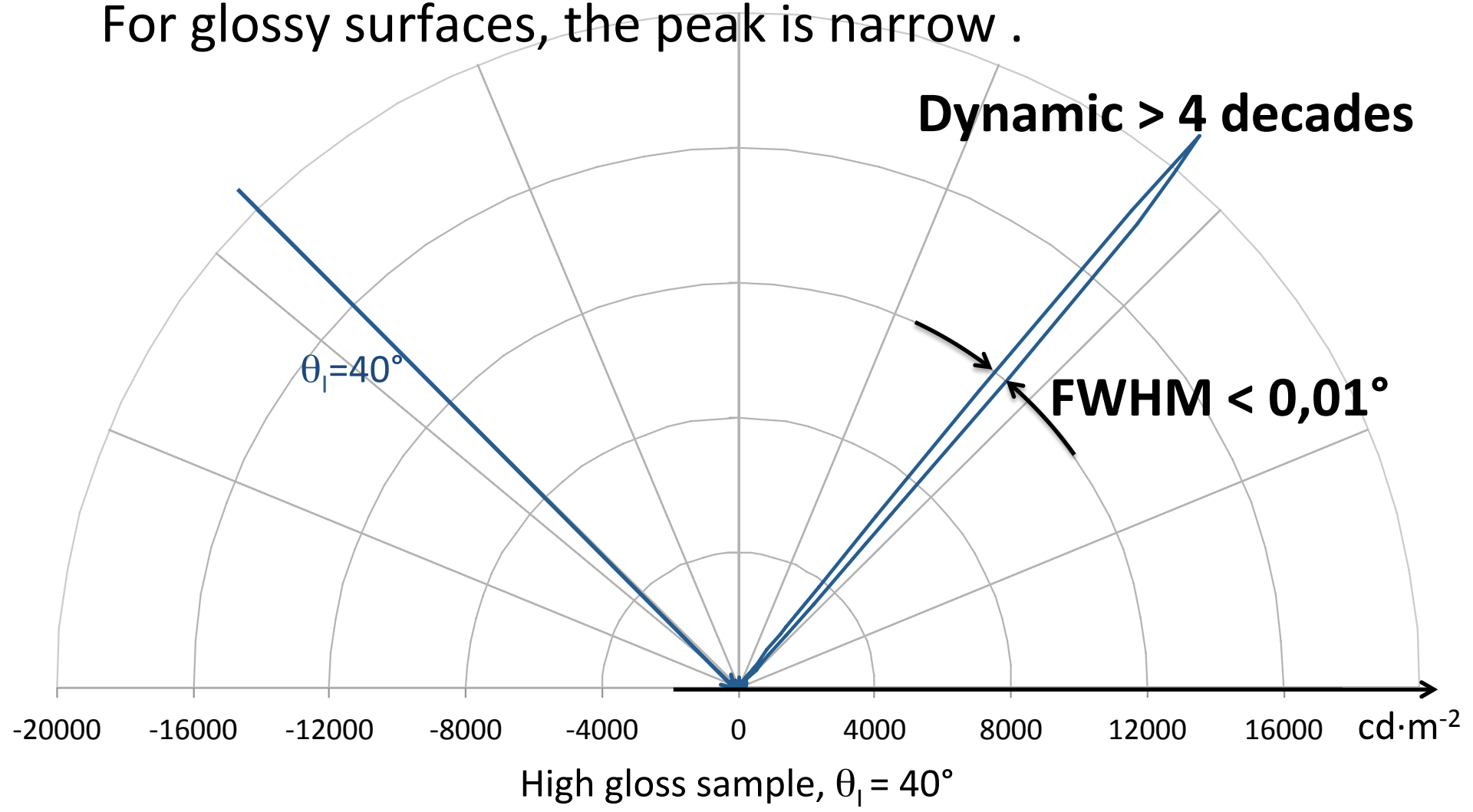
The peak is not symmetrical around the specular direction



Sanded black glass, $\theta_l = 40°$

Few things to know about the pecular peak

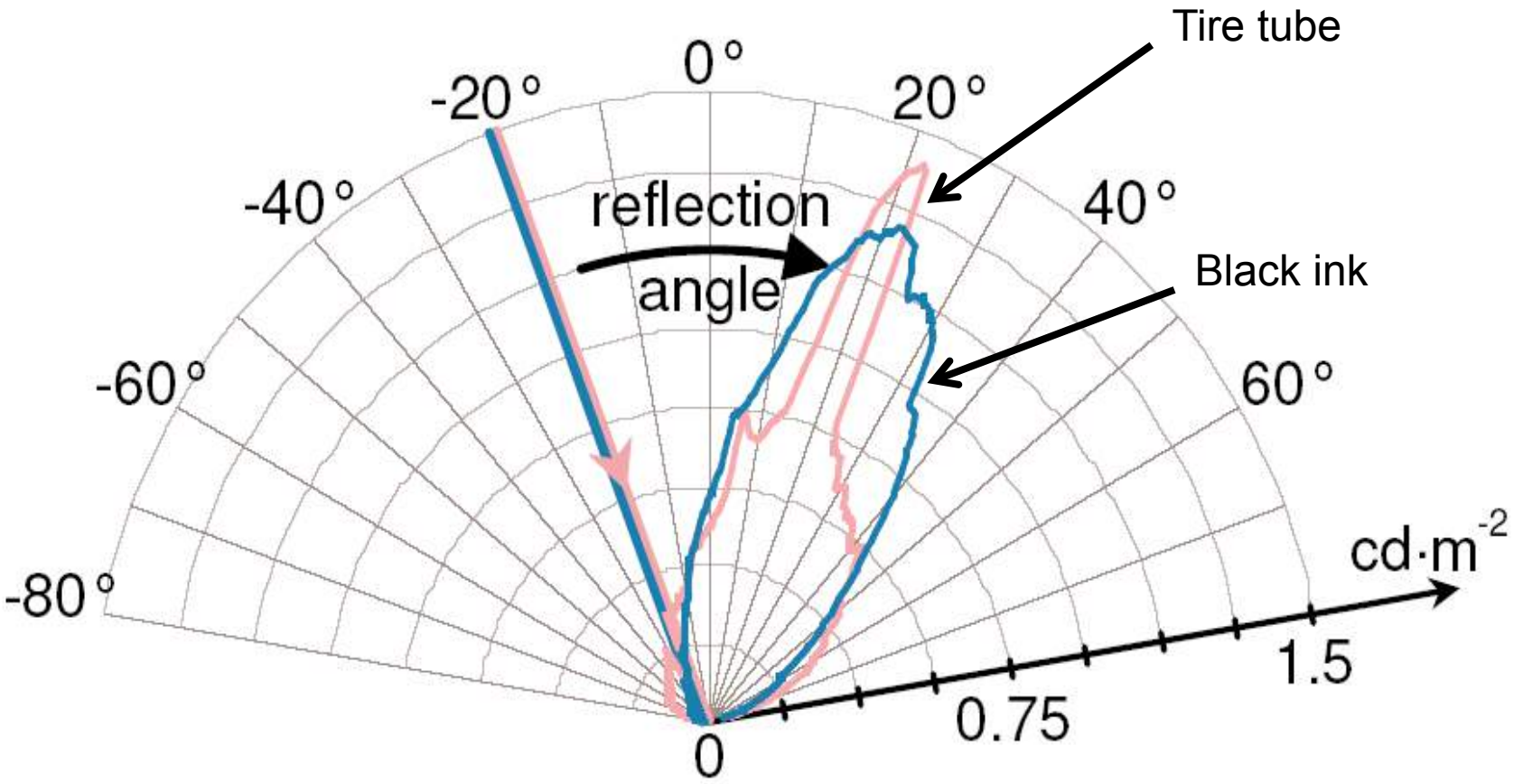
For glossy surfaces, the peak is narrow .



High gloss sample, $\theta_l = 40°$

Few things to know about the pecular peak

The shape of the peak depends upon the material



Same gloss but different material, $\theta_l = 40°$

Reminder

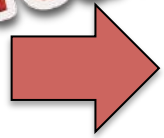
- Gloss can be ranked
- Gloss can be measured
- Gloss is in and around the specular direction

reminder

- Gloss can be ranked
- Gloss can be measured
- Gloss is in and around the specular direction

From empirical approach

From optical approach

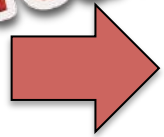


Around the specular direction we have a peak

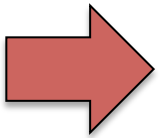
- Gloss can be ranked
- Gloss can be measured
- Gloss is in and around the specular direction

From empirical approach

From optical approach



Around the specular direction we have a peak



Assumption :
If we measure the peak, we measure the gloss?

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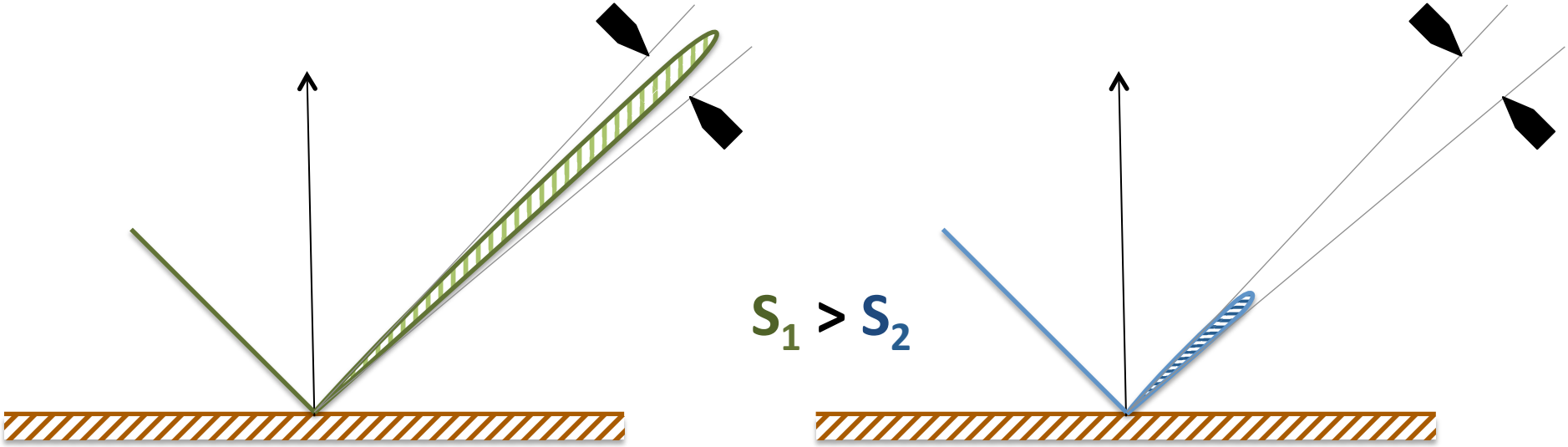
Principle

Gloss is connected with the specular peak area.

The glossmeter measure the flux in the specular, within a given aperture.



High gloss

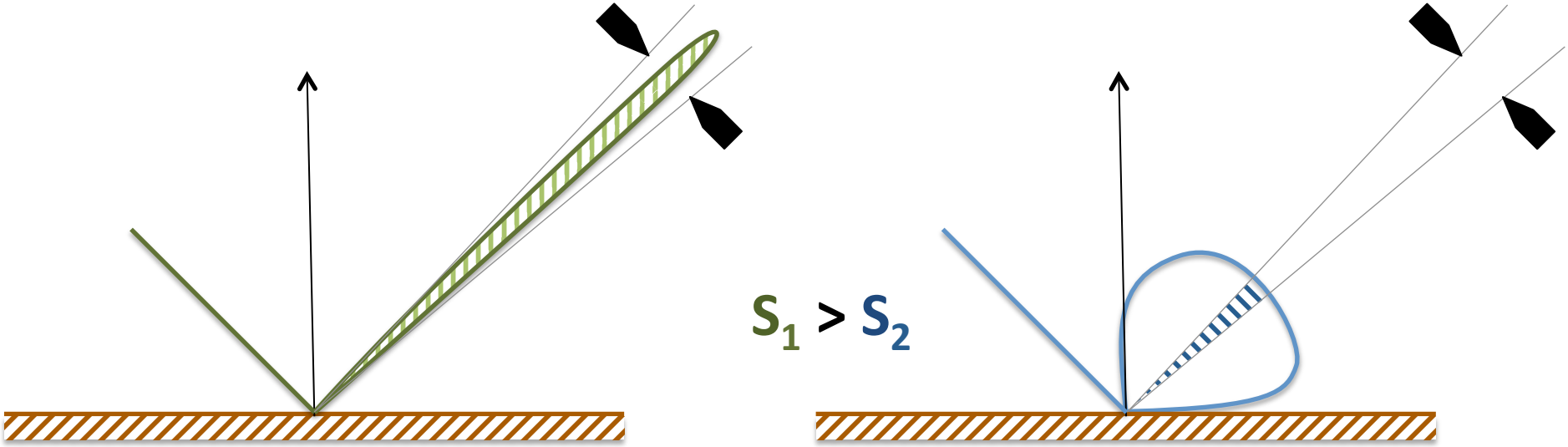
Low gloss

Case of 2 peaks of different height

Principle

Gloss is connected with the specular peak area.

The glossmeter measure the flux in the specular, within a given aperture.



High gloss

Low gloss

Case of 2 peaks of different width

Glossmeter – ISO 2813

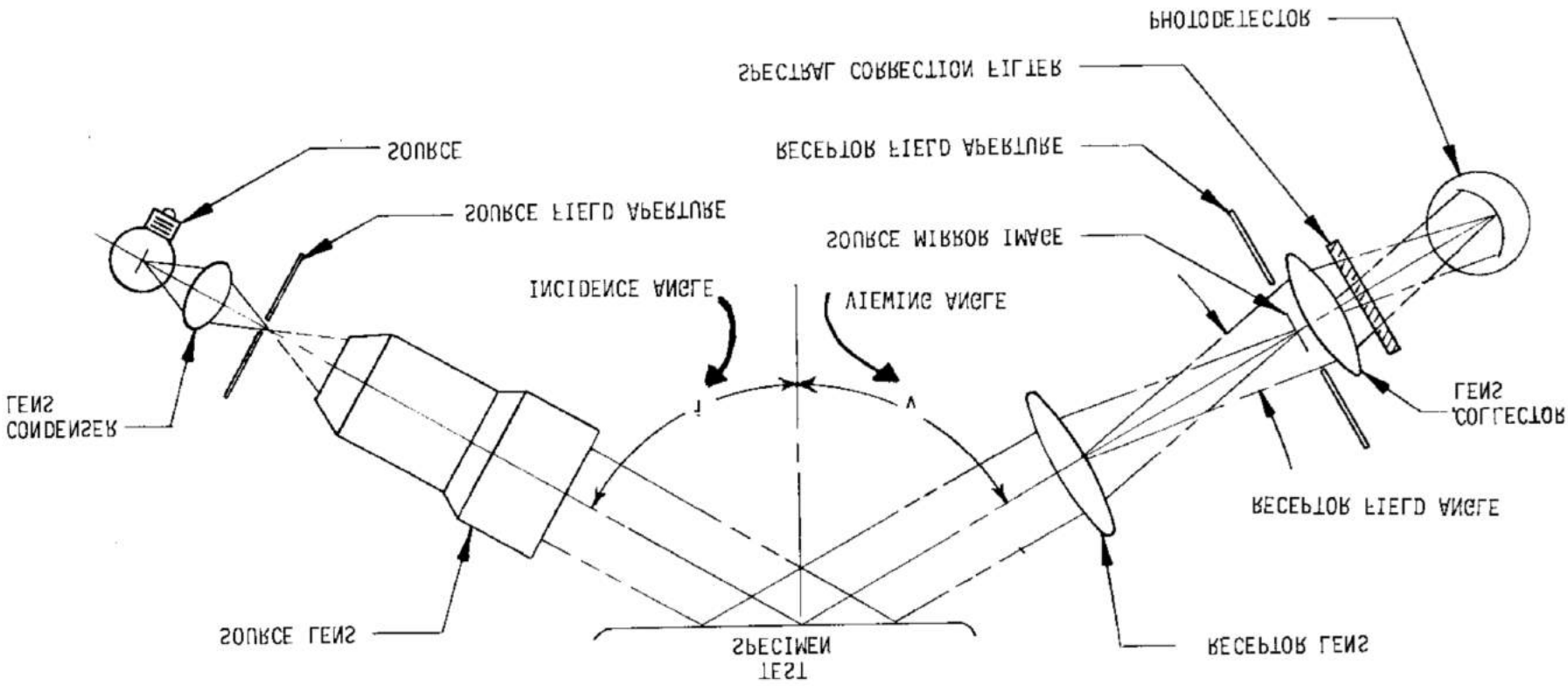
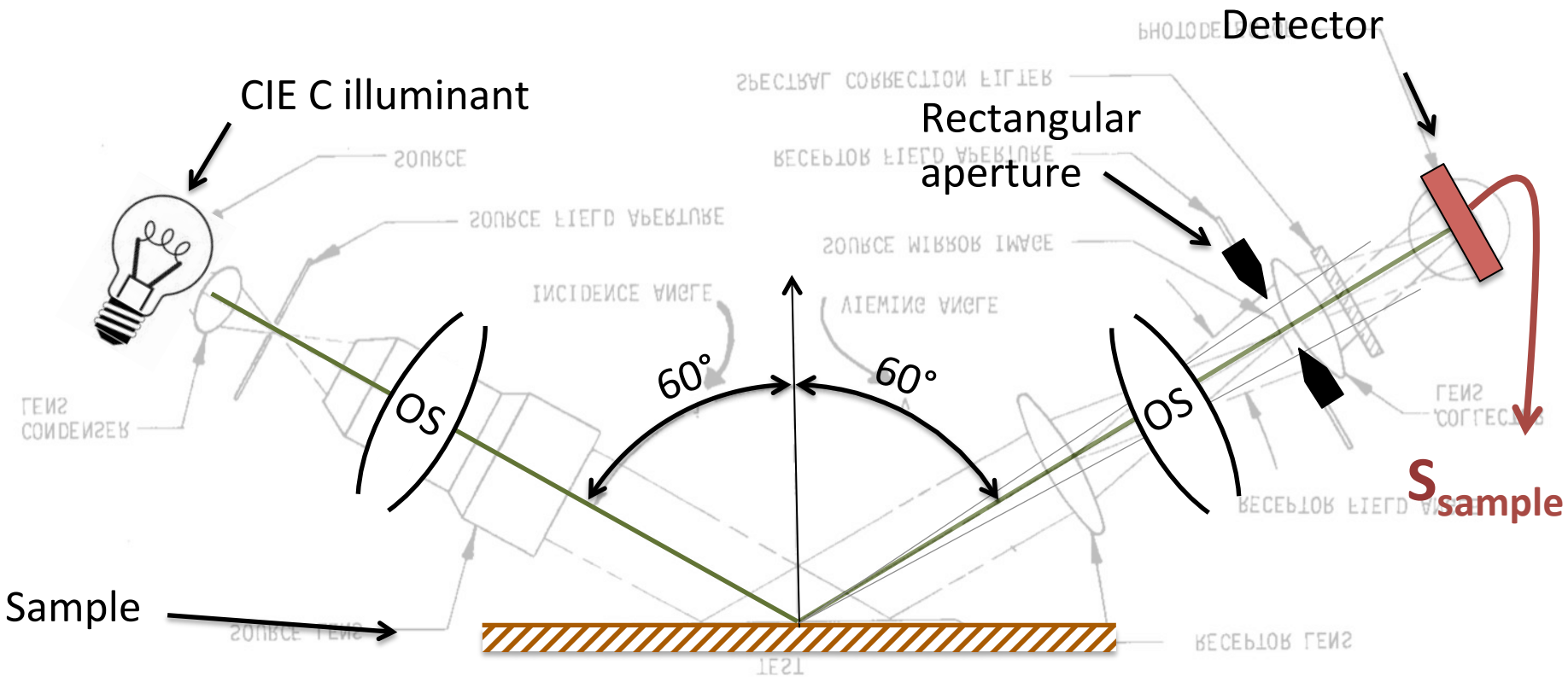
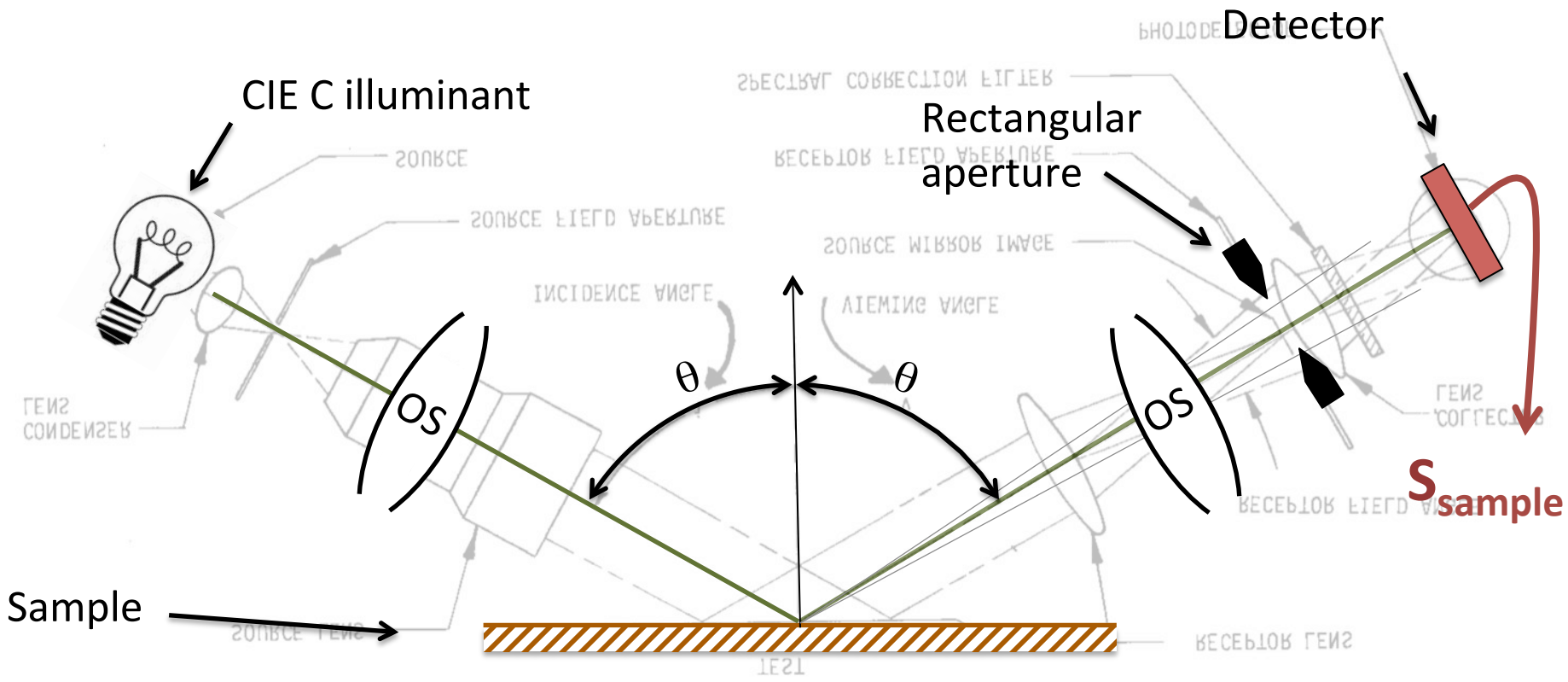


Figure extracted from ASTM D523

Glossmeter – ISO 2813



Glossmeter – ISO 2813

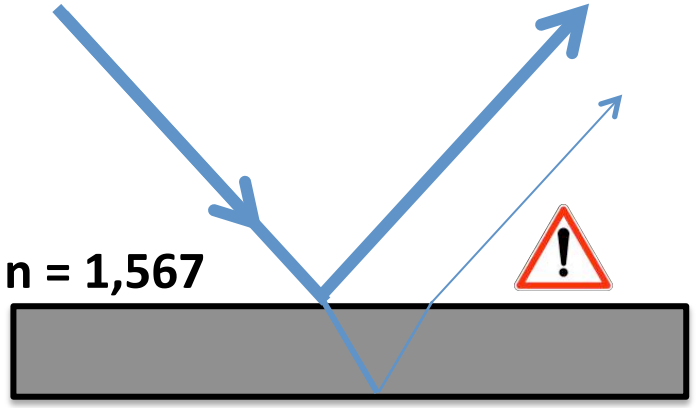


$$\text{Gloss} = 100 \times \frac{S_{sample}}{S_{Standard}}$$

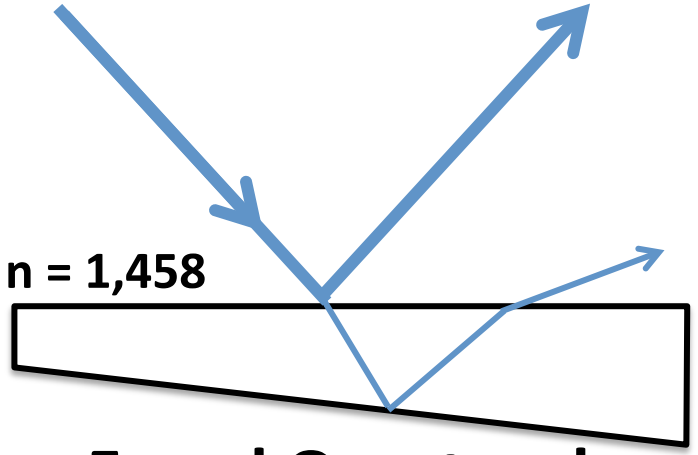
ISO 2813 — few details

Standard artefacts

7.1 *Primary Standards*—Highly polished, plane, black glass with a refractive index of 1.567 for the sodium D line shall be assigned a specular gloss value of 100 for each geometry. The gloss value for glass of any other refractive index can be computed from the Fresnel equation **(5)**.



Black glass



Fused Quartz edge

ISO 2813 — few details

Geometry 60°

Historically, measurements are made for an incident angle of 60°, and a rectangular aperture.

ISO 2813 — few details

Geometries 85°

blabla

ISO 2813 — few details

Geometries 20°

blabla

ISO 2813 — few details

Standardized Geometries:

- ☞ 20°: high gloss (°1951)
- ☞ 60°: semi-gloss (° 1939)
- ☞ 85°: low gloss (°1951)
- ☞ 45°: ceramics & plastics
- ☞ 75°: pulp & paper industry

	In-plane	Out-of-plane
	Aperture angle θ	Aperture angle θ
Source	0.75° ± 0.25°	2.5° ± 0.5°
20° receptor	1.8° ± 0.05°	3.6° ± 0.1°
60° receptor	4.4° ± 0.1°	11.7 ± 0.2°
85° receptor	4.0° ± 0.3°	6.0° ± 0.3°

Other Standards related to surface gloss

STANDARD	NUMBER	GEOMETRY	MATERIAL
ASTM	D523	overall	-
	C346	45°	Ceramics
	C584	overall	Polished ceramic whitewares
	D1223	75°	Paper
	D1455	60°	Emulsion floor polish
	D1834	20°	Waxed paper
	D2457	overall	Plastic foil
	D3134		Color/Gloss tolerances, practice
	D3265	overall	Carbon black – tint strenght
	D3928		Gloss/sheen uniformity evaluation, test
	D4039	overall	Reflection haze of high gloss surfaces
	D4449		Gloss differences – surface of similar appearance, visual evaluation, test

Other Standards related to surface gloss

STANDARD	NUMBER	GEOMETRY	MATERIAL
ASTM	E179		Selection of geometric conditions for measurement of reflection/transmission properties of materials
	E430	overall	High gloss surfaces via goniophotometry
	E97S	45° en 0° reflectance factor	Matte surfaces
BS	3424:Part 28 Method 31	overall	General
	3900 D5	20°, 60°, 85°	Non-metallic paint films
	3962 Part 1	overall	Wood
	61612 Part 12	20°, 45°, 60°, 85°	General
DIN	67530	overall	Smooth painted and plastic surfaces
ISO	2813	20°, 60°, 85°	Non-metallic paint films
JIS	Z 8142	75°	General
	Z 8741	overall	General
NFT	30-064	overall	Paint
SS	18 41 84	overall	Paint and varnish
TAPPI	T480	75°	Paper
	T653	20°	Paper

Other Standards related to surface gloss

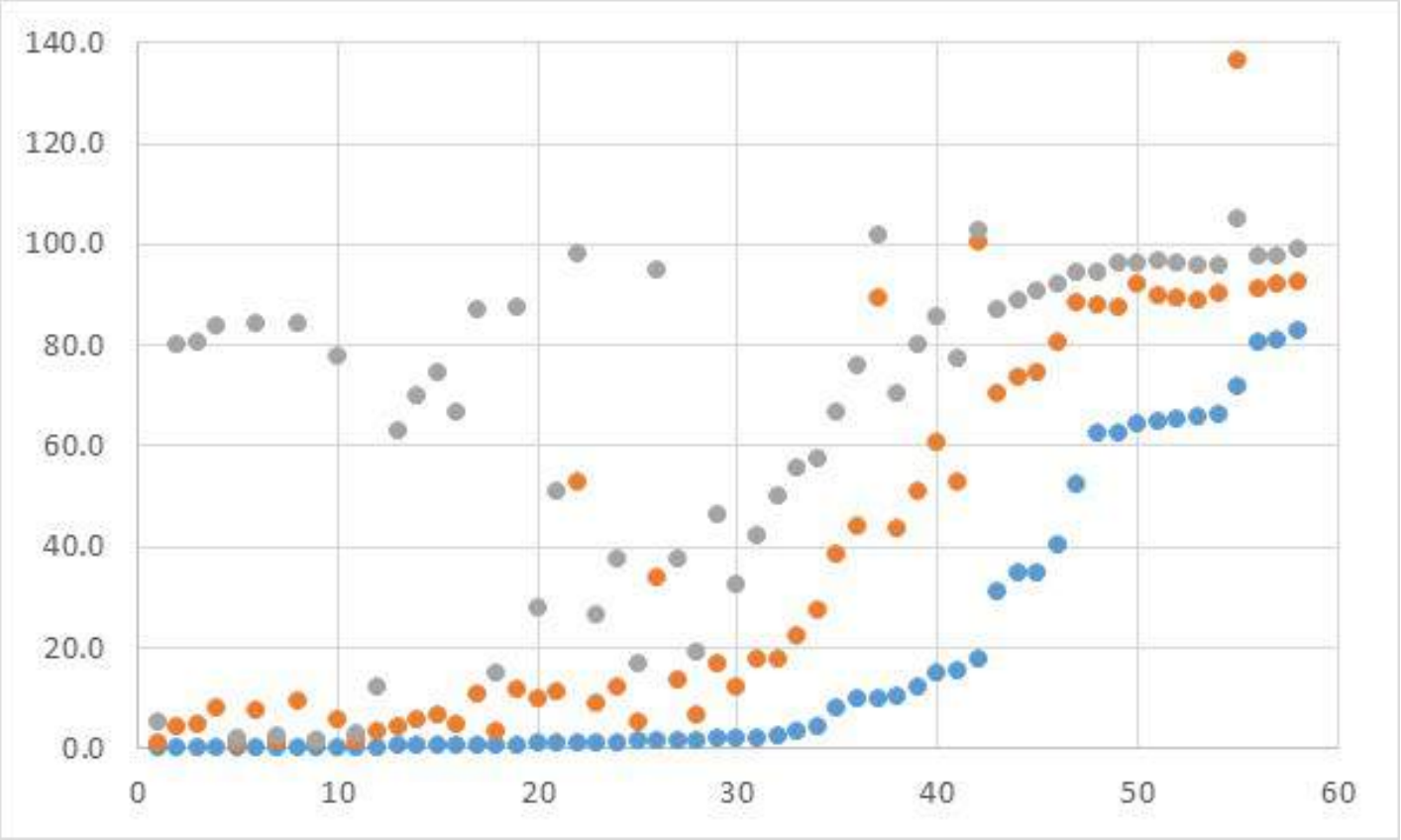
Fabrikant	toestel	Geometrie
Hunterlab	ProGloss II 3-angle (20°, 60°, 85°)	20°, 60°, 85°
	ProGloss II 60°	60°
	ProGlos II 75°	75°: papier (TAPPI)
	D48-7 75° glossmeter	75°: papier (TAPPI)
Konica Minolta	Multi Gloss 268	20°, 60°, 85°
		Uni-gloss meter met 60° geometrie mogelijk
Photovolt Instruments	P/N 0490600	20°, 60°, 85°, conform ASTM D523, D 2475; ISO 2813; DIN 67 530
	P/N 0490610	20°, 60°, 85°, conform ASTM D523; ISO 2813, 7668; DIN 67 530
	P/N 0490620	20°, conform ASTM D523, D2475; ISO 2813; DIN 67 530
	P/N 0490645	45°, conform ASTM D2475; C 346
	P/N 0490660	60°, conform ASTM D523, D 2475; ISO 2813; DIN 67 530
	P/N 0490675	75°, conform JIS Z 8741
	P/N 0490685	85°, conform ASTM D523, D 2475; ISO 2813; DIN 67 530
X-Rite	AcuGloss60	60°
	AcuGloss TRI	20°, 60°, 85°
RhoPoint Instr.	NG 20/60/85/S	20°, 60°, 85°
	NG 75	75°: papier
	NG 60/S	60°
	NC: Novo Curve	Niet gespecifieerd, conform ISO 2813 en BS 3900 D5 - **Voor gebogen oppervlakken**

Other Standards related to surface gloss

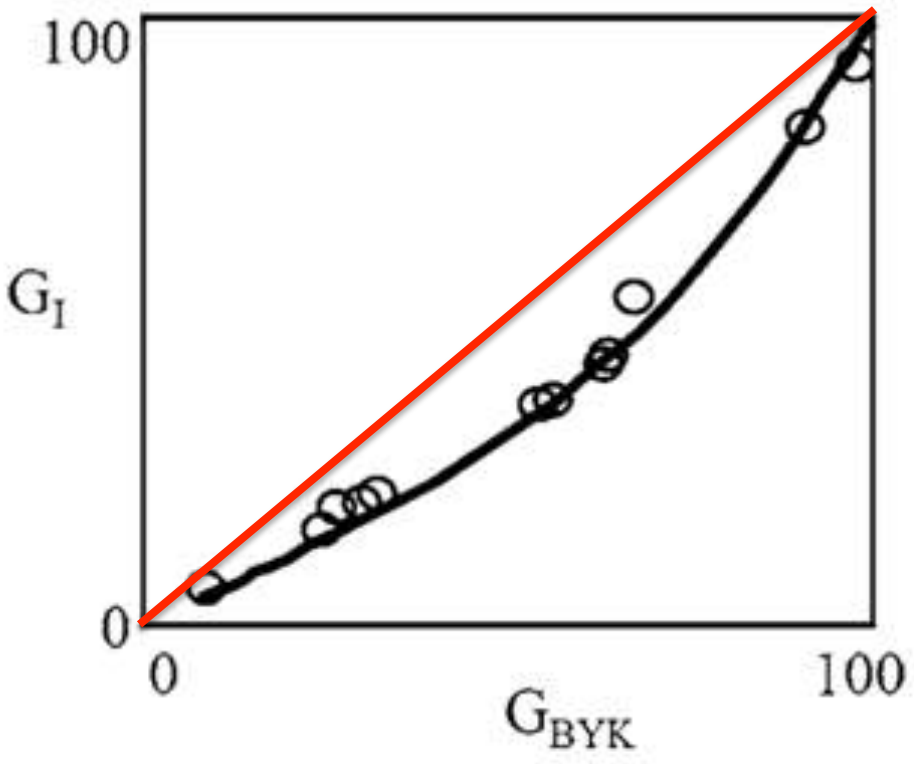
Fabrikant	toestel	Geometrie
BYK Gardner	B 4512	20°
	B 4501	60°
	B 4515	85°
	B 4535	45°
	B 4553	75°
	B 4520	20°, 60°, 85°
Sheen		
Bench glossmeter	Ref 157/60	60°, conform ASTM D523, 2457, D 1455; DIN 67530; ISO 2813; BS 3900 en 6161 part 12
	Ref 157/20-60	20° en 60°, conform ASTM D523, 2457, D 1455; DIN 67530; ISO 2813; BS 3900 en 6161 part 12
	Ref 157/60/SO	60°, conform ASTM D523 en DIN 67530
	Ref 157/75	75°, conform TAPPI T.480 OM-90
Glossmaster	Tri-glossmaster	20°, 60° en 85°
	Glossmaster 20°	20°
	Glossmaster 60°	60°
	Glossmaster 85°	85°, alle Glossmaster toestellen zijn conform ISO 2813; ISO 7668; ASTM D 523, D2457; DIN 67530; JIS Z 8741
Minigloss	101 N 60° glossmeter	60°, conform BS3900:D5; ISO 2813; DIN 67530; ASTM D523, D1455; JIS Z 8741
Microgloss	Microgloss 45°	45°
	Microgloss 75°	75°
	Tri-microgloss Plus μ	20°/60°/85°, conform ASTM D523; DIN 67530; ISO 2813. Meet ook de laagdikte (tot 500 μm) van coatings.
Zehntner	ZGM 1020	5 toestellen naargelang configuratie: 20°, 45°, 60°, 75°, 85°
	ZGM 1023	3 toestellen, 1 met 20°, 60° en 85° geometrie
	ZGM 1022	Dual-angle versie: 20° - 60°; 20° - 75°; 20° - 85°; 45/0 – 60°

Limitations of specular gloss meters

Uncorrelated scales



Inter-instrument agreement

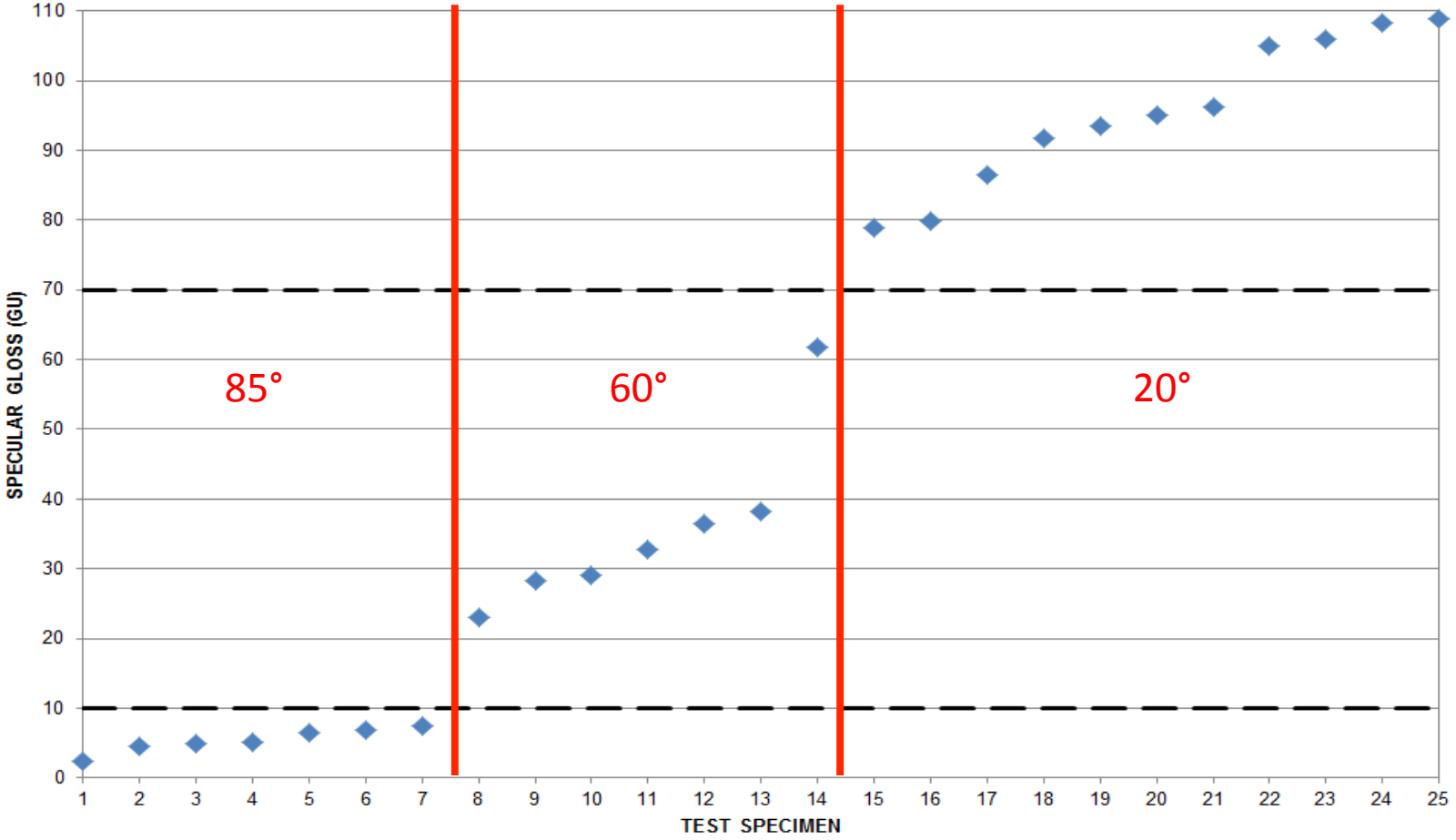


Arney et al., J. Imaging Sci. Technol., 2006

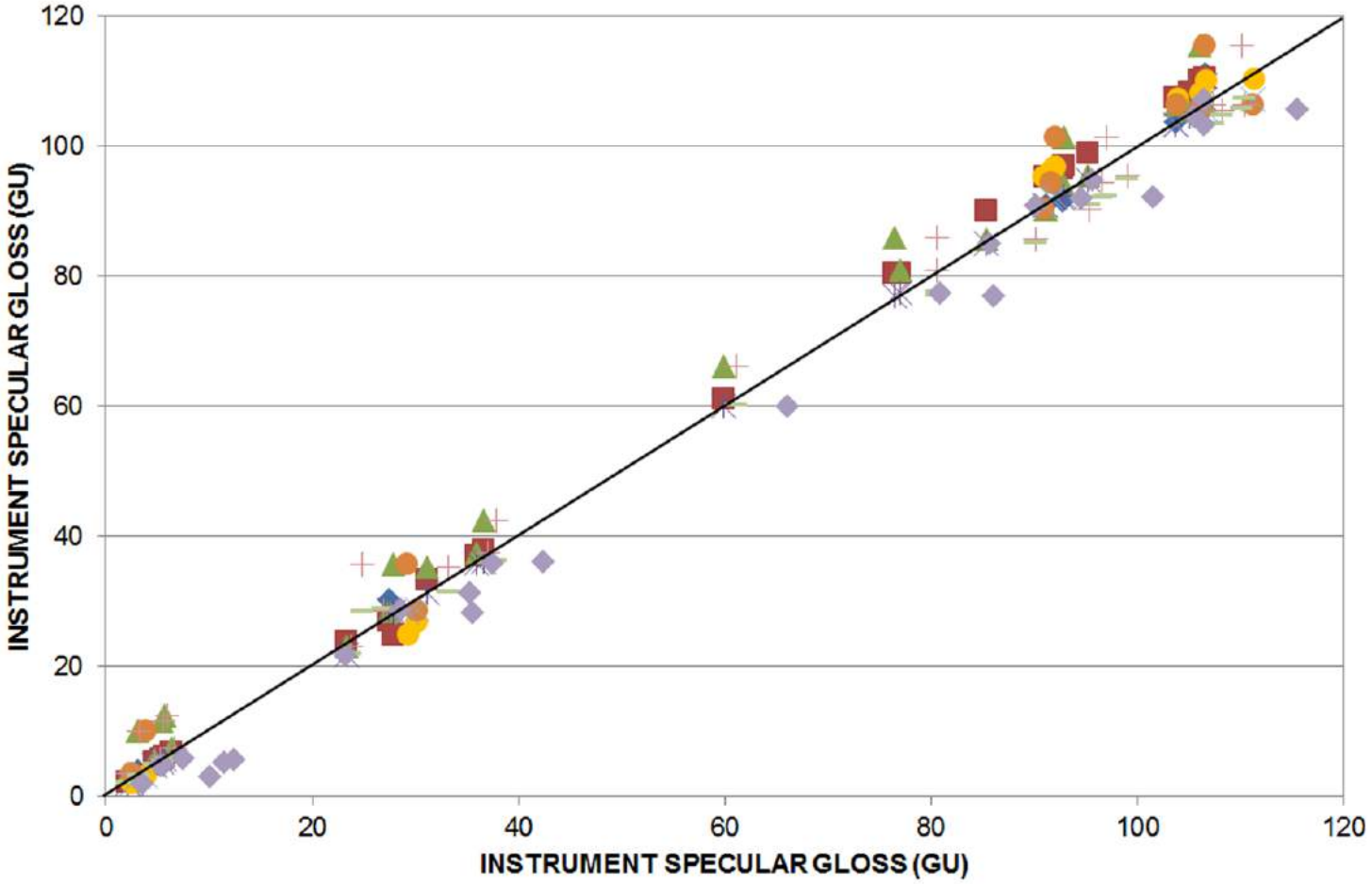
Inter-instrument agreement

Manufacturer	BYKGardner		Rhopoint/Minolta		Zehntner	
Instrument type	micro-TRI-gloss	Micro-TRI-gloss S	IQ Flex 20	IQ Trigloss	ZGM 1110	ZGM 1120
Measurement geometry	20°/60°/85°	20°/60°/85°	20°	20°/60°/85°	20°/60°/85°	20°/60°/85°
Repeatability	± 0.2 GU	± 0.2 GU (± 0.1 GU)*	± 0.2 GU	± 0.2 GU	± 0.1 GU	± 0.1 GU
Reproducibility	± 0.5 GU	± 0.5 GU (± 0.2 GU)*	± 0.5 GU	± 0.5 GU	± 0.5 GU	± 0.5 GU
Calibration traceability	BAM	BAM	BAM	BAM	BAM	BAM

Inter-instrument agreement



Inter-instrument agreement



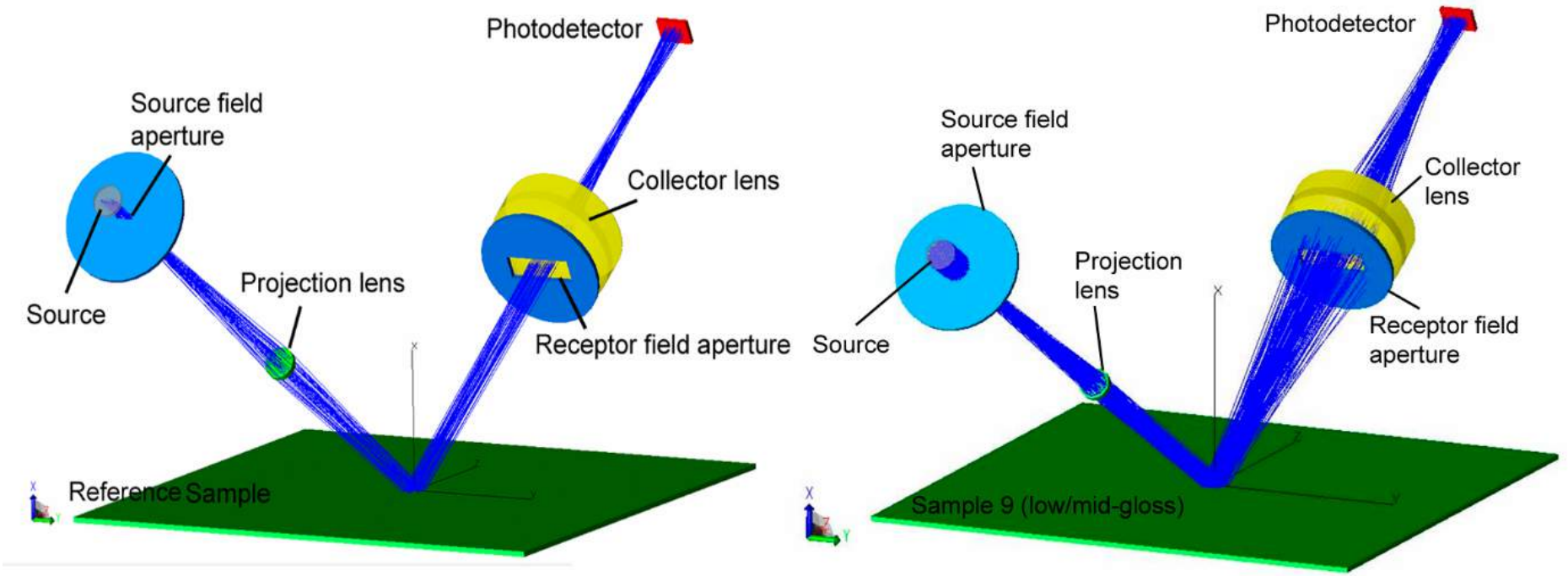
Inter-instrument agreement - repeatability

Sample	Repeatability (GU)	Sample	Repeatability (GU)	Sample	Repeatability (GU)
1	0.7	10	12.6	19	1.0
2	0.4	11	17.1	20	4.1
3	3.0	12	3.1	21	3.6
4	3.3	13	4.4	22	2.2
5	4.1	14	7.0	23	3.2
6	2.7	15	8.3	24	3.8
7	6.4	16	5.7	25	4.4
8	11.3	17	0.9		
9	11.2	18	2.4		

Inter-instrument agreement - reproducibility

Sample	Reproducibility (GU)	Sample	Reproducibility (GU)	Sample	Reproducibility (GU)
1	0.8	10	10.7	19	13.9
2	0.9	11	4.1	20	14.3
3	1.9	12	1.6	21	9.2
4	1.4	13	6.2	22	7.7
5	1.8	14	6.1	23	7.2
6	1.8	15	3.2	24	8.5
7	2.7	16	8.9	25	9.1
8	2.2	17	9.9		
9	3.3	18	10.5		

Inter-instrument agreement



Leloup et al., J. Coat. Technol. Res., 2016

Aperture dimensions + non-ideal angular conditions:

- deviations of 2GU for mid-gloss samples
- Aperture dimensions more important that angular offset

Outline

- What is gloss ?
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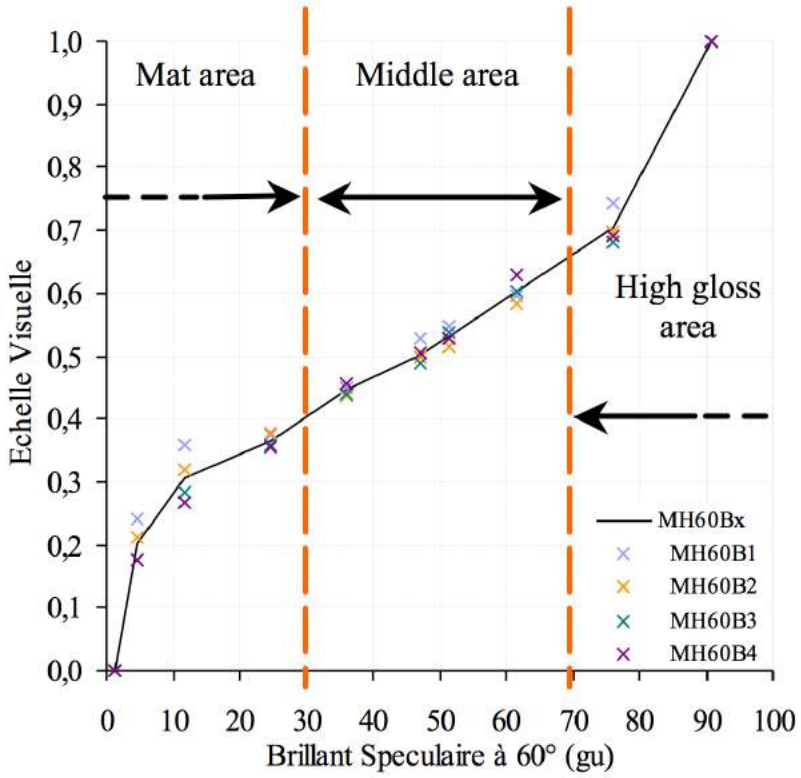
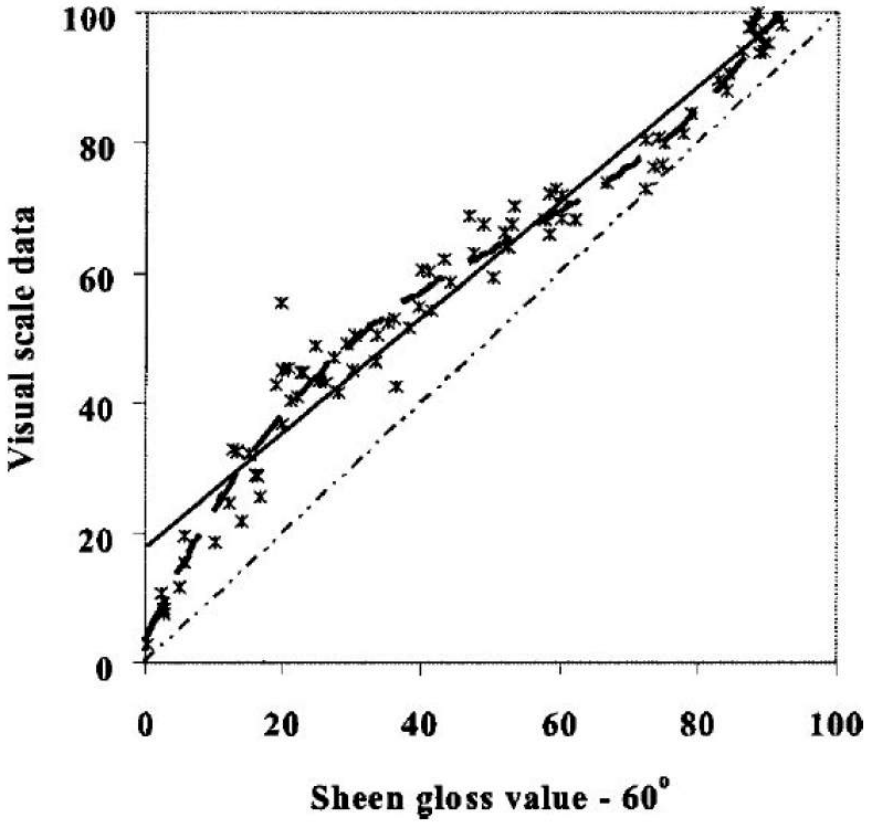
- Gloss as a multivariable quantity
  - Visual approach
  - Existing instrumentation
- Future chanllenges
- Discussion

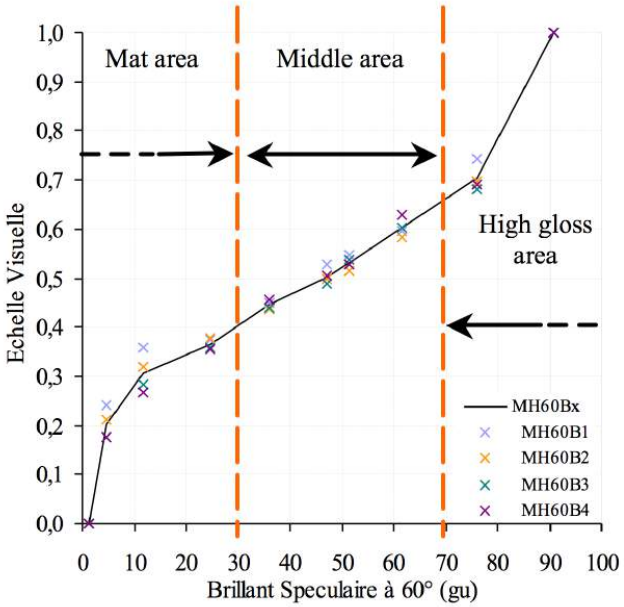
Correlation with the visual sensation



Obein et al (JOV 2004)

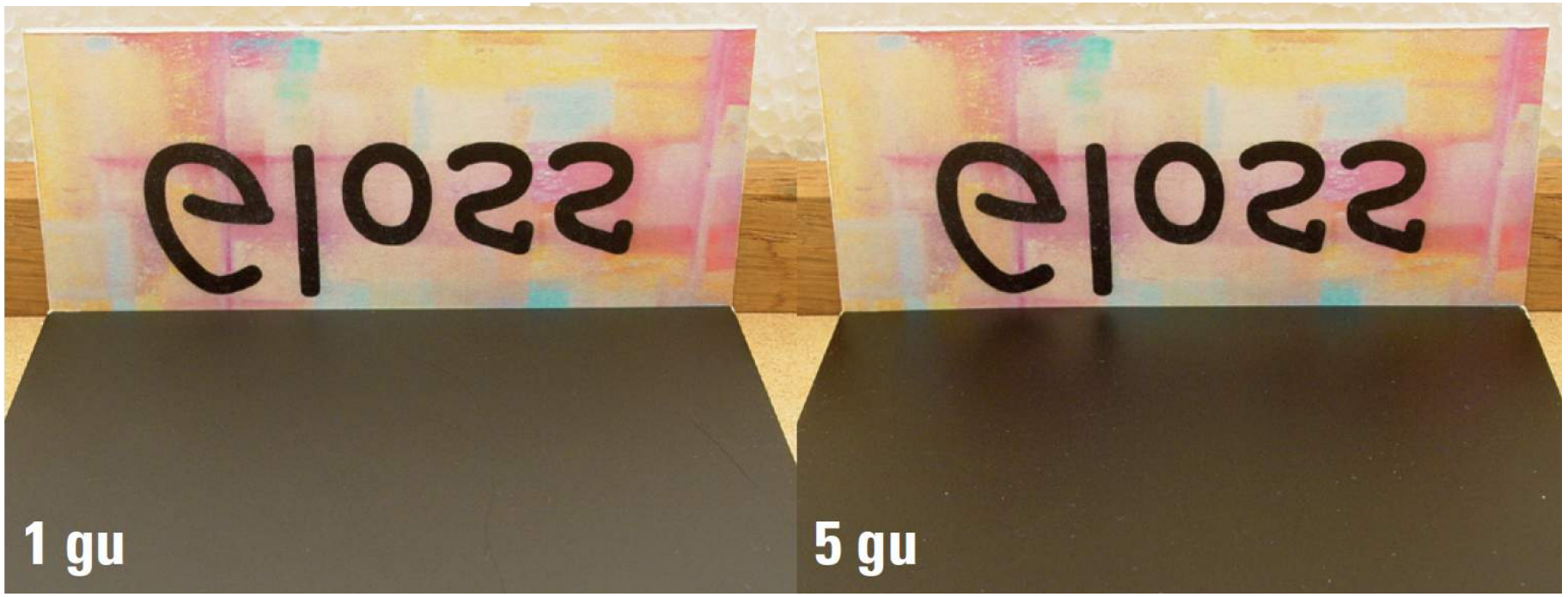


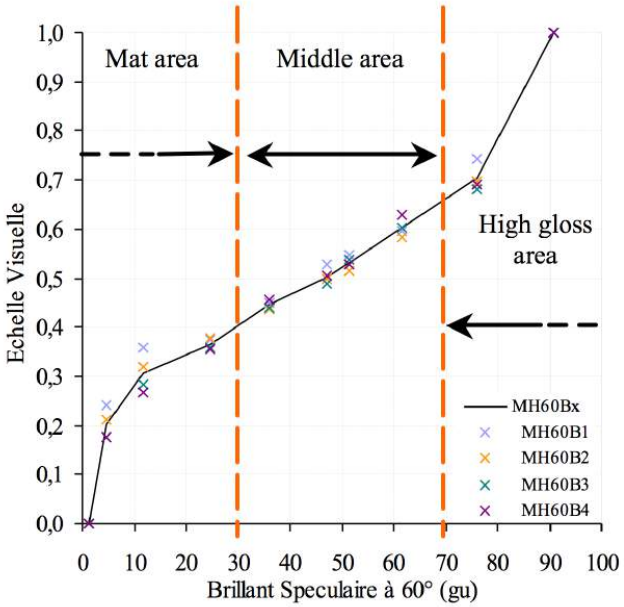
Ji et al (JOSA 2006)



Correlation with the visual sensation

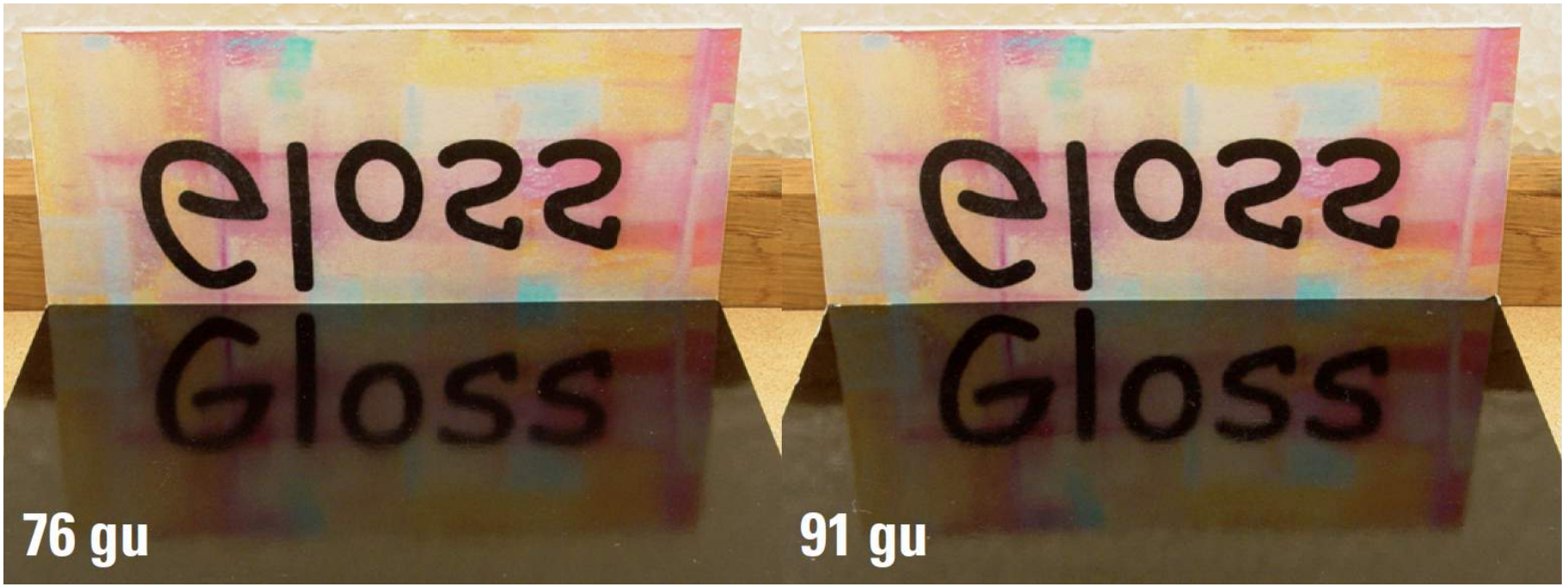
Mat samples

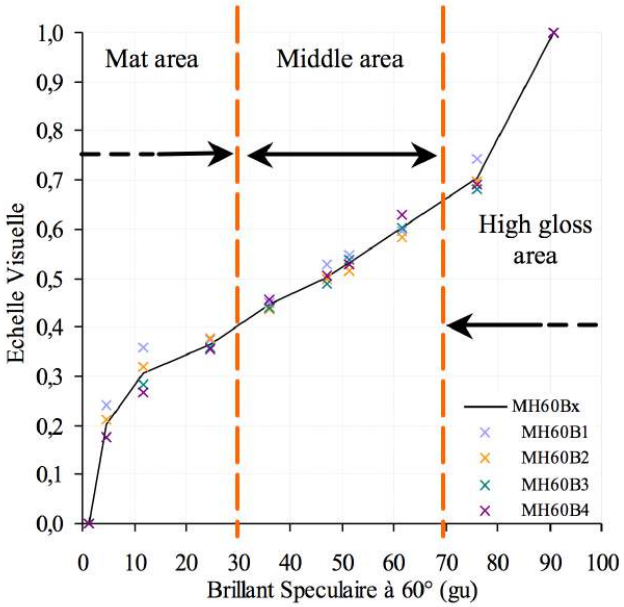




Correlation with the visual sensation

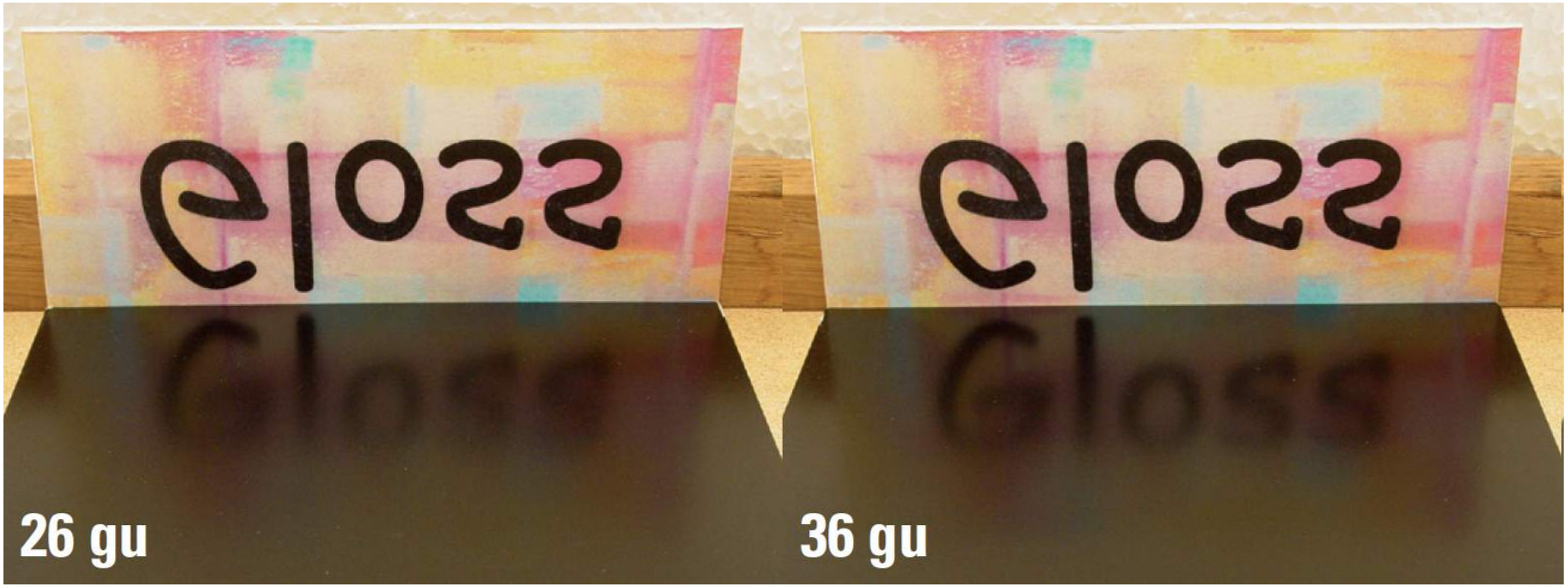
High gloss





Correlation with the visual sensation

Middle area



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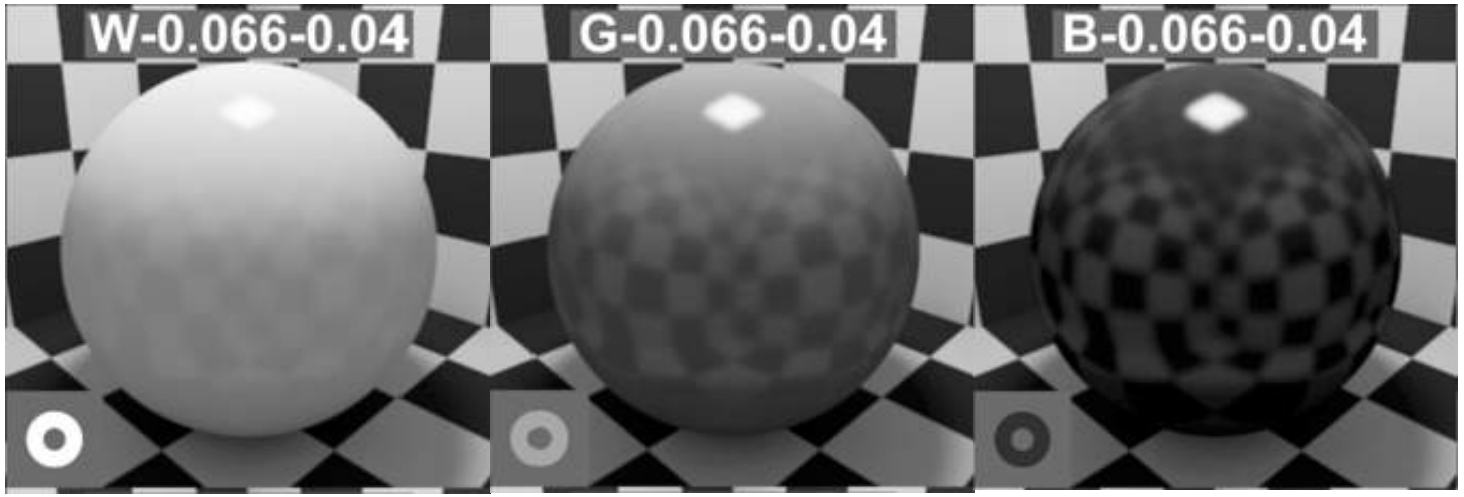
Gloss as a multivariable quantity

Ranking of a mixt of 3 black, 3 grey and 3 white samples from NCS gloss scale

Why is it difficult ?

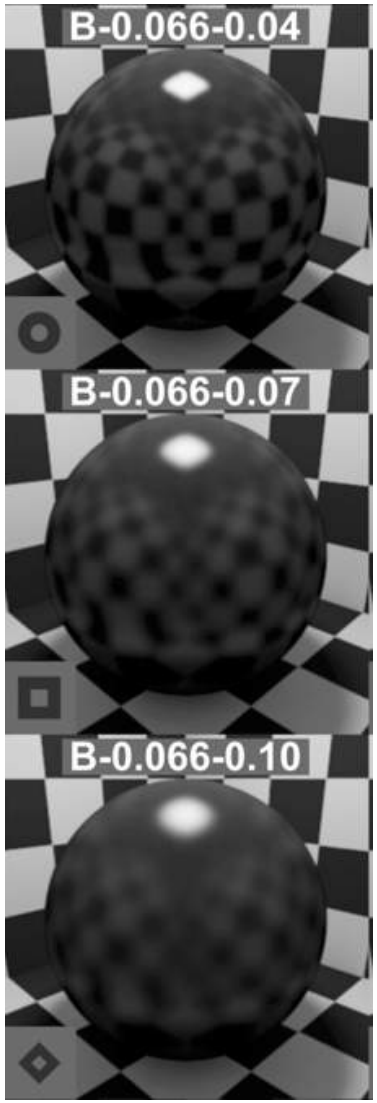
Which of the 3 spheres appears the most glossy?



Ferwerda et al., 2001

Contrast effect

Which of the 3 spheres appears the most glossy?

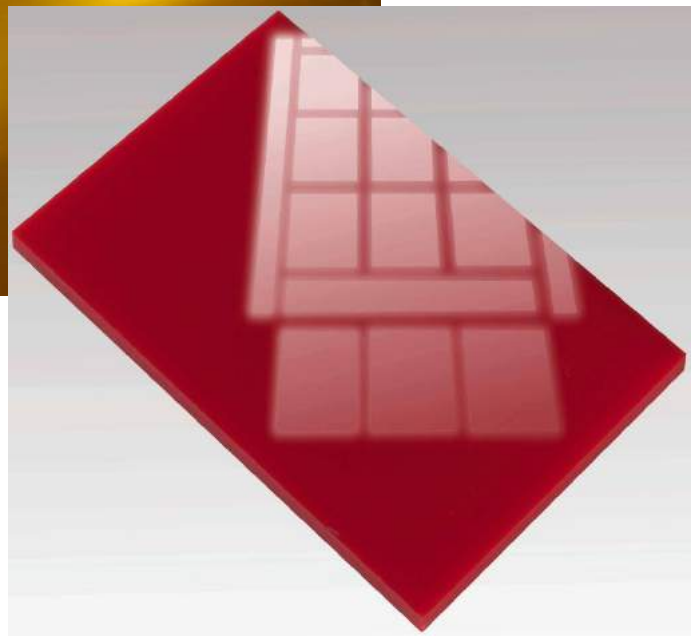


Distinctness-of-image

Ferwerda et al., 2001

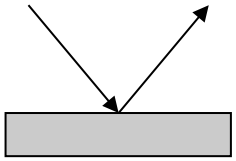
Which of the 2 bottles appears the most glossy?

haze

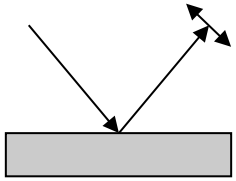


Visual criteria to evaluate gloss

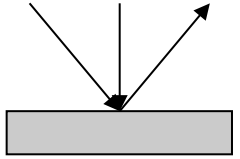
Hunter



specular gloss

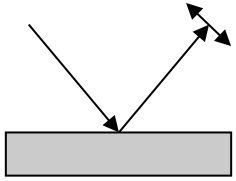


distinctness-of-image gloss (DOI)

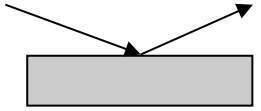


contrast gloss

GLOSS ATTRIBUTES



haze



sheen

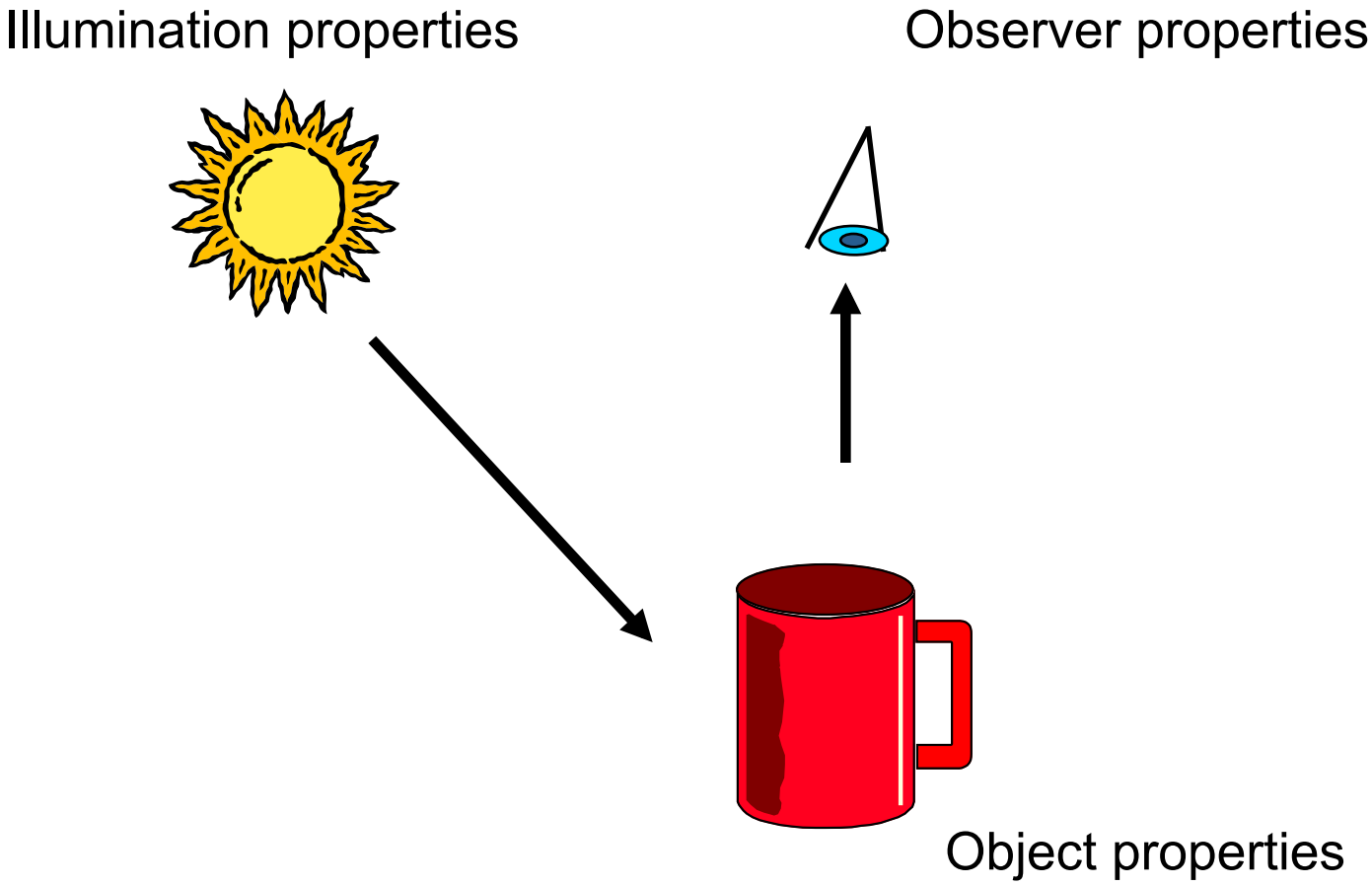
Surface-uniformity gloss (orange peel, mottle, etc.)





HAZE
GLOSS
ORANGE PEEL

Parameters influencing visual gloss perception



Type and geometry of illumination

ASTM Recommendation – ASTM D4449-15

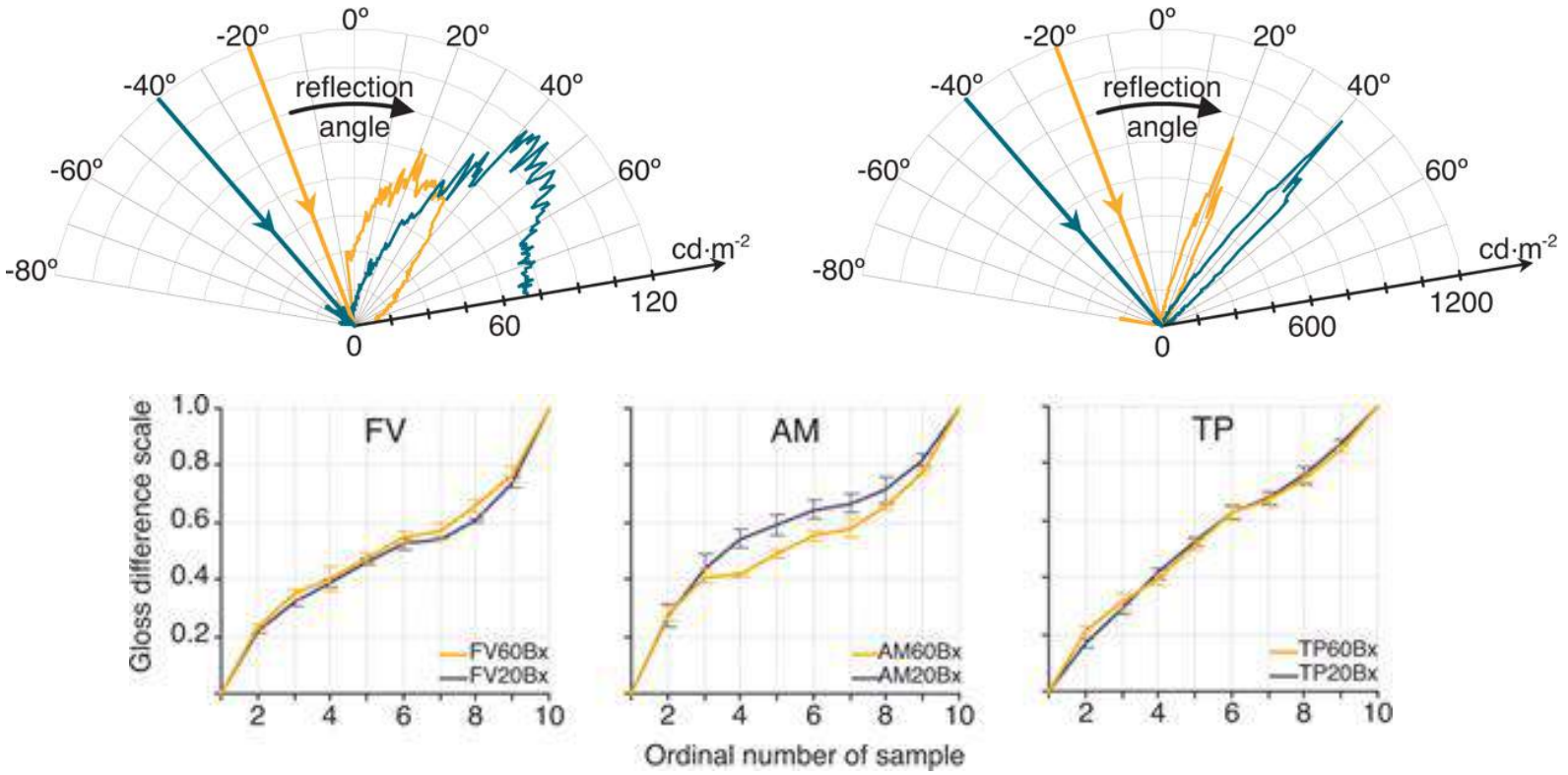
Standard Test Method for Visual Evaluation of Gloss Differences between Surfaces of Similar Appearance

2 types of illumination:

- A modified desk lamp
- A bare filament lamp

Angle of illumination (and viewing)

Relatively insensitive to the exact geometry involved



Obein et al., JOV, 2004

➡ Gloss constancy

Type and geometry of illumination

- Digital imagery representation - Large flexibility
  - Object representation under complex lighting conditions

e.g. Application of illumination/environment maps, BRDF models, etc.



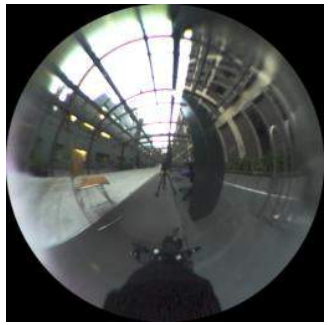



Image courtesy of Paul Debevec

Illumination maps

Teller Images

(a)

(c)

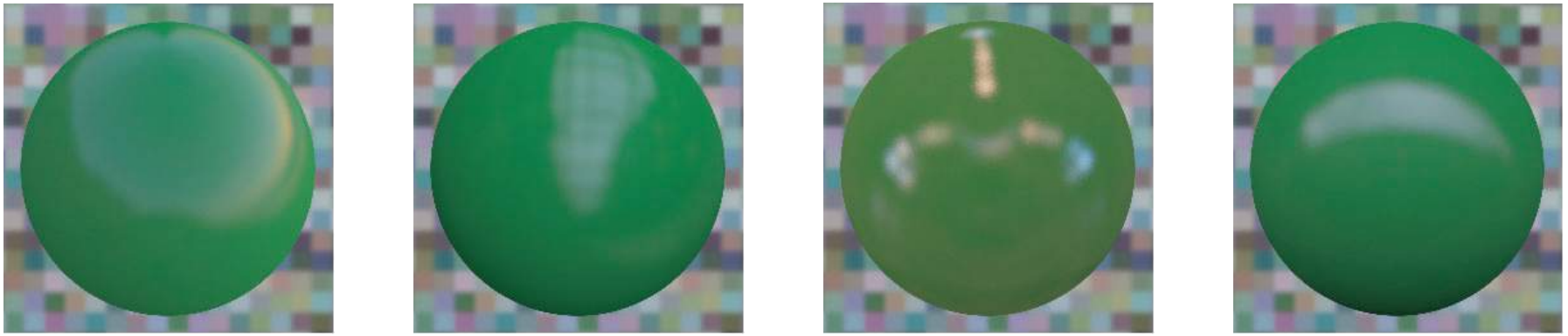
Debevec Images

(b)

(d)

Illumination geometry

- **<u>Influence of the illumination geometry</u>**



Fleming et al., JOV, 2003

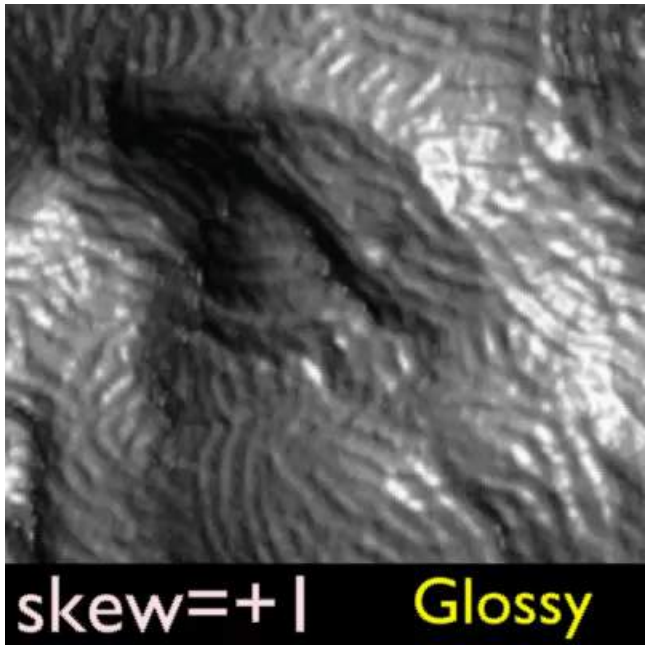
- gloss assessment differs according to lighting conditions
- gloss constancy -> for natural lighting

Object properties

3D shape
Mesotexture
Surface colour
…

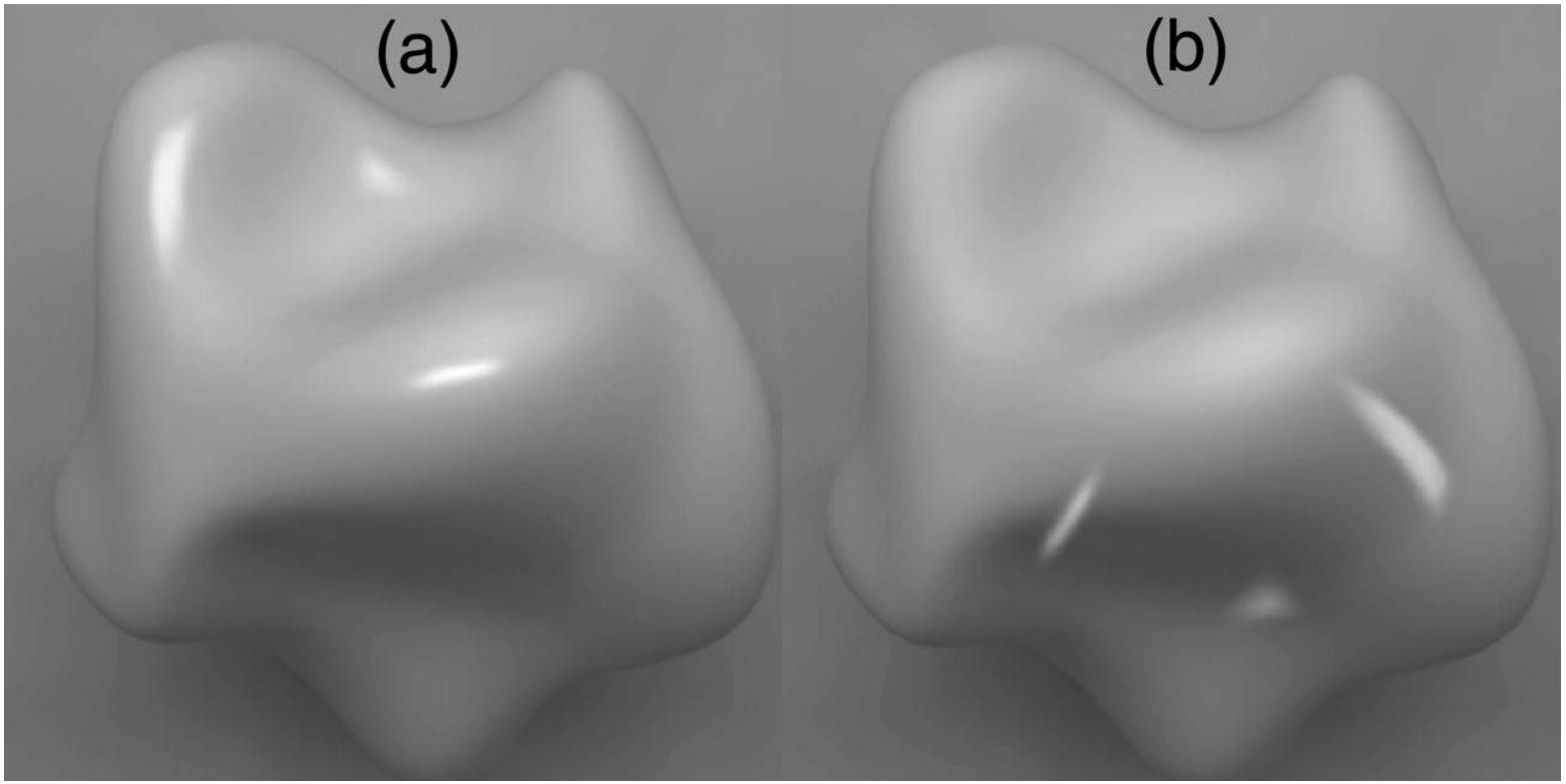
3D shape vs. luminance gradient

Strong interactions between highlight and intensity gradient (luminance variations) on the surface



Anderson et al., JOV, 2009

Orientation congruence



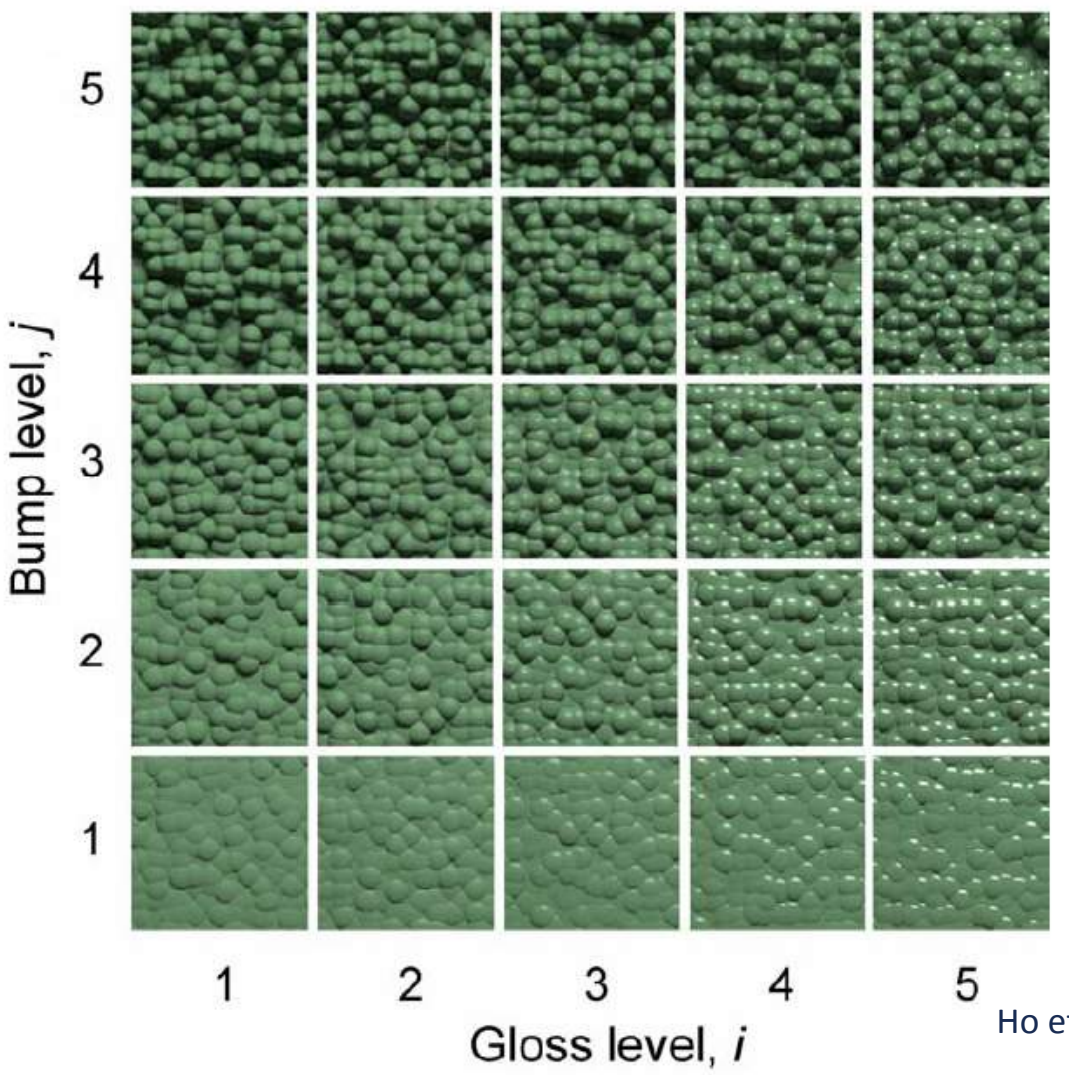
Marlow et al., JOV, 2011

3D shape and mesotexture



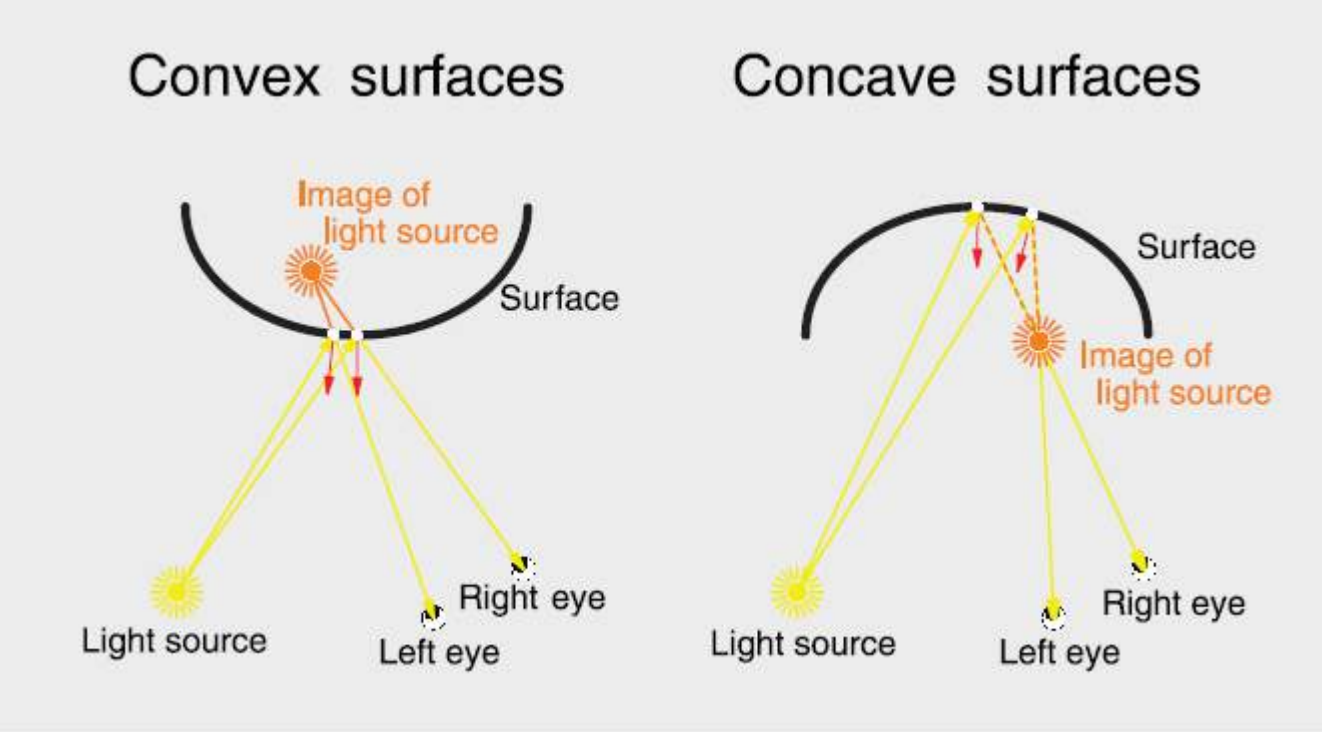
Vangorp et al., ACM Trans. Graphics, 2007

3D and mesotexture



Ho et al., Psych. Sci., 2008

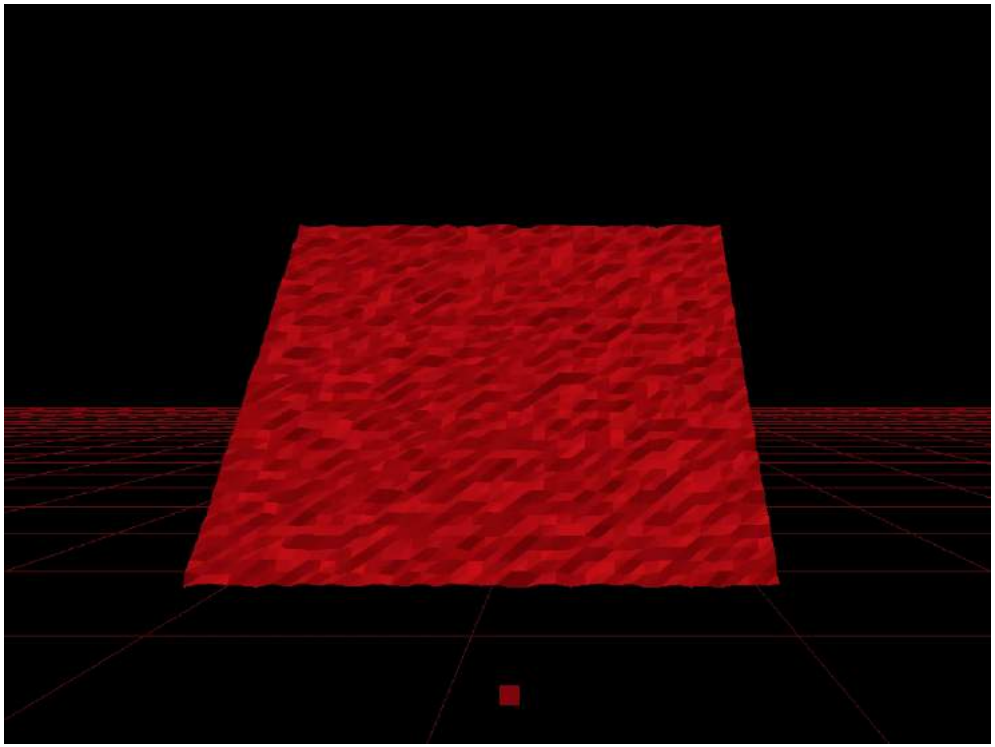
Viewing conditions: binocular depth cues



Kerrigan and Adams, JOV, 2013

- Authenticity of gloss perception in enhanced by binocular depth cues

Viewing conditions: head motion



Sakano and Ando, JOV, 2010

Observers should look at a surface from multiple angles in order to recognize the visual cues

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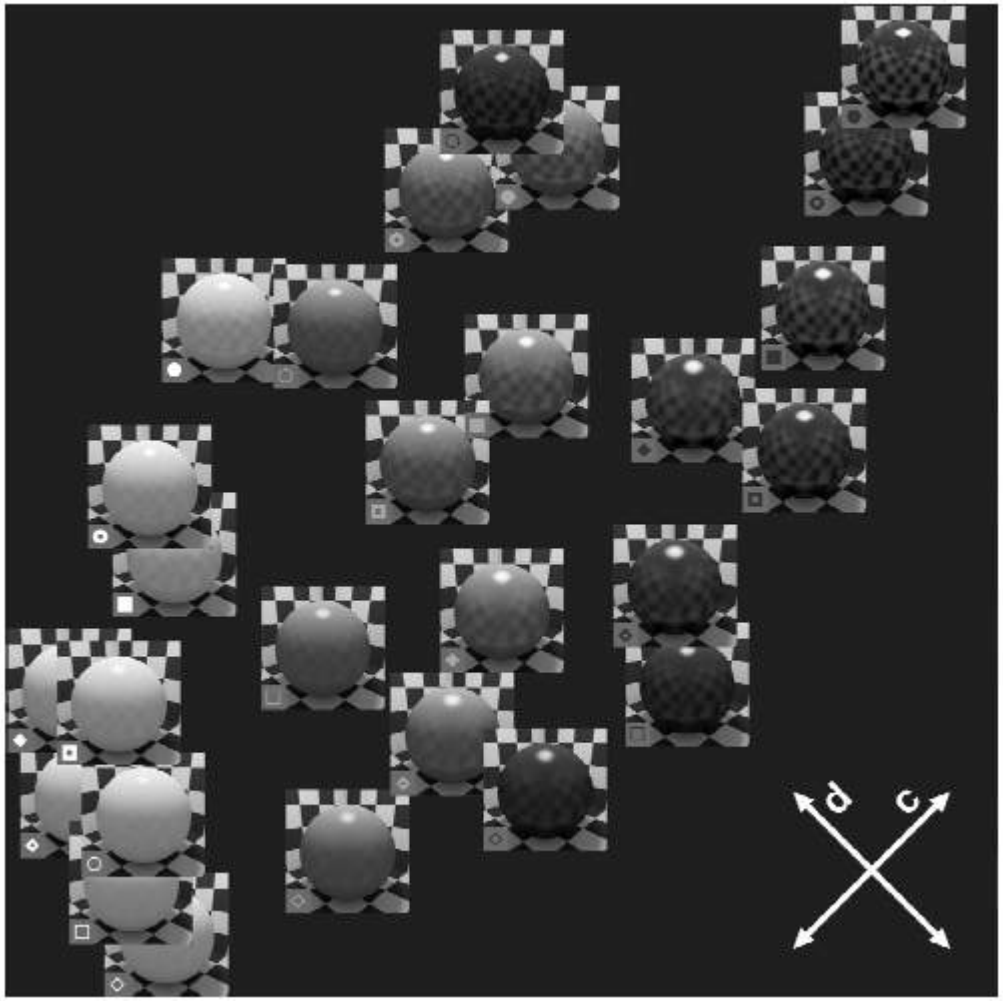
Multi-dimensional nature



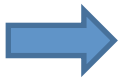
Discussion

Change in the way of thinking about optical appearance characterization

estimate the actual physical properties

vs

rely on a set of properties of the proximal stimulus



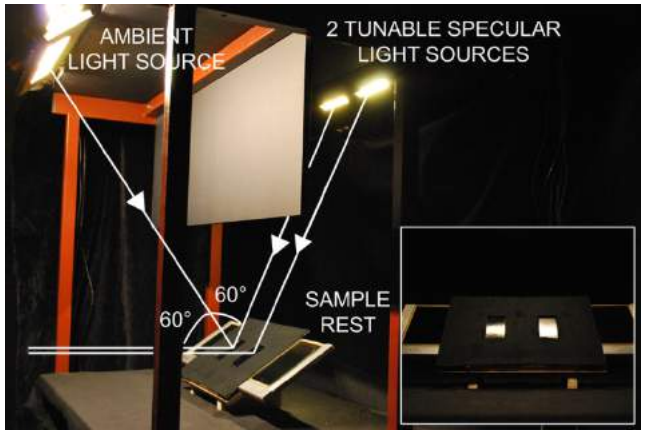
Identify and characterize diagnostic features

A Gestalt approach

Gloss does not correspond to a single physical property of a surface, but it is formed by an appraisal of the entire scene…

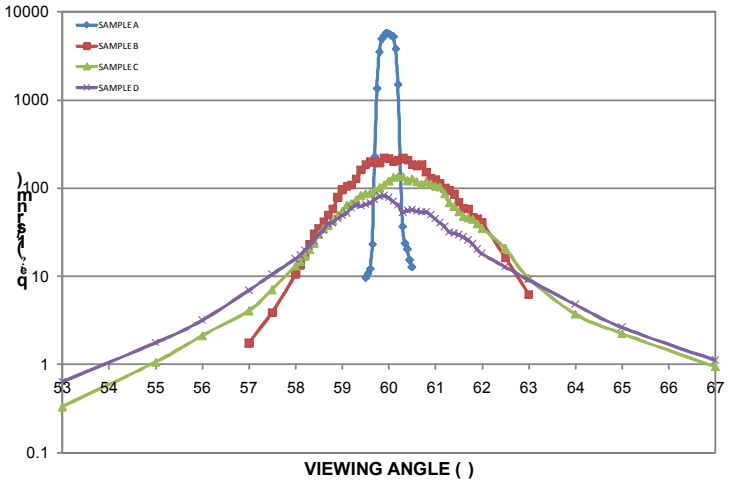
Conflicting cues…

- psychophysical study
  - Test booth
    - 2 tunable specular light sources
      - Fortimo LLM LED modules Philips
    - 1 background light source



  - 4 samples
    - A: glass, rear side painted black
    - B/C/D: 3C gloss scale, N001/N002/ N003

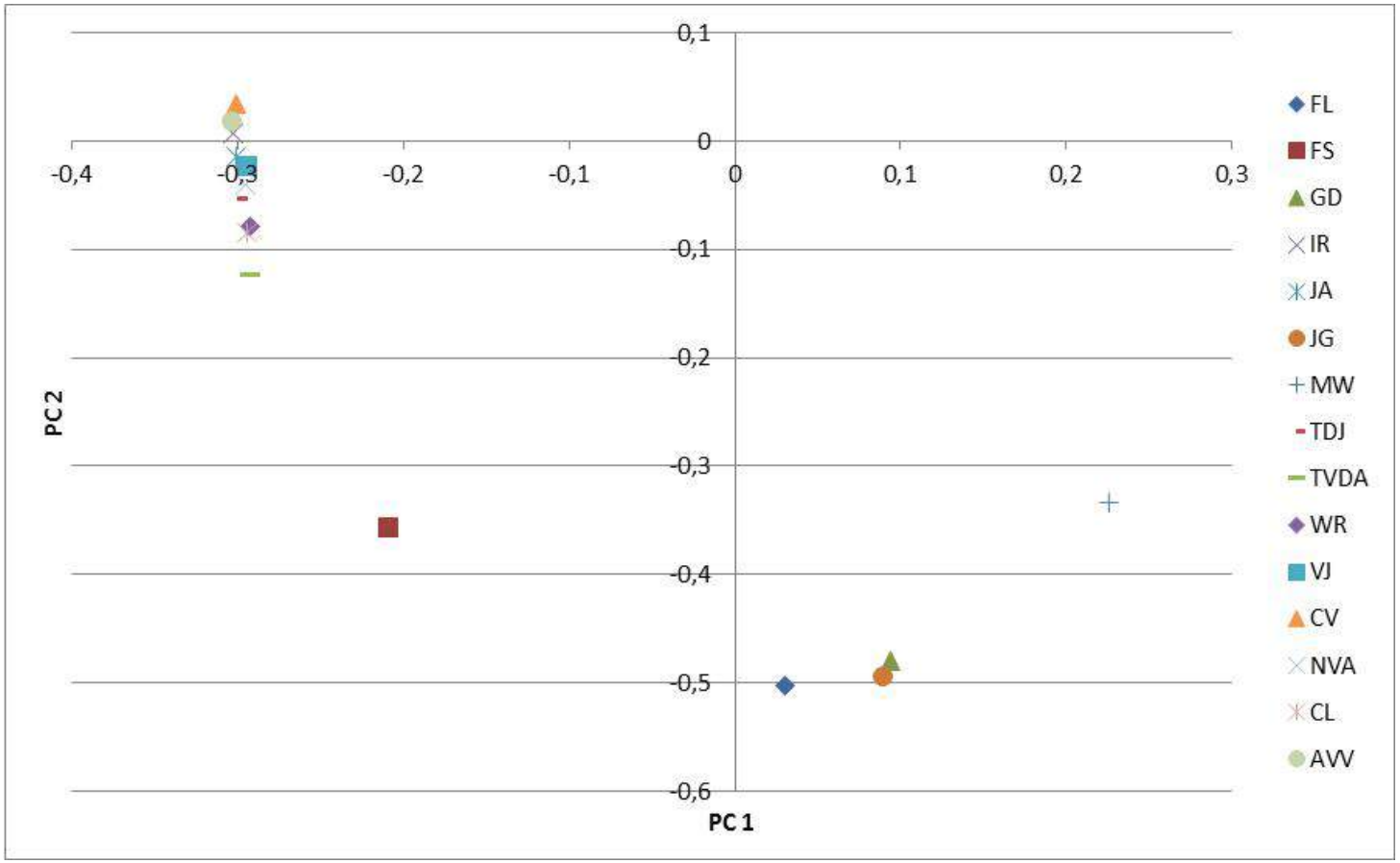
SPECULAR GLOSS		20°		60°		85°	
Sample	# measurements	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
A	5	85.0	0.4	91.0	0.2	99.2	0.0
B	5	52.1	1.3	88.3	0.4	94.2	0.5
C	5	31.6	0.7	70.7	0.5	88.0	0.3
D	5	16.7	0.5	54.4	0.5	78.7	0.6



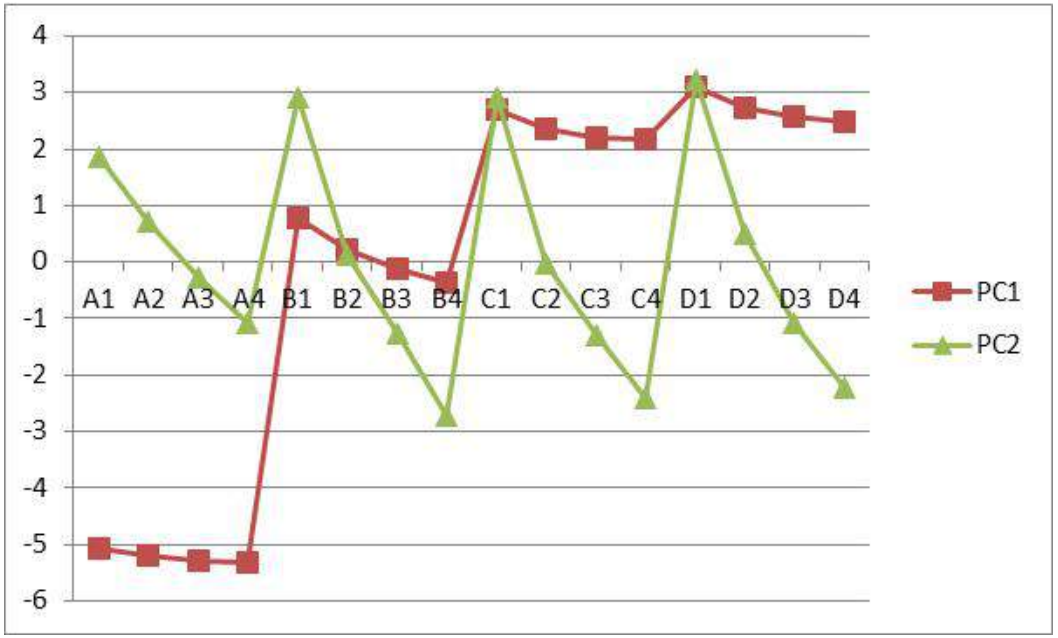
- 4 samples, but 16 stimuli!
  - By individual adjustment of luminance of both specular light sources
  - L_{im} tuned to be equal or different on different samples
  - 4 levels applied (low / medium-low / medium-high / high)

- 16 stimuli: sample (A/B/C/D) + level of L_{im} / BOI (1/2/3/4)
  - {A1; A2; …; D4}
  - A1 vs D4: generation of stimuli with conflicting cues!

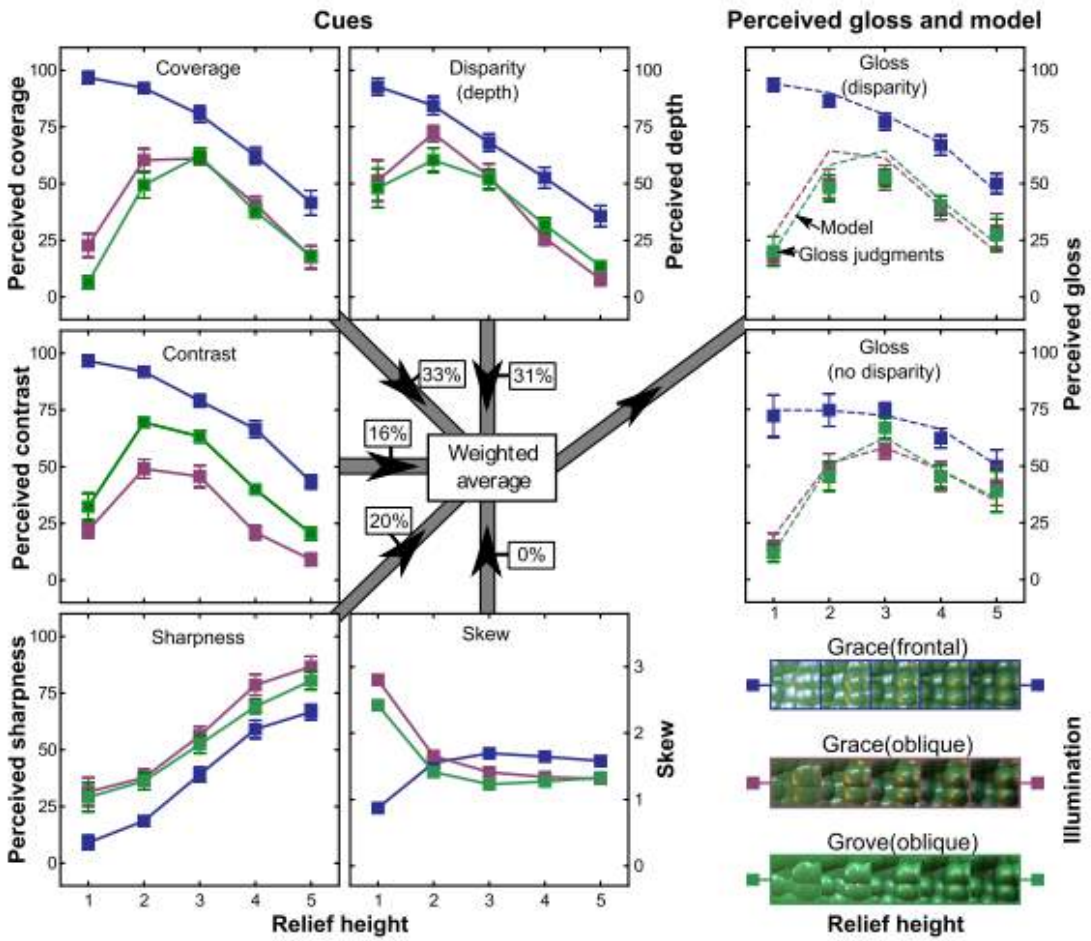
- PCA analysis



PCA scores (of 16 stimuli projected on PC1 and PC2)



➡ Disambiguation model



➡ Cue combination

Image-based approach

To be updated by Frédéric (2 slides).

Compleixity of specular peak

To be updated by Gael (2 slides).

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