Bidirectional Reflectance and Texture Database of Printed Special Effect Colors

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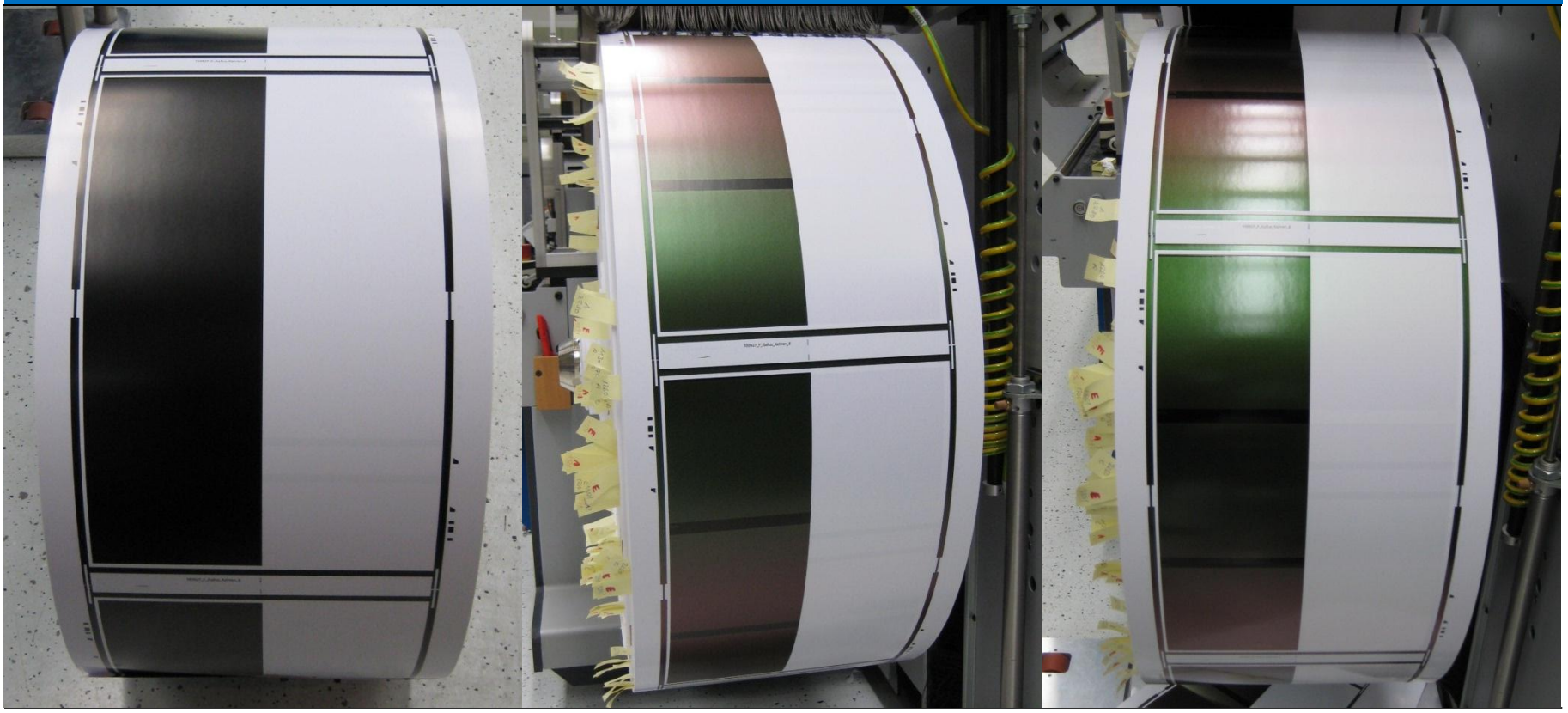
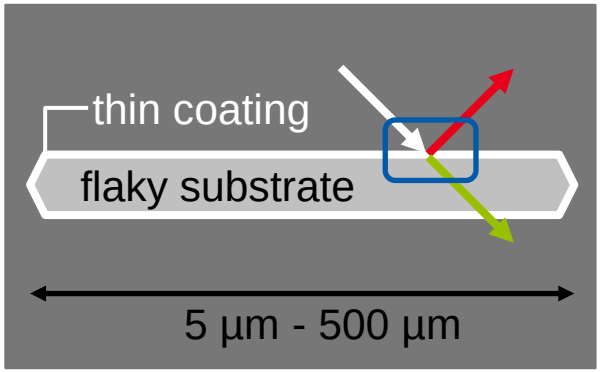
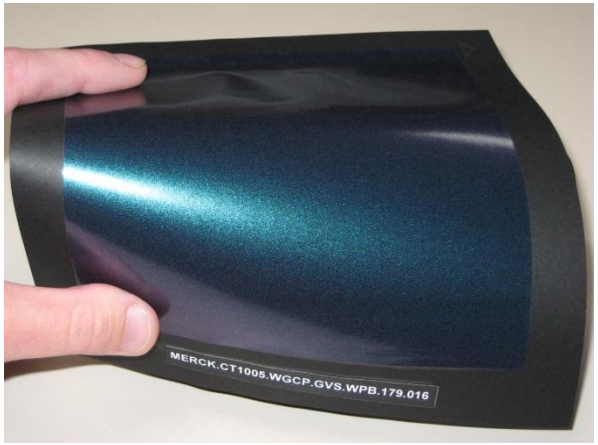


Introduction – Background and Problem

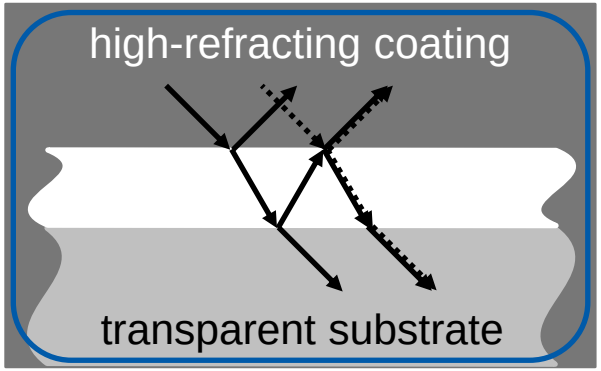


special effect pigment

- background:
  - geometry-dependent color due to interference effect
  - clearly visible texture caused by particle size

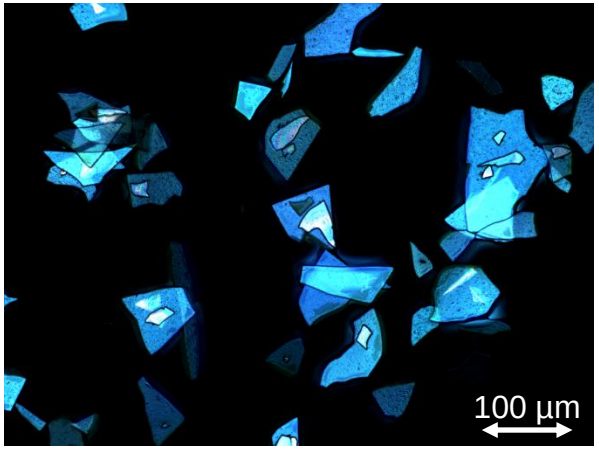


blue pigments on black paper



thin-layer interference

- problem:
  - no founded assortment of measuring geometries
  - no appropriate set of appearance correlates



particle size of 5 µm to 300 µm

Introduction – Objectives and Application

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- objectives:
  - this paper: information about a new reflectance and texture database
  - my research: investigation of essential appearance correlates
- application:
  - printing industry: tolerances for process control and quality assurance
  - computer graphics: physically-based rendering using measured bidirectional data

large color spread

large color spread and high texture intensity

high texture intensity

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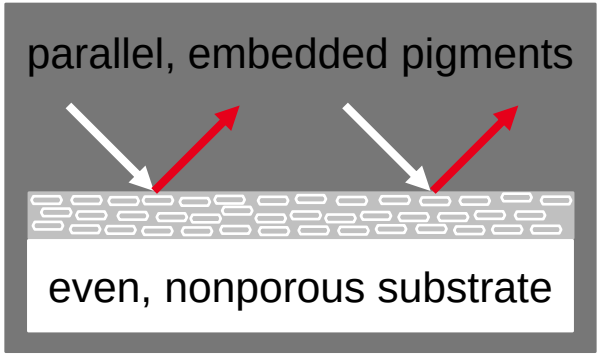
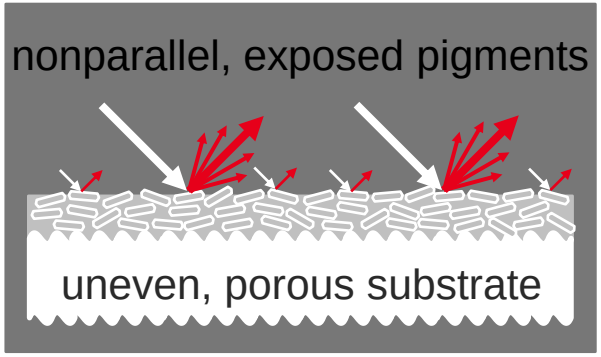
Samples – Printing Substrates



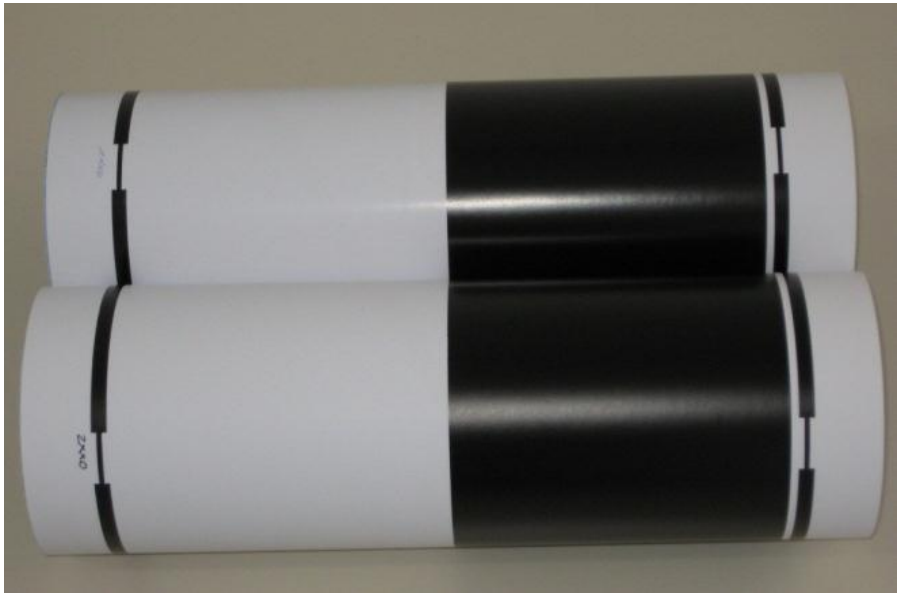
glossy coated paper: sharp color shift and high gloss intensity



matte coated paper: blurry color shift and high texture intensity

two wood-free art papers with a grammage of 120 g/m² provided by Stora Enso Research Center Mönchengladbach

glossy coated paper Lumi Art



matte coated paper Lumi Silk

Samples – Printing Press

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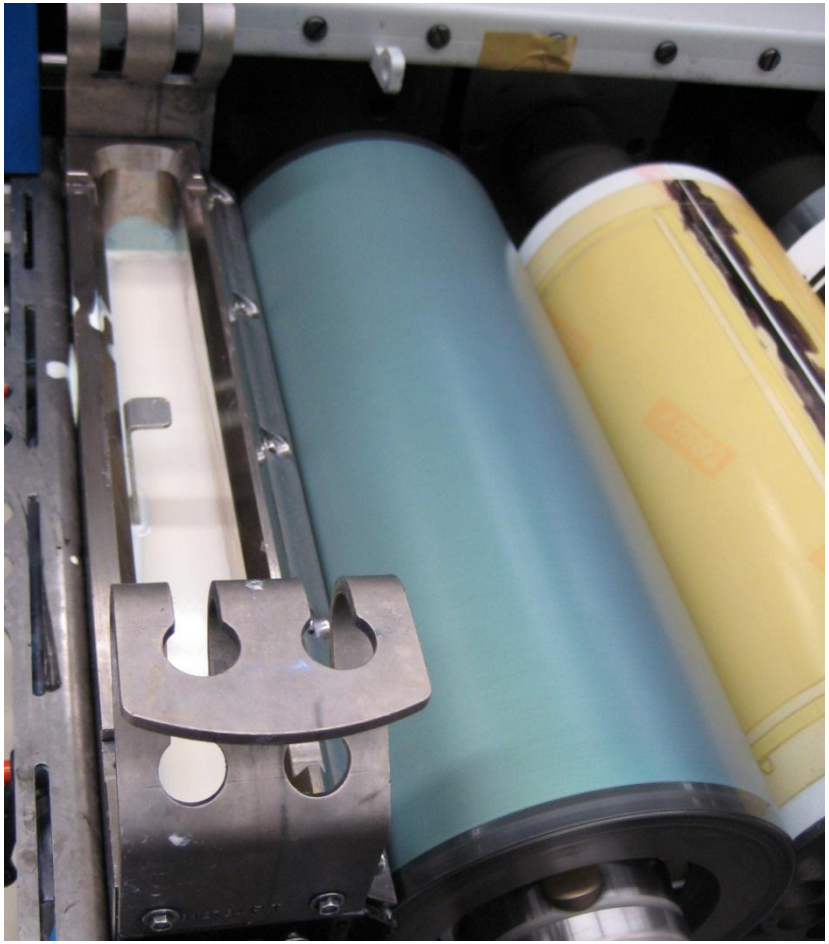
modular design and flexo unit of web-fed printing press Gallus RCS 330



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Samples – Digital Masters and Printing Plates

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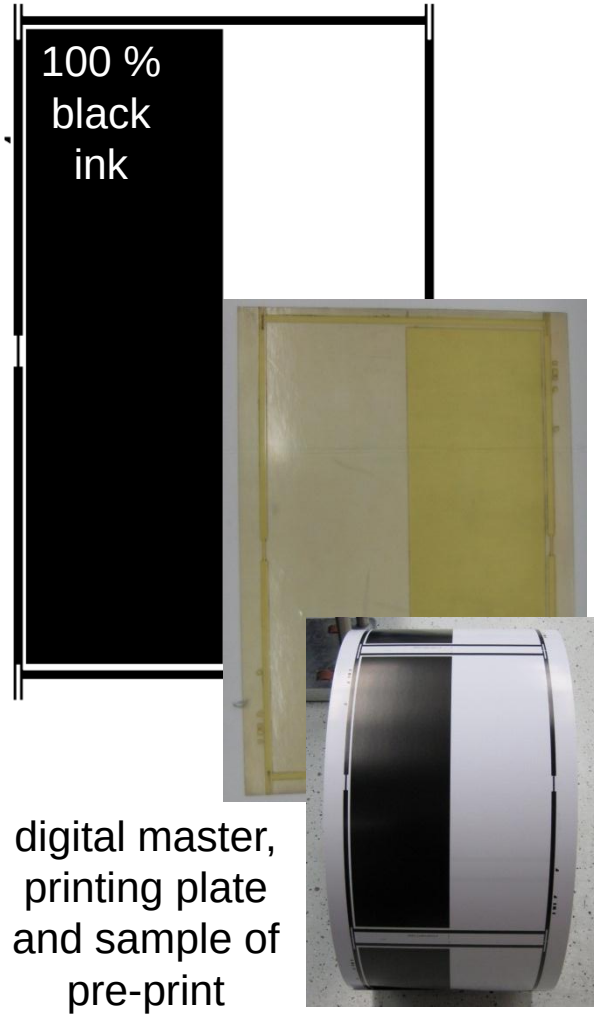
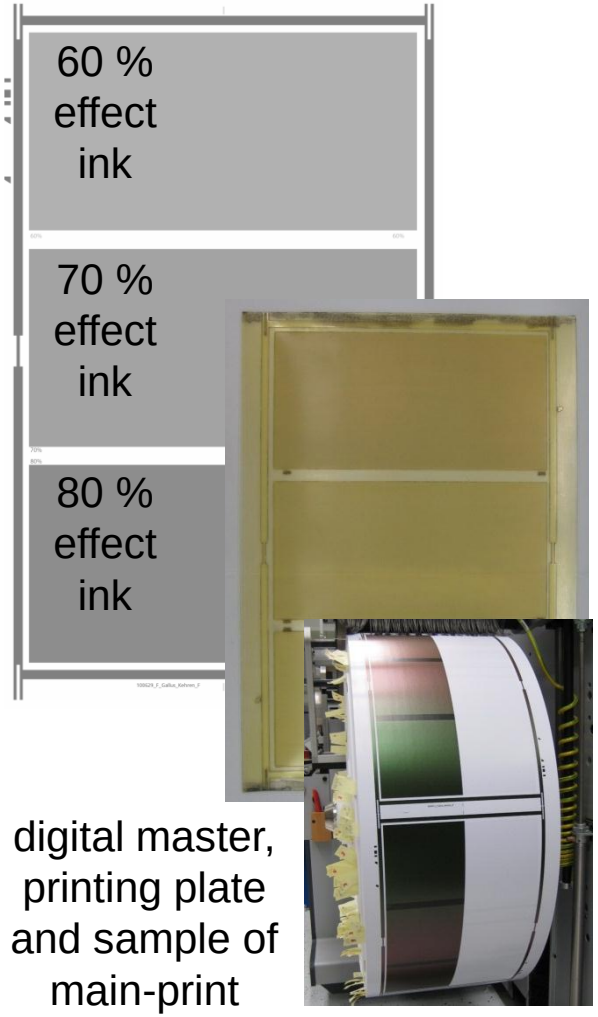


digital master, printing plate and sample of pre-print



digital master, printing plate and sample of main-print

digital master, printing plate and sample of post-print

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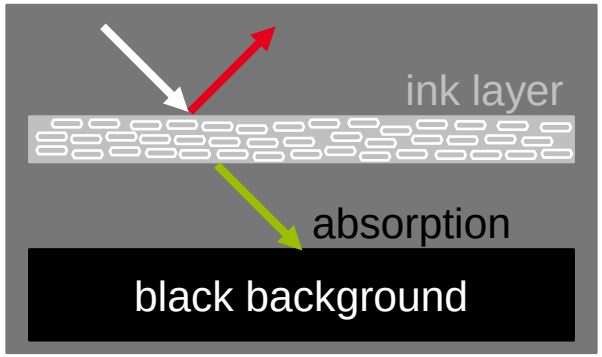
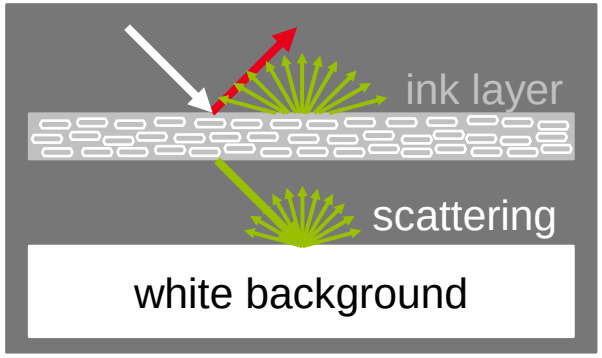
Samples – Pre-Print with Black Absorption Ink



absorption on black background: no contribution to interference effect color



scattering on white background: superposition of complementary color

sample after pre-print with water-based flexo ink Aqualabel Black of Siegwerk Druckfarben AG

Samples – Main-Print with 28 Special Effect Inks

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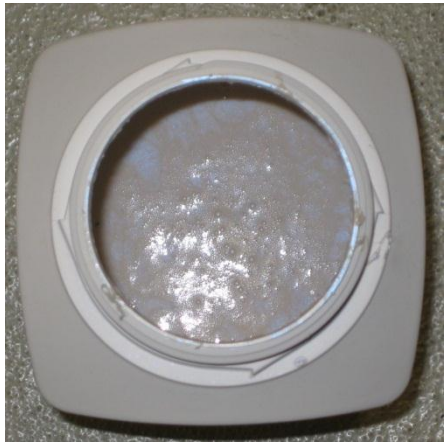
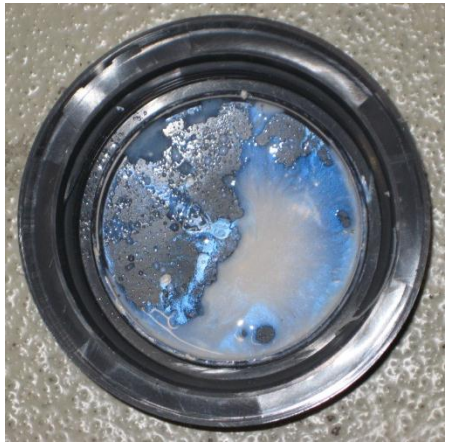
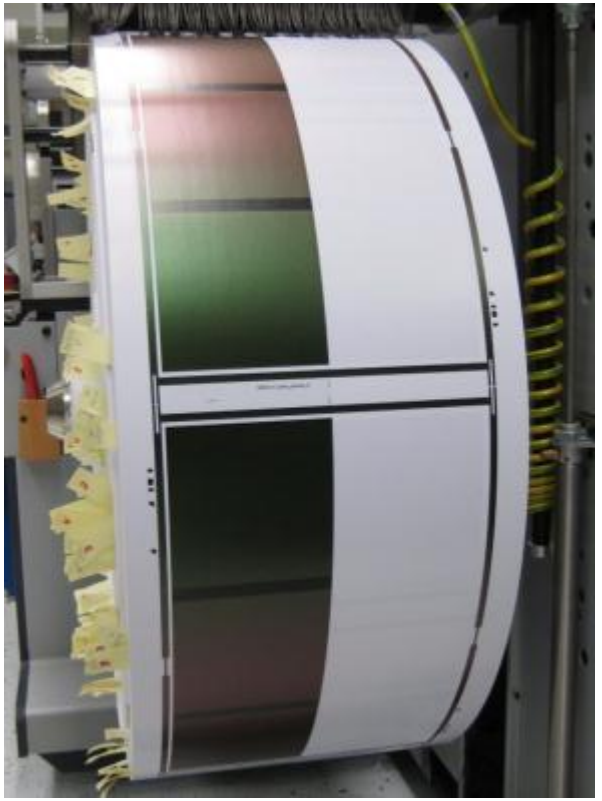




- 3 silver white pigments
- 3 gold pigments
- 3 iron oxide pigments
- 8 interference effect pigments
- 7 multi-color pigments
- 4 sparkle pigments

} 28 pigment types



sample after main-print with one of 28 water-based special effect inks provided by MERCK KGaA

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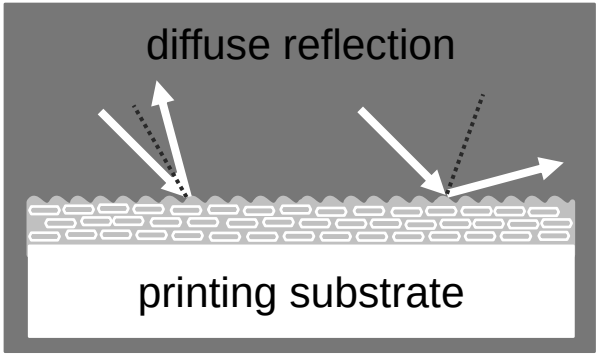
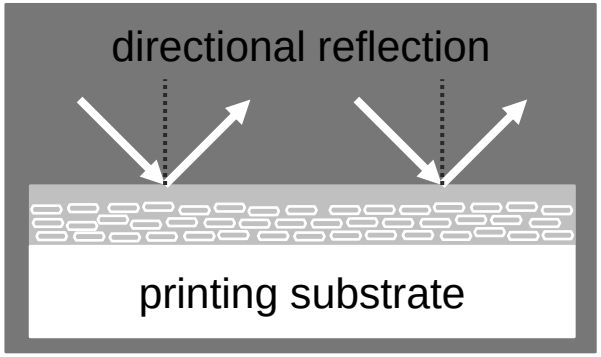
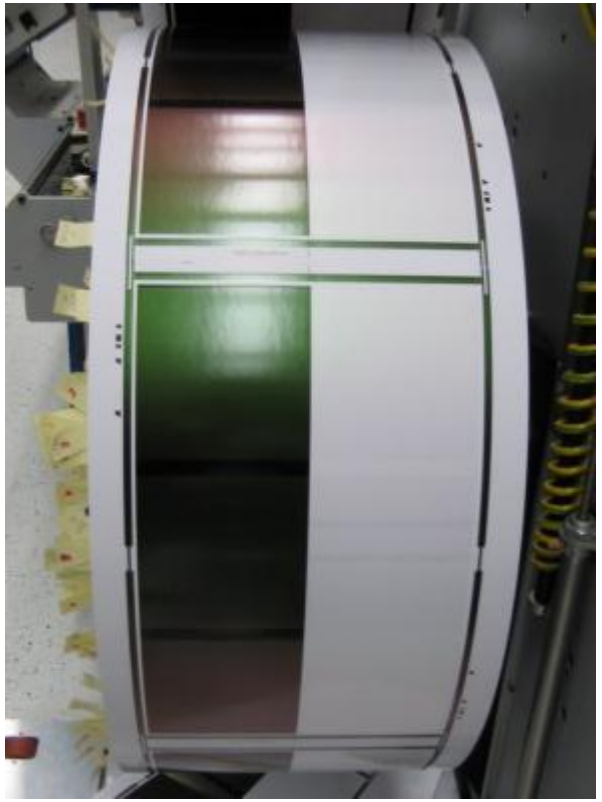
Samples – Post-Print with Clear Gloss Varnish



somehow diffuse reflection on uneven ink surface: lower gloss intensity



more directional reflection on even varnish surface: higher gloss intensity



sample after post-print with clear UV-curing gloss varnish Senolith of Weilburger Graphics GmbH

Samples – Sample Set

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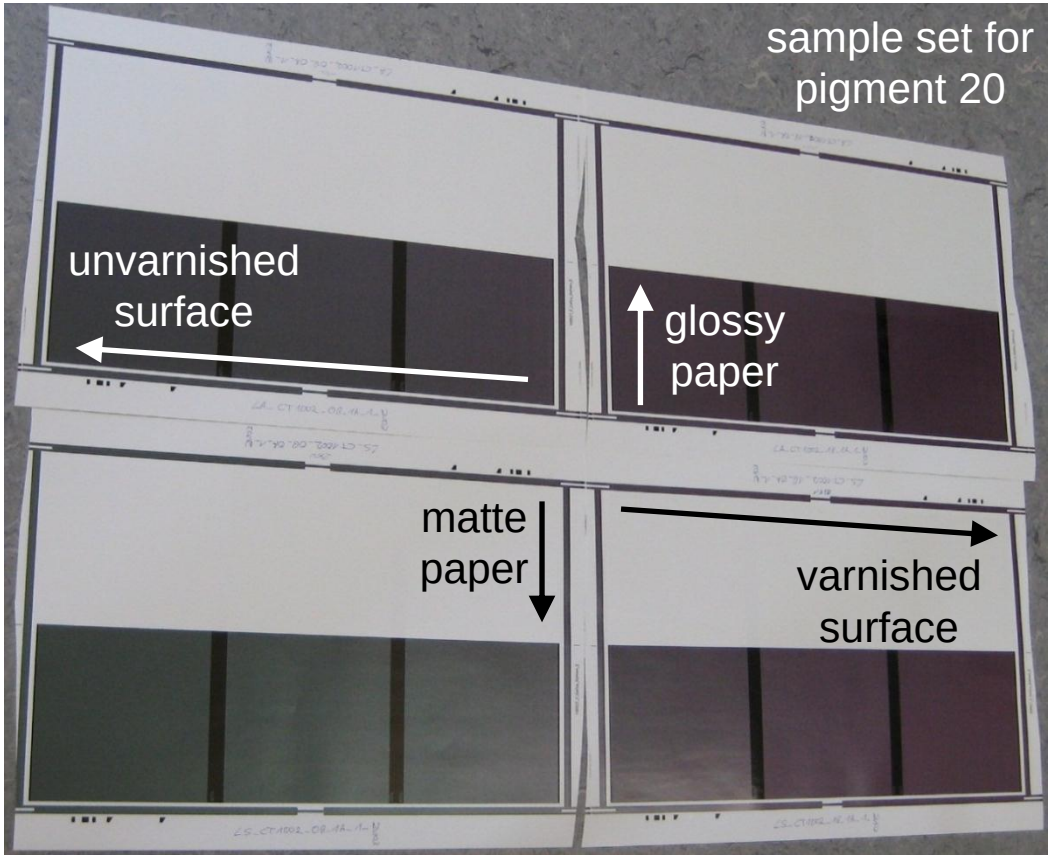
2 paper grades x 2 background colors x 28 pigment types x 2 varnishing states x 3 tonal values = 672 printed samples

- 2 paper grades
  - glossy coated paper
  - matte coated paper
- 2 background colors
  - black printed background
  - white paper background
- 28 pigment types
- 2 varnishing states
  - unvarnished surface
  - glossy varnished surface
- 3 tonal values



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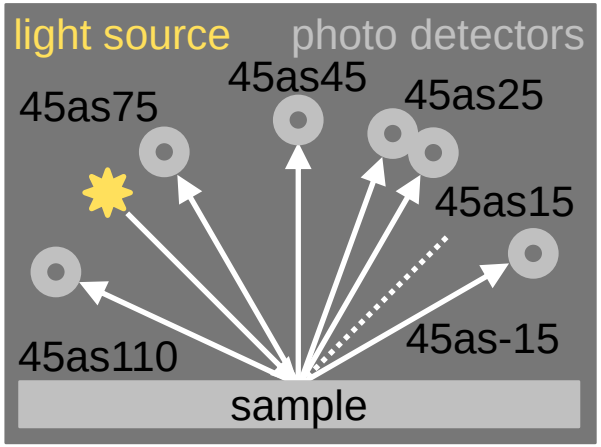
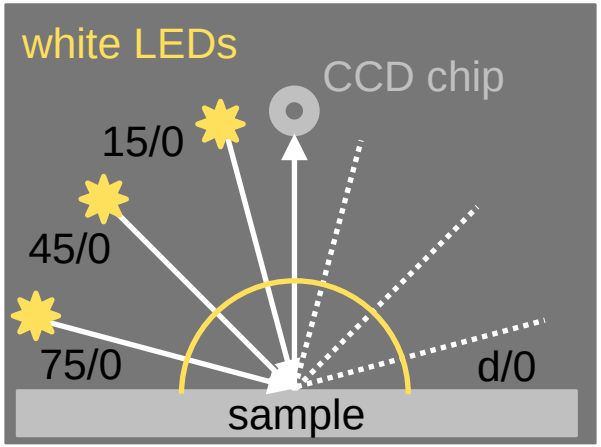
Measurements



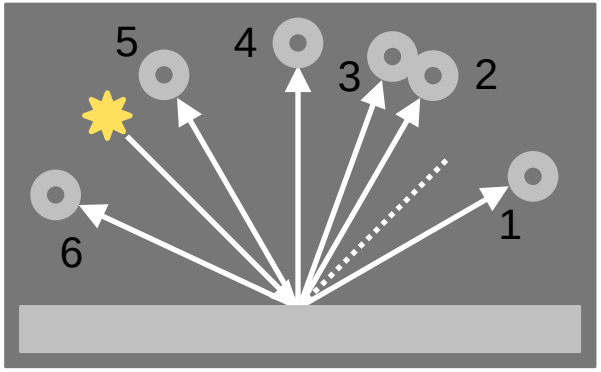
spectral measurements in 6 geometries



spatial measurements in 4 geometries

multi-angle spectrophotometer
BYK-mac of BYK-Gardner GmbH

Evaluation – Hue Difference Sum



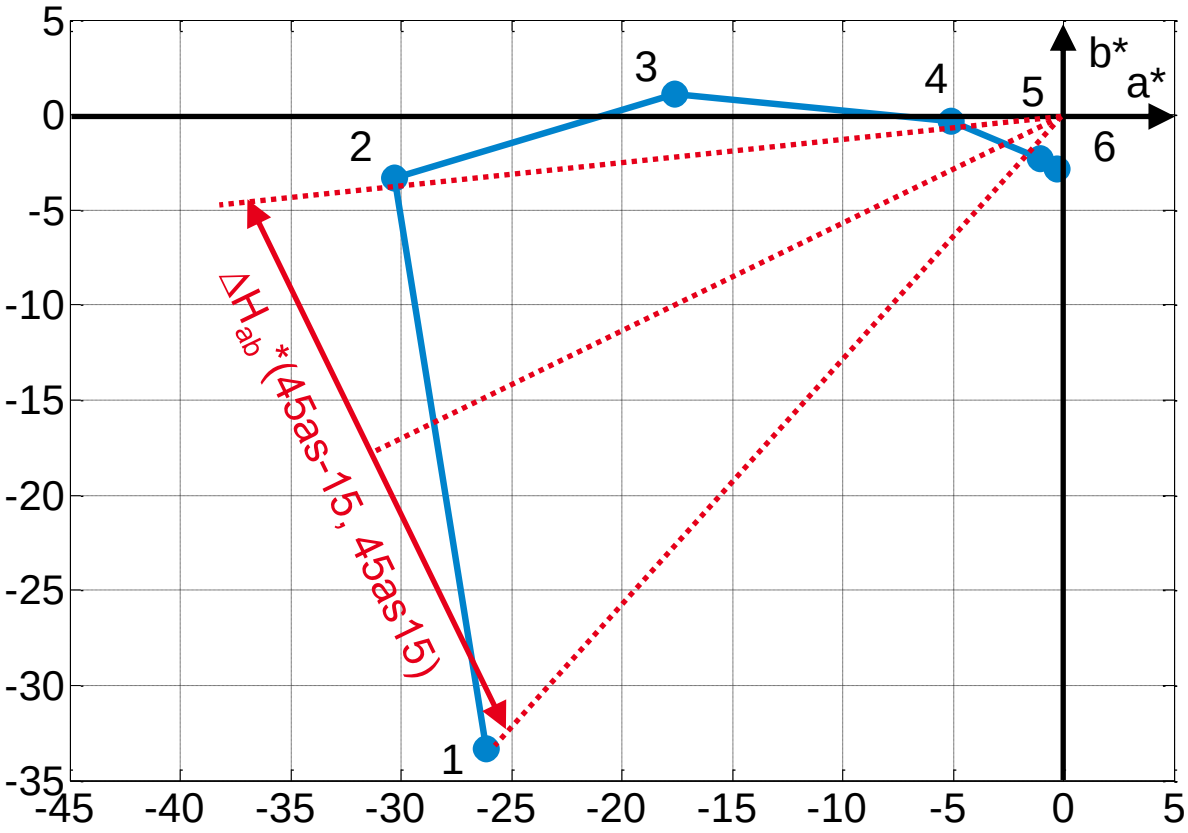
hue difference

$$\Delta H^*_{ab} = \sqrt{\left(\Delta E^*_{ab}\right)^2 - \left(\Delta L^*\right)^2 - \left(\Delta C^*_{ab}\right)^2}$$
$$= \sqrt{\left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2 - \left(\Delta C^*_{ab}\right)^2}$$

hue difference sum

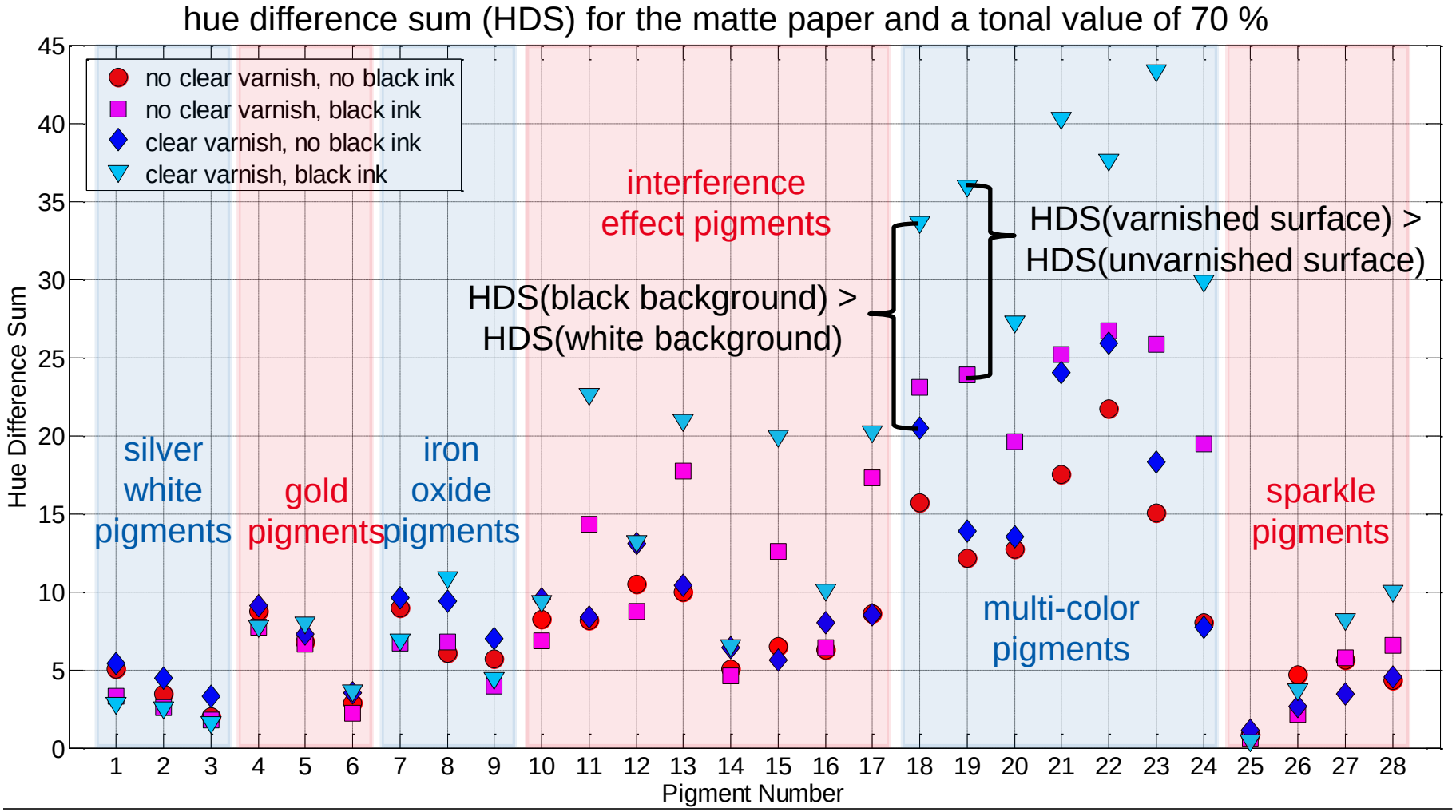
$$HDS = \sum_{i=1}^{5} \left| \Delta H^*_{ab}\left(45as\delta_i, 45as\delta_{i+1}\right) \right|,$$

$$\delta_1 = -15, \delta_2 = 15, \delta_3 = 25,$$
$$\delta_4 = 45, \delta_5 = 75, \delta_6 = 110$$

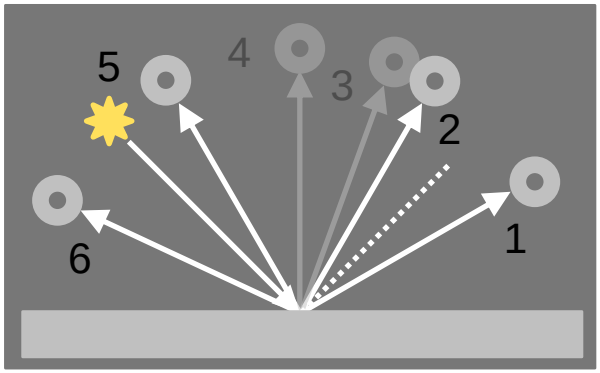


hue difference between color coordinates of aspect line for pigment 22 on matte paper without clear varnish and black ink

Results – Color Spread



Evaluation – Distinctness-of-Image Gloss



near-at-gloss luminance

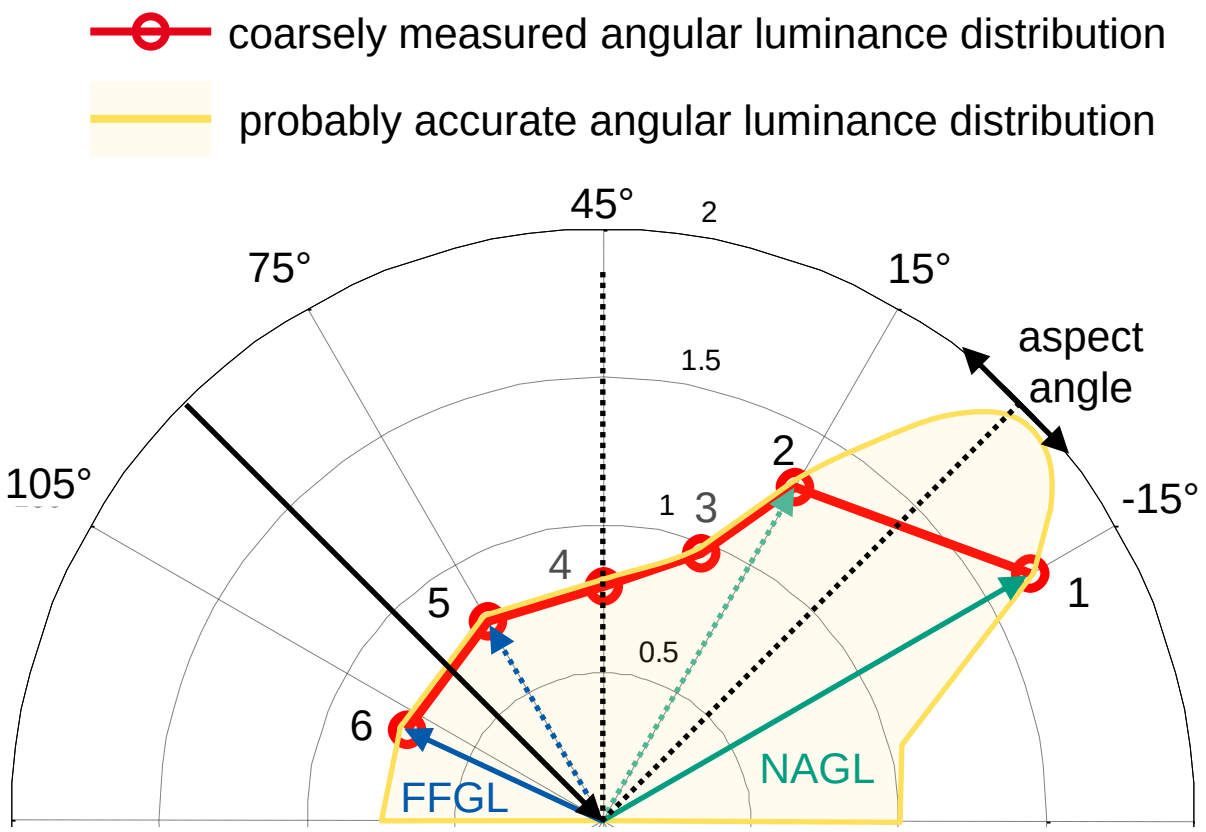
$$NAGL = \max\left(Y(45as-15), Y(45as15)\right)$$

far-from-gloss luminance

$$FFGL = \min\left(Y(45as75), Y(45as110)\right)$$

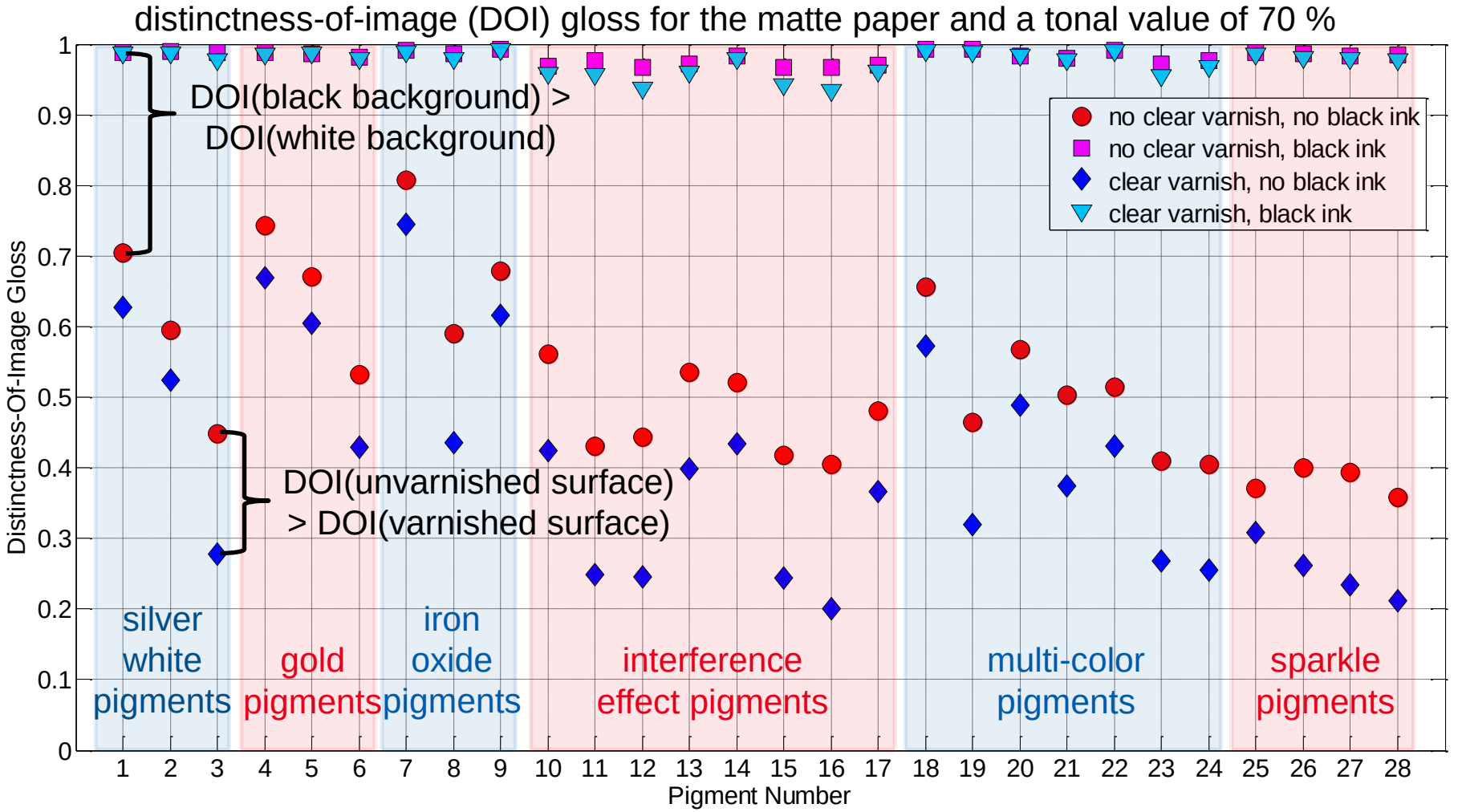
distinctness-of-image gloss

$$DOI = \frac{NAGL - FFGL}{NAGL} = 1 - \frac{FFGL}{NAGL}$$

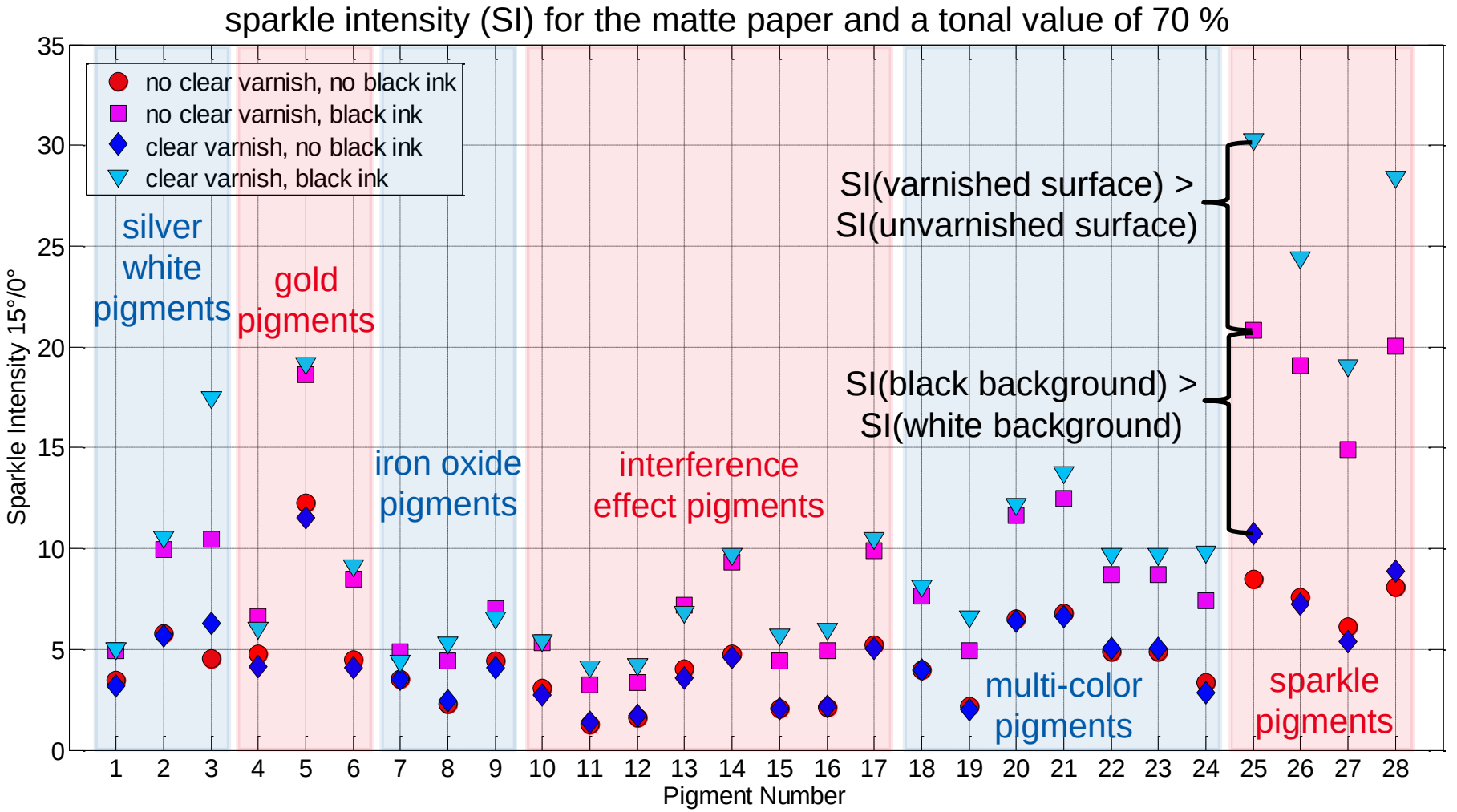


angular luminance distribution for pigment 10 on matte paper without clear varnish and black ink

Results – Gloss Intensity



Results – Texture Intensity



Conclusion

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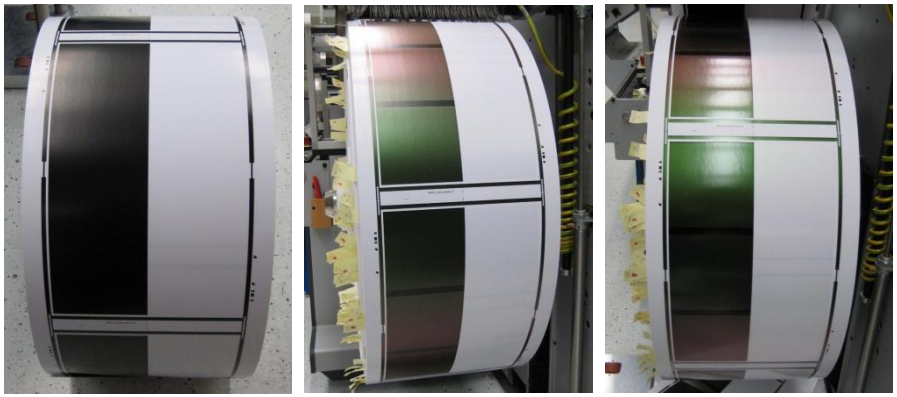
- samples and measurements:
  - 2 paper grades
  - 2 background colors
  - 28 pigments types
  - 2 varnishing states
  - 3 tonal values

  } 672 printing setups } 224 data sets



- evaluation and results:
  - high hue difference sum describing color spread for multi-color pigments, black background and varnished surface
  - high distinctness-of-image gloss describing gloss intensity for black background (and unvarnished surface)
  - high sparkle intensity describing texture intensity for sparkle pigments, black background and varnished surface

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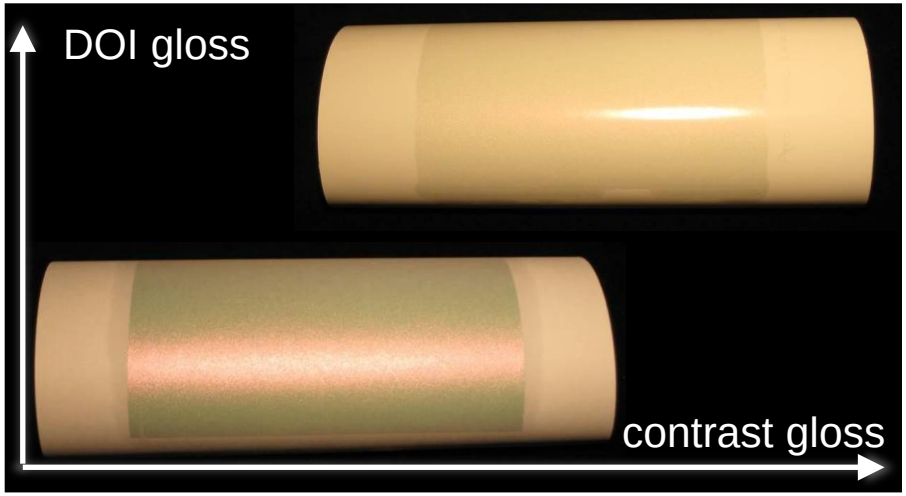
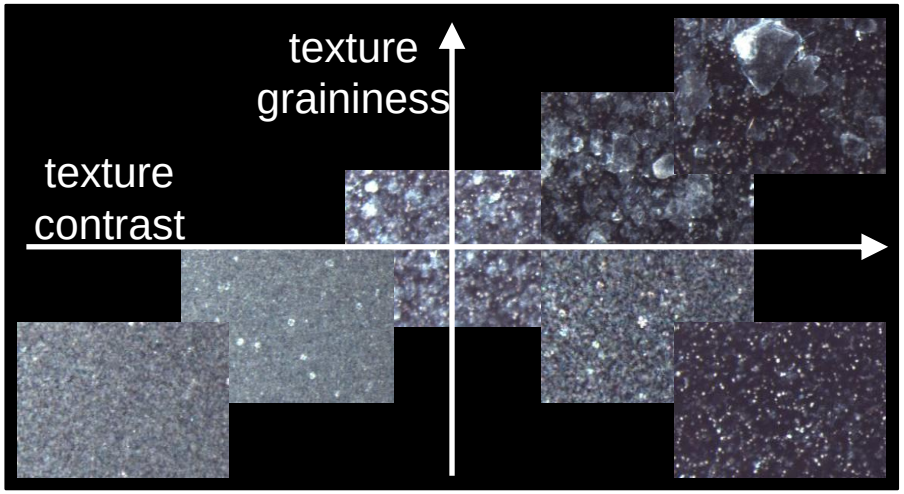
Outlook

- measurements and experiments:
  - robot-based gonioreflectometer of Physikalisch-Technische Bundesanstalt (PTB)
  - magnitude estimation of appearance differences
- evaluation and results:
  - multidimensional scaling – number of essential appearance correlates
  - principal component and correlation analysis – names of appearance correlates

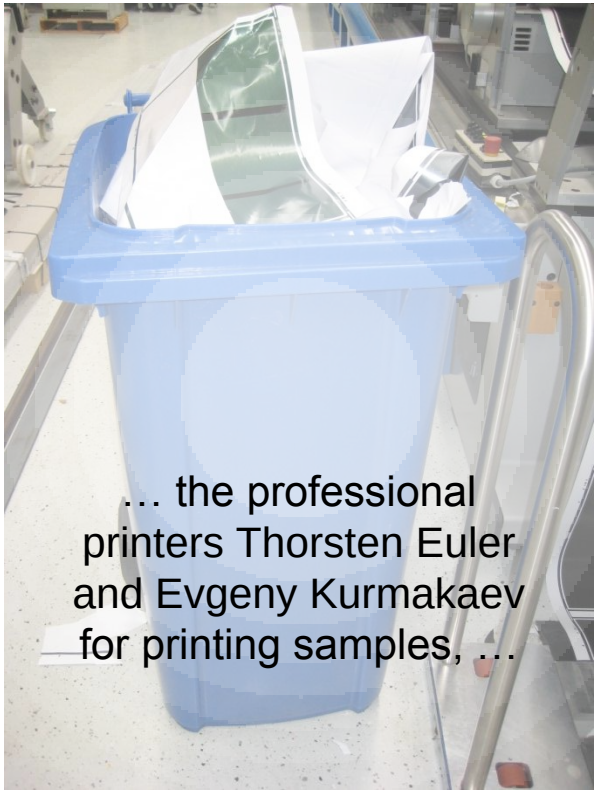




Acknowledgment

We thank …

… Paul-Heinz Dähling of Stora Enso Research Center Mönchengladbach for paper reels, …



… Andreas Becker of Merck KGaA for the printing inks, …

… Martin Schmitt-Lewen of Heidelberger Druckmaschinen AG for machine runtime, …

… the professional printers Thorsten Euler and Evgeny Kurmakaev for printing samples, …

… the student assistant Tobias Schwind for measuring samples.

Thanks for your attention.

Are there any questions?

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