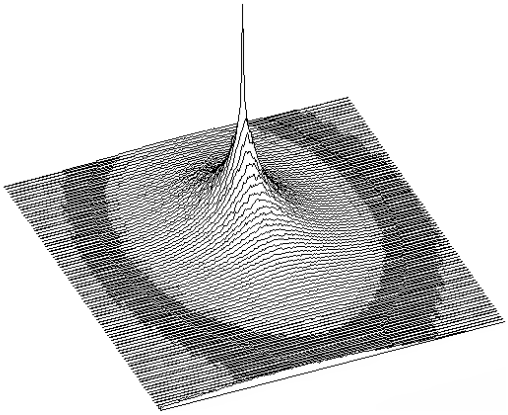
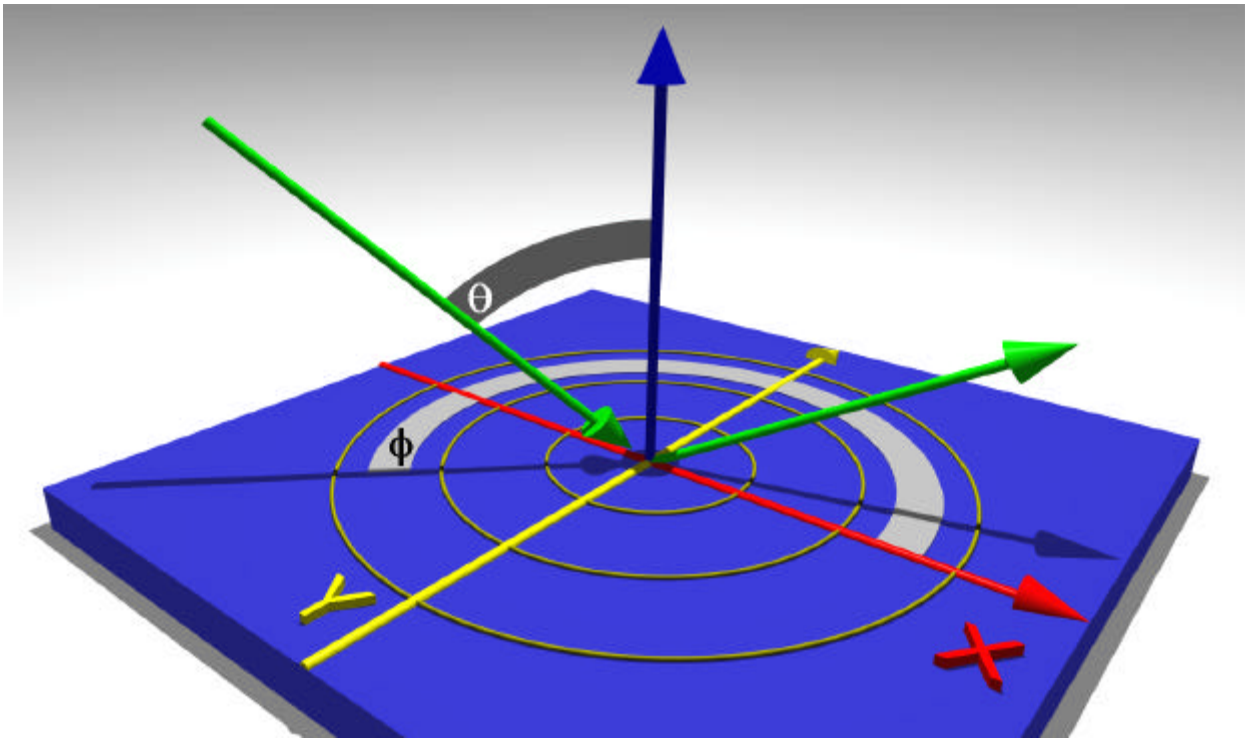


# BSDF-Meter

## BSDF Evaluation from the PSF

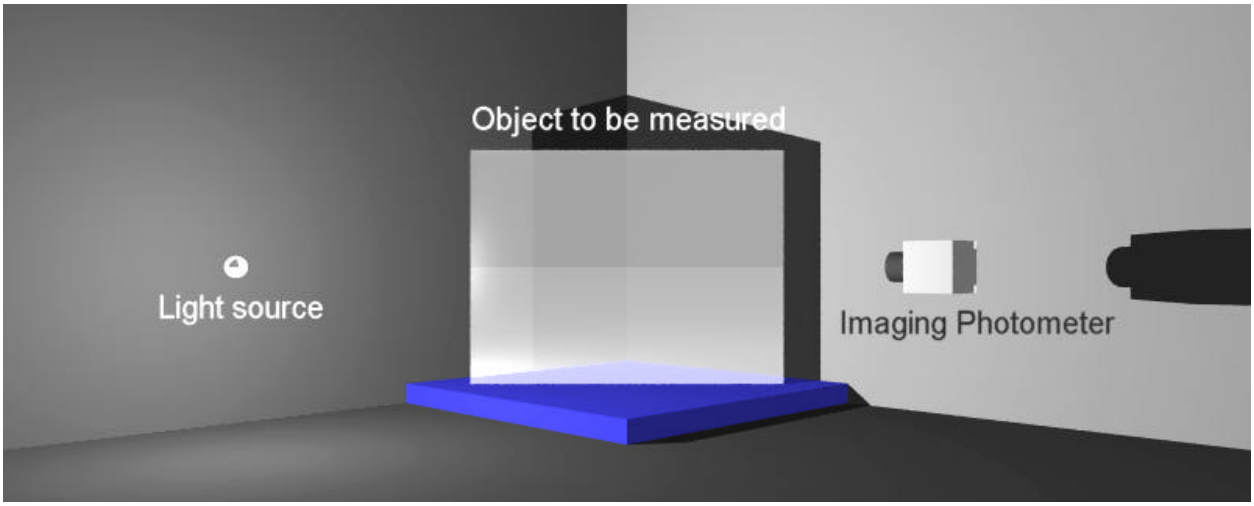



## Features

Revision 07-07-1

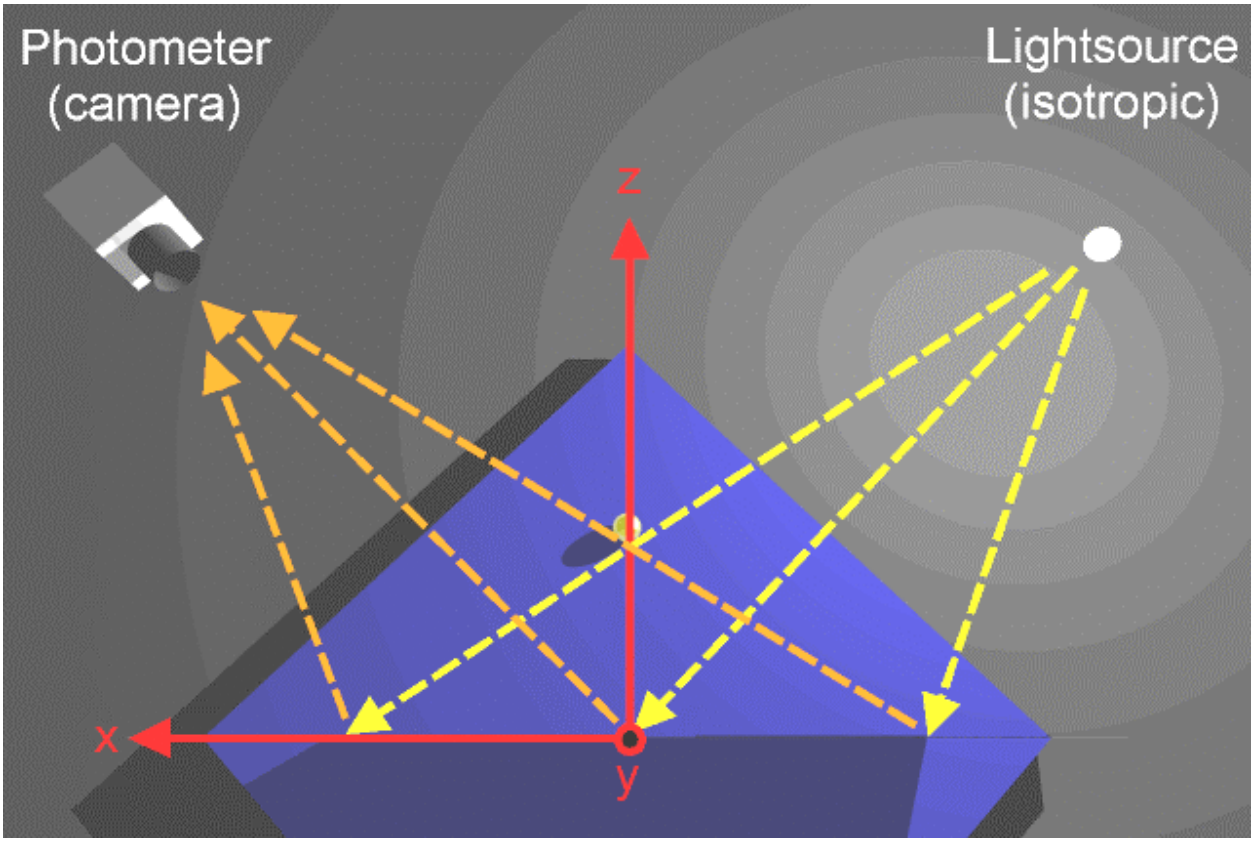
Display-Metrology & Systems
D-76135 Karlsruhe
www.display-messtechnik.de
Version 07-05

## The PSF to BSDF Method

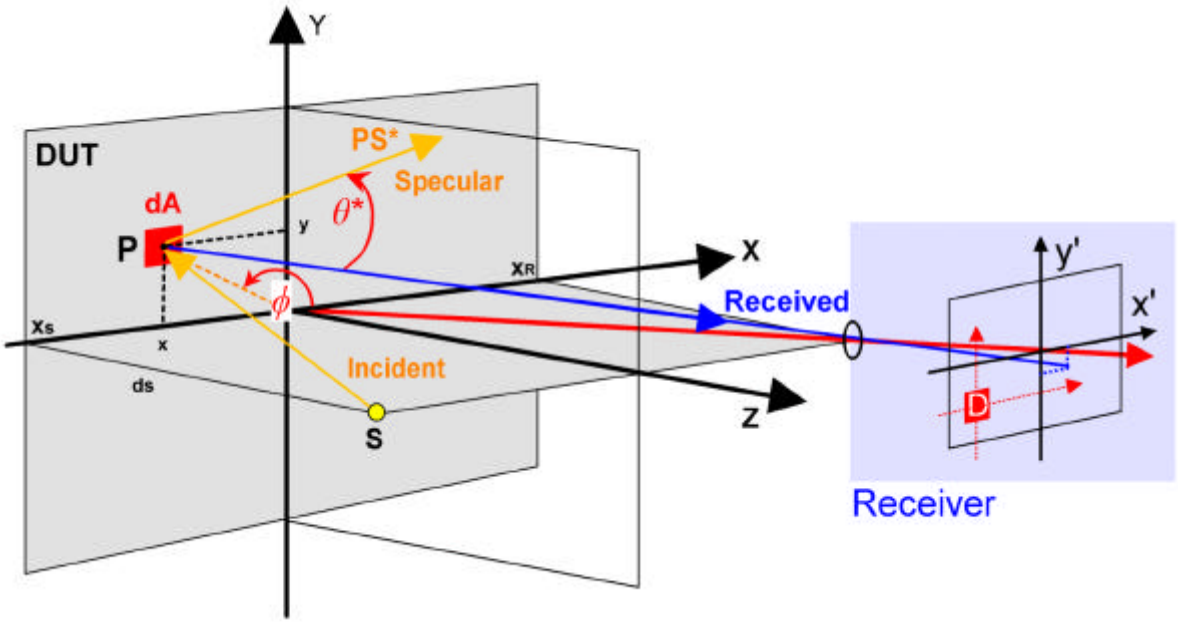



The PSF2BSDF-method evaluates the distribution of light scattered from a plane sample (*bidirectional scattering distribution function*) from the 2-dimensional point-spread-function (PSF) usually measured with an imaging photometer.

The *bidirectional scattering distribution function* (BSDF) is a generalization of the concept of the BRDF (*bidirectional reflectance distribution function*) since it comprises scattering effects for both *transmission* and *reflection*.




Top-view on the arrangement of isotropic point-source, sample and imaging photometer.




Coordinate-system for description of the geometry of light source, S, object to be measured (DUT) and imaging photometer, (receiver, usually an imaging photometer).

## Measurement Procedure

Imaging photometer and light-source are both arranged within a plane perpendicular to the object of measurement (DUT). The angle of inclination of both devices should be the same. The specular reflection component **must** be included in the "luminance image" of the photometer.

> The distance of source and receiver to the sample determine (1) the range over which the directions vary across the sample area and (2) the angular resolution of the measurement. With increasing distance (at constant DUT area) the angular range decreases and the angular resolution increases.

The imaging photometer must be focused on the light source. The focus is adjusted after placement of a mirror (e.g. polished black glass) at the location of the DUT.

The entrance pupil of the optics of the imaging photometer has to be set to a minimum either by adjustment of the iris of the lens or by use of an additional aperture stop.

After adjustment of the source intensity (must remain constant during the measurement) the distribution of the light reflected by the sample must be measured (relative luminance).

Then, under identical geometrical conditions and at the same intensity of the light source the luminance of a known plane reflectance reference has to be measured for evaluation of the illuminance across the sample area. The illuminance is related to the luminance of the (diffuse) reflectance reference by a factor which has to be constant over the area.

Division of the distribution of the reflected luminance (of the sample) by the reflected luminance of the reflectance reference (this division is done for each single pixel of the intensity images) yields the reflectance for each area element of the sample.

From this lateral distribution of reflectance the directional reflectance distribution (BRDF / BSDF) is calculated.

## Advantages of the approach

- simple and compact apparatus without moving parts for directional scan,
- self-alignment about the specular direction,
- insensitive to uncontrolled parameter variations = excellent robustness,
- spectral analysis possible (spectrally tunable source or receiver),
- applicability to non-flat surfaces with arbitrary shape,
- simultaneous recording of all reflection components,
- small system signature for separation of the specular peak from the haze.

## Limitations

- sample must be uniform over area included in the measurement,
- BRDF of the sample must be invariant to source inclination
  (over the range of directions included in one measurement),
- limited range of inclinations centered about specular
  (a range of ±20° can be covered with a resolution of < 0.1° FWHM).

## Applications

- electronic displays and their components (touch-panels, diffusers, anti-glare layers),
- paintwork (automotive, graphics),
- arbitrary scattering surfaces and films in
- transmission (windows),
- reflection (paper).

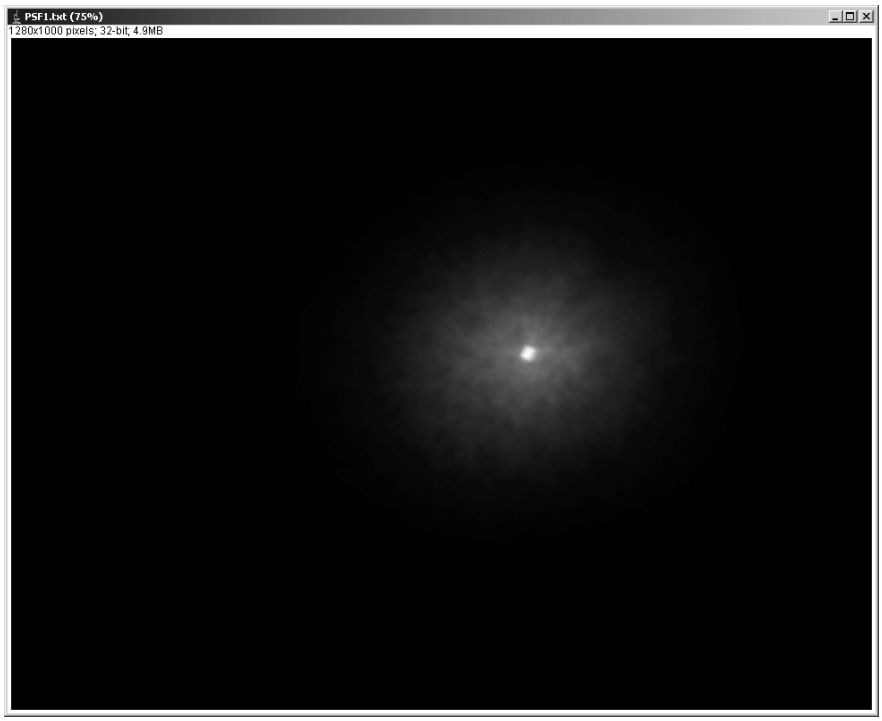
The PSF2BSDF approach has been introduced to the public on the occasion of the SID Conference 2004 in Seattle. The method and its implementation is protected by a patent in Germany [6].

## Product delivery and installation

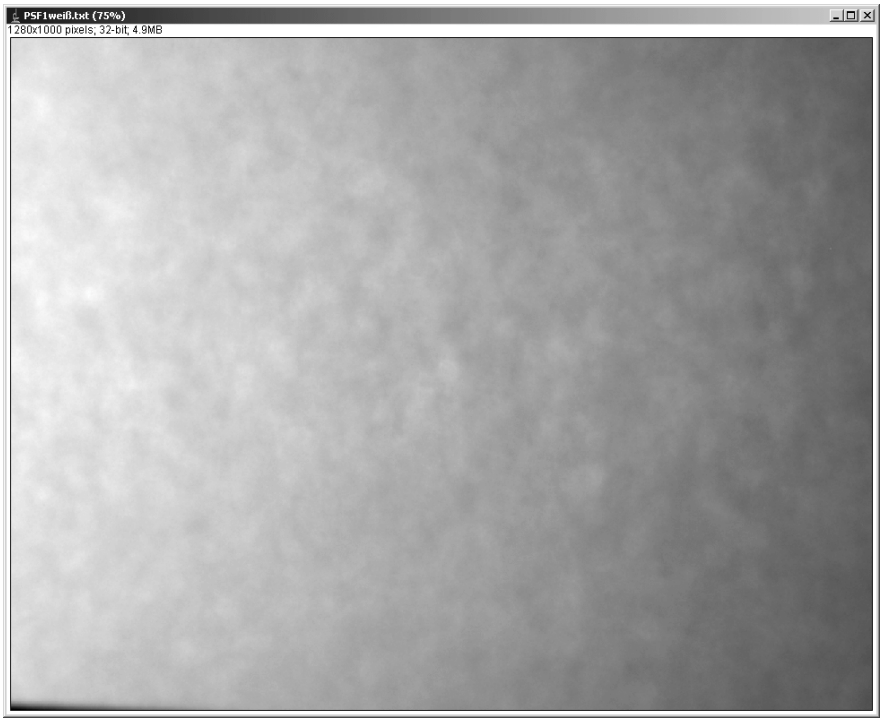
The PSF2BSDF evaluation software is delivered on a USB-stick ready for use. No explicit software installation is required.



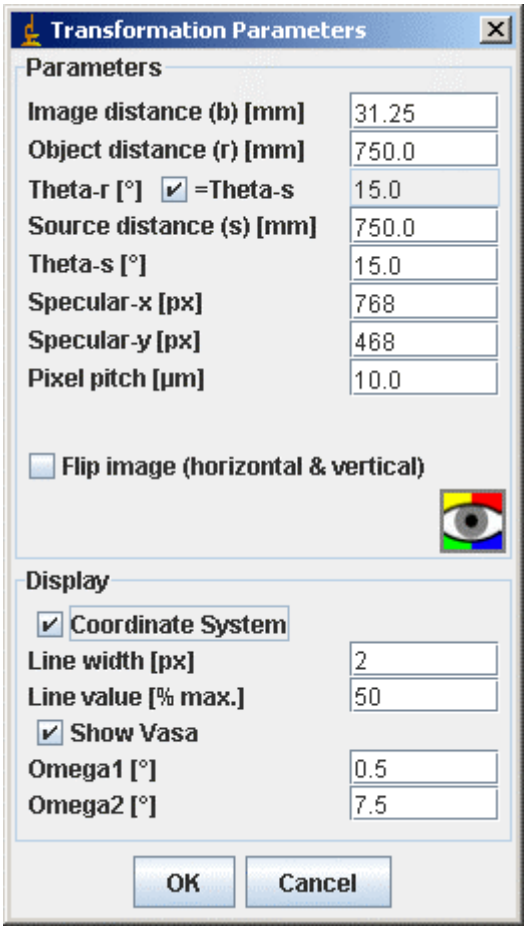
# Example



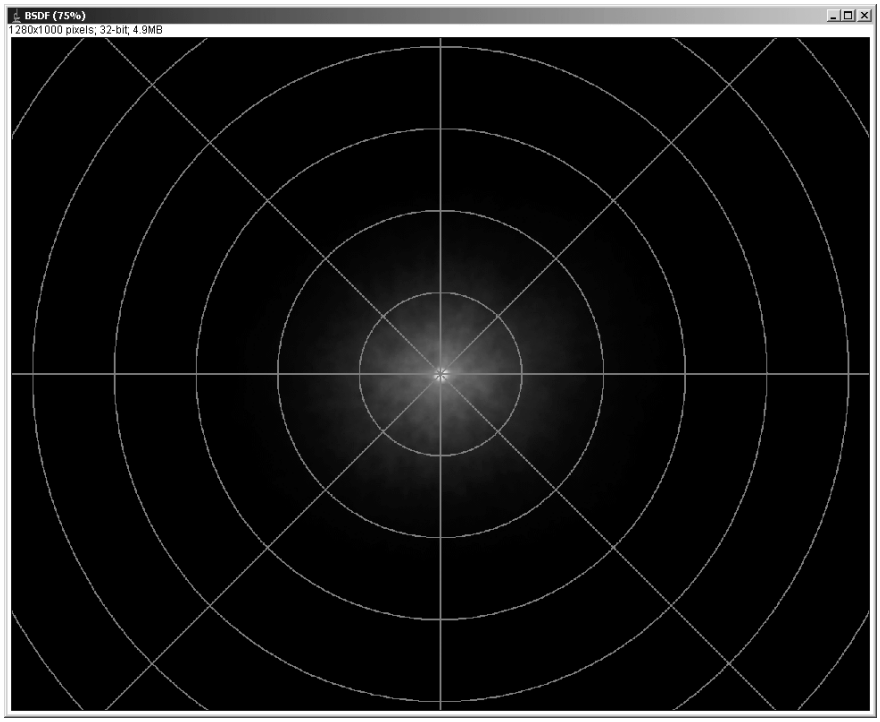

PSF lateral luminance distribution of the DUT measured with an imaging photometer, specular peak located at x=768 and y=468.




PSF lateral luminance distribution of the reflectance reference measured with an imaging photometer.

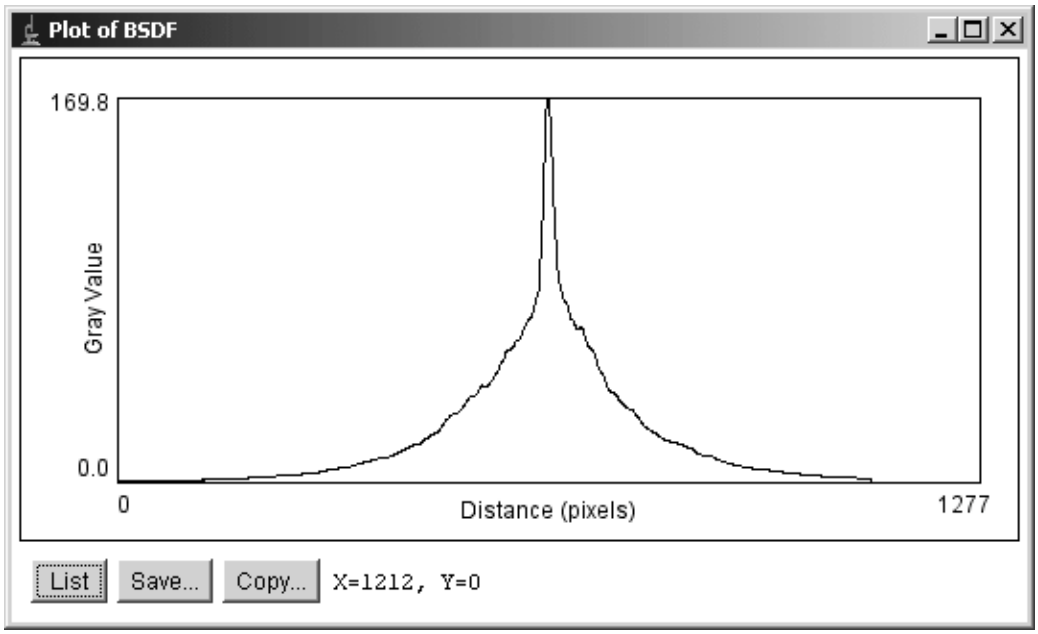



Parameters and settings used for the transformation PSF to BSDF

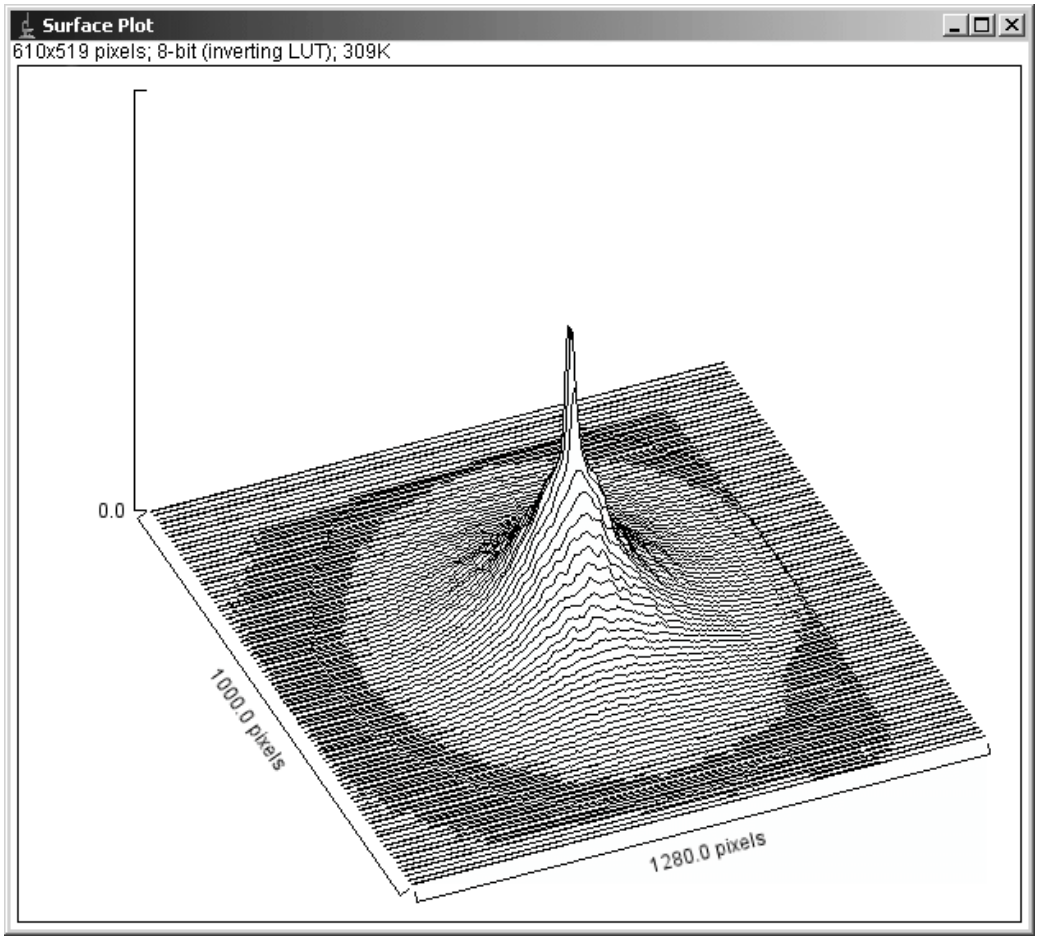



BSDF resulting from the transformation of PSFs shown above with polar coordinate system centered about the specular direction, with coordinates $\theta^*$ and $\phi^*$.

## Further evaluations and representations

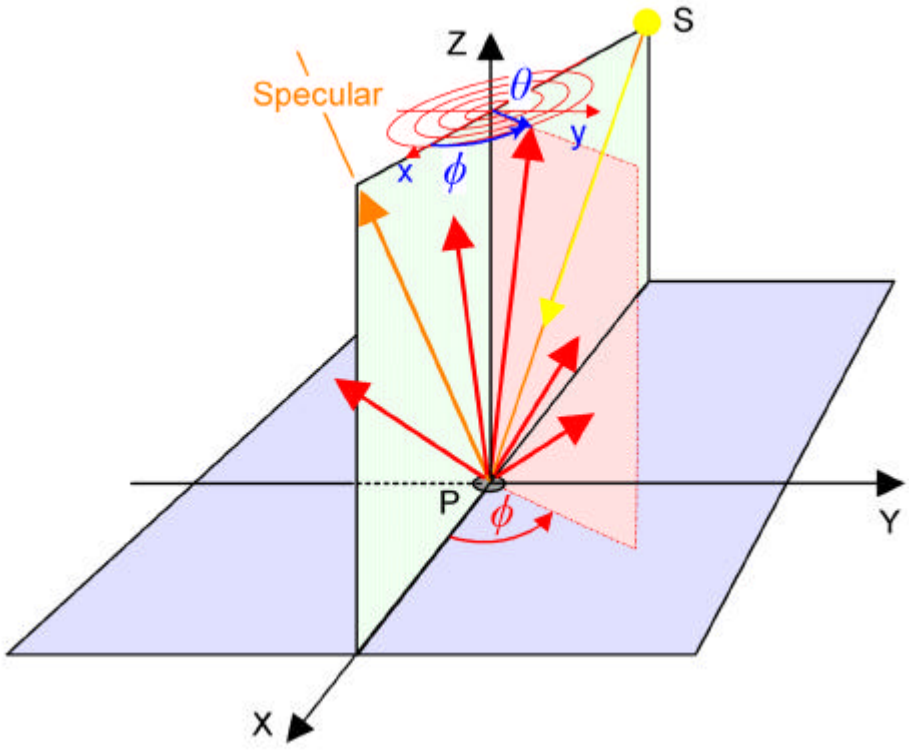



Profile of the DUT reflectance through the specular direction (ImageJ *Analyze* → *Profile*).

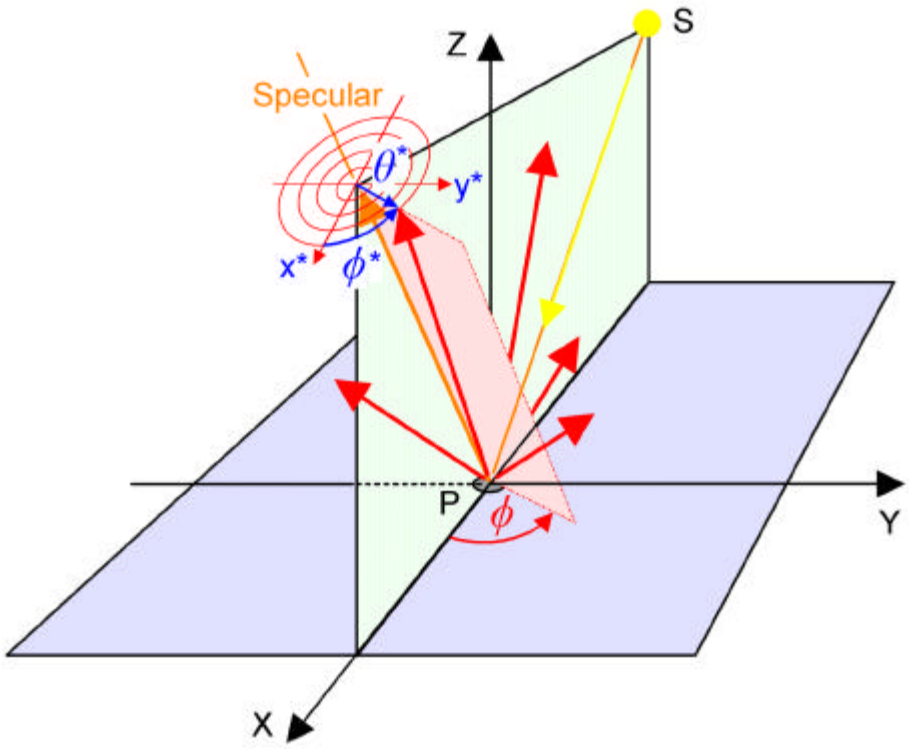



Graphical representation of the directional distribution of reflectance (ImageJ *Analyze* → *Surface Plot*).

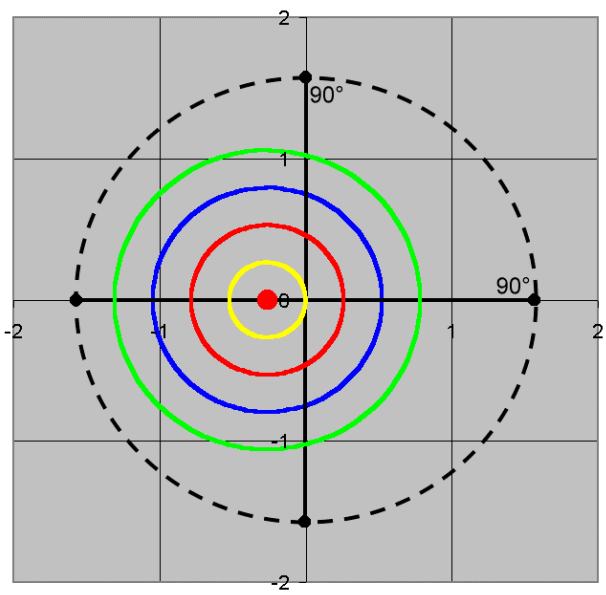
## Coordinate Systems

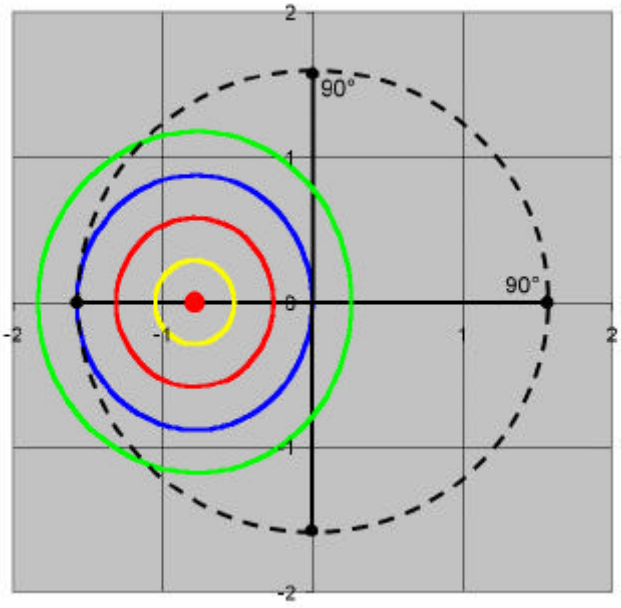



Coordinate system centered about the surface-normal of the plane DUT (xy-plane) with inclination θ and azimuth ϕ (***normal coordinate system***).

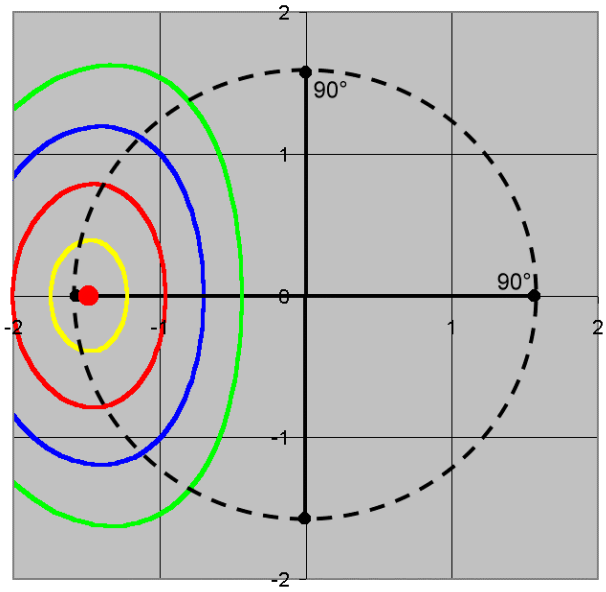



Coordinate system centered about the specular direction with inclination $\theta^*$ and azimuth $\phi^*$. The results of the BSDF-meter are given in this coordinate system (***specular coordinate system***).

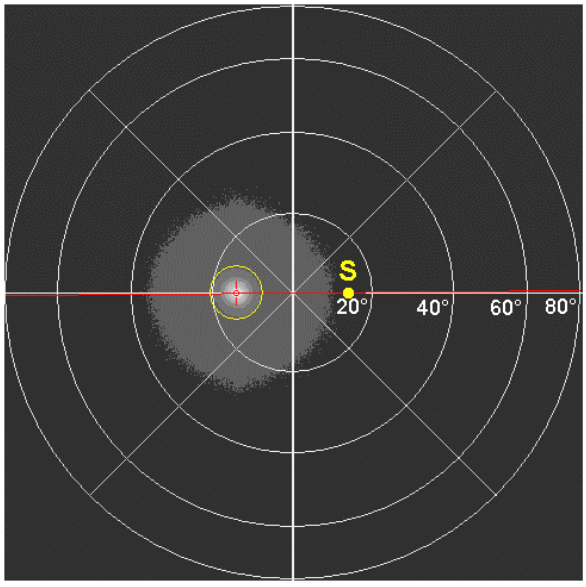



Coordinate system centered about the DUT normal (black dashed circle, 90°), 15° (left) and 30° (right) inclined coordinate systems with inclinations 15° (yellow), 30° (red), 45° (blue) and 60° (green) inclination.




85° inclined coordinate system with inclinations 15° (yellow), 30° (red), 45° (blue) and 60° (green) inclination.




Coordinate system centered about the DUT normal with circles for 20°, 40°, 60° and 80° inclination, haze of reflection with specular beam at an inclination of 15° (measured result).

In the coordinate system centered about the DUT normal, loci of constant inclination are given by circles. In inclined coordinate systems these loci are not circles, but the deviation slowly increases and becomes significant and obvious above 15°.

Results of the BSDF-Meter are always given in an inclined coordinate system centered about the specular direction.

## Literature references


1. M. E. Becker: "Display Reflectance: Basics, measurement, and rating", Journal of the SID, November 2006, Volume 14, Issue 11, pp. 1003-1017

2. M. E. Becker: "Measurement and evaluation of display scattering", Journal of the SID, 13,1(2005), pp. 81-89

3. M. E. Becker: "Measurement and Evaluation of Display Scattering", Proceedings of the SID'04, pp. 184 – 187

4. M. E. Becker: "Evaluation and Characterization of Display Reflectance", DISPLAYS 19 (1998), pp. 35-54

5. M. E. Becker: "Evaluation and Characterization of Display Reflectance", SID'97 Digest, pp. 827 – 830

6. Patenschrift DE 2004 015 473 B3