Bi-directional Photogoniometer for Advanced Glazing Materials based on Digital Imaging Techniques

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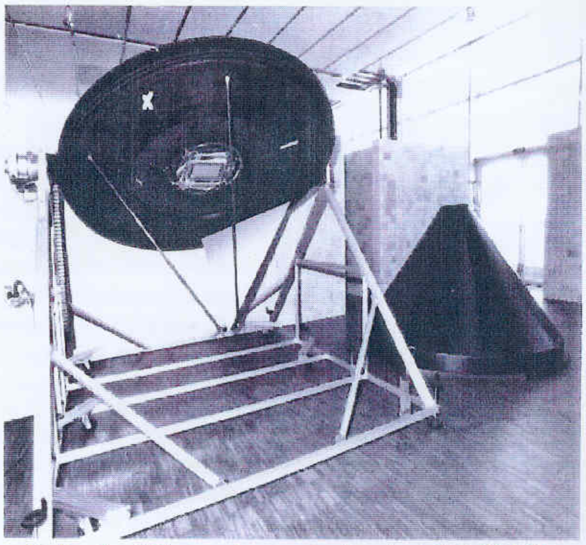
The photogoniometer is composed of a computer-controlled movable mechanical support, presenting two main rotation axes that are powered by DC motors. It uses an accurate and reliable gear technology (harmonic drivers) and is controlled by a micro-computer. The light source is placed 6 meters above. It consists of a short-arc discharge lamp (2.5 kW HMI) combining high luminous efficiency (96 Lumen / Watt) with a daylight-close spectrum (5600 K); it is placed in a floodlight projector equipped with a hyperbolic mirrored reflector, Fresnel lens and an optical conic element to enhance beam uniformity. A high illuminance uniformity is observed on the sample (better than 3%).

There is no movable photometer measuring the transmitted illuminance in each direction, as in the classical photogoniometer conception: instead, a spectrally and photometrically calibrated CCD camera is pointed towards a triangular screen, painted with a spectrally neutral diffusing white paint (LMT photometer paint). The CCD camera (Kappa CF 8/1 DXCair, images of 752 x 582 pixels) proposes computer-selected integration times from 100µs to hours; the lowest integration time used is 40ms, because of light source frequency effects. The diaphragm aperture is fixed manually. A conic cap is fixed on the main platform (around the camera and the screen) in order to avoid parasitic light; the measurements are performed in a 5m x 5m x 8m dark room.

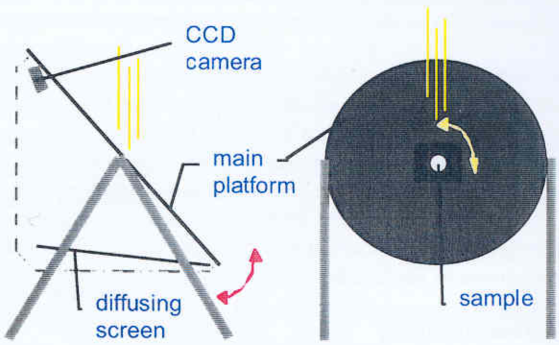
The rotation of the main platform ($\theta = 0°$ to $90°$) and the sample holder ($\phi = 0°$ to $360°$) determine the incident beam direction; six positions of a 360° rotating ring, moving underneath the main platform, on which the camera and the screen are fixed, leads to a representation of the complete transmission hemisphere, without any inter-reflections. The driving software allows a fully automated sample characterisation. Only about 2 to 4 minutes are necessary to achieve a set of BTDF data for one incident direction, against hours for classical photogoniometers. The sample holder allows free sample sizes, with a maximum size of 40cm x 40cm. A set of diaphragms is used to limit the measured area to 10, 17, 24, and 30cm diameter. An area of 10cm diameter corresponds to a resolution in transmitted directions of 5°; an appropriate calibration of the device could lead to better resolution, with smaller samples, or to lower resolution with bigger samples.

The luminances are measured inside discrete areas on the screen image (216 areas for 5° resolution), by averaging calibrated pixel values. Saturation and under-exposure effects are avoided by an automated selection of several integration times, followed by a superposition of image parts of appropriate luminance dynamics. The incident illuminance on the sample plane is measured with an LMT lux-meter. The obtained BTDF "screen" values are mathematically converted into final BTDF (or q) values, coming out from the sample centre.

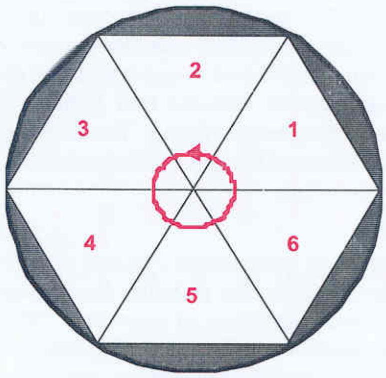
A sample characterisation leads to two outputs: a data file containing the sample description, the mathematically integrated light transmittance and the BTDF values; a 32 bits image representing the transmitted hemisphere by a recomposition of the 6 calibrated sixths. The data can then be treated to provide graphical results for say a prismatixc film such as a photometric solid showing incident direction and BTDF values in spherical coordinates.



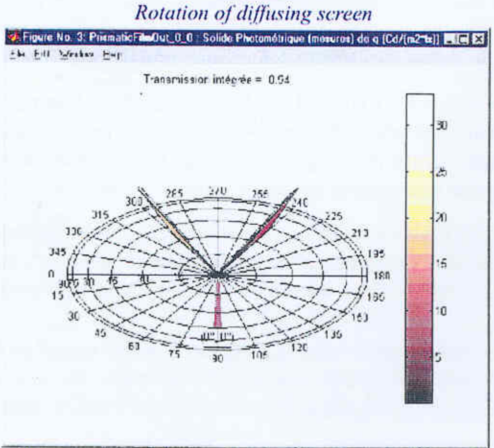
Bi-directional Photogoniometer developed at LESO-PB/EPFL. The CCD camera (absent on the picture) is fixed on the rotating ring at the cross mark.



Rotation of main platform and sample holder



Rotation of diffusing screen



Photometric solid example of a 3M prismatic film, with normal incidence