# Measuring Reflective Properties of Surfaces Using Reflectophotometer

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***Abstract*—Modern computer lighting design programs use for simplification reasons during calculations surfaces of purely diffuse reflection. For more accurate calculations it is necessary to use real reflective properties of surfaces that can be measured by a reflectophotometer. The reflectophotometer of the Department of Electrical Power Engineering, FEE CTU in Prague, allows measuring reflective properties of surface samples 2 by 2 cm. ReflectoSoft, an application designed especially for this reflectophotometer, enables measurements of BRDF in the Klems system of patches. The measured values can than be stored into a XML file containing the BRDF matrix of 145 × 145 elements. The results can be viewed using the software BSDFViewer.**

***Keywords*—reflectophotometer; OPTE-F3K; ReflectoSoft; BSDFViewer**

## I. Introduction

The human gets 80 to 90 % of information about the surroundings through the eyes. How objects affect luminous flux constitutes what we call the object's appearance. Most light-active surfaces around us are secondary light sources. Light emitted from primary light sources (sun, artificial light sources), hits a surface, changes its properties, is reflected and thus transmits information about the nature of the object's surface. The photometric properties of material surfaces are especially important in the design and construction of light-active surfaces in terms of reflected light flux spatial distribution , e. g. to reduce brightness in certain directions while maintaining maximum efficiency of the arrangement.

## II. Reflectophotometer OPTE-F3K

Measuring reflective properties of surface materials can be carried out using the reflectometer OPTE-F3K of the Department of Electrical Power Engineering (Fig. 1). This device requires a Bruel & Kjaer Type 1100 luminance contrast meter [1] with an external optical sensor to measure reflective properties of material surfaces. The sensor is fixed in the reflectophotometer, its output connected to the contrast meter and the analog luminance voltage output fed back to the reflectophotometer.

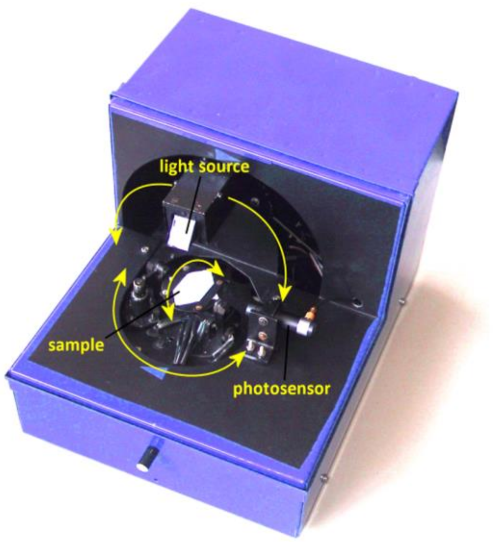


Fig. 1. Reflectophotometer OPTE-F3K without sample cover.

### A. Measuring Principle

To measure luminance spatial distribution of a sample's surface for different incident light ray angles it is necessary to rotate the light source and sample. To make this movement possible, stepper motors are used enabling rotation of the sample around two axes and rotation of the light source around a single axis.

For measuring the spatial distribution of the brightness of the measured sample surface for different incident angles light rays it is necessary to sample and the light source rotate. For this purpose, the reflectometer incorporates stepper motors rotating the sample around two axes and the light source along one axis. Angle arrangements can be found in Fig. 2.

According to Fig. 2 the sample is placed on a pad with its vertical axis *N* enabling rotation from $\gamma = 0°$ to $\gamma = 180°$. This pad can also be tilted from horizontal position $\beta = 0°$ to vertical position $\beta = 90°$. The reference light source can be rotated from range α = 0° to α = 180°. Angles α, β and γ can be set with an accuracy of 0.5° [2].

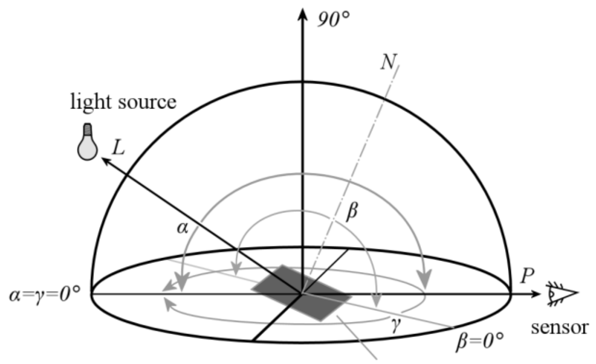


Fig. 2. Angle setup of the sample and light source used by OPTE-F3K.

The device is of relatively small dimensions (20 x 26 x 18 cm) implying the maximum size of the measured material samples to be 2 x 2 cm with thickness of 0.5 cm. Samples with very rough surfaces can be measured, since the device illuminates only a small part of the sample's surface [2].

The mechanical design of the device makes it impossible to set all angle combinations of incident beam and sample. This limits the measurable samples to samples exhibiting isotropic reflective properties.

## II. REFLECTOSOFT

After upgrading the electronics of OPTE-F3K it has been enabled to set angles of all three built-in stepper motors (light source, sample rotation and tilt), turn motor power supply on and off, get position of motors and more via virtual USB serial port that has been chosen due to the lack of DE-9 connectors on most computers.

A Java application has been programmed making automated measurements of sample's reflective properties possible. After the reflectometer has been connected to the computer and an echo response has been received by ReflectoSoft, an automated measurement can be started.

Incident light ray angle and sample tilt and rotation angles are chosen to conform to Klems patches. The hemisphere is subdivided into 145 patches according to Fig. 3 and Tab. 1.

TABLE I. ANGLE RANGES AND NUMBER OF PATCHES FOR EACH SPHERICAL SEGMENT OF KLEMS PATCHES (FIG. 3).

| **Spherical segment angle range** | ***from*** | 0° | 5° | 15° | 25° | 35° | 45° | 55° | 65° | 75° |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***to*** | 5° | 15° | 25° | 35° | 45° | 55° | 65° | 75° | 90 |
| **Patch amount** | | 1 | 8 | 16 | 20 | 24 | 24 | 24 | 16 | 12 |

Using angles from Tab. 1 makes it possible to export measured data into BSDFViewer format. Because OPTE-F3K is able to measure only isotropic reflecting sample surfaces, all

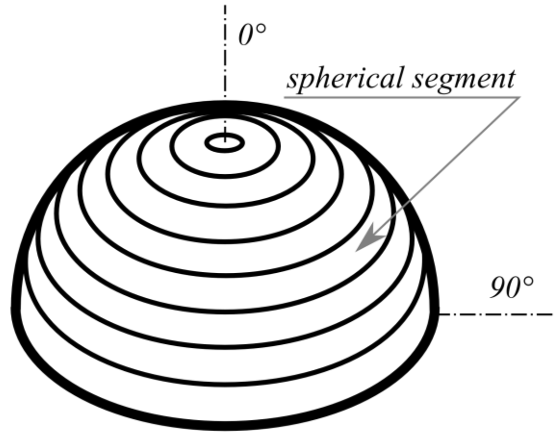


Fig. 3. A hemisphere subdivided into Klems patches.

missing data required by the BSDFViewer format must be filled in, i.e. symmetric values have to be copied and rotation applied.

To avoid interpolation during rotation, each spherical segment is subdivided into a constant number of patches being the least common multiplier of all spherical segments. Looking at Tab. 1 all spherical segments will be subdivided into 240 patches.

During the automated measurement quaternions of angles α, β, γ and luminance are stored to a text file chosen by the user in CSV format. To make visualization of the measured data possible using the application BSDFViewer, the measured data can also be exported into a BSDFViewer XML file format.

## III. INTRODUCTION (*HEADING 1*)

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### A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive."
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- Use a zero before decimal points: "0.25," not ".25." Use "cm3," not "cc." (*bullet list*)

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Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in

$$a + b = \gamma \tag{1}$$

Note that the equation is centered using a center tab stop. Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(1)," not "Eq. (1)" or "equation (1)," except at the beginning of a sentence: "Equation (1) is ..."

### D. Some Common Mistakes

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- The subscript for the permeability of vacuum $\mu_0$, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o."
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- In your paper title, if the words "that uses" can accurately replace the word using, capitalize the "u"; if not, keep using lower-cased.
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TABLE II. TABLE STYLES

| **Table Head** | **Table Column Head** | | |
|---|---|---|---|
| | ***Table column subhead*** | ***Subhead*** | ***Subhead*** |
| copy | More table copy[a] | | |

[a.] Sample of a Table footnote. *(Table footnote)*

b.

Fig. 1. Example of a figure caption. *(figure caption)*

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization," or "Magnetization, M," not just "M." If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization (A ( m(1)," not just "A/m." Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)," not "Temperature/K."


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## References

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Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

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To have non-visible rules on your frame, use the MSWord “Format” pull-down menu, select Text Box > Colors and Lines to choose No Fill and No Line.


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