ENERGY DISTRIBUTION ON A PLANE IN THE CASE OF OPTICAL SYSTEMS WITH LARGE LIGHT SOURCES

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In this paper, is studied the energy distribution on a plane in an optical system, that can be also the image plane, when there are large objects or large light sources. The light sources can have different forms, spectral radiance, spatial and polar distributions of the intensity (predefined or defined by the user). The sources defined by the user can be plane or spatial. The optical system can have uniform or nonuniformity optical coatings and optical materials selectively absorbed. A detector characterized by a spectral sensitivity can be on the analysed plane. One analyses an illumination system with an ellipsoidal mirror on which an optical coating of cold mirror type was achieved.

1. Introduction

More often tan not, the study of the energy distribution on a plane of an optical system, cannot be done with the classical programmes for designing optical systems when we have large defined 3D light sources whit spectral radiance, polar and spatial distribution of the intensity as an object for the optical system. That's why in a programme for designing optical systems, special functions must be created to deal with this problem[1]. Also, if on the plane where we study the energy distribution, there is a detector with a given spectral sensitivity, it is necessary to determine the detector response taking into account the object (the light source) and the parameters of optical system that preceeding the plane. The created functions must have the possibility to work with the 3D surfaces defined by the user (source surface, diopter surfaces, opaque surfaces), light sources with spectral radiances, spatial and polar distributions of the intensity defined by the user, absorbing materials for diopters, optical coating library, detector with a spectral sensitivity defined by the user. Also, one must work with a great number of rays.

2. Light propagation through optical systems with optical coatings

The energy distribution on the image plane depends on the object (light source) characteristics and on the optical system parameters. The optical system can change the ray intensity by the absorbtion in the optical system materials and by the reflection and transmission on the diopter surfaces (with or without optical coatings). Considering the diopter without coating as a diopter with a zero thickness optical coating, the way in which the optical coatings change the intensity and the state of polarization of the incident rays on the coating must be determined. If this function is implemented into a designing program of optical systems, then incidence angles on diopters are known (or can be deduced). The relative intensity and the polarization state of the rays passing through the optical system are to be determined. Let's take the general case where at the input of the optical system, the light is partially polarized. A partially polarized light beam can be considered a superposition of the unpolarized light and the elliptical polarized light, namely it can be specified by five parameters: total intensity I_t ($I_t = I_{polarized} + I_{unpolarized}$), the degree of polarization P, orientation angle of the ellipse major axis, ratio between ellipse axis lengths and the phase difference δ between the normal components of the electric field. As we know these parameters for the incident light of the optical system , we must determine the way in which these parameters are changed by the light propagation through the optical system. We consider an object point, a source of light out of which n rays are starting and they are passing through the entrance pupil of the optical system. If the object point is at infinite, then the rays are generated using an equidistant rectangular mesh in the entrance pupil and all the rays have the same total intensity and polarization state. If the object is at a finite distance then the rays are generated so that every ray delimitates equal solid angles.

The optical coatings on the diopters surfaces are generally non-uniform. One considers the non-uniformity to be symmetrical related to the optical axis of the diopter and for this reason it is described by means of the point sag, all the points belonging to the intersection of a plane normal to the optical axis (

placed related to the diopter vertex by means of the sag) and the diopter surface have the same uniformity. The non-uniformity on a certain diopter surface of an optical coating produced in a certain geometry of evaporation, can be numerically evaluated[2].

The software functions were implemented into the WINOPTIC V1.0[3] program and the optical coatings are stored up by means of the STRAT V5.2[4] program. The algorithm for determining the response of a detector placed on the image plane (not necessarily) is shown in Fig. 1.

The sources defined by the user are stored in ASCI files where the characteristics of the elementary sources are given. The defined source has a proper reference system related to which the elementary sources are positioned. The parameters of the elementary sources are: the elementary source origin, the normal to the elementary source, the elementary source radiance, the source type (an index to a source with a defined spectral radiance), the polar distribution type of intensity (an index to a defined polar distribution). The elementary sources of plane source type emit only on the exterior surface, the normal to the elementary source being always directed towards the exterior.

As the light source can stop some rays of the optical system, an opaque surface of light source form are introduced. The surfaces defined by the user are stored in the ASCI files where the characteristics of the elementary surfaces composing the surface are given. The elementary surfaces are plane, of a trapezoidal form, that can degenerate into a triangle. The defined surface has a proper reference system related to which the elementary surfaces are positioned. The elementary surfaces parameters are: proper reference system origin of the elementary surface, coordinates of proper reference system axis of the elementary surface, points describing the contour of the elementary surface given in the proper reference system.

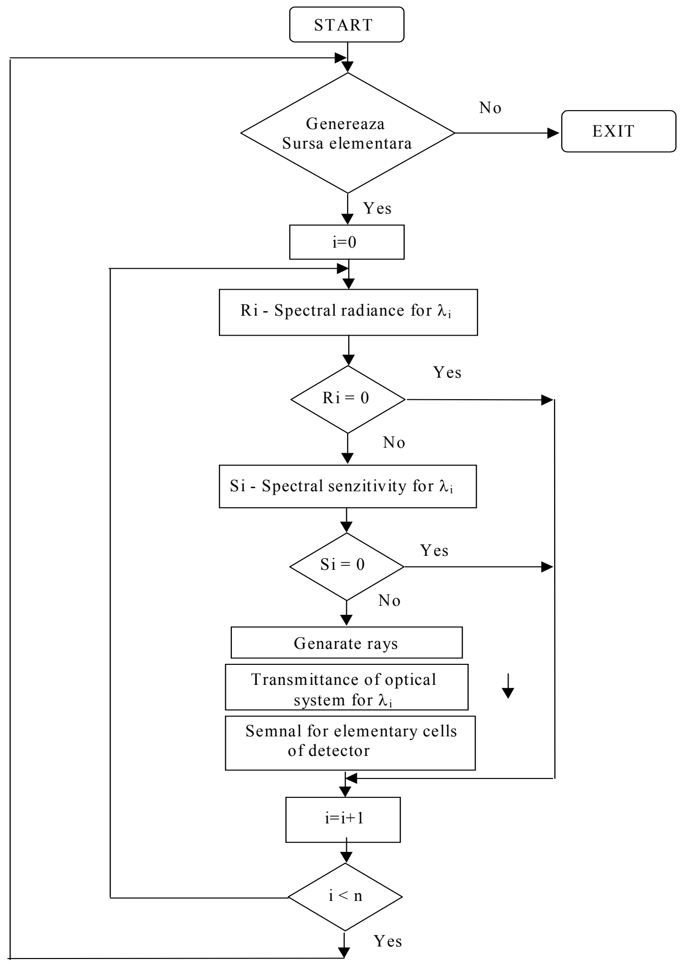


Fig. 1. Flowchart of determination of intensity distribution.

3. Illuminating system with ellipsoidal mirror

For the most devices where strong power light sources are used, to eliminate the thermal radiation one can use cold mirrors. In order to capture as more light as possible from the source, one can use ellipsoidal or paraboloidal mirrors. One example is the illuminating system shown in Fig.2. The system consists of a BK 7 ellipsoidal with the surface equation:

$$x^2 + y^2 = -0.64z^2 + 128z$$

The ellipsoidal mirror diameter is 156mm and the sag is 80 mm. The light source is considered to be like in Fig. 3, centered in the first ellipse focus at 40mm from the ellipse vertex. The light is unpolarized with a constant spectral radiance. The source surface is divided in elementary sources, in 40 elements on the circumference and 12 on the height. The light source emits only on the exterior surface.. A cold mirror optical coating is achieved on the mirror surface, having the following structure:

$M/\ 2L\ (H_1L_1)^7\ (H_2\ L_2)^7\ 0.5H\ /S$ (I)

where - **L, L_1, L_2** - SiO_2, quarterwave optical thickness at 550, 475nm, 600nm;

H, H_1, H_2 - TiO_2, quarterwave optical thickness at 550, 475nm, 600nm..

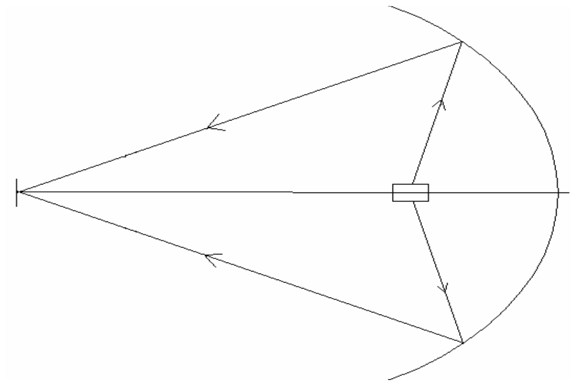


Fig. 2 Illuminating system with ellipsoidal mirror

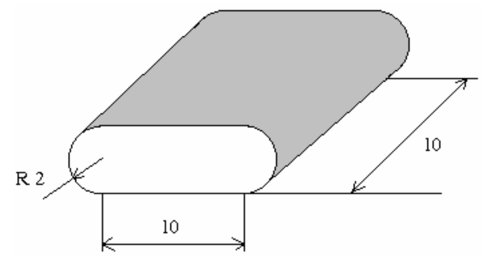


Fig. 3. Light source. Dimensions are in mm.

The spectral reflectance at the normal incidence is shown in Fig. 4, curve 1. Considering that coating is uniform on the mirror surface, the integral reflectance of the mirror is shown in Fig. 4, curve 2, considering that we have a point light source. In order to get a better uniformity of the optical coating on

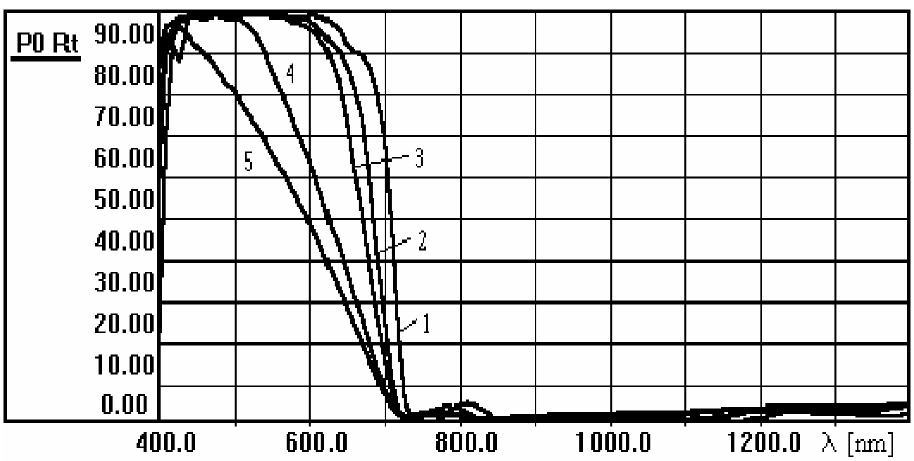
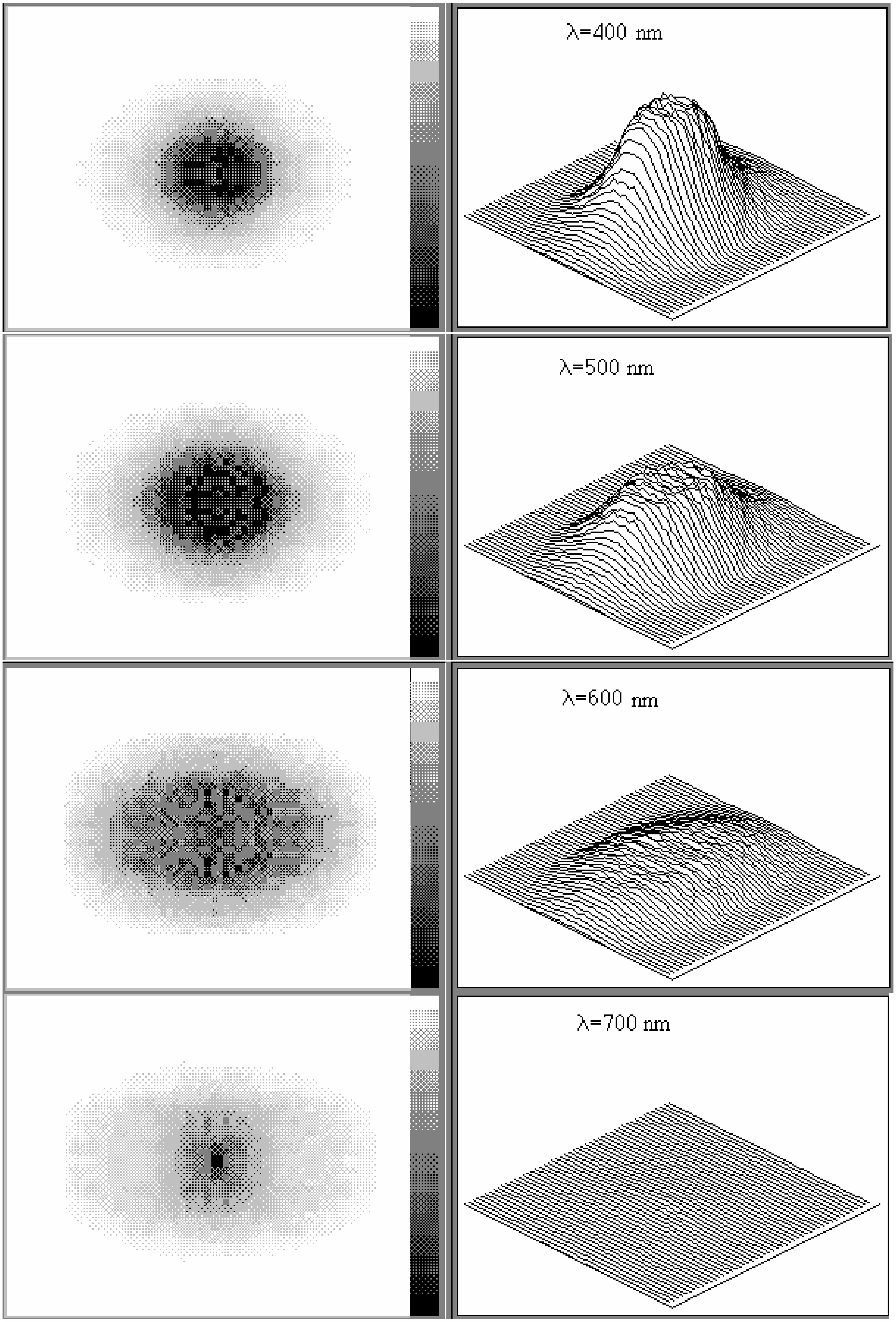


Fig. 4 Mirror reflectance I: 1 – theoretic, 2 – uniform; 3 – aperture 120^0; 4 – aperture 180^0; 5 - aperture 240^0

the mirror surface, the optical coating is achieved by means of a planetary system. In the following calculations, one considers the geometrical coefficient to be symmetrical, depending linearly with the sag, at the diopter vertex a theoretical coating is got (with a geometrical coefficient 1) and at maximum aperture, the geometrical thickness of the coating layers are multiplied by 0.6. Fig. 4 shows the integral spectral reflectance for the coating with the above-mentioned non-uniformity and for different apertures of the mirror, considering that we have a point light source. As it easily can be seen in Fig. 4, for a maximum aperture, the spectral reflectance is strongly changed related to the theoretical one. We consider that the plane where the intensity distribution is determined, is positioned in the second focus of the ellipsoidal mirror. The analysed surface is de 60 x 60 mm^2 ,divided into 50 x 50 cells. For each elementary source, 200 rays are generated. In Fig. 5, the intensity distribution is shown for four wavelengths, where we have the optical coating with the above mentioned non-uniformity. The plot contour images were achieved with a proper scale for each wavelength. One can notice a decrease of illumination for the large wavelengths in conformity with the integral reflectance of the optical coating on the ellipsoidal mirror. In Fig. 6, the intensity distribution is shown on the middle of the image plane(y=0). In Fig. 7, the spectral composition of light is shown in some points (cells) of the image plane. One can notice that the light cells of the image plane have different spectral composition (trichromatic coordinates).


λ=400 nm
λ=500 nm
λ=600 nm
λ=700 nm

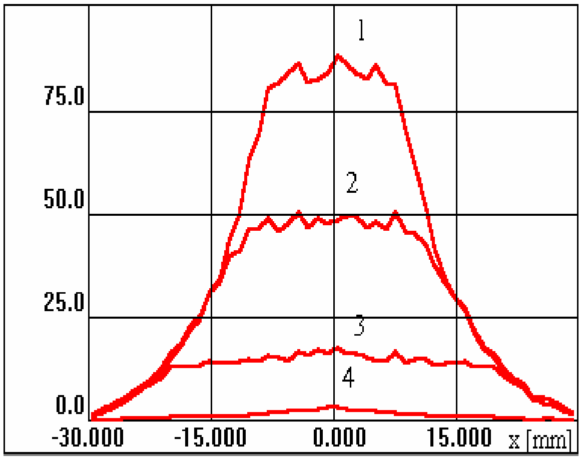


Fig 6. Intensity distribution (y=0) for:
1 – λ=400nm; 2 – λ=500nm; 3 – λ=600nm;
4 – λ=700nm

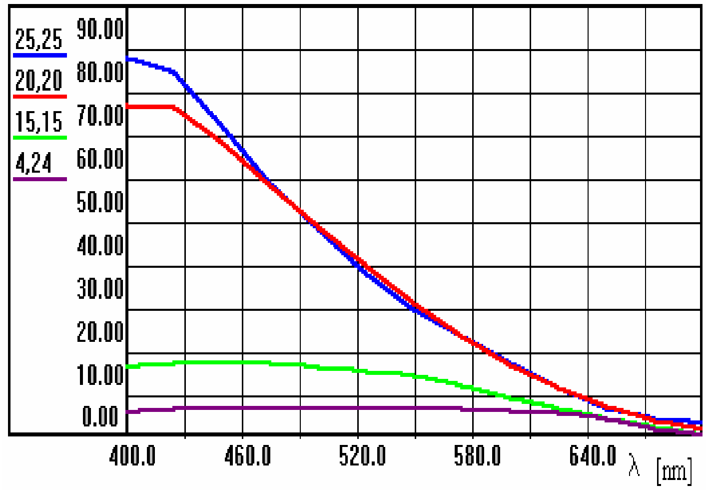


Fig. 7. Spectral composition of light in four points (cells) of the image plane.

4.Conclusions

The created functions allow to determine the energy distribution on a plane in the optical system when we have 3D objects (light sources) with spatial and polar distribution of intensity predefined or defined by the user, optical systems with absorbing materials and optical coatings, in the analysed plane there is a detector with a spectral sensitivity predefined or defined by the user. Intensity distribution can be simultaneously got for more wavelengths that can be composed. The spectral composition of light can be determined in different points of the plane. If the light source is in the object plane and it is of a point form and the plane is the image plane, then from the intensity distribution, one can determine the polichromatic MTF.

References

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