

Organic Glass Intraocular Lenses: a Simulation of Behaviour

AURELIAN OVIDIUS TRUFASU^{1*}, CIPRIAN ION RIZESCU¹, CRISTINA LILIANA ANASTASIA TRUFASU², SORIN-DUMITRU GROZAV³

¹Politehnica University of Bucharest, Mechanics and Mechatronics Engineering Faculty, 313 Splaiul Independentei Str., 060042, Bucharest, Romania

²Edmond Nicolau High School, 3-5 Dimitrie Pompeiu Bvd, 020335, Bucharest, Romania

³Technical University of Cluj-Napoca, Machine Building Faculty, 28 Memorandumului Str., 400114, Cluj-Napoca

The paper is focused on the behavioural simulation of the intraocular organic lenses, defined by geometric characteristics (the accumulation radius, thickness and diameter) [1] and material characteristics, for a certain incident wavelength [2]. The simulation provides a picture of the ray-tracing for the second and third reflection/refraction. At the same time, the user can display the print of a ray on a normal plane related to optical axis direction. The authors designed the simulation program, aimed to evaluate the wounded through the multiple reflections in the spectre available for chosen material. Thus the disparity of a certain parameter will influence the transference through lenses for some radiation or spectre. The paper is designed to be used in optics, to shape the refractive components, and can predict the useful diameter of lenses, diaphragms or aperture stop.

Keywords: organic optical glass, optical layout, multiple reflections, imaging

The paper is based on a few years of work, the authors experienced a gap between real and figured image offered by different optical programs, most of them based on ray-tracing. The real image is more complex than the designed one, even all-optical criteria are taken into account. The authors analysed the second and third order images, due to the cross between the rays of multiple reflection inside the lens. The rate of this second order image seems to be higher than estimated, at least in certain circumstances.

Experimental part

The basics of the program

The fundamentals are the same and well known as main image gaining. The novelty is the environment MAT LAB and the interpretation. The level of light beam resulted as second order images is less than 10% of total light beam. For a better understanding, the authors shall examine only one type of lens, for intraocular use and for organic material, but the program can run any of them. In the telecentric incident light beam (parallel beam), the target of the lens is to focus it to the smallest spot possible and gives the patient the best quality image. The smallest spot occurs not far from the focal length distance f' . The lens support is determined by the former crystalline place and it acts as an aperture stop and limits the amount of the lens which can be used to focus the light. As it is shown further, the amount of light is decreasing due to several reflection and refraction made on previous surfaces. At the same time a lot of second order images are appearing on the field, retina in this case, many of them not so far from focal plan, fovea plan. The authors did not take into account the diffraction and interference, phenomena that are linked to the different shapes of lenses [3]. These new approach will be subject for a development of this program.

User interfaces

The simulation software is easy and friendly, due to its interfaces. Figure 1 and figure 2 present the general view of the interfaces, illustrating the steps to be done in order to define the calculated lens:

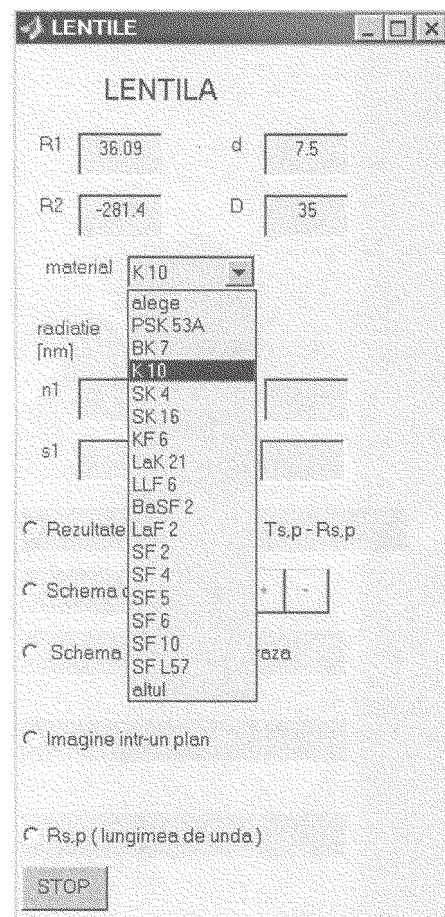


Fig.1. First interface

- input the radius of curvature R1 and R2;
- input the centre thickness d [4];
- input the lens diameter D [5];
- to choose the optical material [4,6]; a library containing the glasses used frequently by the user was built in; - the library gives the refractive index for the wavelengths usually given in glass.

*E email: a_trufasu@yahoo.com

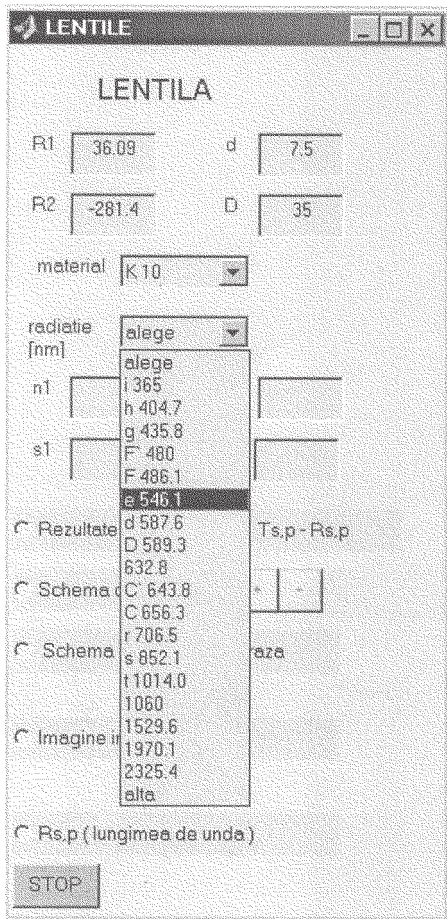


Fig. 2. Second interface

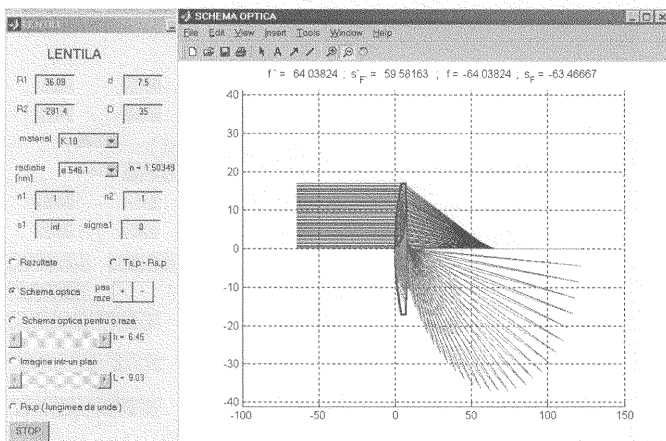


Fig. 3 Optical layout for intraocular lens with first and second order beam

The next step is the optical layout of the defined lens, an intuitive and efficient means that provides (fig. 3):

- the paraxial characteristics [2] (effective focal length f' , front focal length s_F , back focal length s_F');
- the basic parameters [3], such as image distance, magnification, object-image distance;
- the infinite/finite or finite/finite conjugate design for a beam passing through the lens, by the use of an exact trigonometric and vectorial ray tracing; the optical layout shows the effect of the spherical aberration;
- the ghost images produced by the first order and the second order internal reflections.

- catalogues; the refractive index can be written as an input for certain material which was not included in the library must be selected;
- choose the radiation, defined by its wavelength, in nanometers; if the desired radiation is 'other', the user will define the correspondent index of refraction;

- input the index of refraction of the media before and behind the lens respectively [4,6];
- input the object distance ' s_1 ' measured from the lens flanking to the object (infinite or finite);
- angular half field of view ' σ_1 '.

Results and discussion

The simulation software gives the possibility to choose an optical layout for one ray of light passing the lens at a certain height of incidence [1]. Figure 4 illustrates the multiple internal reflections on the lens surfaces. By ray tracing, the first and second internal reflection lead to ghost image, which can be shaped by selection and scale the height of the reference incident ray. The ghost images are superimposed over the main image, do not obstruct it, but they appear as spots, halos and small shadows surrounded by the details of the primary image. The vectorial working out gives the exact position of a ghost image in the meridian plane of the lens; it can be compared with the position either of the primary image or the lens entrance pupil.

The spot size is dependable on the image plane position and on the spherical aberration [7]. This fact can be highlighted by selecting the option 'image in a plane' of the simulation software. Figure 5 presents the image spot in a plane placed at a certain distance from the last surface of the lens. The distance is an input from a mouse click on the optical layout and can fluctuate within an interval from a cursor. The layout released shows the presence of the ghost image in the entrance pupil plane of the lens [8].

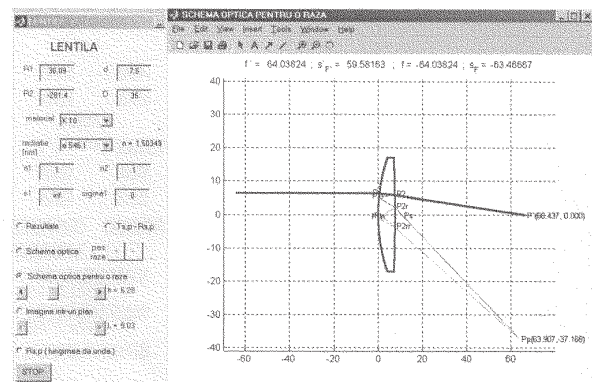


Fig. 4. Optical layout for one ray with first and second order reflection

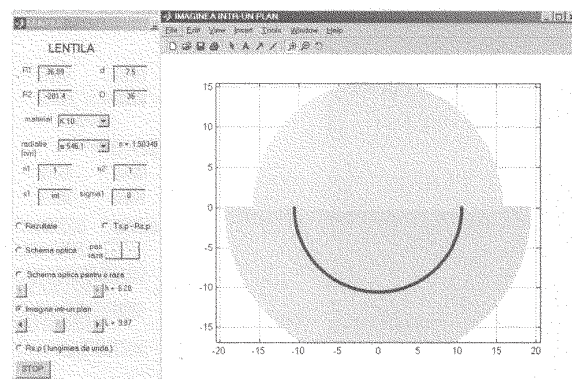


Fig. 5. The image captured on a normal plane on optical axis

The software has other features, most of them dedicated to the lens ability to transfer light by computing the spectral characteristics [1]. The result is: the transmittance of the lens according to the height of incidence, the reflection wounded by multiple internal reflections [9]. These results are presented either numerically [10]: extreme values and the corresponding height of incidence (fig. 6), or graphically

| PARAMETRII SPECTRO-ENERGETICI : TRANSMITANTA / REFLECTANTA | |
|--|---|
| Ts12 min = 89.918929839710131 [%] - h = 17.00 [mm] | Tp12 min = 92.074131117664351 [%] - h = 0.01 [mm] |
| Ts12 max = 92.074129955196014 [%] - h = 0.01 [mm] | Tp12 max = 93.976705942906364 [%] - h = 17.00 [mm] |
| Rs1 min = 4.044734514636916 [%] - h = 0.01 [mm] | Rp1 min = 2.737975286529363 [%] - h = 17.00 [mm] |
| Rs1 max = 5.580810139572249 [%] - h = 17.00 [mm] | Rp1 max = 4.044733688455004 [%] - h = 0.01 [mm] |
| Ts12r min = 0.006321433244319 [%] - h = 11.17 [mm] | Tp12r min = 0.002174679463294 [%] - h = 11.17 [mm] |
| Ts12r max = 0.214507311991367 [%] - h = 9.75 [mm] | Tp12r max = 0.150632051139020 [%] - h = 0.01 [mm] |
| Ts12rr min = 0.000246432908007 [%] - h = 0.01 [mm] | Tp12rr min = 0.00000000002660 [%] - h = 9.78 [mm] |
| Ts12rr max = 3.799203956266268 [%] - h = 17.00 [mm] | Tp12rr max = 3.291018739986856 [%] - h = 16.92 [mm] |
| Ts21r min = 0.209327185906116 [%] - h = 16.92 [mm] | Tp21r min = 0.336725059028070 [%] - h = 16.92 [mm] |
| Ts21r max = 3.787820230453975 [%] - h = 10.44 [mm] | Tp21r max = 3.724153664661044 [%] - h = 0.01 [mm] |
| Ts21rr min = 0.006092678353336 [%] - h = 0.01 [mm] | Tp21rr min = 0.000000004454546 [%] - h = 9.16 [mm] |
| Ts21rr max = 0.235517520251382 [%] - h = 11.17 [mm] | Tp21rr max = 0.048759899925335 [%] - h = 11.17 [mm] |

Fig. 6. Reflection/transmission spectral energetic parameters

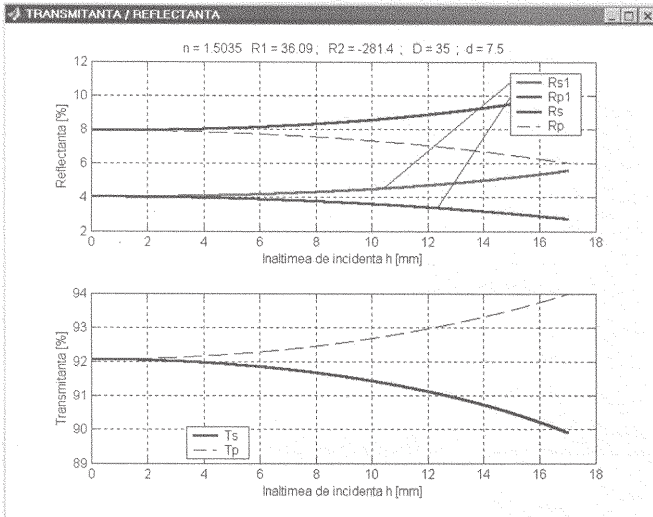


Fig. 7. Reflection/transmission layout

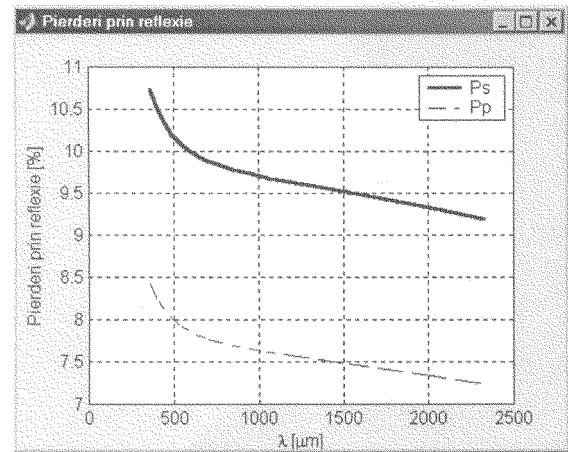


Fig. 9. Reflection/transmission layout

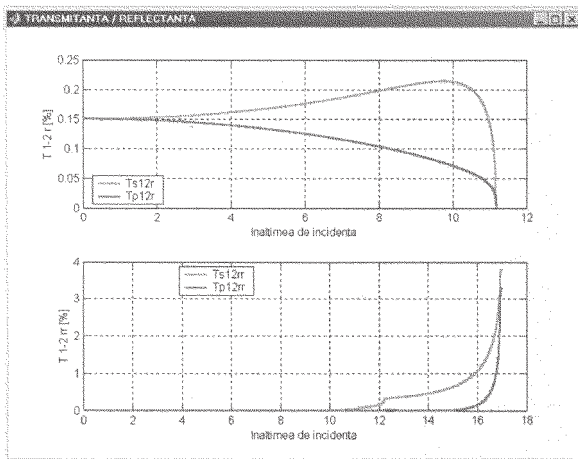


Fig. 8. Reflection/transmission layout

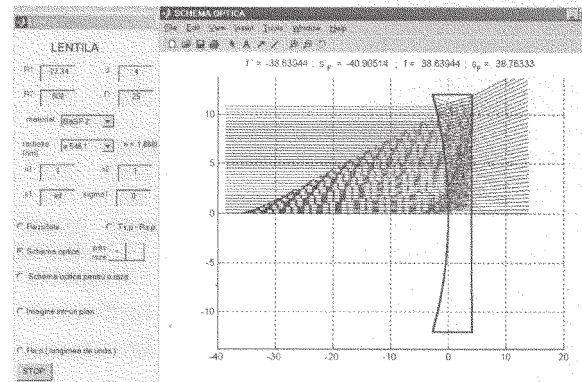


Fig. 10. Reflection lost layout for a divergent lens

[11]: the transmittance due to the beam passing through the lens (fig. 7), the transmittance due to first and second internal reflections which determine the wounded of incident beam (fig. 8 and 9).

The reflection wounded, with significant values for uncoated components, depends also on the radiation wavelength [6]. Software allows the working out the maximum reflection wounded for the defined lens in certain spectral field and optical material [12]. Figure 10 shows a graphical representation of this addition.

The following figures are made for divergent lens. The procedure is pretty similar with convergent lens; differences are only in shapes and curvature of lenses and images.

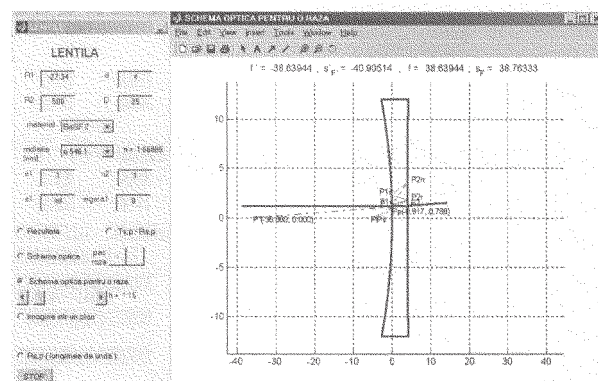


Fig. 11. Second and third order reflection tracing for single ray

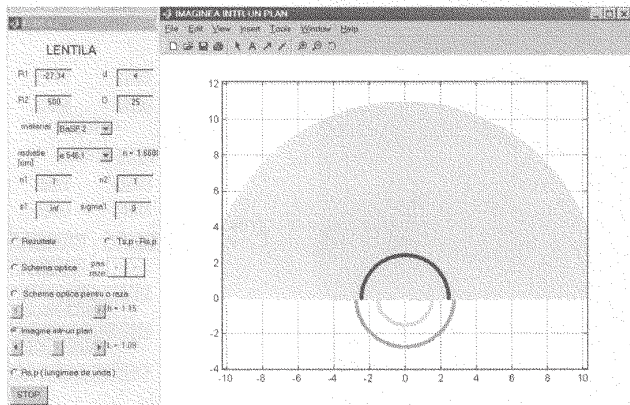


Fig. 12. Image captured in a plane normal on optical axis

Conclusions

The program is useful for anyone interested to see how intraocular lenses work if is taken into account the spread of the light inside and outside. The authors are familiar with many ray-tracing application; none of them are shaped in MAT LAB or in toolboxes.

The authors are grateful to anyone who can suggest any improvement or remarks advantage and disadvantage of this program.

The application can suggest some geometrical placements in the optical layout, the dimensions of the main apertures and the position of the second order images due to multiple reflection and refraction.

References

1. MOISIL, G. C., CURATU, E., Optica; teorie si aplicatii, Editura Tehnica, Bucharest, 1986
2. TRUFASU, A. Ov., Notiuni fundamentale aplicate in optica tehnica, Editura Bren 77, Bucharest, 2000
3. JIPA, S., ILIE, D., ILIE, S., SETNESCU, R., KAPPEL, W., Mat. Plast., **43**, no.3, 2006, p. 186

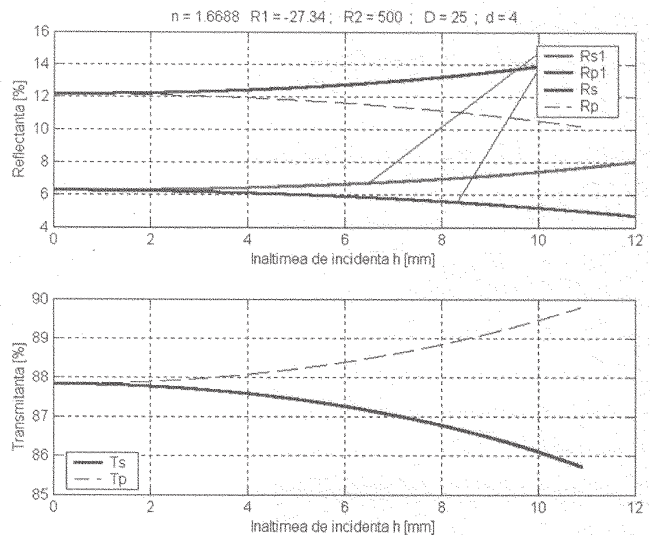


Fig. 13. Transmission/reflection layout

4. CERBU, C., Mat. Plast., **44**, no.2, 2007, p 97
5. STAN, D., TULCAN, A., TULCAN, L., ICLANZAN, T., Mat. Plast., **45**, no. 1, 2008, p 119
6. DUMITRASCU, L., DUMITRASCU, I., DORHOI, D.-O., Mat. Plast., **45**, no.2, 2008, p 217
7. PAUN, V.-P., PAUN, M.A., Mat. Plast. , **46**, no. 3, 2009, p. 339
8. PAUN, V.-P., POPENTIU, F., PAUN, V.A., Mat. Plast., **46**, no.2, 2009, p. 189
9. PAUN, V.-P., Metalurgia International, Special Issue, vol. XIII, 2008, p. 43
10. PAUN, V.-P., PAUN, M.A., TOMA, A., CIUCU, C., POPENTIU, F., Mat. Plast., **45**, no.1, 2008, p. 57
11. PAUN, V.-P., Mat. Plast., **44**, no.4, 2007, p. 393
12. PAUN, V.-P., Rev. Roum. Chim., **49**, no.1, 2004, p. 85

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