Biophotonics Laboratory

Lab Work – October 22nd 2020
h 8.00
Laboratori Didattico di Fisica - Lab.A and Lab.B
Building RM018
Via Castro Laurenziano, 7A – 2nd level

Materials: Optics didactic KIT (ray tracing lamp, cylindrical lenses, cylindrical mirror, bulk and empty half-cylinders, goniometer, millimetre paper)

Part 1

Practice with Snell laws on reflection and transmission at a plane interface. Optics laws for: spherical mirror, diopter, thick lens, thin lens. Divergent and convergent lenses. Image re-construction by ray tracing. Systems of lenses. Geometrical and chromatic aberrations.

Part 2

Task 1 Estimate the refractive index of the material that constitutes the lenses of the didactic kit by means of the experimental verification of the Snell law for the refraction phenomenon.

Use the lamp with a single slit to generate a light ray. Use the bulk plastic half-cylinder and let the ray impinge on its flat air/plastic interface. Ensure the half cylinder is centred on the goniometer and that the ray hits the goniometer at the very centre. List in a table the incidence angles (i) and the respective refraction angles (t). Scatter plot on linear millimetre paper the sin(i) vs sin(t) couples, interpolate with a straight line (that should go through the (0,0) point) and evaluate its slope ($\Delta y/\Delta x$). From the Snell law:

$$n_{AIR}*\sin(i)=n_{PLASTIC}*\sin(t) \text{ with } n_{AIR}=1$$

the slope is $n_{PLASTIC}$. Finally determine the value for $n_{PLASTIC}$.

Task 2 Estimate experimentally the refractive index of the material that constitutes the lenses of the didactic kit by means of the experimental measurement of the value of the critical angle.

Use the lamp with a single slit to generate a light ray. Use the bulk plastic half-cylinder and let the beam impinge on its flat air/plastic interface. Ensure the half cylinder is centred on the goniometer and that the beam hits the goniometer at the very centre. By turning the goniometer measure the critical angle when you get to the total internal reflection condition. At the critical angle, from the Snell's laws:

$$n_{PLASTIC}*\sin(i_{CRIT})= n_{AIR}*\sin(\pi/2)=1$$

from which you can evaluate $n_{PLASTIC}=1/\sin(i_{CRIT})$. Finally determine $n_{PLASTIC}$. Compare the value you found with that you found by the procedure used in the Task 1. Compare the value with that reported in literature for poly-methyl-meta-acrylate in the visible range.
During the execution of the task notice that around the critical angle one can observe a strong dispersion of the light rays with different colour that is caused by the dispersion of $n_{PLASTIC}$.

Task 3: Repeat the Task 1 with the half-cylinder container filled with water. Estimate the refractive index of water by means of the experimental verification of the Snell law for the refraction phenomenon. Verify that the dispersion of the light rays around the critical angle is less pronounced for water.

Task 4: Estimate the radius of curvature of the thin plano/convex lens of the didactic kit. Compare the result with that obtained by using the measurement of the geometrical parameters of the lens (width, sagitta/thickness, side thickness).

Use the lamp with the three slits diaphragm to generate three parallel rays. Align the lens so as the rays impinge normally on the flat surface of the lens. Since at the first interface the beams are not deviated, such interface can be neglected. One can assume that the rays continue parallel in the plastic and that they are refracted by the diopter separating plastic and air. Verify that the rays are focused in a single point on the axis of the lens at a distance p from the vertex of the diopter. By applying the law for the diopter:

$$n_{PLASTIC}/q + n_{AIR}/p = (1-n_{PLASTIC})/R$$

to our specific case we have:

$$n_{PLASTIC}/\infty + n_{AIR}/p = (1-n_{PLASTIC})/R$$

and:

$$p=R(1- n_{PLASTIC})$$

with R<0 since the centre of curvature of the dioptre is on the left hand side with respect to the vertex.
Work out R by using the measurement of p and the value for $n_{PLASTIC}$ you found in the precedent tasks.
Measure with a caliper the dimensions of the lens and work out geometrically R. Compare the value with that obtained by means of the optical measurement.
Use the lamp with the five slits diaphragm to generate five parallel rays and verify that the thin lens gives rise to a spherical aberration if it does not operate under the paraxial approximation conditions. Also, verify that with the bulk half cylinder used for the study of the Snell's laws (thick lens) the aberration is even stronger.