Christoph Marquardt, Gerd Leuchs & Klaus Mantel

Experimental physics 3 for physicists

FAU Erlangen–Nuremberg, winter term 2018/19

https://mpl.mpg.de/en/leuchs/lehre/skripte.html

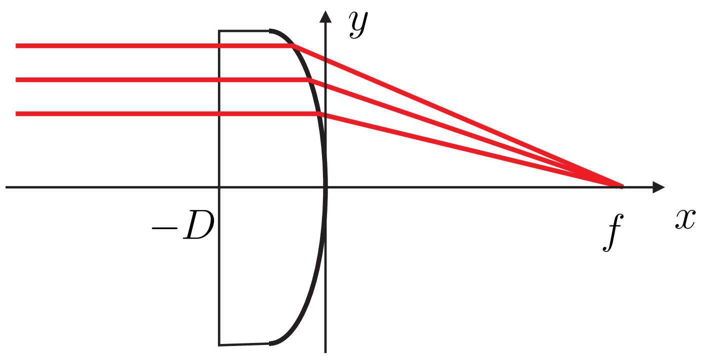
Problem sheet 7

13/14.12.2018

Problem 1: Aspheric lens

Fermat's principle states that optical rays follow a path of maximum/minimum optical length. Let us use this principle to design a perfect lens that will focus all parallel beams (even far off-axis) into a point (focus).

a. Calculate profile of a lens that will have a focal length f (that is a distance between the front surface of the lens and its focus). Take refractive index of the lens material as n. Use geometry depicted at the figure



b. Make comparison between the profile of an aspherical lens with a diameter 4 cm and a focal length 5 cm and plano-convex lens of the same focal length. Assume that refractive index of used glass is $n = 1.5$. Under the analysis plot surfaces of both lenses on the same plot.

Problem 2: Telescope

A telescope is an important optical system that can be composed from only two lenses (or "lens-like elements", such as spherical or aspherical mirrors). The characteristic property of a telescope is that the focal plane of the first lens on the image side matches the focal plane of the second lens on the object side. At the entrance of the telescope we may assume a parallel ray bundle (i.e. light from distant stars).

a. Formalise the above condition by deriving a relationship between the focal lengths f_1, f_2 of the two lenses and their separation d. Note that two telescope designs are possible: two converging lenses (Keplerian telescope or astronomical telescope) or a converging lens followed by diverging lens (Galilean telescope or Dutch telescope). You should take both into account. Prepare a drawing for each design, including beam paths and focal planes.

b. Calculate the overall ray transfer matrix (ABCD matrix) for each telescope design. Calculate the angular and transverse magnifications of these systems. Discuss the results in terms of practical applications, such as observation of astronomical objects or diameter expansion of an optical beam.

Problem 3: Fabry-Perot Interferometer

Figure below depicts principal optical scheme of an interferometer Fabry-Perot. The overall transmission of the interferometer can be calculated considering an interference of multiple beams in the following way. An incident plane wave falls at an angle θ onto the interferometer. One can assume there is no reflection at this mirror due to anti-reflection coating (AR). Then transmitted beam undergoes inside multiple reflections with the reflection coefficient $r < 1$. Note that upon the reflection there is a a phase jump of the field. The output beam is a sum of transmitted beams.

a. Calculate the transmission of a Fabry-Perot interferometer of the length $L_{\rm FP}$ as a function of the mirror reflectivity r and the wavelength of the incident light.
   Hint: $\sum_{n=0}^{\infty} x^n = \frac{1}{1-x}$.
b. For which wavelengths is the interferometer transparent? Determine the *free spectral range*, i.e. the separation between the resonant wavelengths.