INTRODUCTION

The ray optics approximation

Ray Optics is a basic tool that is required to access to modern applications of optics. It will be useful mostly to describe light propagation between the source and the detector.

The problem of electromagnetic wave propagation can (and sometimes must) be described rigorously using Maxwell's equations, but this is usually complex. In many cases, we can forget about the wave nature of light and deal more simply with trajectories along light rays. We then enter the domain of ray optics. One can indeed prove that, starting from Maxwell's equations and going to the limit of the wavelength going to zero, one gets the fundamental principles of ray optics. This demonstration is usually found in lectures or books about electromagnetic theory. In this course, we will start directly from Fermat's principle.

Since we neglect the wave nature of light, the phenomena of interference, polarization (direction of the electric field) and diffraction will be ignored (these are described in the wave optics course). In the same way, energetic considerations, which are an integral part of the radiometry course, will only be addressed here in connection with the geometric etendue of a beam of rays.

In an optical system, all these aspects are intertwined and it is not always obvious to choose the best approach. The clever optician, and in general the clever physicist, is the one who can choose the simplest and least inaccurate model to describe its system. In particular, one should use the simplification provided by ray optics as much as one can. For example, in the study of gaussian beam propagation, where diffraction plays a very important role (it is responsible for instance for the gaussian distribution of the intensity), reasoning in terms of rays gives a very good result as soon as you are away from the regions where the beam is focused. Another example concerns light propagation in optical fibers: before considering propagation modes which have a complex mathematical form, simple reasoning based on ray propagation can already explain a large number of phenomena.

A few experiments where the ray optics approximation cannot describe what happens:

- "shadow" of an object located in a laser beam: the geometrical shadow is surrounded by fringes due to diffraction (Fresnel diffraction in this case, at a short distance);
- diffraction by a small hole: light expands much further than what should have been a light ray.

In those examples, ray optics fails because we force a rapid variation of light on a length scale of the same order as the wavelength.

Structure of this ray optics course

The first part (corresponding to chapters I to IV) recalls the general principles of the propagation of light rays and a few applications (inhomogeneous media, prisms) then presents the problem of rigorous stigmatism, showing that most simple optical systems do not make perfect images.

The second part is devoted to the paraxial (or gaussian) approximation. It will be studied first in general for any optical system (chapter V), which will allow us to show that in that approximation all optical systems make perfect images (apart from chromatic aberrations). The properties of refractive surfaces (limit between two homogenous media), lenses and combination of dioptric systems (chapters VI to VIII), then those of mirrors and catadioptric systems (chapter IX) will be studied in detail.

The third part addresses optical instruments, still in the paraxial approximation, where simple optical elements are combined to perform specific optical functions (observing small objects from close-up or very far away, photography of image projection, etc). It comprises two chapters on general properties of instruments, in view of their magnification (chapter X) and their fields (chapter XI), and an introduction to their photometric properties (chapter XII).

These lecture notes will end on a chapter about chromatic aberrations, studied in the framework of the paraxial approximation. The chromatic aberrations, together with geometrical aberrations, will be part of the optical design course, however this chapter has been kept in these notes.

Bibliography (non exhaustive) relative to this course

In French (except when marked)

Title	*Authors*	*Editor*
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