Invited Paper

Optics education and training in France

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ABSTRACT

The teaching of optics in France has undergone important changes during the past twenty years. After a long period of domination of optics in physics teaching, the part of optics went down ; it is now increasing again both because the cultural role of optics has gained a better recognition and because of professional demand in the ever developing applications of optics in optoelectronic and optronic systems.

1 - INTRODUCTION

There is a clear interest in the international exchange of experience and new thoughts about the teaching of optics at all levels ; future optics education conferences in this new series will be an appropriate framework for presenting communications on such subjects. Because this is the first international optics education meeting however, it appeared useful to set the stage with a review of the status of optics teaching in various places. In this paper, keeping very close to the communcation that was presented by C. Froehly and prepared by P. Chavel, we review optics teaching in France in an historical perspective that allows to better describe its present state. Making a clear distinction between optics teaching for non professionals and optics teaching for professionals appeared as the most sensible outline.

2 - TEACHING OPTICS FOR GENERAL AND SCIENTIFIC CULTURE

2.1 - Secondary school

In the present french system, at age 11, practically everyone enters junior high school. An increasing fraction of the population, that is presently getting close to 50 %, finishes senior high school (around age 18) with the national degree "baccalauréat".

According to the national programs, the third grade in junior high school, named "classe de quatrième", has two hours per week of physics, and about 20 hours during that year are devoted to optics, covering :
- rectilinear propagation, shadows, light sources ;
- the concepts of a real image formed by a lens and of a virtual image formed by a magnifying glass ;
- experiments with a "camera obscura" (i.e. a black box fitted with a pinhole) and with a photographic camera ;

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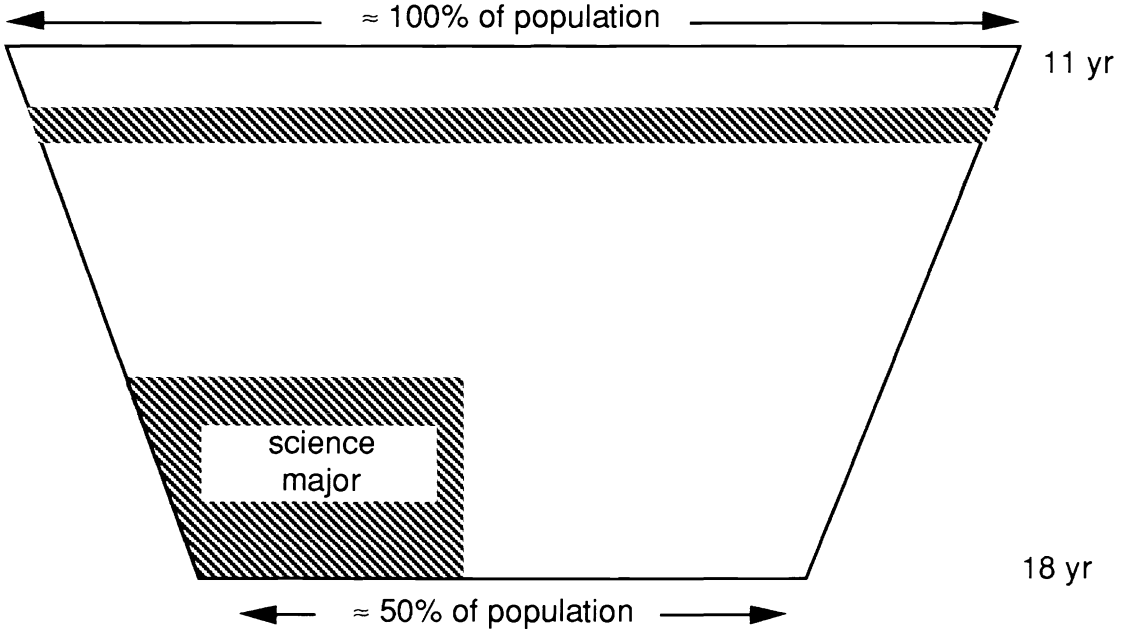
- illustrations and applications in astronomy.

It is appropriate to mention here that the general rule (and in most if not all cases also the reall practice) in France is that physics must be tought both from an experimental and a theoretical point of view, so that all physics courses include lectures, exercices and laboratory courses ; that rule applies to this first case as well as to all others in this article.

In two last years of high school - that for some strange historical reason are known as "classe de première" and "classe terminale" -, students select a major ; a little less than one half of the students choose science majors and they are then offered extensive physics and chemistry courses, including about 30 hours of optics :

- introduction to the phenomena and the laws of reflexion, refraction, interference and diffraction ;
- concept and elementary formulae for the dispersion by a prism and a grating ;
- thin lenses and their gaussian ; application to the photographic lens.



2.2 - Higher education

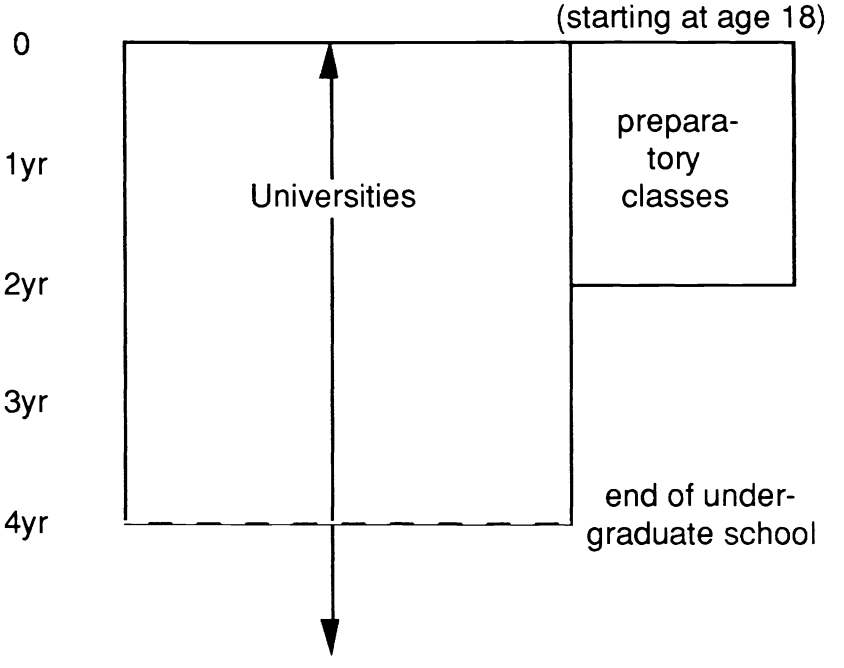
The diagram in this section shows a little part of the fairly complicated french higher education system ; only those cases where optics is taught for not directly professional objectives are shown ; a more complete version will be used in the next section :

- on the right, the two-year preparatory classes leading to the grandes écoles ; the preparatory classes have national programmes ;
- in the middle, the standard university cursus, with various degrees after 2, 3 or 4 years. Each university defines the details of its own cursus and there is no national programme.

Optics is treated as part of physics rather than electrical engineering and is included int the requisites for every physics student. We shall describe two examples,one from each of those two branches :

Optics programmes in preparatory classes through history :

The evolution of the textbook on optics for preparatory classes published by J.B. Baillère in the last half of a century is characteristic of the changes that took place in the way optics was considered in the physics cursus :
- in the 1936 edition ([1]), the 360 pages textbook is the main part of the physics course ; it is the only part published as a book. The content is exclusively geometrical optics, including aberrations, caustics and a systematic description of instruments ;
- in the 1963 edition (2), the 270 pages textbook is one of seven textbooks for the physics course. It includes a fair amount of gausiann geometrical optics and photometry and an elementary description of interferences and diffraction ;
- in the 1987 edition (3) ; the textbook is restricted to 170 pages, it is a still smaller fraction of the complete 5 volumes course ; it includes a rough overview of gaussian geometrical optics and a fair amount of diffraction and interferences, and the photoelectronic effect.
Discussions are presently underways for a new programme of the preparatory classes that would include more optics and make sure that every students spends some time getting familiar the laws of lenses ; more modern aspects of optics may be introduced.



Optics in physics cursus at the university through history :

The same tendency is visible in the optics course at the university, landmarked by some famous textbooks such as those of Verdet (4), Mascart (5), Bouasse (6), Bruhat-Kastler (7) and Fleury-Mathieu (8). Those texts, published in one fat or in several volumes, were supposed to cover all of optics and represented one of the milestones of scientific culture for the university student. At the end of the last century, the famous physics course at Collège de France, thaught by Mascart, was systematically an optics course. The close relation between optics and mathematics, and more precisely between geometrical optics and geometry, was certainly one of the reason for the high respect for optics. Nevertheless, those books cover the experimental and practical aspects of optics as well as the fundamentals. The part played by

optics may be measured by two simple indices : one hundred years ago, the examinations for the credentials for physics teachers in high schools ("agrégation") included about 40 % of optics (9). Around the middle of this century, the undergraduate physics cursus was divided into four parts, optics, thermodynamics, mechanics and electricity.

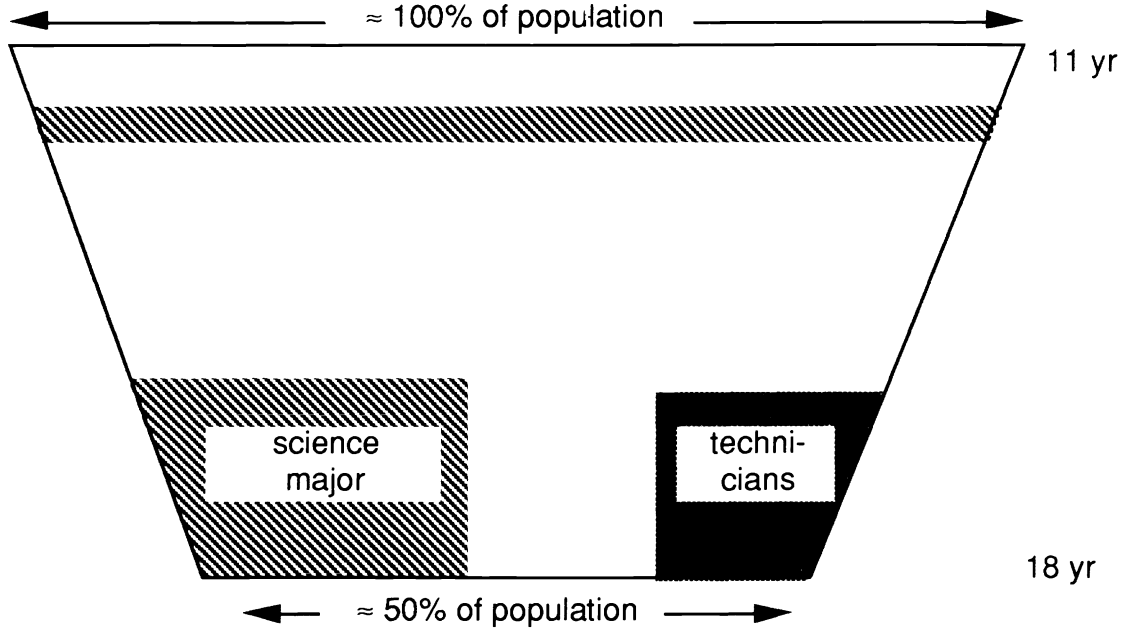
At present, optics is more diluted amongst the physics courses. For example, the physics cursus at Université de Paris-Sud, Orsay, includes :
- in the first year, 10 h of introduction to geometrical optics ;
- in the second year, 15 h on the applications of Maxwell's equations to diffraction, to Fresnel's equations and interferences, with experiments on lasers, gratings, Döppler velocimetry ;
- in the third year, a total of 65 hours cover physical optics, lasers, fiber optics, anisotropic media, spatial filtering, holography ;
- in the fourth year, optics is offered as a 100 h elective ; it includes intermediate geometrical optics, laser optics, coherence and Fourier optics.

To conclude this section, it is clear that after a period of domination optics went through of phase of low interest. Its modern aspects are starting to be considered with more attention in the various physics cursus.

3 - TEACHING OPTICS FOR PROFESSIONAL OBJECTIVES

3.1 - Secondary school

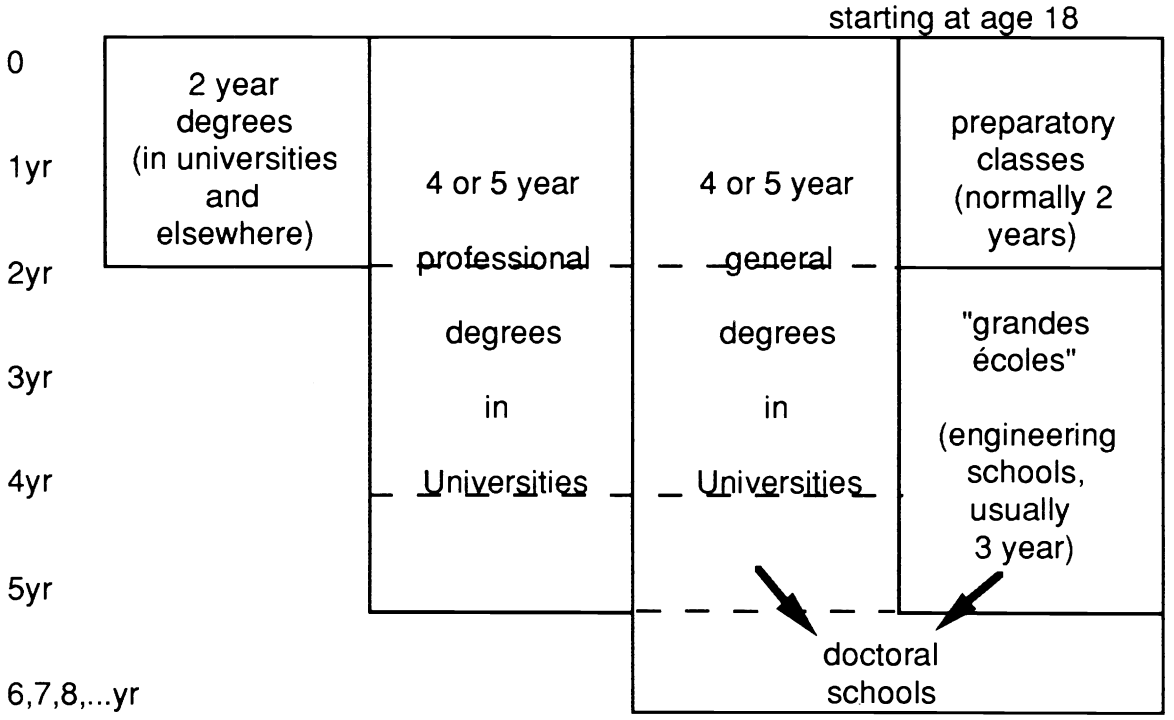
The first case to consider on the aspect of optics teaching for professional objectives is that of secondary school level training. The diagram below complements the one shown in section 2.1 and includes the case of high schools for technicians.



The degree of technician in physics includes a total of 100 hours of optics in two years, with gaussian optics, aberrations, lenses, the eye lens, the photographic camera, and the bases of optical metrology : refraction index measurement, interferences, spectroscopy,

photometry. The degree of technician in optics is delivered by only three or four schools in the country and has a 200 hours programme, including the following laboratory courses :
- measurement of focal length by conjugation
- measurement of frontal distance
- measurement of curvature radius
- measurement of focal length by association of lenses of opposite sign
- measurement of focal length of a thick lens
- measurement of the angle of a prism using a goniometer
- measurement of refraction index using a goniometer
- measurement of refraction index by the Abbe refractometer
- spectrogoniometer
- dispersion
- Young's fringes
- applications of Newton rings
- measurement of the field and magnification of a telescope.

3.2 - Higher education



The above figure complements the one shown in section 2.2 and includes :
- on the left siden, the two year professional degrees, that can be found in high schools and in universities under the respective names "brevet de technicien supérieur" and "diplôme universitaire de technologie" ;
- on the right side, the preparatory classes and the "Grandes Ecoles" ; among those, only the engineering schools are concerned with optics ;
- in the middle, the universities with the general and professional degrees. Doctoral schools are usually sound in universities, sometimes in Grandes Ecoles. The fifth year of higher education in universities is the first year of graduate school ; under the name "diplôme d'études approfondies", it offers courses and on-site training for a specialization. A few

universities offer specialized degrees at the 4 year level in such fields as opticall communications, optometry, optoelectronics.
Let us now cite a few examples of optics training in these institutions.

Two-year degrees :

Two-years degrees specialized in optics or photonics can be found in high schools in Lannion, Lille, Limoges, Morez, Paris and surroundings, and Saint-Louis ; an original scheme has been devised in Limoges, where the students alternate between one week at school and one week in a factory (Micro-Contrôle), helping in the industrial production of optoelectronic devices and systems. There is no two-year degree in optics in the universities, but the two-year degree "mesures physiques" includes a fair amount of optics (about 50 hours) :
- in the first year, gaussian geometrical optics ; two-beam interference and interference metrology ; diffraction gratings ; spectroscopy ; photography ;
- in the second year, Fourier optics ; lasers ; optics fibers ; optoelectronic devices ; photometry, colorimetry.

Five-years degrees :

At least 10 places in the country offer 5 years degrees with a optics as one major subject, eitehr as an elective or as the only major ; doctoral schools in optics can be found in Besançon, Grenoble, Limoges, Marseille, Nice, Orsay, Paris, Saint-Etienne, Strasbourg. The year of specialization in Limoges has 40 students and is entitled "optical and microwave communications". It includes a basic course of 72 hours in optics and 36 hours in optoelectronics and photonics, plus an elective 36 hours course on optical communication components and devices, including fibers and nonlinear optics.

The Ecole Supérieure d'Optique in Orsay, founded in 1920 (at that time in Paris), is the only Grande Ecole that offers a complete cursus in opticsendign with the degree of Optical Engineer. During the 3 years in the school, the students are exposed to over 1200 hours of optics, including 700 hours of courses and exercices, 300 hours of laboratory courses and 200 hours of directed research. Before graduation, they have a six-month on-site training in a laboratory (in many cases outside France).

4 - CONCLUSION

Optics education in France shows a large diversity. Noteworthy trends are :
- everyone in France gets exposed to optics at age 13 ;
- professional training exists at all levels (high school, 2, 4 and 5 years degrees and doctoral schools) ;
- optics has a long tradition of contribution to the basic scientific culture. That tradition has lost some of its importance, but seems to survive and seems even to have attracted some increased interest recently ;
- in the last 20 years or so, the development of fibers, optical telecommunications, optoelectronics, laser welding and optical systems in general have generated large needs ; new professional cursus are arising to fill the needs ; large demands exist on continuing education : optics training for professional objectives is in a phase of considerable growth.

5 - ACKNOWLEDGEMENTS

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