Discovering light: an alternative approach to the teaching of optics & photonics in primary and secondary school

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Abstract: We present a different approach to the teaching of optics in primary and secondary school which focuses on the development of hands-on experiments, enabling young students to have a closer look to optics and photonics.

1. Introduction

Light is an element that draws together many areas of human knowledge (physics, chemistry, biology, astronomy, engineering, art, etc.); moreover, optical phenomena and the technologies based on them are widespread in our daily lives. However, so far, little optics is taught at school, focusing only on basic geometrical optics and leaving behind the rest of optics curriculum as well as experiences towards applied optics laboratories. Kids learn at school how to code, how to build a robot, how to program an Arduino, but not what is a laser, how a camera works, or how the LEDs have changed the way of using light. One of the reasons of this lack of optics teaching can be due to the difficulty of targeting the teaching of light-related questions, as What is light? Where are optics and photonics present in our lives? What lies behind different optical phenomena? What is an optical instrument? How can we explain human vision? How optics is present in nature?

Teaching optics and photonics in primary and secondary schools is a great challenge for teachers, since most of the time scientific teaching is oriented to the knowledge of formulas that requires a previous adequate level. Furthermore, the books on optics and photonics are focused on university teaching where the student has a higher knowledge of mathematics [1,2], and the simulation software, such as OptiPerformer [3], hasn´t an adequate level of physics and mathematics for the primary and secondary school. A second common approach to solve teaching difficulties on complex optical phenomena is by taking advantage of the big amount of already developed experiments and experiences, most of them based on examples from nature or using new technologies (e.g., smartphone). In this way, websites, blogs, YouTube videos, etc. appear as perfect tools to allow teachers to have resources for their lessons, since tutorials to develop experiments with inexpensive and easily obtainable materials [4]. However, developing a complete optics curriculum requires gathering information from different sources and finding and checking the scientific explanations, making finally that teachers tend not to develop this kind of activities

Following this trend, here we show how to teach optics and photonics to young students by performing hands-on experiments which awaken the curiosity and help to understand even complex optical problems at a very early stage. The strategy is completed by a short and simple theoretical explanation of complex optical phenomena.

2. The way towards the vulgarization of optics among primary and secondary students

Outreach activities, in the form of activities in educational centers, museums and science fairs, allow us to spark the curiosity among the young and not so young population. A perfect example are the activities carried out by OSA and SPIE student chapters around the globe to spread knowledge about optics and photonics technologies. The authors of this contribution at some points of their scientific careers were members of the Institute of Optics-CSIC (Madrid, Spain) OSA student chapter (IOSA). This experience allowed us to build a broad and diverse group of optical

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workshops such as “how sunscreen works”, “measure the thickness of a hair”, “build a spectroscope”, “make lenses” or “build a camera”, covering all areas of optics from vision sciences to spectroscopy, nanophotonics, optoelectronics, imaging techniques, etc. (Fig. 1).

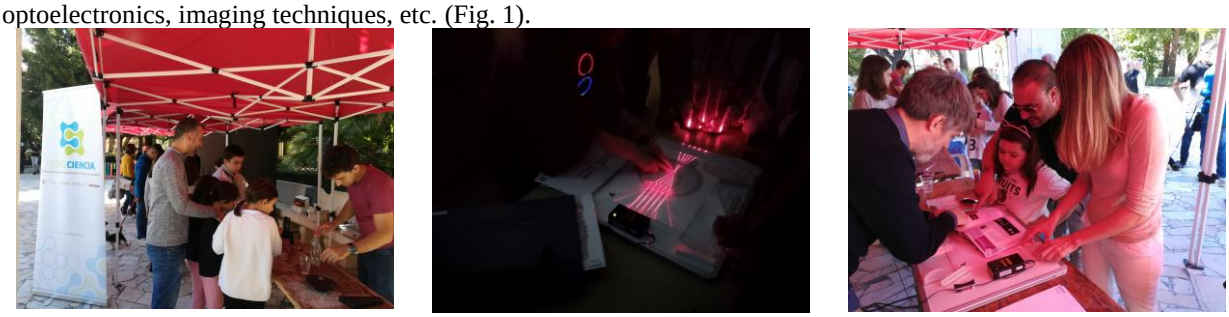

Figure 1. Optical workshops where ray tracing and how to reproduce the functions of the human eye with lenses are explained for the general public. Activity from the project “Discovering light tour” conducted by the the authors of the book “Discovering light” in collaboration with IO-CSIC OSA student chapter and performed at Aspe (Alicante, Spain).

However, outreach only is not enough to teach optics and photonics and push forward the knowledge about these technologies of the future. The primary and secondary educational curriculum has a very reduced content in optics, consisting exclusively of geometric optics that includes optical systems (mirrors and lenses), ray tracing, laws of geometric optics, the human eye and its defects and optical instruments (microscope, telescope, camera, etc.). This means that large areas of optics and photonics are not studied, at least explicitly, and causes students to start university degrees with significant deficiencies in these topics.

The collaboration with teachers allowed us to observe that, beyond a necessary training in optics and photonics for teachers, it is necessary to extend the curriculum from the area of physics to physical optics talking about the optical properties of light (polarization, color, etc.). A combination of small theory pills and hands-on experiments is needed to make this further knowledge of optics and photonics possible and accessible to all kind of schools.

That is why the authors, together with other colleagues, decided to write a "popular science book on optics and photonics" which include a brief theoretical introduction and a set of experiments and experiences to support this theory [5]. “Discovering light. Fun optics experiments”, edited by SPIE, OSA and CSIC , covers all the topics of optics and photonics, including their more technological or biological perspectives, and tries to be simple and informative without losing rigor. A few examples of these small theory pills and hands-on experiments are: “Change of Wave! Polarization and Birefringence” in which the concept of wave motion of light is explained and how it can be achieved that this movement is confined to a plane; “An Extraordinary Light: The Laser” in which the special properties of laser light are described; or “Nothing here, nothing there: invisibility with mirrors and lenses” in which it is shown how to achieve the invisibility of an object using optical elements.

For all these reasons, “Discovering light. Fun optics experiments” has become an excellent guide for primary and secondary teachers, which allows them to go beyond what is set out in the curriculum in a simple and entertaining way.

3. Conclusions

In this contribution we offer a series of useful tools for teaching optics and photonics at educational levels such as primary and secondary school, from simple experiences and workshops to a complete book including theory and experiments in optics and photonics that can be easily performed without the need for advanced prior knowledge or extremely specialized materials. We present a different way of disseminating optics and reaching the largest possible audience, being rigorous as well as entertaining, managing to arouse interest and curiosity for this exciting branch of physics.

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