Introduction to Fiber Optics and Telecommunications

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Introduction and principles

The evolution of technology and the development of new solutions that directly affects our everyday life demand the establishment of a sound scientific and technological literacy in our societies. From early ages our youngsters and pupils should have an enduring and efficient knowledge update especially in what concerns key proficiency and aptitudes. It is so important to promote the pedagogical conception development and production of new materials and equipment that may allow the introduction, in-school but also in informal learning environments, to basic concepts of recently developed high-tech including the underlying scientific theories.

In our days, in our Information (or better Knowledge based) Society, telecommunications play a fundamental, crucial, role. With the massive increase of the amount of information that needs to be exchange, virtually in real time, between all the points of the globe, all the telecommunications system had to be redesigned and renewed in the last decades. At present, optical fibers are at the foundation of all modern telecommunications system. It was its sprouting and development which allowed telecommunications development to the level that we now observe and to what is already foreseen in a near future. Thus optical fibers and waveguides are surely our day's one of the most important domains of physics and of Science and Technology in general.

The light propagation phenomenon in optic fibers, or waveguides in general, apart from being amply inquisitive and intriguing for the layperson (and the young are especially receptive to the solving of such strange and vanguard type "enigmas"), can be explained, on a first approach, with the use of some basic and fundamental rules of geometric optic. Hence, its study may not only serve as a way to motivate and stimulate pupils for the study of Physics and Sciences in general but also to contribute to the learning process of some concepts and basic competencies of the higher importance in physics in general and optics in particular, that are often even included in the natural sciences and physics curriculum of most of our primary and secondary EU schools.

In this perspective, the development of an introductory kit intended to the experimental study of wave guidance optical fibers and telecommunications, was

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considered essential to the scenery of almost total absence, as far as we know, of this type of pedagogical materials in Portugal.
The kit which consists on an integrated and coherent set of materials, equipment and introductory activities' manuals to Optical Fibers and Telecommunications, was developed in the frames of the Hands-on Science Network based on the authors' previous work supported by the former Instituto de Inovação Educacional.
This experimental kit to Optic Fibers and Telecommunications introduction enrols itself in the hands-on experimental approach to Science and Technology teaching/learning process that we advocate [1-3]. The use of this sort of material in the different levels of education, to whom it is intended to, will contribute to a more effective prosecution of the established specific objectives of learning in terms of acquired knowledge, but also on what concerns the development of critical spirit, observation capability, creativity and on pupils active and autonomous engagement in the critical analysis of problems and situations. Furthermore it may become an important motivational factor for the study of physics and natural sciences.
In a systematic way we could enumerate the pursuing set of objectives [1-9] with this type of activities: to establish a basic knowledge in the field and make it possible for pupils to acquire aptitudes and elementary competencies in a modern top importance domain as optical fibers and telecommunications is by hands-on experimental practice; to contribute to the development of the active study of sciences by means of hands-on experimentation; to contribute for teachers knowledge update concerning wave guidance optical fibers and telecommunications but also on essential aspects of optics; to enhance pupils commitment on physics and natural sciences study as earlier as at elementary school up to secondary vocational training and even higher education level; to encourage the use of experiments execution as essential science learning tool; to familiarize (/introduce) pupils to the scientific method, developing critical spirit and observation abilities as tools essential to all science related activities; to stimulate creativity; to stimulate pupils active and autonomous engagement on critical analysis of problems and simple situations in science and technology fields; ultimately inducing the recognition of the usefulness of physics and science in general in the everyday life [8].

Brief introduction to optical fibers and its use on telecommunications

Light (electromagnetic radiation) propagation in waveguides and optical fibers [10, 11] is a process indubitably fascinating however of complex explanation. Yet, the basic process is simple and well-known for a long time. It is all about total reflection or, if you prefer, total internal reflection of light. When light in its path finds a surface of separation (dioptre) between two mediums of different optical properties, part of the light is transmitted (refracted) and part of it is reflected. When the transition occurs from a more optically dense material to one with lower refractive index the transmitted light is shifted away from the normal to the dioptre in the light' incidence point. Increasing the inclination of the incident light impinging onto the dioptre, at a certain point, the light will "go out" perpendicularly to the dioptres' normal not being

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transmitted. Above a certain angle limit of incidence only reflection will occur: the total reflection. The process is easily envisioned in a transparent recipient with water. As well also the process of successive multiple total reflections where light bounces inside a material, as it happens in optic fibers, in a pipe or glass plate, or, simply … in a block of gelatine!

The properties and characteristics of different types of optical fibers readily available allow the replacement of conventional materials in wide range of situations such as in illumination and decoration, on several medical applications, artwork cleaning, in different types of sensors and … in telecommunications.

In this domain (of outstanding importance in nowadays life) the importance of optical fibers became unsurpassable and was the introduction of fiber optics that leads to the current level of development in the telecommunications area. As an example: a 5 mm diameter optic fiber cable can replace a 7,5cm diameter copper cable employed some years ago. It is 25 times lighter and lasts 2 to 4 times more. The cables can be longer - 20 km (even 40km) - than copper cables which demand repeaters from 1 to 1km. The major drawback is still the costs involved. Fiber optics are made of a rather pure glass - 1km of this glass is as or more transparent than a normal window' glass (5mm thick). But... while a normal telephone line (2 copper wires) allows the transmission of 24 simultaneous calls, with a pair of fibers 24,000 or even 100,000 to 150,000 simultaneous communications can be established. The profits in transmission capacity will be still more noticeable in the transmission of TV signals. While with UHF modulation it is allowed the transmission of 10 channels, with an optical-fiber cable system this number raises to 100,000 channels. Digital signals transmission capacities superior to 200 superior Tbit/s.km are commonly obtained.

The market' demand for optical fibers is ever increasing been the telecommunications area responsible for almost half of it. Application on long distance communications (transoceanic submarine cables) increased significantly in the 90's. Cable television (CATV) is now one of the main applications of optical fibers. Annually the world-wide optic fiber market puts into motion over 10.000 million Euros with a steady growth.

Among the advantages of optical fibers uses we can summarize the following: low loss in transmission; immunity to noise and electromagnetic interference; high broadband width (nowadays massive amounts of information need to be transmitted between distant places all over the world); information transmission security; is made of insulator material; small dimension and low weight; high flexibility (when coated) and resistance to temperature and chemical agents; and low cost. The disadvantages are: fragility of non-coated fibers; difficulty to execute derivations; delicate connection between fibers and other components; and sensitivity to cosmic radiation.

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Fiber optics and telecommunications introductory kit

So as to reach the proposed objectives, it was planned and established an integrated and logical set of experiments' guides materials and equipments (as simple and low-priced as possible) which allows the accomplishment of simple and attractive experimental hands-on activities of introduction to Optical Fibers and Telecommunications.

A set of 15 experimental works was prepared, with increasingly complexity in order to promote the improvement of our youngsters critical and autonomous engagement along this learning process. First it starts with light guidance' observation in solids (glass blocks, prisms...) and liquids (tap water flow...) and, eventually, light guides made of eatable gelatine (for pupils of elementary and pre-school). Thereafter we move forward to the observation and study of different types of optical fibers (always plastic ones or strongly protected in order to prevent accidents) including fibers for ionizing radiation detection, the concept and use of remote illumination and image manipulation, fiber cables use on monitors and on rudimentary scanners. The preparation of fibers and cables as well as with its connections will be followed by the study of light propagation on different types of fibers and with diverse constraints. Light sources and detectors will be studied and a direct voice communication system (energy conversion: sound-electric-luminous-electric-sound) is to be set-up and used. Finally it will be assembled an elementary telecommunication system using optical fibers introducing also a first approach to the information codification problem.

In what concern the manuals/guides, it was intended to cover all sorts of doubts and questions that pupils may have, with an intuitive structure and simple and direct explanations as complete as possible, always appealing to the student's critical active intervention.

The protocols are simple and formative just pointing the student/group towards the execution of their work'. Frequent appeal is made towards critical reasoning and careful observation. Attention is drawn to some situations that should be observed and critically analyzed in a more diligent manner. In general, the teacher or monitor will be responsible for this task and will also have to raise some questions (whenever possible making use of comments, questions or commentaries pupils will make along the process) of informative and formative nature leading the student to raise questions and open new insights. Whenever possible it is suggested that pupils should be allowed to establish the way and steps of execution of their experiments and also project new, their own, experiences.

The carrying out of all experiments, in the proposed order, will be relatively time consuming and require the learning process to be consolidated. Thus the kit may be used in succeeding years from the first to the last years of school.

Conclusion

The goal of the physicist is to discover understand and explain the physical world which surrounds us.

To observe (seeing critically) is the first and essential step in this process. Then doubts and problems should be raised and critically analyzed. New situations and

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sceneries are to be foreseen and constructed. Always in an active and engaged way.
The students should observe discuss convey and criticize their own conclusions and, as possible as it can be, establish/decide what to do next… constructing their own knowledge. Making Science...
The enhancement of student's specific knowledge is important but Science demands work responsibility and Method. It is precisely in this direction that the teacher/educator first efforts must focus.
The exposure to knowledge or the access to its sources is not a sufficient condition so that the learning occurs!

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