

Experiencing Photonics: An Experimental Concept to Inspire the Next Generation of University and High School Students

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Photonic technologies are central to modern research, industry and daily life. However, academic and school curricula often lack time for intensive and hands-on engagement with this field. To address this gap, an experimental concept with educationally prepared materials has been developed to convey selected photonic topics to high school and university students.

1 Introduction

Photonic technologies play a crucial role across various research and industrial fields, including medical imaging, spectroscopy, optical communications, and quantum technology. Despite an increasing demand for highly qualified professionals in these areas, foundational photonic concepts are progressively disappearing from German school and university curricula. A prime example is the laser; despite its indispensability as a coherent light source, its working principle is no longer a standard curricular requirement in high school education. In Baden-Württemberg, laser physics is merely an elective topic in advanced high school courses alongside topics like relativity and astrophysics [1]. This reduction of school content in the field of optics prevents students from developing an early interest in optical sciences, ultimately contributing to lower university enrollment in photonics-related disciplines. To counter this educational deficit, a dedicated photonics learning module was established within the student laboratory at the University of Stuttgart, providing high-quality experimental setups supplemented by accompanying teaching materials. The following sections outline the structural design of the student laboratory and its integration into university education, followed by concrete experimental implementations using polarization as an example.

2 Overview and application of the student laboratory experiments

The student laboratory at the physics education research group of the University of Stuttgart enables high school classes to conduct hands-on experiments on modern physics topics. Due to significant financial costs and technical complexity, the required equipment - covering fields such as radioactivity, atomic physics, quantum technology, and photonics - is typically unavailable in standard school environments. The core educational principle relies on self-directed experimentation using authentic, research-grade laboratory equipment. Educational research demonstrates that working with

genuine scientific instruments and materials enhances student interest and motivation in STEM disciplines [2, 3].

For pre-service physics teachers at the University of Stuttgart, active participation in the student laboratory for at least 24 hours of teaching support per year (approximately six school visits) is a mandatory component of their degree program. This integration serves a dual purpose in teacher training: first, prospective teachers practice and refine their pedagogical skills in a controlled, supportive environment; secondly, they gain practical experience in experimental preparation, assembly, and execution. Furthermore, these experimental setups are not restricted to school visits. In an adapted form, they can be also integrated into university courses for students, such as advanced modules on physics education for teacher students and introductory and advanced physics laboratory practicals for students in a wide variety of physics-related fields.

3 Overview of the Photonics Experiments

The photonics experiments are categorized into five core topics: light sources, photodetectors, properties of light, photonic technologies, and photonic applications. Experimental setups and accompanying digital learning materials (primarily interactive H5P-modules within Moodle courses) are continuously developed, evaluated, and refined through bachelor's, master's, and doctoral theses.

The section on light sources focuses on a comprehensive overview of light generations and emission characterization, comparing for example thermal emitters, gas discharge lamps, fluorescence, and various laser systems characterized by distinct wavelengths and emission bandwidths. Photodetectors examine the operating principles and important characteristics of thermal detectors, photoresistors, photodiodes. In the properties of light module, students determine fundamental optical parameters, including polarization, Gaussian beams, and spectral compositions using spectrometers. The topic of photonic technologies focuses on

developing practical alignment skills, such as optical fiber coupling, which secondary and undergraduate university students typically lack. Finally, photonic applications demonstrate applied setups including Michelson interferometry, quantum key distribution systems using the BB84 protocol, and different single-photon experiments.

4 Experiments on Polarization

Polarization is a fundamental property of electromagnetic waves with widespread applications in quantum entanglement, laser physics, liquid crystal displays, and glare reduction in photography. Linear polarization is a mandatory topic, but it is covered only briefly in high school physics courses [4]. Even at the university level, polarization is typically part of introductory physics lectures, but often only shortly.

An engaging contextual entry point is 3D cinema technology. It bridges the gap between theoretical formalism and practical application. Comparing historical and modern 3D visualization techniques allows students to evaluate different physical approaches to achieve stereoscopic vision. The experiment begins with anaglyph technology shown in figure 1, which uses colour filters, to first understand the principle behind how an artificial sense of depth is created. Next, linear polarizers replace colour filters to separate left and right eye images. Finally, quarter-wave plates are also used to illustrate the technique currently deployed in commercial cinemas (Fig. 2).

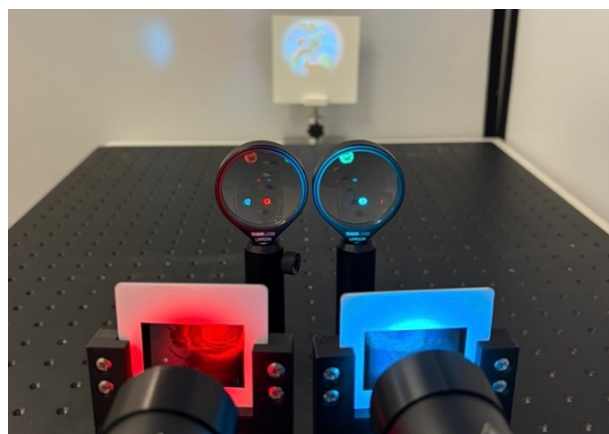


Fig. 1 Experimental setup of the 3D cinema using anaglyph technology, where the slide is illuminated with red light on the left and cyan light on the right. Both images are projected onto the screen using lenses and can be viewed with anaglyph glasses.

Through this real-world application, core concepts such as the transverse nature of light waves, polarizer mechanisms, birefringence, and component-wise wave addition are taught. The 3D cinema experiments were evaluated across 8th-grade classes, basic and advanced high school physics courses, and with university students. Participant feedback was very positive, primarily because of the

illustrativeness, its relevance to real life, and the direct connection between theory and practical application. In addition, the fact that the participants were allowed to conduct their own 3D cinema was very well received. Following final revisions, the materials will be permanently integrated into the student laboratory and offer potential for implementation in introductory university practical courses.

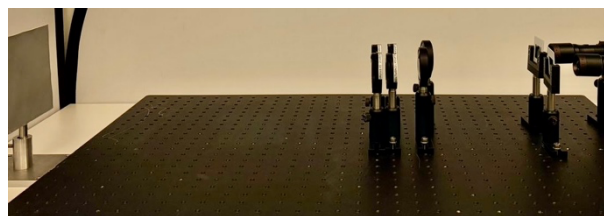


Fig. 2 Experimental setup of the 3D cinema based on circular polarization, where light passes through the slide, lenses, polarizing filters, and retardation plates to become left- and right-circularly polarized.

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