Enriching the Course Material for Principle and Technology of Laser: Structured Light as an example

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Abstract: Structured light is one of the research frontiers in optics and phonics. By introducing structured light into principle and technology of laser, the physics insight can be enhanced, and the simulation and experimental capability can be well trained.

1. Introduction

Principle and technology of lasers (or taught separately) has been a compulsory course for undergraduates in many universities. The content of laser resonator is usually one of the key point in these courses, where the propagation of electromagnetic wave, the eigenmodes of the electromagnetic field and the resonator, the selection of modes is introduced, the knowledge and impression for the field distribution of laser beam is thus initially shaped, for example, Hermite-Gaussian mode and Laguerre-Gaussian mode, or the superposition of several eigenmodes. Meanwhile, there is growing research and application interest in structured light [3, 4], which has been an emerging topic for optics and photonics, as well as interdisciplinary investigation. It has been proofed that structured light can be generated directly from a laser resonator [5]. In this paper, we will briefly show that introducing structured light in to the course can enrich the content of the course, help to rising up the interest of the students and training them comprehensively.

2. Enhancing the fundamentals of laser

Structured light is derived from the ability to tailor light, usually referring to the spatial control of its amplitude, phase, and polarization [5]. Introducing the concept and content of structured light into the course can help to enhance the mastering of the fundamentals of laser. For example, laser modes that carry orbital angular momentum (OAM), vector beam that contains complex polarization state (azimuthal modes, radial modes, or superposition of the modes), "non-diffraction" beam like Bessel beams and Airy beams, laser beam has unique intensity profile such as donut beam and flat-top beam, can be produced from a laser cavity.

Students can learn from those "new" content that the output beam from a laser can be more complex than that contains a "Gaussian" shape through cavity design. As indicated in ref.[3] that the first structured light may be attributed to the classical and famous interference fringes observed by Thomas Young in 1803, which is relatively easy to be observed after the invention of the laser. Then the interference between/among the structured light may again propose the topic for study and investigation, which combines the content of laser and physical optics. In addition, those structured light usually has interesting propagation properties that different from the knowledge learned from classical textbooks.

3. Challenge in computer simulation

Computer simulation is one of the basic capability required for undergraduates, which can help to shape the logical thinking. Especially, computer simulation of laser resonator can help to analysis and design a high-performance laser. Up to now, there have been sufficient open computer simulation sources for the classical eigenmodes from the resonator (Hermite-Gaussian mode, Laguerre-Gaussian mode, and the Linearly Polarized (LP) mode from fiber optics), which is written for different computer programs such as MAPLE and MATLAB.

More complex field distribution can be calculated through the method from Fox and Li [6]. Nevertheless, because of the classical course and classical content, the computer simulation is well known and stay almost unchanged for years. By introducing structured light into the course, the content and task for computer simulation of laser resonator can be significantly enriched and broadened, and the technical challenge for computer simulation is also increased because of the "new concept" and their continuously broadening frontiers.

4. More experimental techniques and results

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Structured light is far beyond a scientific concept, it has been widely demonstrated, manipulated and applied (which would be briefly discussed in next section). In ref. [7], the authors have shown the output laser mode can be flexibly controlled through a "digital laser", in which one of the cavity mirror (the basic component for a laser resonator) is replaced by a phase only spatial light modulator. The capability can be further trained by multiplexing 200 spatial modes with a single hologram, as demonstrated in ref.[8]. Those experiments, if built into teaching tools, can bring a vivid class environment because the function of shaping the laser is introduced, in addition, the principle and usage of the component for structured light generation (spatial light modulator, digital micromirror devices, and so on) can be learned and mastered, which could broaden the experimental study of classical lasers. In addition, if the propagation property and the laser-matter interaction phenomenon is to be investigated by using this "new" laser, the whole experimental tools and even the classroom could be re-considered and re-invented.

5. Conclusion and prospect

As indicated in ref. [9, 10] that these spatially complex optical fields have attracted numerous attention such as microscopy, metrology, micromanipulation, laser communication, material processing, and so on. One (or a little more) lectures that covers the research frontiers of structured light can not only increase the curiosity, but also stimulate the self-learning interest for further investigation. It has been briefly discussed that if structured light is introduced into the classical principle and technology of laser course, the course material can be comprehensively enriched, the fundamentals of laser beam can be enhanced, and the simulation and experimental teaching of a "laser" will even be re-defined. Nevertheless, it is to be noted that, principle and technology of laser has become a classical course for years in many universities, so usually it has relatively steady content and even fixed "class hour" for each chapter, it is actually challenging to merge the new content that covers all the aspects of structured light into the classical course, which requires continuously exploration and optimization.

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