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Report on the Doctoral Thesis

"Experimental investigation of spatiotemporal nonlinear phenomena in multimode optical fibers"

submitted by **Karolina Stefańska**

The thesis submitted by Karolina Stefańska deals with the field of nonlinear photonics, and more precisely with spatiotemporal nonlinear phenomena in guided-wave optics. This area has been extensively studied over the past two decades and remains an active field of research nowadays, with ongoing advancements in both fundamental physics and potential applications. Ms Stefańska's work is particularly original, as she has opened and explored new directions in the field throughout her PhD.

In my opinion, the thesis is of an exceptionally high standard, both in terms of presentation and scientific content. It is very well written, with a clear and rigorous style that makes it easy to read and comprehend. The figures are clear and of excellent quality, and the bibliography is thorough, given the extensive literature in this field. All information necessary for understanding the results is included. The scientific content, which will be detailed below, is also of an outstanding level, characterized by its scientific rigor and the depth of its analyses.

After a general introduction (Chapter 1) that places Ms Stefańska's work in its context, the main body of the thesis is organized into four principal chapters. Chapter 2 is a comprehensive introduction to the fundamental concepts of linear and nonlinear light propagation in optical fibers, essential for understanding the rest of the thesis. It includes a detailed and accurate description of fiber mode properties, leaving the feeling that the candidate perfectly masters the fundamentals of guided wave optics. The chapter also reviews the basic linear and nonlinear properties of optical fibers, which, although more conventional, is still well-written and informative. The following three chapters form the core of Ms Stefańska's doctoral work. While their topics may initially appear quite distinct, she successfully managed to find a story line through the increasing complexity of modes involved in nonlinear processes, ultimately providing a coherent structure to the entire document.

Chapter 3 explores the Raman-assisted generation and trapping of solitons between two polarization components through cross-phase modulation in two highly birefringent photonic crystal fibers. Although the literature on this specific topic is already quite extensive, making the novelty of this chapter somewhat limited, a series of detailed experiments is presented for both fibers. The impact of laser power, fiber length, and input polarization is systematically investigated and analyzed. These numerous and meticulous measurements demonstrate Karolina Stefańska's strong experimental skills, methodology, and rigor. However, I found that there were too many experimental results presented; it would have been more effective to isolate and summarize the key findings to emphasize the studied phenomenon without overwhelming the reader. Nevertheless, the chapter contains some clear and notable results that have been published in a peer-reviewed journal.

The following chapter focuses on the study of quasi-CW four-wave mixing in graded-index multimode optical fibers. It begins with a comprehensive presentation of the various theoretical tools used to analyze this process and their limitations, particularly in the case of large detuning. I found this section highly interesting, comprehensive, and informative. It demonstrates the candidate's critical perspective with regards to published work and helps to clarify the ambiguities that sometimes surround such analyses in the literature. Ms. Stefańska then presents an extensive set of experimental results, interpreted in terms of intermodal, intramodal, and cascaded four-wave mixing (depending on the fiber used) based on the thorough model she introduced earlier. The highlight of these experiments is the first observation of a strong mid-IR Stokes peak, which represents a significant experimental achievement. Once again, the experiments are meticulously conducted, the methodology is remarkable, and their interpretation is clear. I found this chapter to be very thorough and informative, further enhanced by the candidate's excellent writing skills.

In Chapter 5, Ms. Stefańska presents an original experimental observation of discrete conical waves in a multimode step-index fiber, drawing an analogy with the well-known conical wave emission in bulk media. I consider this the most impressive achievement of her PhD, as the experimental complexity is notably higher than in the previous chapters, yet the quality of the measurements remains exceptional. The results demonstrate a solid understanding of the underlying nonlinear dynamics, interpreted in terms of intermodal dispersive radiation emitted from an optical shock. Both the quantity and quality of the results in this chapter are remarkable. The interpretation and analysis are highly relevant, allowing the candidate to showcase her scientific maturity by linking the discrete modal content of optical fibers to the continuous set of modes characteristics of free-space media. It is also important to note that measurements involving modal content analysis in highly multimode systems are often delicate; the excellent agreement between the measurements and numerical simulations or theoretical predictions further highlights Ms. Stefańska's ability to perform high-level experimental research.

Through her doctoral thesis, Karolina Stefańska has developed impressive experimental skills, and her rigorous analysis clearly demonstrates a high degree of scientific maturity. She has leveraged these skills to conduct high-level research that is internationally recognized, as evidenced by three first-author publications in highly-ranked peer-reviewed journals. In view of the high quality of her doctoral thesis, I recommend proceeding to the oral examination without any hesitation.

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Alexandre Kudlinski