Nonlinear dynamics of unidirectionally coupled semiconductor lasers

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ABSTRACT

Nonlinear optics plays a key role in the study of complex dynamics in semiconductor lasers, with major implications for next-generation photonic technologies. In this work, we provide an overview of the nonlinear phenomena observed in different types of semiconductor lasers, particularly distributed feedback (DFB) lasers and broad-area vertical-cavity surface-emitting lasers (BA-VCSELs). The focus is on the emergence of complex dynamics, including chaotic regimes, as well as the exploitation of these behaviors for chaotic synchronization.

Two experimental studies have already been conducted and published in this context. The first investigates optical injection and chaos synchronization in DFB lasers, highlighting synchronized regimes and their robustness for cryptographic applications. The second explores the fascinating nonlinear dynamics of BA-VCSELs, revealing a self-induced chaotic regime that has been scarcely studied until now. Additionally, ongoing work examines unidirectional injection between two BA-VCSELs to further understand dynamic interactions in these multimode systems.

These investigations contribute to a deeper understanding of nonlinear behaviors in semiconductor lasers and open promising perspectives for applications in secure communications, chaotic signal generation, and optical neuromorphic computing.

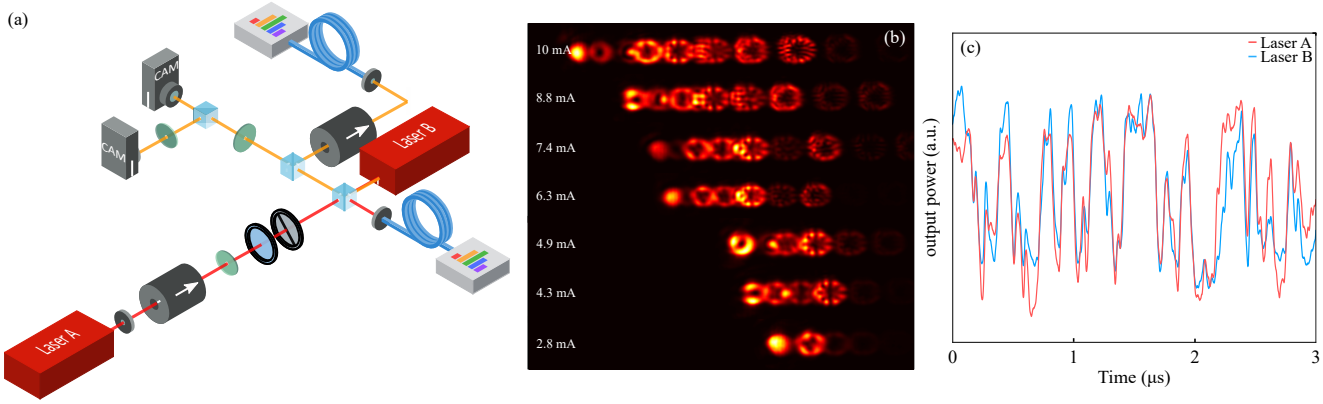

Figure 1. (a) Schematic representation of the experimental setup. Laser A: Master laser; Laser B: Slave laser. (b) Evolution of the spatio-spectral images for u polarisation in function of the pump current for the master laser. (c) Times series of the master (red) and slave (blue).