Non-Hermitian Coherent Microcavity Laser Arrays

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Two coupled photonic oscillators can exhibit modal properties that have quantum mechanical analogs, such as non-Hermiticity and parity-time symmetry (PTS) [1, 2]. We discuss a coupled pair of vertical cavity surface emitting laser (VCSEL) diodes, such as shown in Fig. 1(a) to study these properties. The VCSEL array is designed to promote optical coupling while each element is electrically independent, allowing for variable gain or loss to be applied. To understand the supermode properties we have used coupled mode theory [2] and have recently extended the theory to semiconductor lasers by also incorporating the rate equations [3].

From our analysis Fig. 1(a) also shows the predicted modal behavior as a function of varying carrier injection and gain, which includes Hermitian, non-Hermitian, and PTS behavior at an exceptional point [4]. Fig. 1(b) shows an representation of the coupled array with independent carrier injection into cavity A and B, the carrier reservoir, the resulting stimulated emission producing the photon reservoirs that are coupled, and finally the resulting optical output. Fig. 1(c) and (d) shows the experimentally observed far-fields and near-fields, which are in agreement with our coupled rate equation analysis. This research is an important step to leverage non-Hermitian photonics into practical applications, examples of which will be discussed.

Fig. 1: (a) 2x1 coupled VCSEL array and simulated modal properties; (b) representation of various modal behaviors; (c) measured far-field and (d) near-field showing modal behaviors.

References