Ultrafast pulse generation in integrated arrays of Anapole nanolasers

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One of the main challenges in photonics is the integration of ultrafast coherent sources in silicon compatible platforms at the nanoscale [1]. Generally, the emission of ultra-short pulses is achieved by synchronizing the cavity modes of the system via external active components, such as, e.g., Q-switch or saturable absorbers. Consequently, the required optical setups are complex and difficult to integrate on-chip. To address these difficulties, we propose a novel type of integrated source based on the spontaneous synchronization of several near-field nanolasers. We design our near-field lasers by considering the nonlinear amplification of non-radiating Anapole modes [2]. Anapoles represent an intriguing non-conventional state of radiation, whose excitation is responsible for the formation of scattering suppression states in dielectric nanostructures [3]. Due to their inherent near-field emission properties, an ensemble of anapole-based nanolasers represent an ideal candidate to investigate and tailor spontaneous synchronization phenomena in a silicon-compatible framework. Additionally, their mutual non-linear interaction can be precisely controlled within standard nanofabrication tolerances.

We investigated the nonlinear emission from an ensemble of anapole-based nanolasers with our Finite-Differences in Time- Domain simulator NANOCPP, which solves a dispersive set of 3D Maxwell-Bloch equations without approximation [5–9]. The single nanolasers were composed of three-dimensional III-V semiconductor nanostructures. By inducing the formation of a fundamental anapole state in correspondence of the emission frequency of the amplifying semiconductor, we obtained a lasing emission composed of purely evanescent waves (Fig. 1-a). By coupling several anapole sources the system behaves as an integrated ultrafast pulse generation device (Fig. 1-b), in which the collective emission is collected by a silicon waveguide. Interestingly, the system achieves a stable mode-locked emission with optical pulses of less than 100fs (Fig. 1-c). The pulse duration and the repetition rate of the system can be tuned by varying the relative position of the anapole emitters, as shown in Fig. 1-d where the system is optimized to produce *ps* optical pulses.

Fig. 1 Generation of ultrafast pulses from a chain of anapole-based nanolasers. (a) Near-field emission from a 3D anapole nanolaser. (b) Schematic representation of our ultrafast generation device. (c,d) Steady-state emission from the system. The pulse duration and repetition rate can be controlled by optimizing the geometry of the system.

Example References

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