Topological photonics and topological lasers

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Topological Photonics is an emerging and novel field of research, adapting concepts from condensed matter physics to photonic systems adding new degrees of freedom. After the first demonstrations of topological photonic insulators [1,2], the field has moved on to study and exploit the inherent non-hermiticity of photonic systems and the interplay with their topological nature. In my talk, I will attempt to give an overview about the quickly emerging field of topological photonics. In this context, I will discuss topological lasers as a prime example of using topological concepts potentially for new technologies in the broad context of synthetic (photonic) matter. Examples will be given from novel photonic lattice devices resulting from the coupling of individual vertical III-V semiconductor microresonators.

Here, the so-called exciton-polaritons – hybrid states of light and matter – can emerge in the strong coupling regime. By choosing precise lattice geometries we are able to tailor optical band structures realizing novel photonic lattice. Here, the specific geometry as well as the hybrid light-matter nature allow for ways to break time-reversal symmetry and implement topologically non-trivial systems. Here, we were able to experimentally demonstrate the first exciton-polariton topological insulator, manifesting in chiral, topologically protected edge modes [3]. In order to study topological effects in combination with optical non-linearities, so-called topological lasers have been envisaged and realized. They exploit topological effects to efficiently couple and phase-lock extended arrays of lasers to behave like one single coherent laser. The major drawback so far is that the emission appears in the plane of the topologically protected light propagation, thus hindering light extraction. Here, we have presented the first experimental demonstration of a topological insulator vertical cavity laser array [4], using the so-called crystalline topological insulator model. Starting for the above mentioned examples, I will give an overview of the field of topological optical lattices and lasers and give an outlook on emerging novel materials beyond III-V semiconductors, such as organic materials, transition metal dichalcogenides and perovskites [5,6].

[1] Rechtsman et al. Nature **496**, 196–200 (2013).

[2] Hafezi et al., Nat. Photon. **7**, 1001–1005 (2013).

[3] Klembt et al., Nature **562**, 552–556 (2018).

[4] Dikopoltsev et al., Science **373**, 1514–1517 (2021).

[5] Dusel et al. Nano Lett. **21**, 6398–6405 (2021).

[6] Shan et al., Nat. Commun. **12**, 6406 (2021).