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Towards Electrically-Pumped Monolithic InP-Based Topological Lasers

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Abstract: We report the design and process development efforts made towards realizing electrically-pumped InP-based topological lasers. Preliminary data on optically-pumped structures reported here serve as the stepping-stone for achieving this new class of lasers. © 2021 The Author(s)

OCIS codes: 140.2020 Diode lasers; 140.5960; Semiconductor lasers; (350.1370) Berry's phase; (140.3948) Microcavity devices.

The recent advent of topological concepts in photonics has brought into attention the significant potential of this area to obtain increased coherence, reliability and lowered threshold in arrays of microlasers [1]. Motivated by the demonstration of optical pumping in a topological laser, we engaged in the fabrication and optimization of electrically pumped topological lasers [2] with various topologies [1,3] monolithically integrated. In particular, we are targeting arrays with toroidal shapes [4] that provide areas for additional feedback loops, and Quantum Hall Effect structures [3]. Here we report our progress in material and device processing towards these goals.

Figure 1 shows a tight-binding model of microring arrays with an implementation of synthetic phase similar to Ref. [1]. The inside and outside topological modes have spectrally separated densities of states. The role of this type of simulations is to explore the scalability of mode power with the size of the array and the spatial separation between inner and outer perimeter modes as a function of torus width. These simulations are informed by FDTD modeling of coupling parameters between rings.

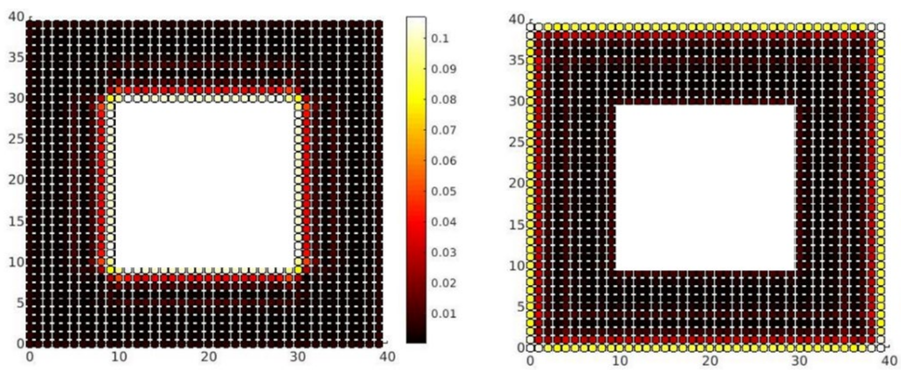

Figure 1. Modeling of toroidal microlaser arrays, with inner and outer perimeter topological modes. (In collaboration with AFRL- Sensors Directorate). The mode power increases linearly with the lateral size of the array. Shown: 40 × 40 array, torus width = 10 ring layers. For widths less than 4 layers we notice mode overlap.

A schematic of the epitaxially grown InGaAsP/InP heterostructure wafer structure shows the location of gain region in the resonators. The periodic array of ring resonators and link resonators are realized to mimic the quantum spin Hall effect of photons. The topological edge modes could occur when pumped at the perimeter with a lossy interior. We currently succeed in fabricating the optically pumped structure. Figure 2 displays the scanning electron microscopy (SEM) images of the etched devices. Square-shaped mesas with a radius of 5 µm, as shown in Figure 2(b), were defined by electron beam lithography and subsequent dry etching. All the structures were dry etched and smooth sidewall and almost vertical sidewall were obtained. An EBL resist was used as etch mask for the CH_4-Ar-based dry etching with an Oxford Plasmalab 100 ICP-RIE system. The $CH_4/H_2/Ar$: 4/40/20 sccm plasma had a RF/ICP power of 150/200 W at 4 mT.

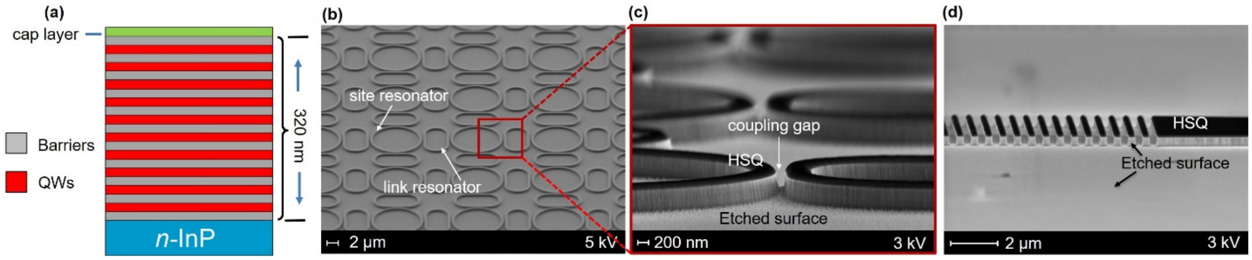

Figure. 2. (a) Schematic of the epistack of optically-pumped topological insulator lasers, (b) plan-view SEM images of the dry-etched topological structures, showing a part of the (b) 10 × 10 array, (c) expanded view of the link and site resonators and (d) vertical grating coupler for light outcoupling

Here we report the recent progress made for achieving electrically-pumped monolithic InP-based topological lasers. Details of these experimental results obtained will be presented in the conference. More efforts are underway to realize such devices with exciting properties and functionalities.

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4. References

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