Towards Topological Laser Based on Dielectric Photonic Crystals

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Abstract

Topological insulators constitute a new phase of matters insulating in bulk but conducting at edge or interface [1, 2]. With topological protection, the edge states are robust against disorders and defects. This concept was first proposed for electronic systems and has recently been applied to photonic systems, including photonic quantum anomalous Hall effect and quantum spin Hall effect [3, 4]. The photonic topological insulators provide ideal platforms for photonic applications, which always require defect-tolerant properties to reduce losses. However, most photonic topological states work in the microwave frequency band, and require external magnetic field, which hinder their usages in applications.

Wu and Hu proposed a scheme to achieve topological photonic crystals by using dielectric materials [5]. Starting from honeycomb structure, they adjust the locations of pillars and get a pair of topological edge states with opposite orbital angular momenta, which play the role of pseudospin, at the interface between topological and trivial photonic crystals. Because only dielectric materials are used, this scheme can be pushed to the optical frequency band and no external magnetic field is required.

In the present work, as the cavity for lasing [6], we construct the topological interface states achieved in the above scheme. In a tight binding picture, the equation of motion of the system can be written as [7-9]:

$$i\dot{c}_n = \sum t_{nm} c_m + \left(\frac{i g_n}{1+|c_n|^2} - i\gamma\right) c_n$$

where c_n presents the wave function of photonic atom at site n, t_{nm} is the hopping coefficient between nearest-neighboring sites of honeycomb lattice, γ is the loss uniform in the system, and g_n is the gain at site n. By adjusting the real-valued hopping coefficient t_{nm}, we can design topological and trivial photonic crystals [7], between which there yield topological interface states.

By numerical solving the above equation, we successfully observe a pseudospin-dominated lasing behavior where the topological interface states are active. Single-mode lasing [8, 9] is confirmed in a considerable range of gain value.

To summarize, we have constructed a lasing system with the cavity composed by the topological interface channel in dielectric photonic crystals. Our system shows typical pseudospin-dominated lasing phenomena. We are going to explore the possibility of this scheme as a promising platform for laser design.

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