Topological Photonics Meets Lasers

Topological insulators represent a new phase of matter: insulating in bulk, but with a robust edge conductance. These topological edge states are extremely robust, show unidirectional propagation, and are immune to imperfections, defects or disorder. Such "topological protection" is now known to be present in many physical systems, ranging from photonics and cold atoms, to acoustics, to mechanical systems. In recent years, research in topological photonics has flourished, with numerous platforms that allow topologically protected transport of light.[1,2]

Until recently, research on topological systems in all scientific fields has been carried out in passive, linear and conservative settings. The idea of introducing properties such as nonlinearity and non-Hermiticity to topological systems has raised many fundamental questions, while posing several technological challenges. This year, we demonstrated that topological protection can be combined with gain and loss to give rise to a new kind of laser that emits in a topologically protected edge mode—a topological-insulator laser.[3,4]

Being fully compatible with standard optoelectronics platforms, such a laser exhibits protection against defects and disorder, and remains highly efficient even in the presence of cavity imperfections. This is a significant departure from previous attempts in which external magnetic fields were applied to make a laser unidirectional.[5] The topological-insulator laser that we designed consists of an aperiodic array of 10×10 coupled ring resonators on an InGaAsP quantum-well wafer. This 2-D setting comprises a square lattice of ring resonators, coupled to each other via auxiliary links. The intermediary links are judiciously spatially shifted to introduce a set of hopping phases, establishing a synthetic magnetic field that yields topological features.[2]

To promote lasing of the topologically protected edge mode, we optically pump the outer perimeter of the array while leaving the interior elements lossy. The topological-insulator laser operates in a single mode, even considerably above threshold, whereas corresponding topologically trivial realizations lase in an undesired multimode fashion. More importantly, the topological laser displays a slope efficiency considerably higher than that in the corresponding trivial realizations, even in the presence of defects and disorder.[3,4]

Our results pave the way towards a new era of active topological photonics, in which topological protection, nonlinearity and gain, combined in nontrivial ways, can give rise to new active photonic devices such as lasers, sensors and antennas. OPN

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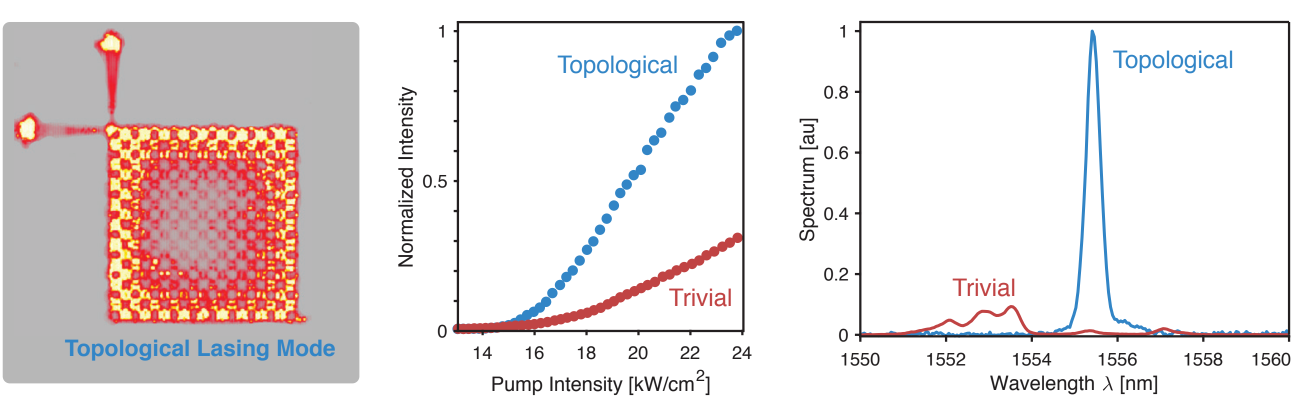

Left: Top-view photograph of the lasing pattern (topological edge mode) in a 10×10 array of topologically connected resonators, and the output ports. Center: Output intensity versus pump intensity for a topological-insulator laser and its corresponding trivial counterpart. The enhancement of the slope efficiency is approximately threefold. Right: Emission spectra from a topological-insulator laser and its topologically trivial counterpart.