Exploiting Duality Using Metamaterials

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Electromagnetic duality treats the electric and magnetic fields on an equal footing and is a fundamental symmetry in the microscopic Maxwell's equations when there are no external charges and currents. The presence of materials generally breaks such symmetry. By using metamaterials, different forms of duality can be restored and be used to manipulate light. A helicity-preserving metamaterial mirror for all angles can be designed as a simple demonstration. Next, by pairing up the electric-magnetic dual operation and a time-reversal operation, we can explore parity-time (PT) symmetric metamaterials through a redefinition of parity operator. PT phase transition of coherent perfect absorption and unidirectional reflectionless at exceptional point are demonstrated, which will be useful for designing tunable subwavelength optical elements with extreme sensitivity. Finally, we extend our discussion to a continuous version of dual symmetry. By gauging a specially designed dual symmetry for two dimensional wave propagation, we explore how pseudo magnetic fields in the real space can be synthesized using metamaterials, which can be used to demonstrate optical spin Hall effect, topological one-way edge states and transformation optical elements with unidirectional functionality.