Photonic topological insulator: creation of a spontaneous lateral atomic recoil force

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We show that the presence of a photonic topological insulator (PTI) surface can create a quantum recoil force on an excited atom. This recoil force is a results of emission into a nonreciprocal, unidirectional, scattering-immune, and topologically protected surface-plasmon polariton. The resulting spontaneous, unidirectional lateral recoil force scales approximately as $1/d^4$, where d is the atom-PTI separation, in addition to the usual component of the Casimir-Polder force normal to the interface. We obtain an exact solution for this quantum force, which is proportional to the atomic excited state population and to the slope of the self-consistent electric field at the dipole position. We also derive an analytical quasi-static approximation, valid when $d/\lambda \ll 1$, showing that the quasi-static lateral force scales as $1/d^4$. For a biased-plasma realization of the PTI, the direction of the recoil force is 90 degrees to the applied bias, with the sign determined by the atomic transition frequency. For this system we also study the nature of the nonreciprocal surface modes at the PTI-vacuum interface, which exhibit quasi-hyperbolic dispersion, resulting in narrow SPP beams, with group velocity perpendicular to the equi-frequency contour. We consider both an initially excited atom, a continuous pump scenario, and a thermal nonequilibrium problem. Our predictions can be tested in cold atom/molecules experiments.