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Quantum-state-controlled photodissociation of ultracold diatomic molecules

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At ultracold temperatures, collisions and reactions of atoms and molecules exhibit quantum mechanical behavior, since only the selected quantum states of the reactants and products can participate. The breaking of a diatomic molecular bond by coherent light, or photodissociation, is a basic process that exhibits many quantum mechanical features when performed at ultralow energies. Photodissociation of diatomic strontium molecules is highly amenable to a high-precision experimental and theoretical treatment, and we discuss this reverse collision process in the regime of up to a few millikelvin, where the molecules are prepared in specific quantum states in an optical lattice at microkelvin temperatures. We demonstrate coherent superpositions and matter-wave interference of the reaction products, effects of barrier tunneling, an ability to control the process with weak magnetic fields, and a transition from quantum mechanical to quasiclassical behavior as the kinetic energy of the photofragments is increased. Ultracold photodissociation additionally provides an excellent test of quantum chemistry models in the scattering continuum, is well suited for experimental studies of scattering continua that are less amenable to theory, and serves as a coherent source of monoenergetic atomic or molecular fragments.