Optically-induced Magnetization and Charge Separation for Quantum Information and Magneto-Photonics

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Abstract

In recent years light has shown to cause intense magneto-electric (M-E) phenomena under non-relativistic conditions in individual molecules. Intense magnetic response has been induced in spinless, non-magnetic materials by ultrafast conversion of orbital angular momentum to rotational (or librational) angular momentum [1]. This ultrafast conversion between different forms of angular momentum is driven by a 2-photon interaction that enhances the orbital moment and obeys P-T symmetry. As a result, magnetic dipole (MD) scattering as intense as first order electric dipole (ED) scattering has been reported in a variety of materials at light intensities of \( I \sim 10^9 \) W/cm\(^2\). This result implies that large magnetic fields at the optical frequency might be realizable at non-relativistic intensities without currents or coils. We discuss two ramifications of magneto-electric processes for quantum information: (a) optical generation of microscopic magnetic fields without electronics, and (b) control of the coupling of qubits through the use of all-optical Rabi splitting or Zeeman shifting of their magnetic sublevels.

Evidence of M-E rectification (or static charge separation) within individual molecules will also be presented. The rectification field is generated despite inversion symmetry of the unperturbed medium through an interaction driven jointly by the electric and magnetic fields of the pump light. This interaction in principle enables transient charge separation or energy conversion (light energy to electricity) and magnetic photonic switches with unusual geometries. The effect of M-E charge separation was observed in pentacene using a time-resolved second harmonic generation technique with beams intersecting at ninety degrees. A laser beam with a tilted wavefront acted as the optical pump with photon energy well below the bandgap to induce M-E rectification in the centrosymmetric, insulating crystal. The DC electric field of the M-E charge separation then mediated a (cascaded) four-wave-mixing interaction that induced second harmonic (M-EFISH) generation of the probe pulse. This permitted us to resolve the dynamics of M-E charge separation with femtosecond accuracy for the first time.
