Simulation of ultrashort laser pulse propagation with high-order dispersion, Raman scattering, and shock formation

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Modern laser technology is capable of producing ultrashort laser pulses (shorter than 100 fs) with intensities in excess of 100 TW/cm^2 when spatially focused. At these intensities the laws of linear optics break down and the interaction of light with matter becomes more complicated as a result of nonlinear optical effects. Also, at these ultrashort pulsewidths the material response times that were otherwise considered to be instantaneous now become significant. These finite responses give rise to effects such as high-order dispersion, stimulated Raman scattering, space-time coupling (linear shock formation), and self-steepening (nonlinear shock formation). We have performed simulations of ultrashort, high energy laser pulses by numerically solving a modified nonlinear Schrödinger Equation. This equation is modified to include the dramatic effects of these finite material response times on linear and nonlinear optical processes in bulk materials. Our simulations accurately predict the effects of ultrashort pulse propagation using much less time and computational power than solving Maxwell's equations directly (i.e. FDTD).