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Semianalytical fluid study of the propagation of an ultrastrong femtosecond laser pulse in a plasma with ultrarelativistic electron jitter

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The interaction of a multi-petawatt, pancake-shaped laser pulse with an unmagnetized plasma is studied analytically and numerically in the blowout regime of fully relativistic electron jitter velocities and in the context of the laser wakefield acceleration scheme. A set of novel nonlinear equations is derived using a three-timescale description, with an intermediate timescale associated with the nonlinear phase of the electromagnetic wave and with the spatial bending of its wave front. The new nonlinear terms in the wave equation, introduced by the nonlinear phase, describe a smooth transition to a nondispersive electromagnetic wave at very large intensities, and the simultaneous saturation of the previously known nonlocal cubic nonlinearity. The temporal evolution of the laser pulse is studied by the numerical solution of the model equations in a two-dimensional geometry, with the spot diameter below 100 microns. The most stable initial pulse length is found to be somewhat larger than 1 micron, but a rapid stretching of the laser pulse in the direction of propagation to around 10 microns ensued, due to the nonlocality of the plasma response, followed by the bending of the laser wave front.

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