Generation of femtosecond acoustic soliton pulses in sapphire

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Nonlinear acoustic bulk waves and the formation of shock waves have been studied for a long time. Only recently low temperature experiments and femtosecond optical excitation schemes have revealed the formation of soliton trains in bulk crystals by a subtle balance between elastic nonlinearity and natural acoustic dispersion. We present interferometric pump-probe experiments in sapphire that demonstrate a gradual change from the generation of acoustic shock waves at room temperature to acoustic soliton trains at cryogenic temperatures. Direct measurements reveal shock fronts at room temperature as short as 1ps and at 18K soliton widths below 500fs. Further we show that all measurements can be accurately tracked by results from numerical simulations of the Korteweg-de-Vries-Burgers equation, that takes into account temperature dependent viscosity, nonlinearity, and dispersion. From this fact and the analysis of the supersonic velocities, we conclude that acoustic solitons as short as 200fs are formed.(Peter van Capel and Jaap Dijkhuis, Phys.Rev.B81 14106 (2010)).