Tracking a light pulse through a waveguide in space and time

M.L.M. Balistreri, J.P. Korterik, L. Kuipers, N.F. van Hulst

Applied Optics group
MESA+ Research Institute and Department of Applied Physics
University of Twente, P.O.Box 217, 7500 AE Enschede, The Netherlands
E-mail: m.l.m.balistreri@tn.utwente.nl

We present first direct observation of the propagation of a femtosecond laser pulse in space and time through a waveguide structure. With an interferometric photon scanning tunneling microscope (PSTM), the local amplitude and phase of the pulse were retrieved with high spatial, spectral and time resolution. The relative field profiles, the wave vectors and the spectra of the pulses in the TE_{00} and TE_{01} modes in the waveguide have been experimentally determined.

The propagation of light in the classical domain is well described with the plane-wave approximations of the Maxwell equations. Predictions in classical optics based on the Maxwell's theory have never been known to be in contradiction with experimental evidence[1]. However, interesting dynamical effects are overlooked when the plane-wave limit is used for the propagation of a short pulse in (non)linear dispersive media[1]. Dynamic effects like, self-phase-modulation, self-focusing, and self-compression of a femtosecond pulse propagating through a nonlinear dispersive medium can occur. These effects can lead to the splitting of a pulse in two pulses, the occurrence of phase singularities in a pulse, the reshaping of a pulse, the generation of second harmonic-pulses, ultrashort-pulses and solitons.

The generation of solitons in fibers and other nonlinear dispersive media is subject of active research, because solitons are one of the promising candidates to enable ultra high-speed telecommunication networks. Pulse dynamics in waveguide structures and photonic band gap materials (photonic crystals) is investigated, because these structures could also play a key role in telecommunication networks. However, most current investigations of dynamical effects in (non)linear dispersive media are numerical simulations. Thus, it is important to explore experimental methods to fully characterize the propagation of an ultrashort-pulse in (non)linear dispersive media.

Experimental investigations of the propagation of ultrashort-pulses in (non)linear dispersive media have been largely limited to "black-box" type characterization of the medium. The known incoming pulse and the measured outcoming pulse are compared with a theoretical model. By cutting slices from the medium it is possible to study the internal pulse development, but this method is destructive to the medium[2]. To obtain full information on pulse propagation through a medium time-resolved measurements are crucial. An experimental method enabling the observation of the dynamical effects inside the medium in space and time has so far been lacking.

The last few years a so-called photon scanning tunneling microscope (PSTM) has proven its unique capacity to measure the intensity distribution of the optical field locally inside photonic structures[3-5]. We will present the nondestructive visualization of a femtosecond pulse propagation through a linear dispersive waveguide structure in space and time using an interferometric PSTM. This microscope is based on the heterodyne interferometric PSTM[6,7], recently developed by our group, and provides the full amplitude and phase information of the pulse traveling through the waveguide structure.

References

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