Tracking fs light pulses in space and time through advanced photonic structures

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The propagation of short light pulses through advanced photonic structures like photonic crystals is influenced by the interplay of various physical mechanisms, for instance by the strong material dispersion and the low group velocity. To study the complex interplay between different mechanisms as pulses propagate through a structure, **local** time-resolved measurements are crucial.

As the development of photonic (crystal) devices advances, so does the need to monitor the transient behavior of optical pulses as they propagate through such devices. However, taking a peek inside a photonic structure is far from trivial as conventional optical microscopy is limited by the diffraction limit. What occurs inside the device therefore remains mostly hidden. Recently we demonstrated [1] a non-invasive technique based on an optical photon scanning tunneling microscope (PSTM) that can be used to "visualize" pulses as they propagate through an optical device with both temporal and spatial resolution (see fig 1). As we make use of a heterodyne detection scheme both the amplitude and the phase information [2] on the pulses is retrieved at the same time.

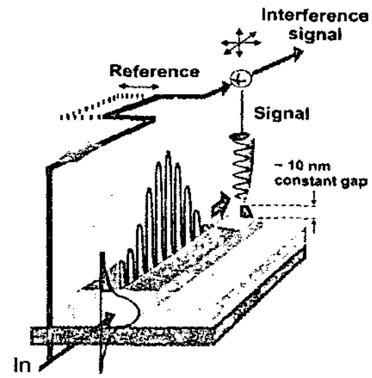

Fig 1: Schematic representation of the local measurement of pulses using a PSTM.

With this technique we have recently been able to observe time-resolved "ballistic" motion of ultrashort pulses within a cylindrical microcavity. Figure 2 shows a measurement for a fixed reference time in which a 120 fs pulse has just passed a ring-resonator. It is clearly visible that part of the pulse is coupled to two different modes in the resonator. By repeating this measurement for different reference times the motion of the pulse in the cavity is followed in time. This example of the direct visualization of the time evolution of light pulses in a complex photonic device shows how new insights into their behavior can be obtained.

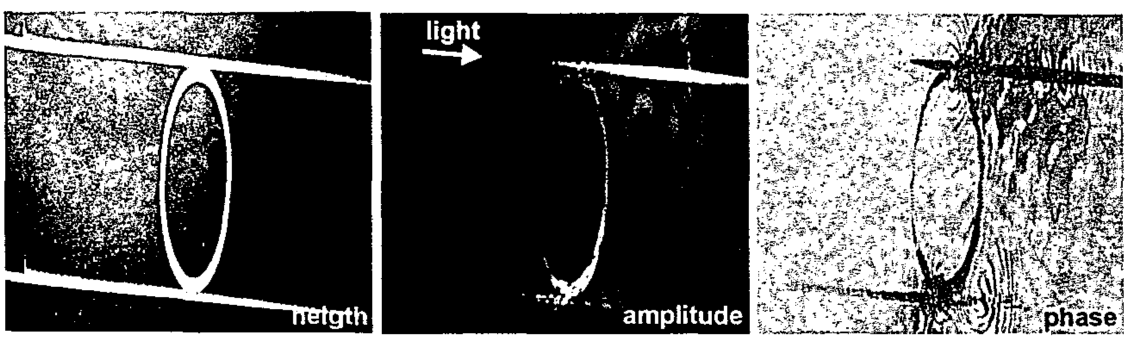

Fig. 2: Visualization of the time resolved motion of a fs pulse (120 fs, λ = 1300 nm) through a cylindrical ring-resonator (radius 25 μm) measured by the PSTM. From left to right: the simultaneously measured topography of the structure (~250 x 70 μm) and the optical amplitude and phase of the pulses. The optical amplitude clearly shows that part of the pulse which passes the resonator is coupled into the resonator. Two different modes can be distinguished. The resonator structure has been fabricated by Dion Klunder and Alfred Driessen (University of Twente).

[1] M.L.M. Balistreri, H. Gersen, J.P. Korterik et al., *Science* **294** (5544), 1080 (2001)
[2] M.L.M. Balistreri, J.P. Korterik, L. Kuipers et al., *Phys. Rev. Lett.* **85**, 294 (2000)

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