Visualizing the flow of light with near-field optical microscopy

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Conventionally, the investigation of light propagation in advanced photonic structures, like photonic crystals, is performed with the following scheme: light impinges on the structure and the reflected and/or transmitted light is collected; the relation between incoming and outgoing light is then compared with a theoretical model. While a good agreement may give a satisfying sense of understanding, a lack of agreement may leave both the experimentalist and theoretician stranded. Particularly in structures with a strong interaction between geometry on the nanometer scale and optical properties, this situation can be highly undesirable. The power of near-field optical microscopy is that the light propagation inside the structure can be mapped and related directly to the geometry.

Recently, we have succeeded in measuring not only the distribution of the local amplitude but also the phase evolution of light as it propagates through photonic structures. With the new instrument we have observed phase singularities in relatively simple waveguides. Coherent measurements on small photonic crystals reveal unexpected variations in the local refractive index in addition to rich scattering phenomena in which whole networks of phase singularities are formed.

These days, we are also able to track femtosecond laser pulses through a waveguide structure in space and time. By comparing the measured displacement of the pulse in the structure with the simultaneously measured wavevectors, we can separate the phase- and the group velocities inside the structure.

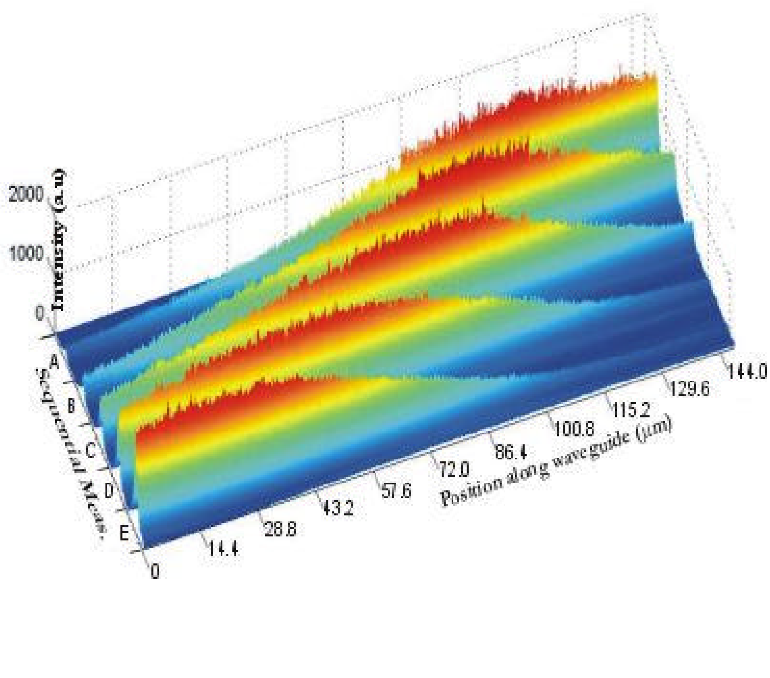

Figure: 5 Measurements of a femtosecond pulse in a waveguide. Between each measurement the "reference time" is changed by 130 fs. The propagation of the pulse during this time is clear.