Mapping Phase and Amplitude of Optical Field Distributions in Fiber Bragg Gratings.

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Developments in the technique of Near-field Scanning Optical Microscopy (NSOM) [1] have made possible the mapping of both amplitude and phase of electric fields in photonic devices using simple interferometry. Combined with heterodyne techniques, this gives very high sensitivity within the technologically important 1.5μm wavelength regime. We describe experiments that use this capability to study one of the most important telecommunications components, the fiber Bragg grating.

Interferometric SNOM allows us to measure the amplitude and phase of the optical field within the fiber Bragg gratings directly. The evanescent fields, which are usually protected by the fiber cladding, are exposed by polishing off the cladding on one side of the fiber. These fields are measured using photon scanning tunneling microscopy (PSTM), and detection is achieved using a heterodyne fiber interferometer. The laser source is tunable across the first order stop band region of the grating. The low index contrast and high degree of perfection of the periodic structure, combined with its long length, mean that measurements are not dominated by out-of-plane scattering or scattering from the beginning and end of the grating, which have been problematic in many NSOM investigations of photonic crystals.

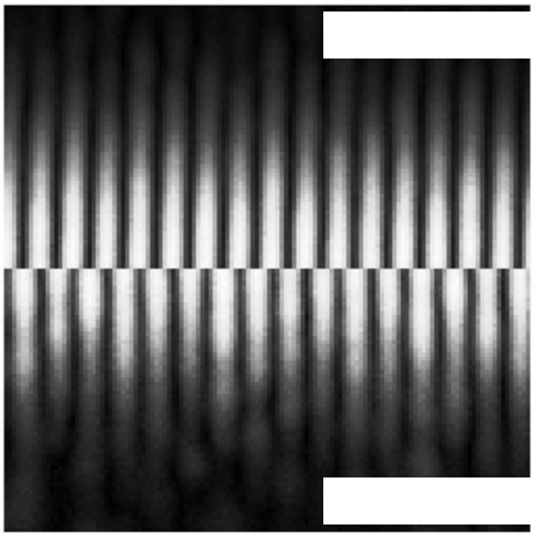

Figure 1 – Composite greyscale image of the electric field amplitude as a function of position with laser wavelength tuned (a) above and (b) below the stop band. Image is 9μm x 18μm, and divided along the center line, which is along the fiber core.

The reflection spectrum of the fiber Bragg grating is complex, and shows bands due to the structure of the 1D photonic crystal formed by the refractive index variation along the core, as well as other bands due to the interaction of the core and cladding modes. Each of these bands has been studied by tuning the probe laser to the appropriate wavelength. The standing wave along the grating can be considered to be the sum of two counterpropagating waves. The application of heterodyne techniques allows us to deconvolve the amplitudes and relative phases of the two counterpropagating components, and show that they agree well with predictions based on grating theory [2].

In addition, the variation of the physical positions of field antinodes can be measured as a function of wavelength. As the laser wavelength is increased through the grating stop band, the antinode position is predicted to shift from the high index to the low index grating regions, a shift of ~λ/4, or Λ/2. As an example of what can be achieved using this mode of imaging, we have measured this position shift directly, and the composite image of field antinodes at wavelengths above and below the stop band shown in figure 1. This technique will be applicable to study the more complex structures possible in fiber gratings, such as deliberately introduced defects, or phase slips.

References

[1] M. L. M. Balistreri, J. P. Korterik, L. Kuipers, and N. F. van Hulst, *Physical Review Letters* **85**, 294 (2000).

[2] J. C. Gates, J. D. Mills, and W. S. Brocklesby, *Applied Physics Letters* **83**, 1890 (2003).