2438

Optical Characterization Of Holey Fibers Using NSOM techniques

C.W.J Hillman, W.S. Brocklesby, T.M Monro, W. Belardi and D.J Richardson
Optoelectronics Research Centre, University of Southampton. Southampton. UK. SO17 1BJ.

A holey fiber (HF) is an optical fiber whose optical properties and confinement mechanism are defined by air holes that run the entire length of fiber, rather than a traditional high index core and low index cladding. These fibers can offer many variations on the traditional mode profiles of core/clad fibers. One area of particular interest is the ability to produce tight confinement of the optical mode, and thus high effective nonlinearity when compared to standard fibers.

In order to understand the properties of holey fibers, it is necessary to know the structural profiles and optical mode profiles in some detail. Each different pattern of holes will have individual optical mode properties, which can be calculated using knowledge of the exact physical structure of the fiber. The current work describes how we can use NSOM-based techniques to measure the optical mode structure. This is compared with the calculated mode structure, which relies on very accurate atomic force microscope (AFM) images of the physical structure.

Most characterization of holey fibers relies upon mode measurement by imaging the end of the fiber, and structure measurement using scanning electron microscopy. Both these techniques have drawbacks. Holey fiber modes can be extremely small, making imaging difficult. One of the interesting things about holey fiber modes is that they can have evanescent components in radial directions, where the light extends into the air holes in the fiber. These cannot propagate through a traditional imaging system. These components can be available to a near field measurement. The physical profile needs to be accurate to better than 10nm in order for the mode calculations to be effective – this resolution is much more easily obtained through AFM than SEM techniques.

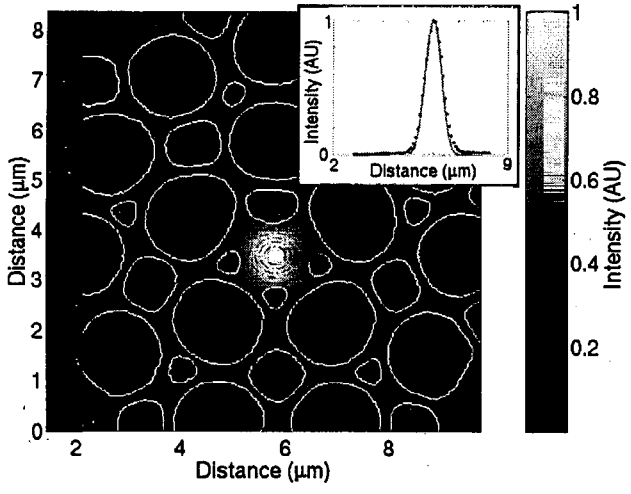

Figure 1 - Contour plot of topography and grey scale/contour plot of measured mode profile. Inset shows comparison of theory and measured data.

To obtain a direct experimental measurement of the near field mode profile[1], we have applied technologies developed for scanning near field optical microscopy (NSOM). The greyscale image in Fig.1 shows the data collected in a NSOM scan with an aluminized tip held 10nm above the fiber surface. The inset plots a cross-section from both the NSOM data and theoretical predictions made using the hybrid orthogonal function method described in Ref. [2]. Good agreement can be seen. The small discrepancy between the modes can be attributed to tip width and low intensity fiber cladding modes. For these measurements the experimental $1/e^2$ width was 0.710µm, as opposed to our theoretical estimate of 0.632µm. NSOM techniques can be used to explore the field at small distances inside the holes, and also to explore the transition from guided mode to free space propagation. These NSOM-based techniques will ultimately prove invaluable tools with which to better characterize the unique and exciting properties of this new class of optical fiber.

References

[1] D.J. Butler, K.A. Nugent, and A. Roberts, *Journal of Applied Physics*, **75(6)**, 2753-2756 (1994)
[2] T.M.Monro, D.J.Richardson, N.G.R.Broderick, and P.J.Bennett, *IEEE Journal of Lightwave Technology*, **17**, 1093-1102 (1999)