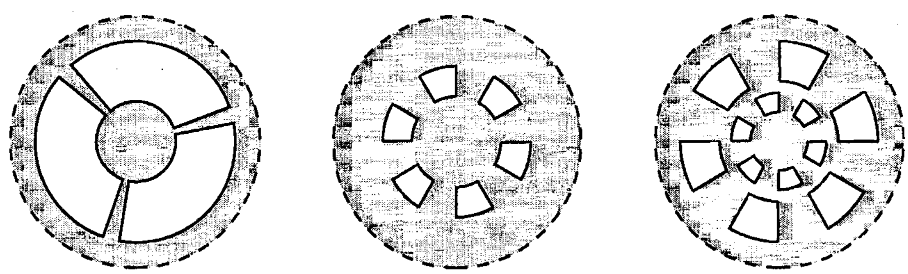
Leaky Modes in Microstructured Optical Fibres with Annular Sectors

L. Poladian[1] and T. M. Monro[2]

[1] *Optical Fibre Technology Centre, University of Sydney, NSW 2006, Australia*
[2] *Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, U.K.*
(02)93511933, (02)93511911, L.Poladian@oftc.usyd.edu.au

Microstructured or holey optical fibres are a novel class of fibres that have attracted much interest recently because they can be tailored to have properties (dispersion, nonlinearity, mode size) very different from conventional fibres. These structures can consist exclusively of air holes arranged around a solid core region in a uniform background. Since such fibres do not have any raised index regions, they cannot support true bound modes. They can, however, possess leaky modes where the light is trapped within a region surrounded by air holes. Such modes suffer confinement losses due to energy leakage between and through the holes. The confinement loss is given by the imaginary part of the complex effective mode index n_{eff}. Existing basis function expansion (Galerkin) techniques (using plane waves [1] or Hermite-Gaussians [2]) give most modal properties except for the confinement loss. Methods such as BPM can be used to find confinement loss [3] but are numerically intensive; and, recently, a multipole method has been used which is restricted to circular holes [4]. The technique presented here has the simplicity of a Galerkin technique but can also find confinement loss and complements existing methods by applying to a holes in the shape of annular sectors. Typical structures are shown below.



The field inside a circular domain of radius R is expanded as follows

$$\psi(r,\phi) = \sum_{m,n} A_{m,n} e^{im\phi} (\frac{r}{R})^{|m|} \left[\cos(\frac{(2n+1)\pi r}{2R}) + \epsilon_{m,n} \sin(\frac{(2n+1)\pi r}{2R}) \right]. \tag{1}$$

Substituting into the wave equation and integrating yields a matrix eigenproblem where the eigenvectors give $A_{m,n}$ and the eigenvalues give n_{eff}. When $\epsilon_{m,n}$ is set to zero the standard boundary condition $\psi(R,\phi) = 0$ is obtained, which is adequate for finding bound modes and an initial estimate of n_{eff}. For leaky modes, this initial estimate is used to reset the $\epsilon_{m,n}$ to values approximating a non-reflecting impedance matched boundary and the problem is solved again to obtain an improved estimate of n_{eff} yielding confinement loss. If required, continued iteration can be used to increase the accuracy of the answers. The variation of confinement loss with wavelength and hole dimensions will be presented for a variety of structures.

References

1. J. Broeng, S.E. Barkou, T. Sondergaard and A. Bjarklev, Opt. Lett. **21**, 1547 (2000).
2. T.M. Monro, D.J. Richardson, N.G.R. Broderick and P.J. Bennett, J. Lightwave Technol. **17**, 1093 (2000).
3. M.J. Steel, T.P. White, C. Martijn de Sterke, R.C. McPhedran and L.C. Botten, Opt. Lett. (2001), In Press.
4. T.P. White, C. Martijn de Sterke, R.C. McPhedran and L.C. Botten, Proceedings of OECC/IOCC 2001, 151.