Hollow Core Large Mode Area Fibre Employing a Subwavelength Grating Reflector

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Hollow core large mode area fibres are ideal candidates to guide light at high powers while avoiding non-linear effects and, as such, they are generating much scientific interest [1-3]. A variety of fibres have been investigated, including tube lattice photonic bandgap fibres and Kagomé-latticed photonic crystal fibres. One of the major challenges in obtaining low loss hollow core fibres is related to the unavoidable perturbations induced by the coupling between the core and cladding modes which is responsible for the increase of leakage loss. Recent approach based on the insertion of additional antiresonant elements demonstrates the significance of fibre geometrical parameters and shows leakage loss of an order of ~10^{-4} dB/m [3]. In this paper, we present preliminary results of a novel approach to fibres that guide light in a large hollow core, starting from the high index contrast grating reflector platform [4]. Subwavelength gratings have been used to achieve broadband mirrors with reflectivity greater than 99%. Importantly, the physical dimensions of the grating must be smaller than the wavelength of incident light, which implies that the diffraction order of interest is 0^{th}. Under a surface normal incidence on diffraction grating, evanescent orders in the direction parallel to the grating period overlap with the leaky mode of the grating leading to the effect of guided mode resonance and a destructive interference effect between the two grating modes, which results in high reflection [4].

Starting from the simplest case of a diffraction grating as a binary structure which varies in one dimension we form an equivalent structure in a fibre. We numerically investigate the ultra-high reflectivity feature of a subwavelength grating using the rigorous coupled wave method and we study the leakage loss using a finite element method. Figure 1 (a) shows a cross section of the proposed fibre grating structure where the grating is filled with high index material (n=3.21) and surrounded with air. Design parameters for the structure include: core diameter 20 μm, the grating period Λ=0.787 μm, fill factor 0.77, grating thickness 0.508 μm and the distance between the external solid silica cladding and the annular core 6.5 μm. The effective indices of the two lowest order modes in the hollow core are calculated in case of the grating fibre and compared to the tube fibre with the same design parameters for refractive index and thickness, and can be seen in Fig. 1 (b). We attribute the discontinuities in the dispersion curves of the modes of the grating fibre to the azimuthal resonances i.e. coupling between the airy modes and grating modes, which causes anti-crossings and high leakage loss. Calculating the leakage loss of the core propagating modes reveals the sharp drop of the first higher order mode TE01 and the leakage loss of ~$7x10^{-4}$ dB/m as shown in Fig. 1 (c), which is a few orders of magnitude lower than loss of the fundamental mode, and is attributed to the guided mode resonance effect which appears for particular design parameters and angles of incidence. Ongoing work focuses on equivalent structures that could be manufacturable.

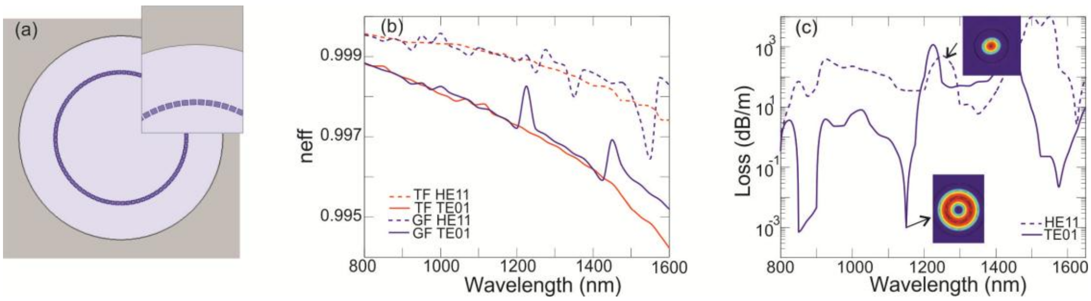

Fig. 1 (a) Schematic cross section of the proposed fibre structure. Inset is showing an enlarged view of the grating structure. (b) Effective index as a function of wavelength for the two lowest order core modes of the tube fiber (TF) and the grating fibre (GF). (c) Computed leakage loss for the GF of the fundamental mode and fist higher order mode.

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