Oblique light propagation along bent slab waveguides

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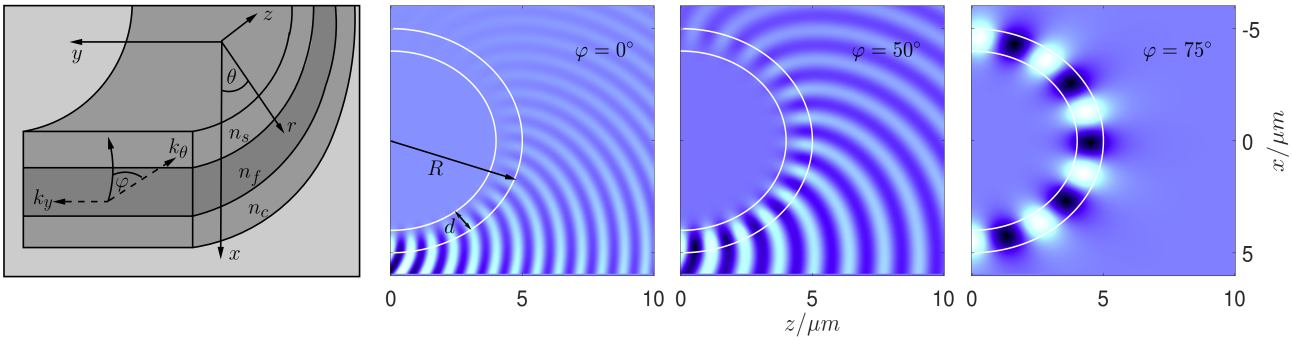
Segments of dielectric tubes support quasi-confined modes that propagate at oblique angles with respect to the axis of curvature. Our analytical model covers the full range of solutions from scalar TE/TM bend modes to lossless tube modes at near-axis propagation angles, with a continuum of vectorial spiral modes in between.

Spiral modes supported by dielectric tube segments

Waveguide bends are basic building blocks for various kinds of integrated photonic circuitry. Fundamental phenomena related to the waveguide curvature can be studied with analytical 2-D models [1] of bent slab waveguides with 1-D cross sections. These models assume that both the structure under investigation and the electromagnetic field are constant along the symmetry axis. Solutions are quasi-guided attenuated waves that propagate along the curved slab, in a direction perpendicular to the axis. In this contribution we reconsider the bent slab structures, now looking at quasi-guided waves that also have an axial wavenumber component. As hinted at in the figure, the curves given by the local wavevectors spiral around the central y-axis, hence we call these fields “spiral modes”.



Spiral modes of a tube structure with radius $R = 5\,\mu$m*, core thickness* $d = 1\,\mu$m*, and refractive indices* $n_s : n_f : n_c = 1.6 : 1.7 : 1.6$*, at a vacuum wavelength of* $1.3\,\mu$m*. Snapshots of transversal electric fields* $\Re\{-\sin(\varphi)E_\theta(r) + \cos(\varphi)E_y(r)\}$ *are shown, for modes at different angles of propagation* φ*.*

Variations of the axial wavenumber parameter k_y translate to varying angles of propagation φ. The familiar 2-D bend modes are obtained for $k_y = 0$, with fields that are constant along y. For near-axial propagation, at φ close to $90°$, lossless waves can be expected that, for specific angles, and envisioning a continuation of the curved segment to a complete dielectric tube, form the guided modes supported by this tube-shaped optical fiber. In between, there is a continuum of vectorial waves, that propagate around the tube axis at varying angles, with varying levels of radiative losses. Our analytical models exploit the facilities for Bessel- and Hankel functions with complex order and argument as provided by the *Maple* computer algebra system. Examples for a series of radii and propagation angles will be discussed, for different levels of refractive index contrast.

References

[1] K. R. Hiremath, M. Hammer, R. Stoffer, L. Prkna, and J. Čtyroký. Analytical approach to dielectric optical bent slab waveguides. *Optical and Quantum Electronics*, 37(1-3):37–61, 2005.