Dispersion engineered tapered fiber photonic nanowires

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We present results on dispersion engineered tapered optical fiber based nanowires. Their characteristics are modelled and calculated, and compared with experimental results from group delay measurements. The detailed analysis is done with focus to applications. Important effects that are included in the analysis, and discussed therein, are the impact of refractive index profile change during the nanowire fabrication process at elevated temperatures, and the optical connection to the nanowire region through biconically tapered transition regions.

It is well known that the occurrence and characteristics of most non-linear optical effects strongly depend on the dispersion characteristics of devices [1]. The fabrication of tapered optical fibers through the flame brushing method is known to allow for a high precision fabrication of nanowires, and their optimization with regard to the desired device properties [2]. The coupling between modes is a characteristic property of tapered fibers, and can be employed in devices [2].

The analysis of most of the propagation characteristics of tapered optical fibers departs from a detailed analysis of the dispersion equations of cylindrical three layer waveguides, i.e. optical fibers with a finite clad and reduced clad diameters. The local mode dispersion relations are found by solving numercially the characteristic equation that is obtained when demanding as boundary conditions the continuity of transverse fields components and their derivatives, both at the radial core/clad and clad/air boundaries.
As the properties of interest, i.e. the points of low (zero) group velocity dispersion, and its variation (flatness) correspond to the third resp. fourth order derivatives of the dispersion relation, it is important to numerically calculate a sufficiently elevated number of points.
Polynomial approximations are a convenient tool to approximate the numerical points with analytical functions, which accelerates the design process. However, care must be taken when dealing with higher order derivatives: the correlation between low order and high order precision has to be taken into account. We studied how the numerical precision and number of points, as well as the kind of polynomial methods, and tolerance, affects the precision when determining the zero dispersion point and its flatness. The results are simplified and convenient engineering design guidelines for this kind of structures.

We compare the predictions with experiments, and find good coincidence when taking into account the actual mode structure of the tapered fiber.

References

[1] M. A. Foster, A.C. Turner, M. Lipson, and A.L. Gaeta, *Nonlinear optics in photonic nanowires*, Opt. Expr. 16, 1300 (2008).
[2] M. Niehus, G.G.M.Fernandes, A.N.Pinto, *Design of a tunable single photon interferometer based on modal engineered tapered optical fibers*, to be published in SPIE Proc. Photonics Europe 2010.

Figures (next page)

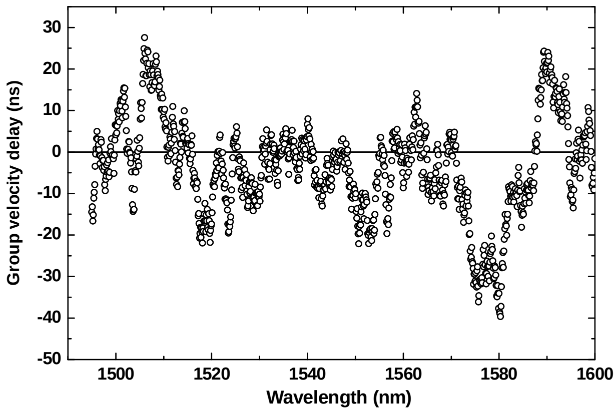

Figure 1
Experimental Results of Group Delay Experiments in Tapered Optical Fibers

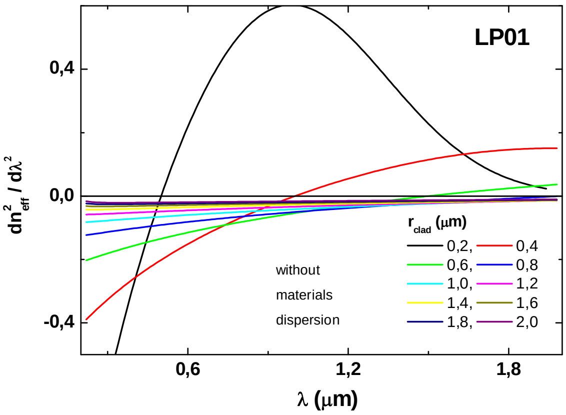

Figure 2
Theoretical Simulation of second order derivative of effective refractive index of furndamental mode in Tapered Optical Fibers, for several clad radii.