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Square and hexagonal shaped hollow-core optical fibers – Novel design variations for antiresonant sensor waveguides

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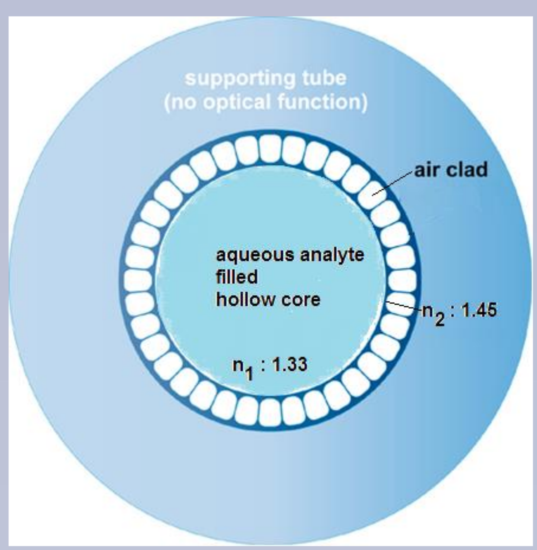
Introduction

Large-mode optical glass fibers with hollow-core structures are promising candidates for various chemical analytical applications, e. g. UV-VIS-NIR absorption or RAMAN scattering spectroscopy. We report on design and charcterisation of new types of polygonal shaped hollow-core fibers based on antiresonant fiber concept. In contrast to typical photonic band gap fibers (PBGF) these fibers are characterized by large hollow cores with about 30 µm cross section. They can be easily filled with gaseous and liquid analytes. A further advantage of this fiber concept is its simple structure and preparation approach (see Poster P3).

The design is characterized by a minimum of web bridges. We demonstrate two fiber types with square and hexagonal hollow core design. The thinness and homogeneity of the bridges correlate to spectral loss minima and spectral positions of antiresonant light guiding bands. Both fibers show a good correspondence between simulation (quasi-analytic waveguide model) and measured spectral attenuation. The novel fibers exhibit an effective single-mode operation in several transmission bands from the near infrared to the UV-range with a minimum attenuation of about 2 dB/m.

Concept and Simulation

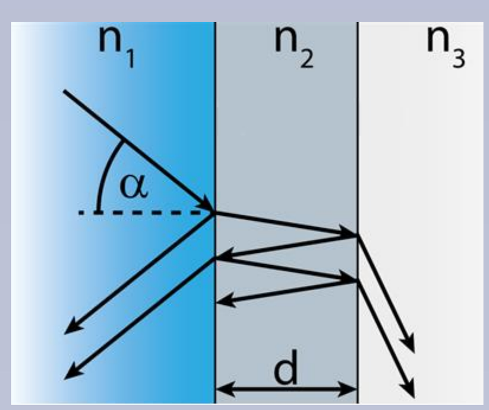
Starting Design



Hollow core –Air Clad fiber

Concept:
Antiresonant core light transmission

Multi beam interference

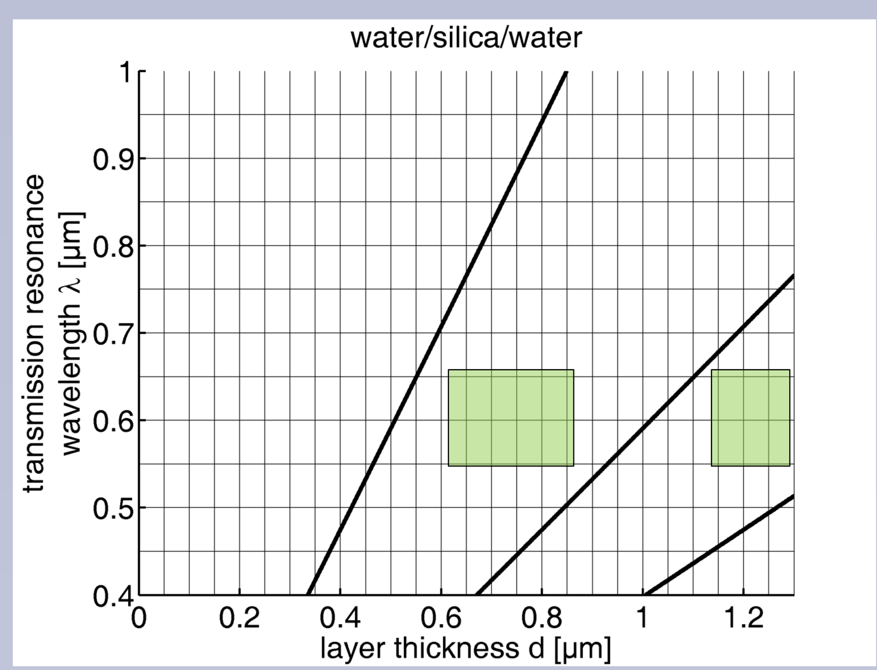


$$\lambda_R = \frac{2d}{m}\sqrt{{n_2}^2 - {n_1}^2 \sin^2\alpha}$$

λ_R : resonance wavelength
m: resonance order

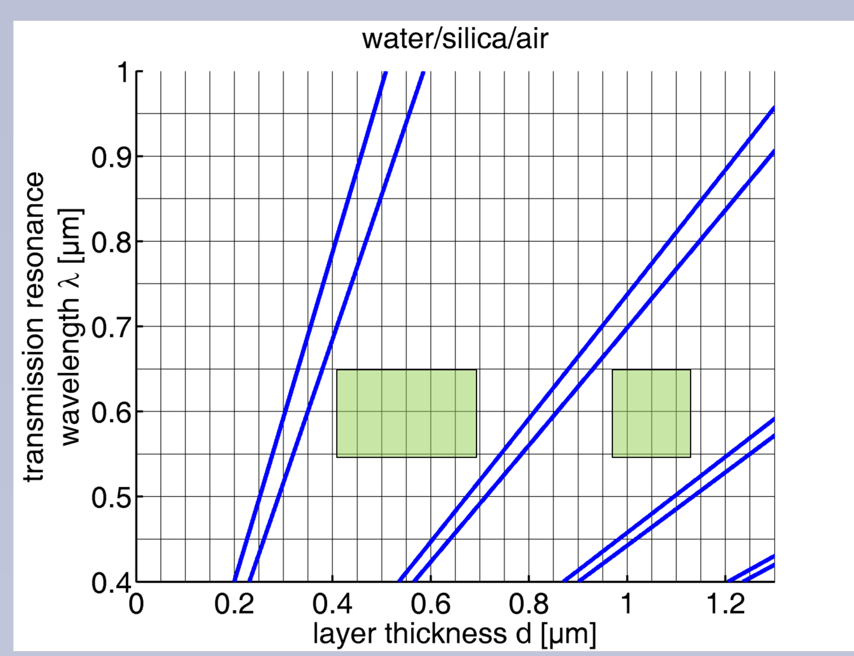
n_1 =1.33 (water)
n_2 =1.45 (silica)
n_3 =1.00 (air)

Resonance positions



water filled core and water clad

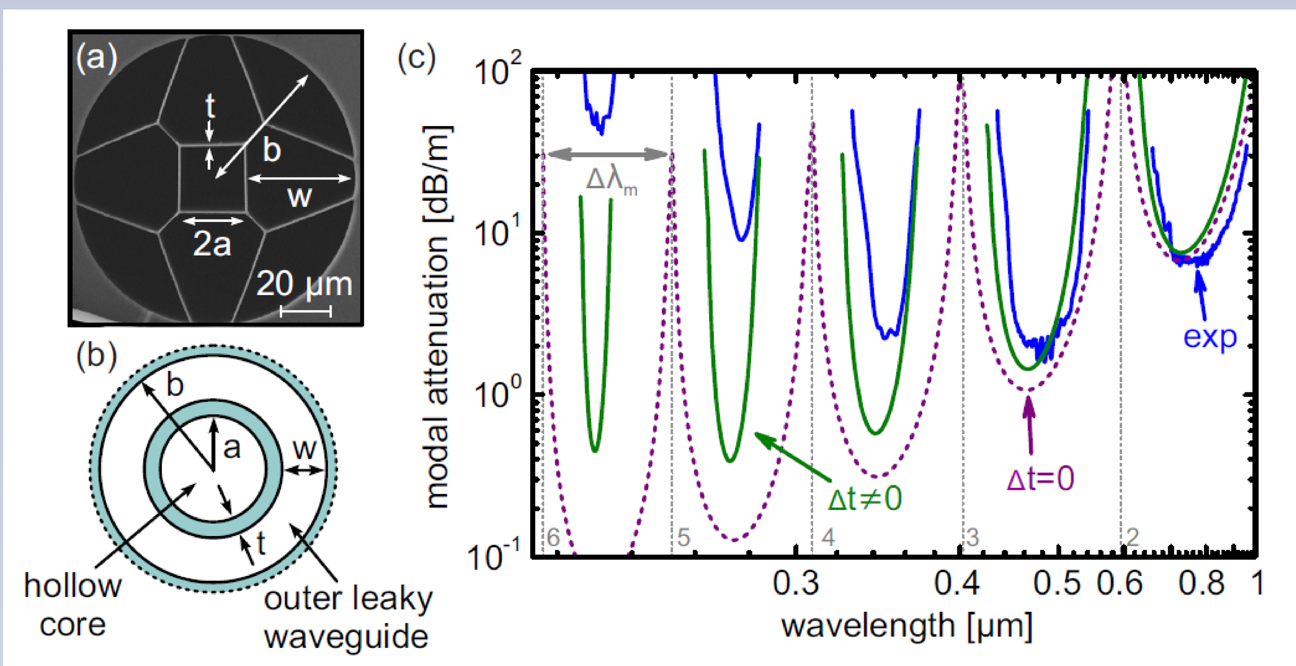
optimal bridge widths:
d = 750nm ±150nm resp.
1270nm ±70nm



water filled core and air clad

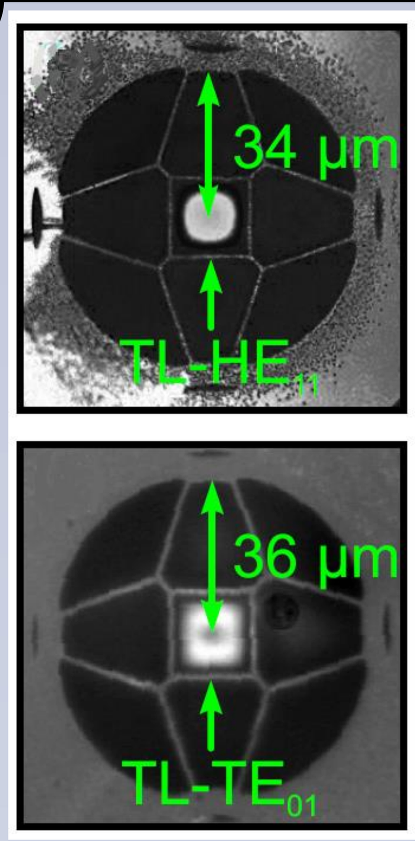
optimal bridge widths:
d = 550nm ±150nm resp.
1070nm ±70nm

Square hollow-core fiber



Hollow core edge length:
2a = 16.6 µm
surrounded by thin silica strands with an average thickness t = 560 nm. Outer radius of the microstructured cladding:
b = 37 µm
Outer fiber diameter: OD = 125 µm
Loss maxima are observed at those wavelengths where the core mode is phase-matched to bridge resonances.

Models: Δt=0 constant bridge width
Δt≠0 variable bridge width

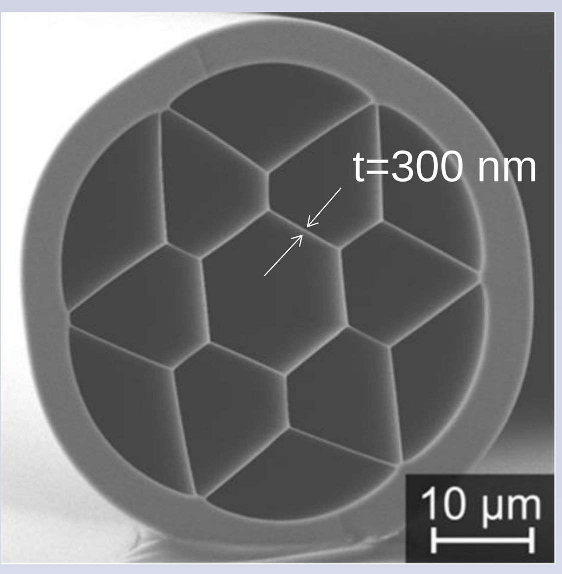


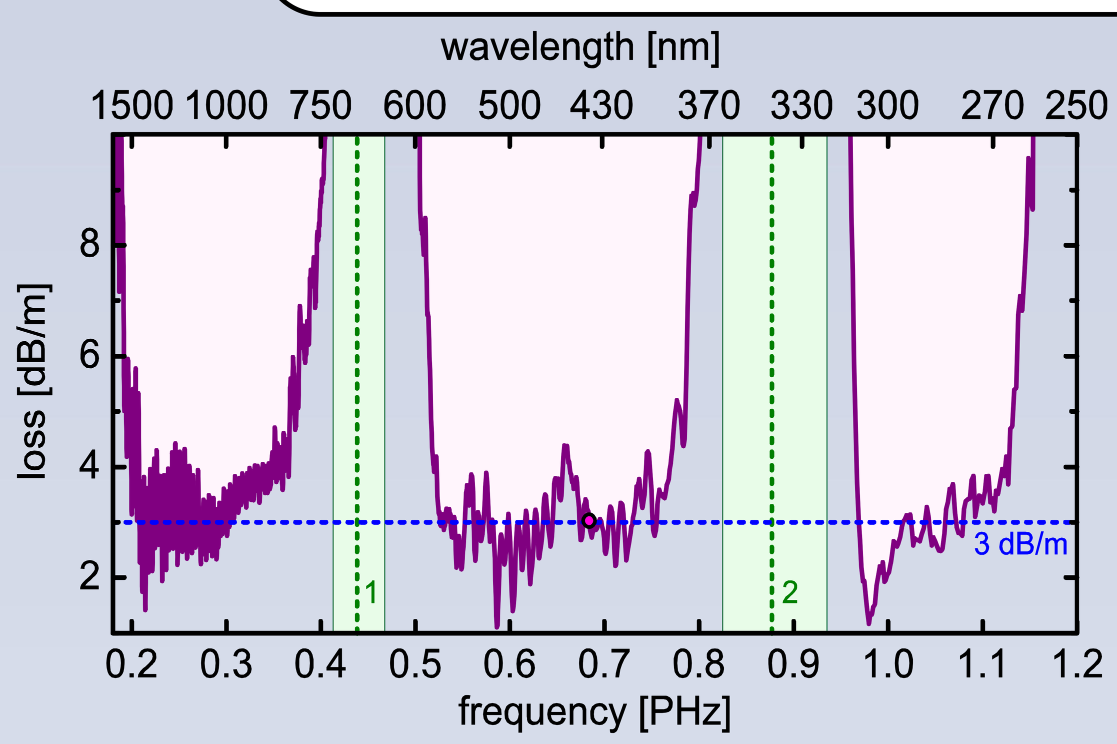
Experimentally measured near field images of the central core modes for two different fiber structures with white light illumination:

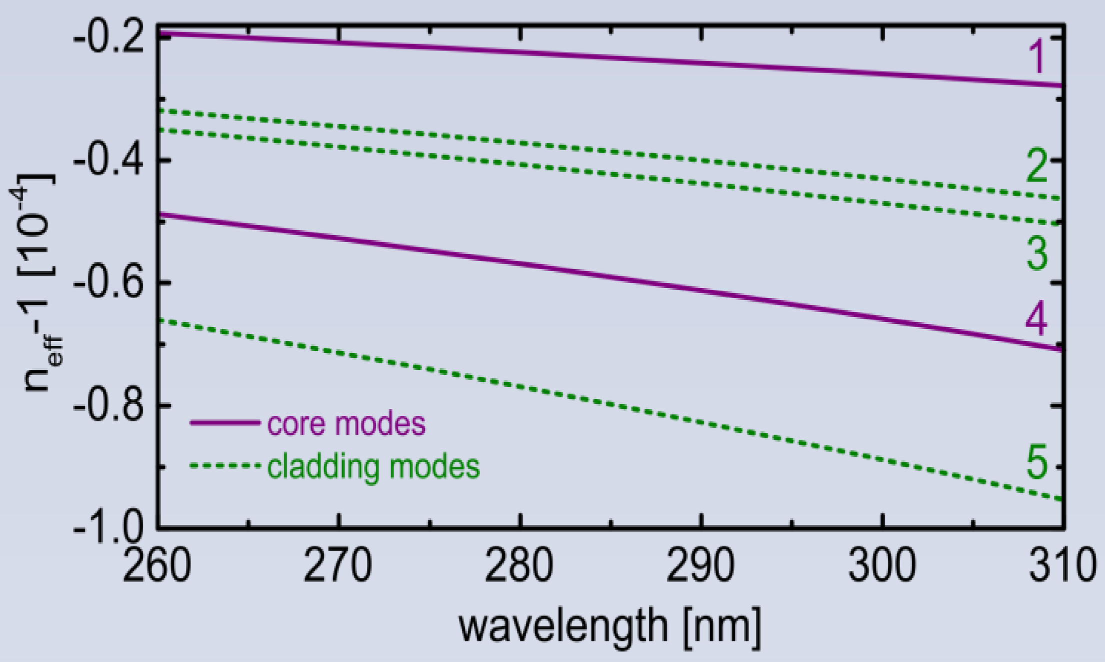
fundamental mode: TL-HE_{11}

next higher order mode: TL-TE_{01}

Hexagonal hollow-core fiber

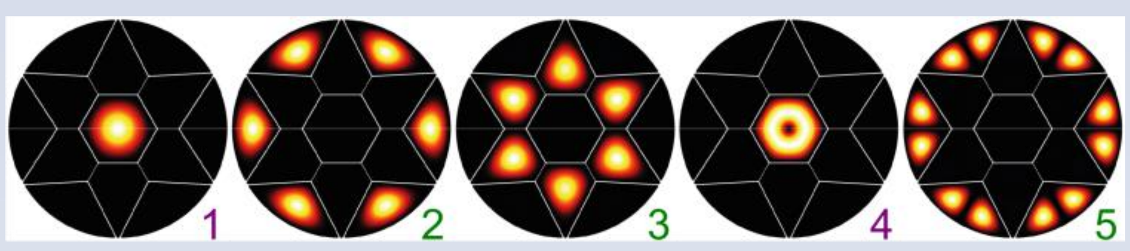






Left:
Spectral loss of the core mode. Except at the strand resonances, it shows an almost constant loss of 3 dB/m

Right:
Spectral distribution of the relative effective index of the first five modes within the shortest relevant transmission band.



Distribution of the Poynting vectors of the different modes at 260 nm

References

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[3] A. Hartung, J. Kobelke, A. Schwuchow, Jörg Bierlich, Jürgen Popp, Markus A. Schmidt,T. Frosch," Low-loss single-mode guidance in large-core antiresonant hollow-core fibers", Optics Letters 40(14) , 3432-3435 (2015)

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