

Measuring mechanical strain and twist using helical photonic crystal fiber

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Overview

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2 Helical PCF

- Theory
- Fabrication
- Results

3 Future Applications

Photonic Crystals

Periodic optical nanostructure composed of varying refractive indices.

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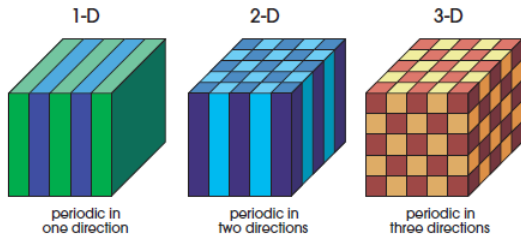


Figure: Joannopoulos, J. D., Johnson, S. G., Winn, J. N. & Meade, R. D. *Photonic Crystals: Molding the Flow of Light*. (Princeton University Press, 2008)

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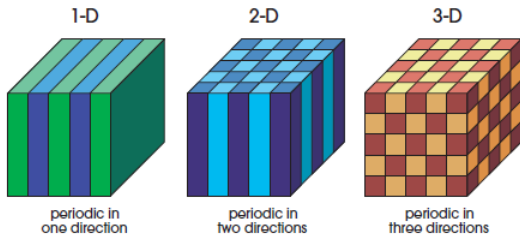
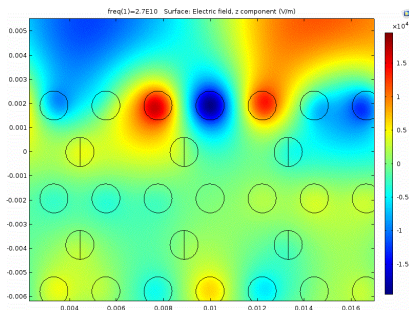


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From the lattice periodicity, interesting effects arise from the photonic crystal system, such as the photonic bandgap.

Photonic Bandgap

Similar to the semiconductor bandgap between the valence and conducting energy bands, the photonic crystal bandgap can prohibit light from propagating inside the crystal structure



PhC Defects

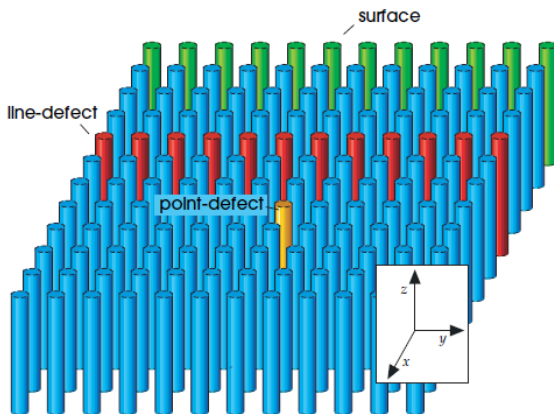


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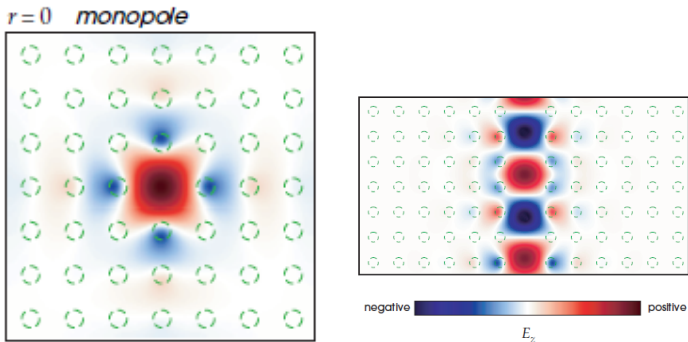


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PhC Fibers

Photonic crystal fibers are optical fibers with a photonic crystal cladding, with rods running along the axis of the fiber

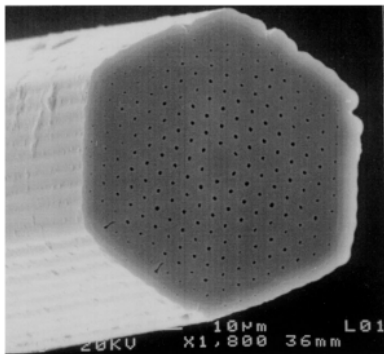


Figure: Birks, T. A., Knight, J. C. & Russell, P. S. J. *Endlessly single-mode photonic crystal fiber*. Opt. Lett., OL 22, 961963 (1997).

Fabrication

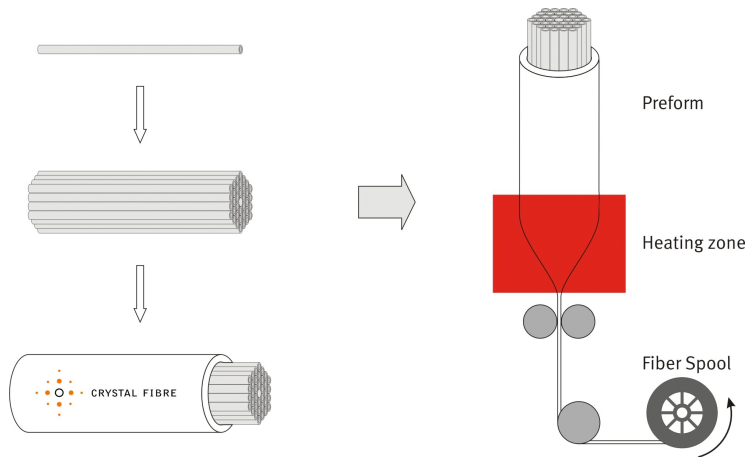


Figure: <http://spie.org/newsroom/1371-photonic-crystal-fiber-characteristics-benefit-numerous-applications>

Photonic Crystals as Waveguides

Conventional Optical Fibers:

- Basic geometry
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Photonic Crystal Fibers:

- Can be single-mode for all wavelengths
- Very precise fabrication

Wavelength shift

Orbital resonance condition is given by $\lambda_R = 2\pi n_{SM} \rho^2 \alpha / |l|$, where

- ρ is radius of the cladding resonance
- n_{SM} is refractive index of the space-filling mode
- α is the twist rate of the PCF

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Differentiating,

$$\Delta\lambda_r = \lambda_{R0} \left(\frac{\Delta n_{SM}}{n_{SM0}} + \frac{\Delta\alpha}{\alpha_0} + \frac{2\Delta\rho}{\rho} \right) \quad (1)$$

where n_{SM0} , ρ_0 , α_0 are values from the unstrained PCF

Wavelength shift

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Change in n_{SM} :

$$\Delta n_{SM} = \frac{n_{SM0}^2}{2} [\nu(p_{11} + p_{12}) - p_{12}] \epsilon \quad (4)$$

where p are the photoelastic coefficients of fused silica

Wavelength shift

$$\frac{\Delta\lambda_r}{\lambda_{R0}} = \left(\frac{\alpha_M}{\alpha_0} - \epsilon \right) - 2\nu\epsilon + \epsilon \frac{n_{SM0}^2}{2} [\nu(p_{11} + p_{12}) - p_{12}] \quad (5)$$

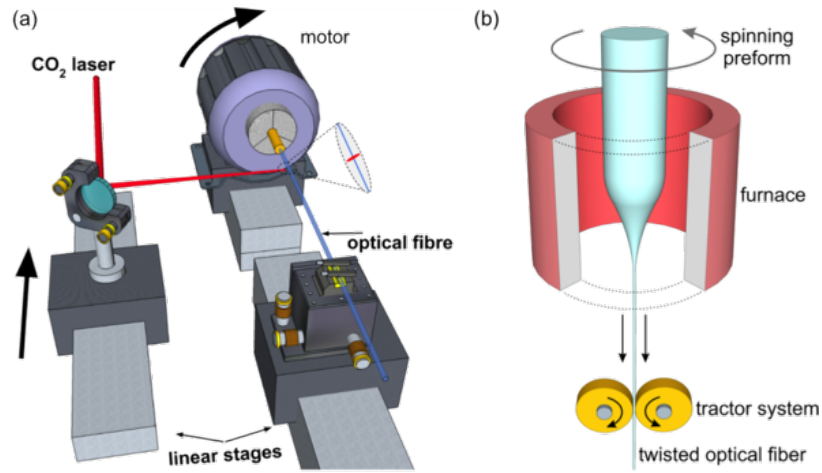
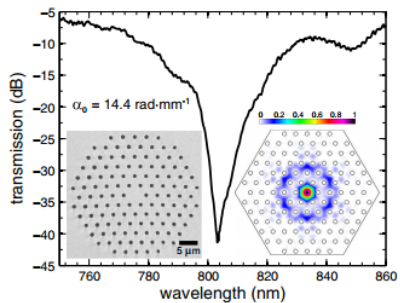


Figure: [://www.mpl.mpg.de/en/russell/research/twisted-pcf-oam.html](http://www.mpl.mpg.de/en/russell/research/twisted-pcf-oam.html)

Experimental Results



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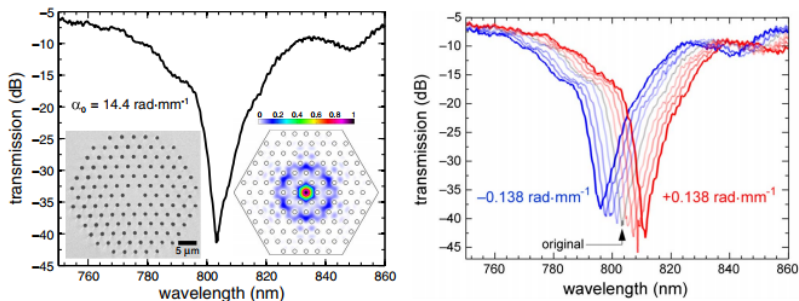
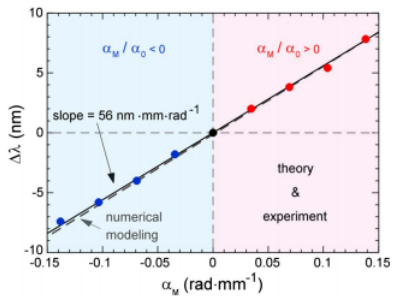


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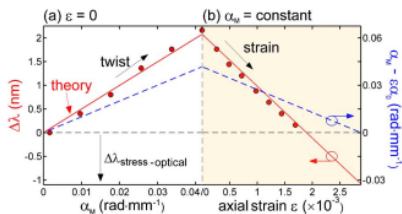
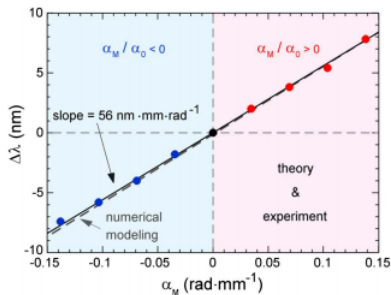


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- OAM multiplexing in optical fibers
- Particle trapping and rotating

References

- Photonic Crystals
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- Photonic Crystal Fibers:
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- PCF fabrication: <http://spie.org/newsroom/1371-photonic-crystal-fiber-characteristics-benefit-numerous-applications>
- HPCF fabrication: <https://www.mpl.mpg.de/en/russell/research/twisted-pcf-oam.html>