Electrical and Computer Engineering Department

Simulation of a Photonic Crystal Fiber

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Purpose: In this experiment, a photonic crystal fiber will be designed and a simulation will be done to determine at what wavelengths and hole diameters the fiber will be single-moded.

Background

Optical Fiber Basics

- Index-guided optical fibers are composed of a core and surrounded by cladding of a lower refractive index.
- They transfer information as light.
- Photonic crystal fibers are a subset of optical fibers that are characterized by a pattern of air holes in their cladding.
- The total internal reflection is when the light traveling through a medium hits a different medium of a lower refractive index at an angle greater than the critical angle, then all light is reflected, meaning it stays in the higher-index medium

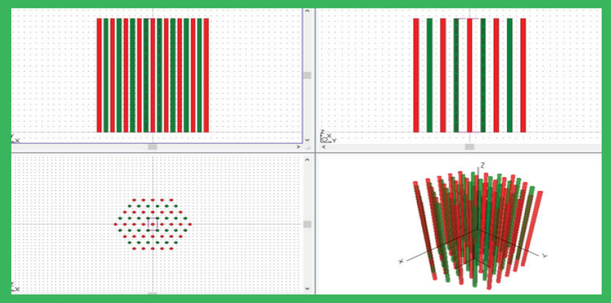
Modes & V Number

- Modes are the various paths that a light ray can take to travel down the fiber.
- Guided modes are the modes supported by the fiber.
- The area of the cross-section covered by a mode remains the same for the duration of the of the length of the fiber.
- Modes have an associated effective index that represents the phase shift that occurs when the light hits the core-cladding boundary.
- The V number is a dimensionless number that determines the number of modes of a fiber.

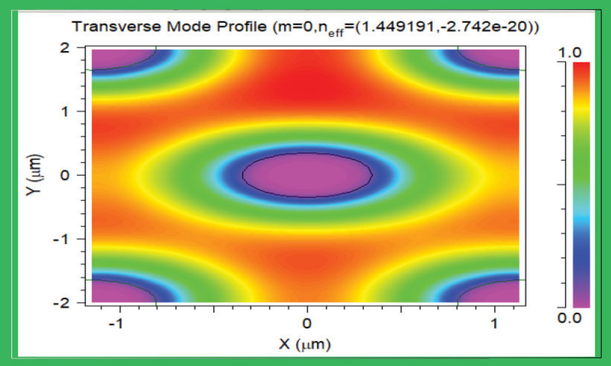
$$V = \left(\frac{2\pi\Lambda}{\lambda}\right)\sqrt{n_0^2 - n_{eff}^2}$$

Procedure

First, the photonic crystal fiber needs to be created in the RSoft CAD environment.



Second, the boundary conditions are launch settings need to be set.



Finally, the variables must be set to change the hole diameter and the wavelength.
Q will vary the wavelength according the following equation where Period = 2.3.

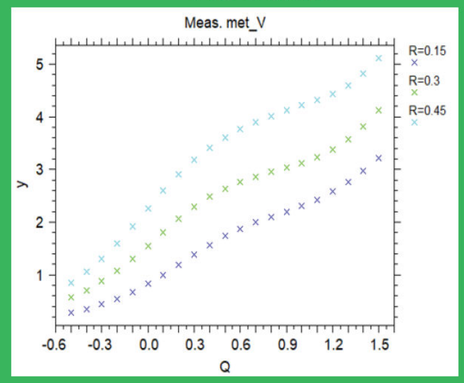
Wavelength = Period/10^Q.

R will vary the hole diameter according to the following equation where Period = 2.3.

Hole Diameter = Period*R

The effective V number will be calculated at each hole diameter and wavelength.

Results



As Q increases, the wavelength decreases, meaning that a smaller wavelength corresponds to a higher V number. As the hole diameter increases, the V number increases.

- R = 0.15 (hole diameter = 0.345 µm), becomes multi-mode when Q = 1.2 (wavelength = 0.1451 µm).
- R = 0.3 (hole diameter = 0.69 µm) becomes multimode when Q = 0.4 (wavelength = 0.9156 µm).
- R = 0.45 (hole diameter = 1.035 µm) becomes multimode when Q = 0.1 (wavelength = 1.827 µm).

Applications

- Knowing the modes supported by the optical fiber is the foundation for all applications in fiber optics.
- They being increasingly used instead of conventional cables because they are faster, more reliable, and less bulky.
- Optical fibers can transmit data very quickly; they are used as Internet cables.
- They are used during surgery to light up and see inside of the body.
- They are being researched to detect cancers and other diseases.