

Simulation of Long-Period Fiber Gratings Formed with Helical Fiber

Introduction

Tools used: BeamPROP, MOST

Long-period gratings are widely used as sensors in a variety of fields such as automotive, aerospace, and medicine. Traditional fiber gratings are formed by UV light exposure through a sophisticated phase mask. It has recently been found that a helically twisted fiber can create a similar effect as long--period gratings, and can therefore be used as sensors. Light in a helically twisted single-mode fiber will couple into multiple interfering cladding modes. The pitch or grating period of the helix will determine how this coupling happens, and therefore how the device will operate spectrally. Much like other grating devices, helical fibers are phase sensitive and require the engineer to carefully design the device to fit the desired characteristics. RSoft's **BeamPROP** simulation tool is ideal for this application as it couples an efficient algorithm suitable for large devices with a robust design tool that allows for arbitrary index profiles.

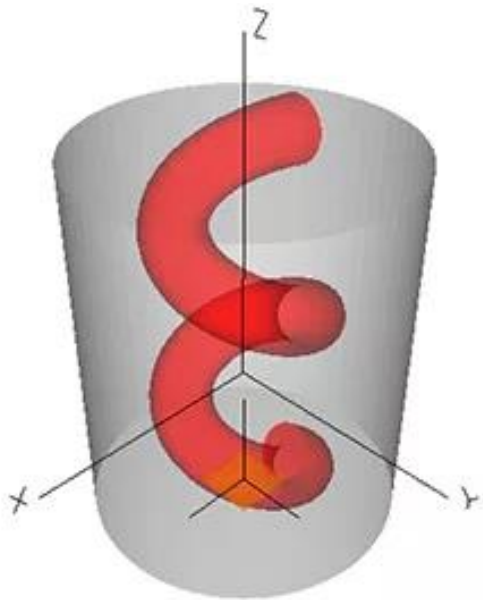


Figure 1. Schematic diagram of a helical fiber

A helical shape corresponding to the single- mode fiber described in Ref [1] and Ref [2] can be easily created in the **RSoft CAD Environment** and is illustrated in Figure 1. A full 3D simulation of the structure was performed using BeamPROP, and the results are shown in Figure 2. Here, we show the power in various modes along the structure as well as the total power in the fiber. Please note that the monitored power of LP1 m modes has been scaled by 2 times due to the rotation symmetry of these modes. BeamPROP software makes it easy and convenient for the user to make measurements of the field propagating in the device. software makes it easy and convenient for the user to make measurements of the field propagating in the device.

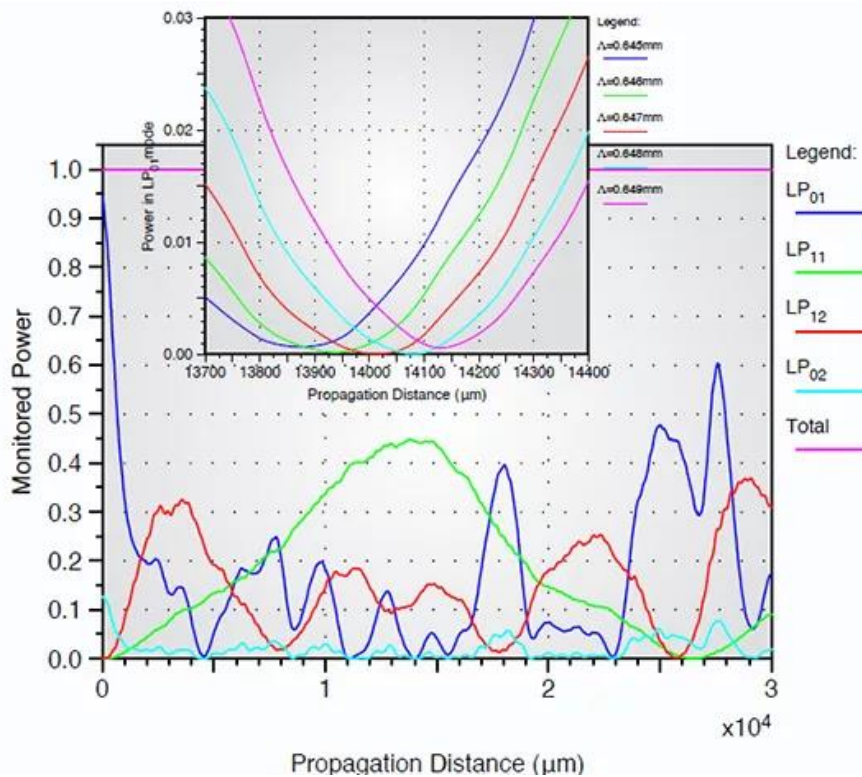


Figure 2. Power coupling between LP₀₇ and cladding modes. These results account for mode degeneracy.

BeamPROP's software package includes **MOST**, a utility which automates parametric studies. This utility can be used to study device characteristics as a function of any design parameter. The inset in Figure 2 illustrates how the grating pitch affects the coupling length. From this, the designer can determine appropriate design parameters and tolerances of a particular device.

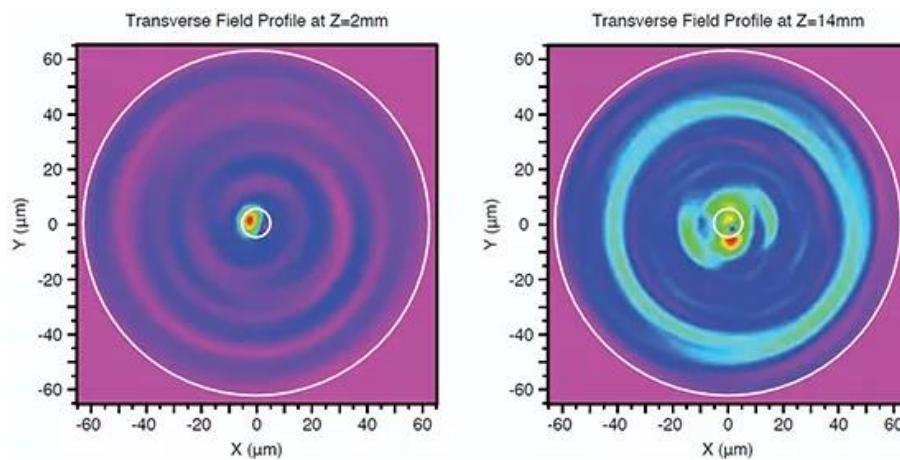


Figure 3. Cross-sectional field profiles at different propagation distances. Left: Transverse field profile at Z = 2mm
Right: Transverse field profile at Z = 74mm

A rigorous tool like BeamPROP provides us with more information than a simple analytical model, which might only account for coupling between the fundamental LP₀₁ and the next higher LP₁₁ mode. BeamPROP, which is based on the Beam Propagation Method (8PM), directly simulates the field propagating in the structure. Therefore, all propagating higher order cladding modes are included. Any power not accounted for in the fundamental LP₀₁ and the next LP₁₁, LP₀₂, and LP₁₂ modes shown resides in even higher order modes. Representative field profiles along the helix shown in Figure 3 also illustrate the highly multimode nature of this device.

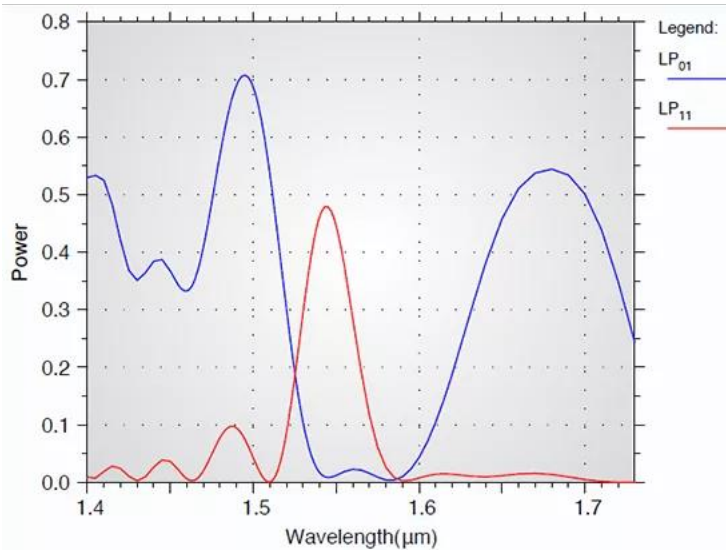


Figure 4. Spectral response of a helical fiber with a pitch of $l/l=0.647\text{mm}$ and grating length $L=74\text{mm}$.

For a fixed pitch of $A = 0.647\text{mm}$ and a grating length $L = 14\text{mm}$, we obtain the spectral response shown in Figure 4 through a parameter scan over the wavelength using MOST.

Once again, BeamPROP provides a robust approach to study the cladding mode coupling in long-period helical fiber gratings, and gives the engineer a key tool in specifying the design and manufacturing tolerances for this long period grating.

References

- [1] G. Shvets, et al, "Polarization properties of chiral fiber gratings; Journal of Optics, Vol. 11, No. 7, May, 2009.
- [2] J Qian, et al, "Coupled-Mode Analysis for Chiral Fiber Long-Period Gratings Using Local Mode Approach," IEEE J. of Quantum Electronics, Vol. 47, No. 11, Nov 2011.

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