ASEC 2024 Conference

The 5th International Electronic Conference on Applied Sciences

04–06 December 2024 | Online

MDPI

Design and FEM analysis of Zeonex Based Porous Core Holey Fiber over telecom bands

Amit Halder[1,2,*], Md. Younus Ali[2], Md. Ryad Tanshen[2], and Zubairia Siddiquee[2]

[1]Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh

[2]World University of Bangladesh, Dhaka-1230, Bangladesh

INTRODUCTION & AIM

Zeonex-based porous-core holey fibers (PCHFs) present remarkable optical properties for telecommunication and sensing applications. Their design enables effective chromatic dispersion management, reduced signal attenuation, and enhanced nonlinear interactions. Using the finite element method (FEM), this study evaluates parameters such as dispersion, confinement loss, effective area, nonlinear coefficient, V-number, and bend loss. The aim is to design and analyze a Zeonex-based PCHF to optimize performance in telecommunication bands by controlling dispersion, minimizing attenuation, and enhancing nonlinear efficiency, while maintaining structural robustness and flexibility.

METHOD

The optical properties of the Zeonex-based porous-core holey fiber (PCHF) were analyzed using the finite element method (FEM) in COMSOL Multiphysics. The fiber's geometry was modeled to incorporate a porous core surrounded by a cladding region with periodic air holes, ensuring precise control of its optical characteristics.

Key steps included:

- **Modeling:** A 2D cross-sectional structure of the PCHF was designed with Zeonex as the base material, incorporating parameters such as core porosity, hole diameter, and pitch.
- **Simulation:** FEM simulations were performed to calculate critical optical parameters, including dispersion, confinement loss, effective area, nonlinear coefficient, V-number, and bend loss.
- **Boundary Conditions:** Perfectly matched layers (PMLs) were used to suppress reflections, ensuring accurate confinement loss analysis.
- **Wavelength Selection:** Simulations focused on the 1550 nm wavelength, a critical window for optical communication.
- **Validation:** The results were analyzed to determine the fiber's suitability for high-performance telecommunication and sensing applications.

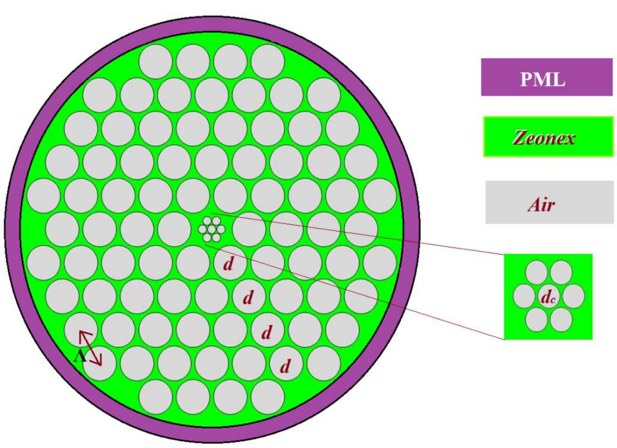

Figure 1: Two-dimensional cross section of the proposed Zeonex based porous core holey fiber.

RESULTS & DISCUSSION

The Zeonex-based porous-core holey fiber (PCHF) exhibited exceptional optical properties, demonstrating its potential for advanced telecommunication and sensing applications.

Dispersion: The fiber achieved a significant negative dispersion of -785.7 ps/(nm•km), which is ideal for chromatic dispersion management in optical communication systems.

Confinement Loss: A low confinement loss of 7.098×10^{-2} dB/cm was observed, ensuring minimal signal attenuation over long distances.

Effective Area: The small effective area of 1.319 μm² enables efficient nonlinear interactions, making the fiber suitable for high-power light transmission.

Nonlinear Coefficient: A high nonlinear coefficient of 61.46 W^{-1} km^{-1} enhances the fiber's capability for nonlinear optical processes, crucial for advanced photonic applications.

V-Number: The calculated V-number of 2.21 indicates single-mode operation, ensuring stable signal propagation.

Bend Loss: The fiber demonstrated excellent structural flexibility with a bend loss of 4.939×10^{-3} dB/cm, suitable for compact and robust optical systems.

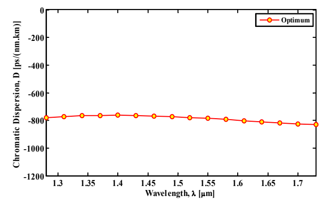

Figure 2: Wavelength vs. Chromatic Dispersion Curve

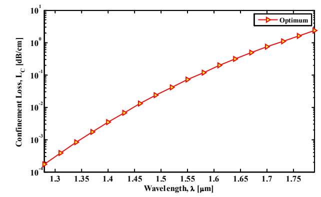

Figure 3: Wavelength vs. Confinement Loss Curve

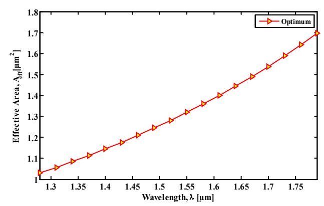

Figure 4: Wavelength vs. Effective Area Curve

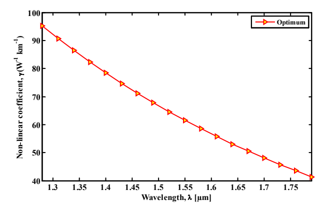

Figure 5: Wavelength vs. Nonlinear Coefficient Curve

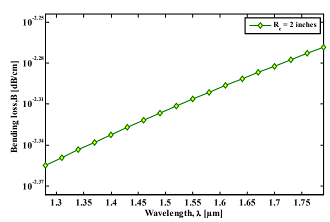

Figure 6: Wavelength vs. Bending Loss Curve

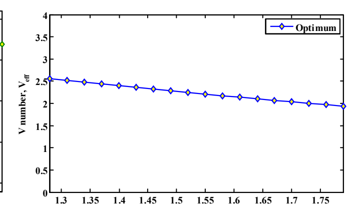

Figure 7: Wavelength vs. V number Curve

The combination of negative dispersion and low confinement loss makes the fiber highly effective for dispersion compensation and long-haul communication. Additionally, the high nonlinear coefficient and small effective area enable efficient nonlinear interactions, making the fiber ideal for nonlinear optics applications. The low bend loss and robust structural properties ensure its practicality in flexible and compact designs. These findings highlight the Zeonex-based PCHF as a promising candidate for next-generation telecommunication networks and photonic sensing technologies.

CONCLUSION

The Zeonex-based porous-core holey fiber (PCHF) demonstrates exceptional optical properties, including significant negative dispersion, low confinement loss, high nonlinear coefficient, and robust structural flexibility. These features make it an ideal candidate for advanced telecommunication systems and photonic sensing applications, offering efficient chromatic dispersion management, reduced attenuation, and enhanced nonlinear performance. This study underscores the potential of Zeonex-based PCHFs in driving innovations in optical communication and sensing technologies.

FUTURE WORK

Future research will focus on optimizing the design parameters of the Zeonex-based porous-core holey fiber (PCHF) to further reduce confinement loss and enhance nonlinear efficiency. Investigations will include expanding the operational wavelength range, exploring alternative geometries for improved dispersion management, and evaluating the fiber's performance under different environmental conditions. Additionally, experimental fabrication and testing of the proposed PCHF will be pursued to validate the simulation results and assess its practical applicability in real-world telecommunication and sensing systems.