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Imaging Fiber Design for Medical Applications

Objective
To design a broad-band imaging fiber for lossless delivery of CO2 laser for medical applications.

Introduction
A medical laser delivery system transmits laser energy to a surgical site of a patient, however 30% of the energy will be lost during the transmission. Our new design provides a solution to the problem. Firstly, it maximizes the bandwidth by using high-refractive-index matrix to compensate the material dispersion permitting high input energy by broad-band wave transmission. Secondly, it decreases the loss by using periodic microstructures within photonic crystal fibers (PCFs) as well as alternating layers (n1/n2) of dielectrics deposited on a metal film inside the hollow core.

Principles
• Effective refractive index:
  \[ n_{\text{eff}} = \text{Re}(n_{\text{eff}}) + j \text{Im}(n_{\text{eff}}) \]
• Mode guiding loss:
  \[ L(\text{dB/m}) = \frac{40 \pi n m(n_{\text{eff}})}{\lambda n_{\text{eff}}} \]
• Dispersion parameter:
  \[ D = -\frac{\lambda}{c} \frac{\partial^2 B(n_{\text{eff}})}{\partial \lambda^2} (\lambda \text{ in } \mu\text{m}) \]

Conclusion
• Various types of infrared fibers and light guiding principles have been studied.
• Schematic structure of the fiber has been designed, and a 3-layer PCF has been constructed and simulated using RSoft.
• The relationship between waveguide dispersion D\text{w} and \lambda has been investigated.
• Future research will focus on the plasmonics enhancement of the fiber.

Results
Figure 1. Fiber delivery set-up for CO2 laser
Figure 2. Photonic bandgap reflector
Figure 3. Ex mode profile of 3-layer PCF
Figure 4. Waveguide dispersion D\text{w} vs. \lambda for PCF with different n\text{matrix}, for compensating highly negative material dispersion D\text{m} and maximizing the bandwidth