DESIGN OF NEXT-GENERATION MID-INFRARED MULTIMATERIAL OPTICAL FIBERS

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MOTIVATION

Optical fibers for communications

Semiconductor integrated optics

- On-chip Ge laser
- Control light on a microchip

Biomedical sensing

- Flexible?
- Remote sensing?

Semiconductor + optical fiber!
MOTIVATION

What kind of materials can we use?

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MATERIALS OPTICAL PROPERTIES
Finite Element Analysis

- RF module → Mode analysis

Study:

- Governing equations
  \[ E(x, y, z, t) = E(x, y)e^{j(\omega t - \beta z)} \]
  \[ \nabla \times (\nabla \times E) - k_0^2 n^2 E = 0 \]
- Materials parameters: \( n \) & \( k \)
- Meshing

\( n_{\text{core}} > n_{\text{cladding}} \)
MODE ANALYSIS IN THE X-Y PLANE

6 μm core diameter at wavelength of 2 μm

What about the optical loss? How to optimize?
CORE SIZE AND WAVELENGTH DEPENDENCE

How to further reduce loss without sacrificing core size?

![Graph showing loss dependence on wavelength and core size.](image)
SECOND LOOK AT MATERIALS PROPERTIES

![Graph of optical constants of various materials](image)

Palik. Handbook of optical constants of solids
\( \lambda = 2.3 \, \mu m \)  

\( \text{SiO}_2 \)  

\( \lambda = 2.3 \, \mu m \)  

\( \text{SiO}_2 \)  

\( n_{Ge} > n_{Si}, \quad n_{Ge} > n_{ZnSe} \)
WAVELENGTH DEPENDENCE

Graph showing the dependence of loss on wavelength for different materials.

- Ge(6 \( \mu \text{m} \))
- Ge(4 \( \mu \text{m} \))/ZnSe(2 \( \mu \text{m} \))
- Ge(4 \( \mu \text{m} \))/Si(2 \( \mu \text{m} \))

Inset graph highlighting the transition at lower wavelengths.

Images showing the distribution of materials at different wavelengths:
- \( \lambda = 10 \, \mu \text{m} \)
- \( 3 \, \mu \text{m} \) scale bars.

Materials include Si, Ge, SiO\(_2\), and ZnSe.
EXPERIMENT
EXPERIMENT

(a) ZnSe cladding thickness:

0.25 \( \mu \text{m} \)  0.73 \( \mu \text{m} \)  1.73 \( \mu \text{m} \)  2.18 \( \mu \text{m} \)  2.74 \( \mu \text{m} \)

(b) Simulation vs. Experiment

(c) Measurement comparison

\( \lambda = 3.39 \mu \text{m} \)

\( \lambda = 10.64 \mu \text{m} \)
CONCLUSIONS

• Mode analysis was performed with the RF module for electromagnetic waves
• Parameters such as wavelength, core diameters, and interfacial layer materials were varied
• Potential application of these semiconductor core optical fibers as mid-infrared waveguides

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THANK YOU FOR YOUR ATTENTION!
BACKUP SLIDES
HIGH PRESSURE CHEMICAL VAPOR DEPOSITION (HPCVD)
SINGLE MODAL REQUIREMENT

\[ V = \frac{2\pi a}{\lambda} \sqrt{n_1^2 - n_2^2} \]

\[
\begin{align*}
V & \leq 2.405 & \text{Single mode} \\
V & > 2.405 & \text{Multimode mode}
\end{align*}
\]