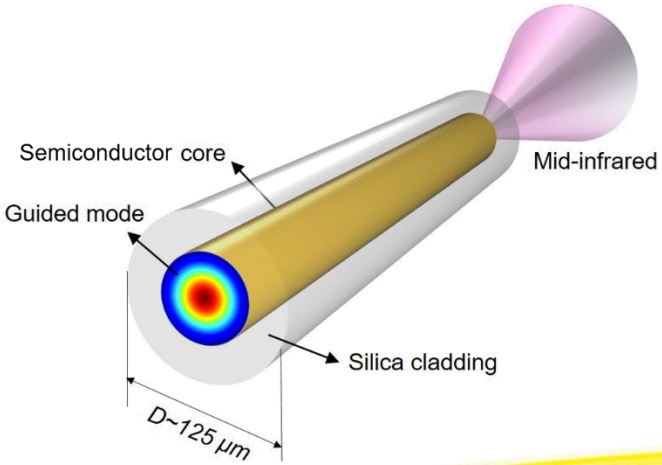
COMSOL CONFERENCE 2016 BOSTON

PENNSTATE 1855

MatSE MATERIALS SCIENCE AND ENGINEERING
COLLEGE OF EARTH AND MINERAL SCIENCES

DESIGN OF NEXT-GENERATION MID-INFRARED MULTIMATERIAL OPTICAL FIBERS



Xiaoyu Ji

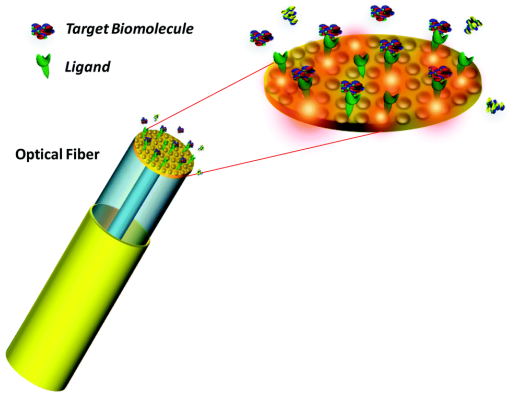
Pennsylvania State University

2016-10-06

MOTIVATION

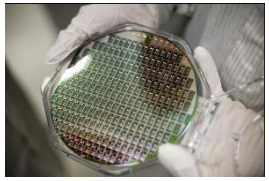
Optical fibers for communications

Biomedical sensing

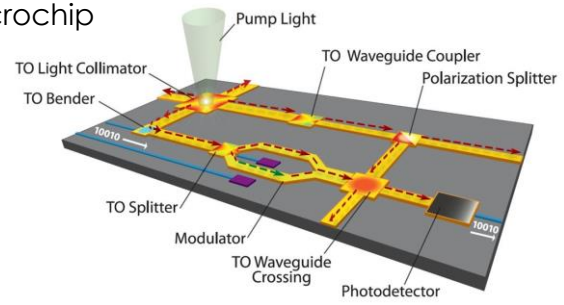


Semiconductor integrated optics

On-chip Ge laser



Control light on a microchip



Flexible?
Remote sensing?

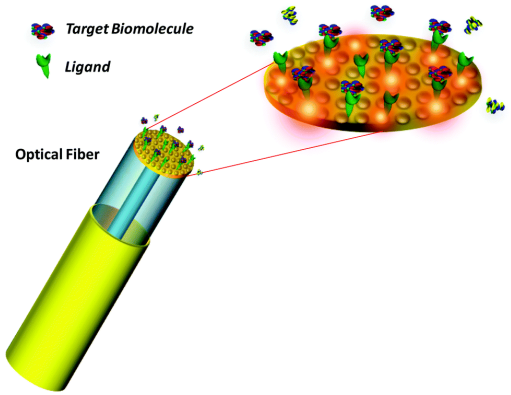
Semiconductor + optical fiber !

www.elprocus.com, Ricciardi *et al*. Analyst, 2015

MOTIVATION

Optical fibers for communications

Biomedical sensing



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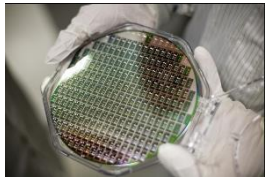

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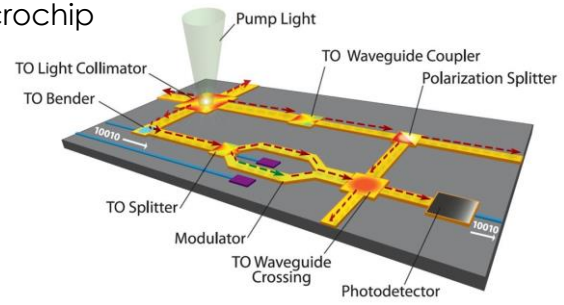
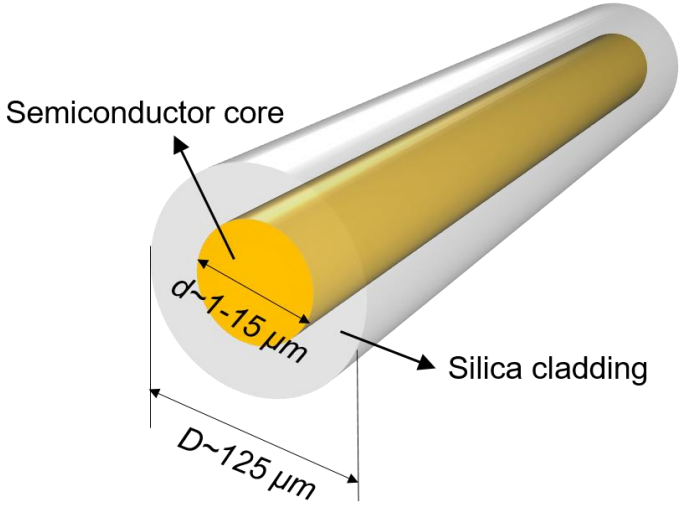
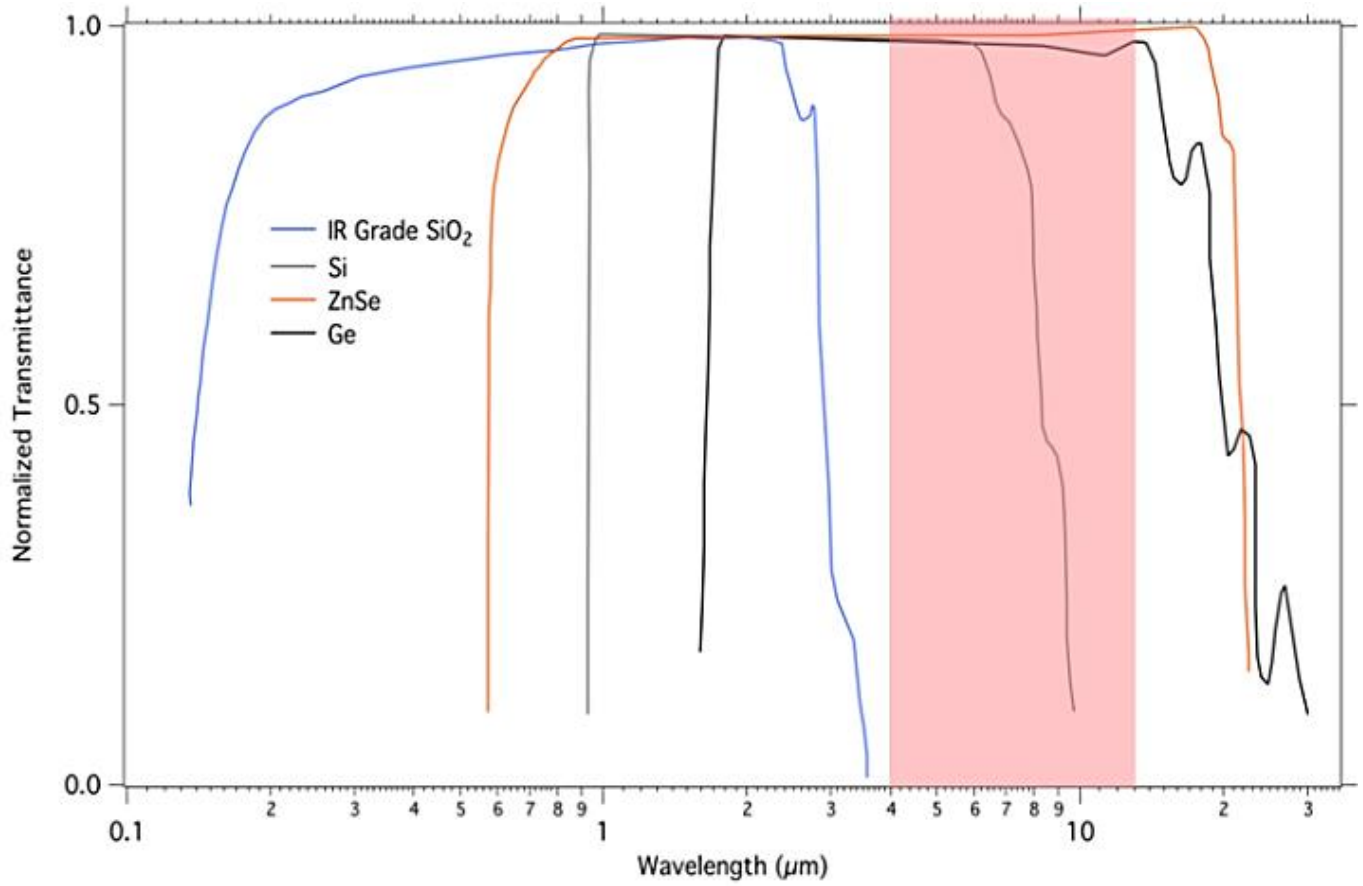




What kind of materials can we use?

www.elprocus.com, Ricciardi *et al*. Analyst, 2015

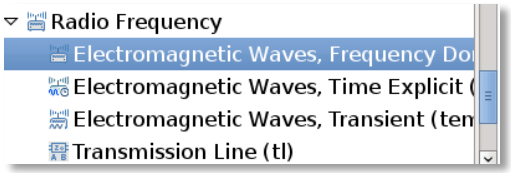
MATERIALS OPTICAL PROPERTIES



Mahesh, Ph.D. Dissertation (2010)

FINITE ELEMENT ANALYSIS

- RF module → Mode analysis



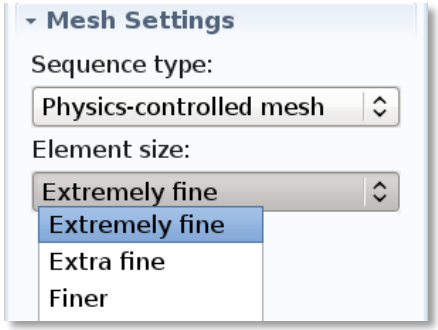
Study:

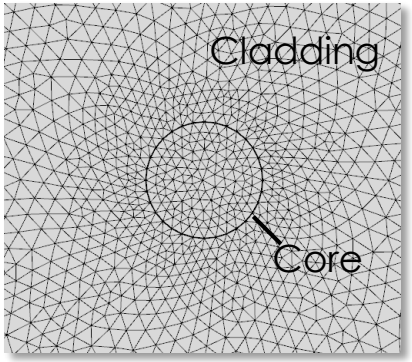
- Governing equations

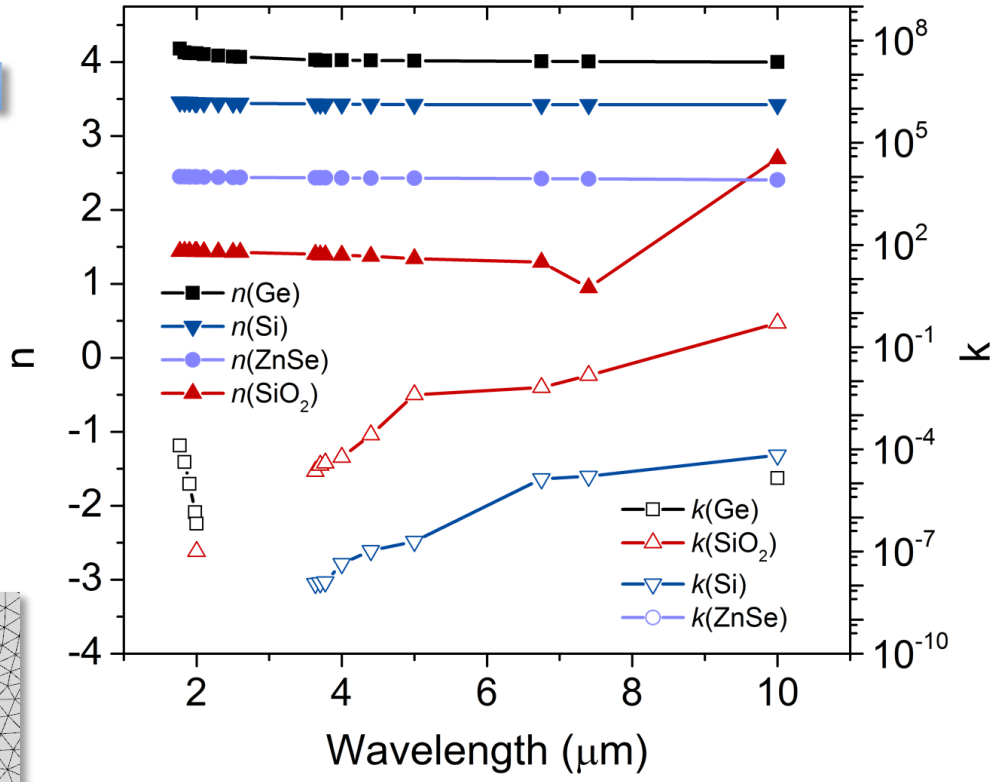
$$\boldsymbol{E}(x,y,z,t) = \boldsymbol{E}(x,y)e^{j(\omega t-\beta z)}$$

$$\nabla \times (\nabla \times \boldsymbol{E}) - k_0^2 n^2 \boldsymbol{E} = 0$$

- Materials parameters: *n* & *k*
- Meshing



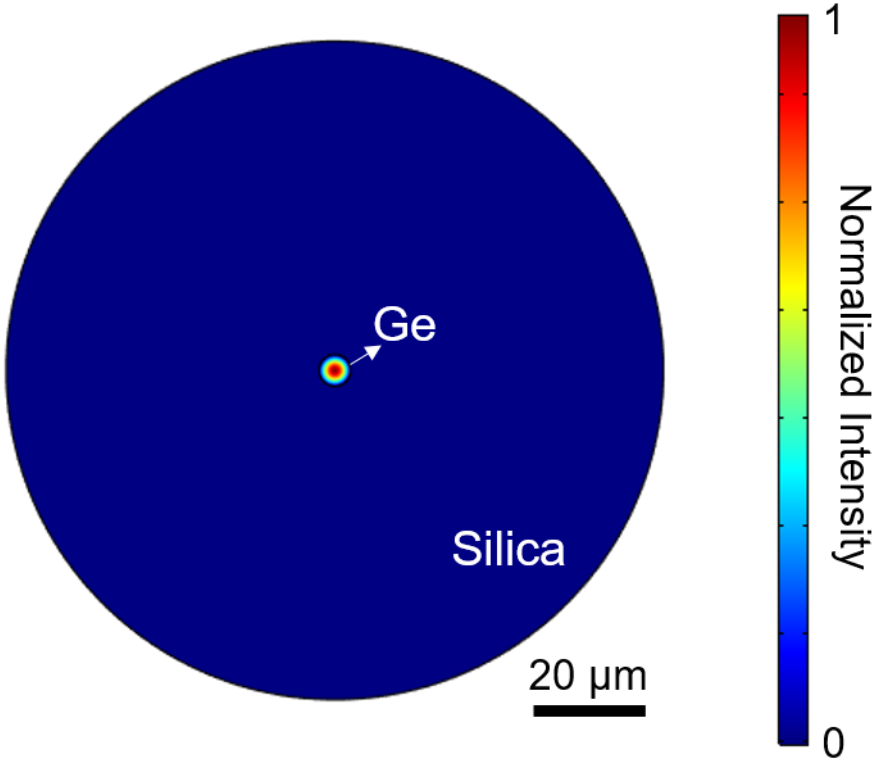




$n_{core} > n_{cladding}$

Palik. Handbook of optical constants of solids

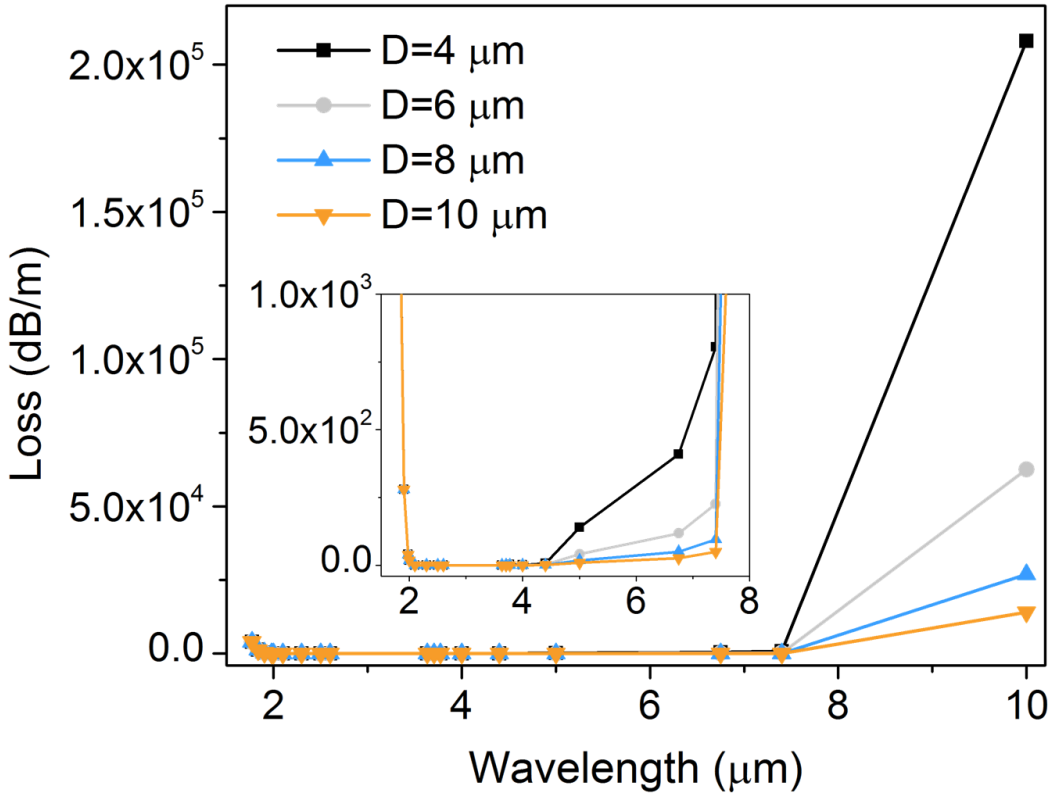
MODE ANALYSIS IN THE *X*-*Y* PLANE

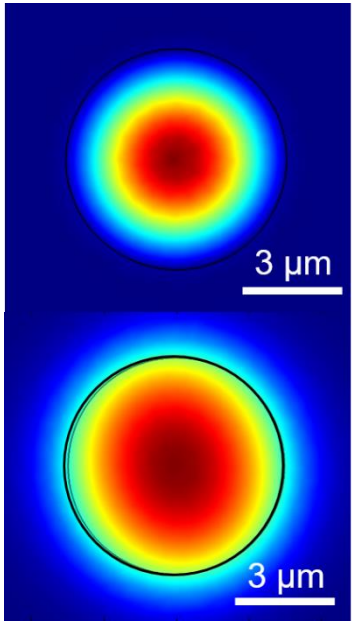


6 μm core diameter at wavelength of 2 μm

What about the optical loss? How to optimize?

CORE SIZE AND WAVELENGTH DEPENDENCE



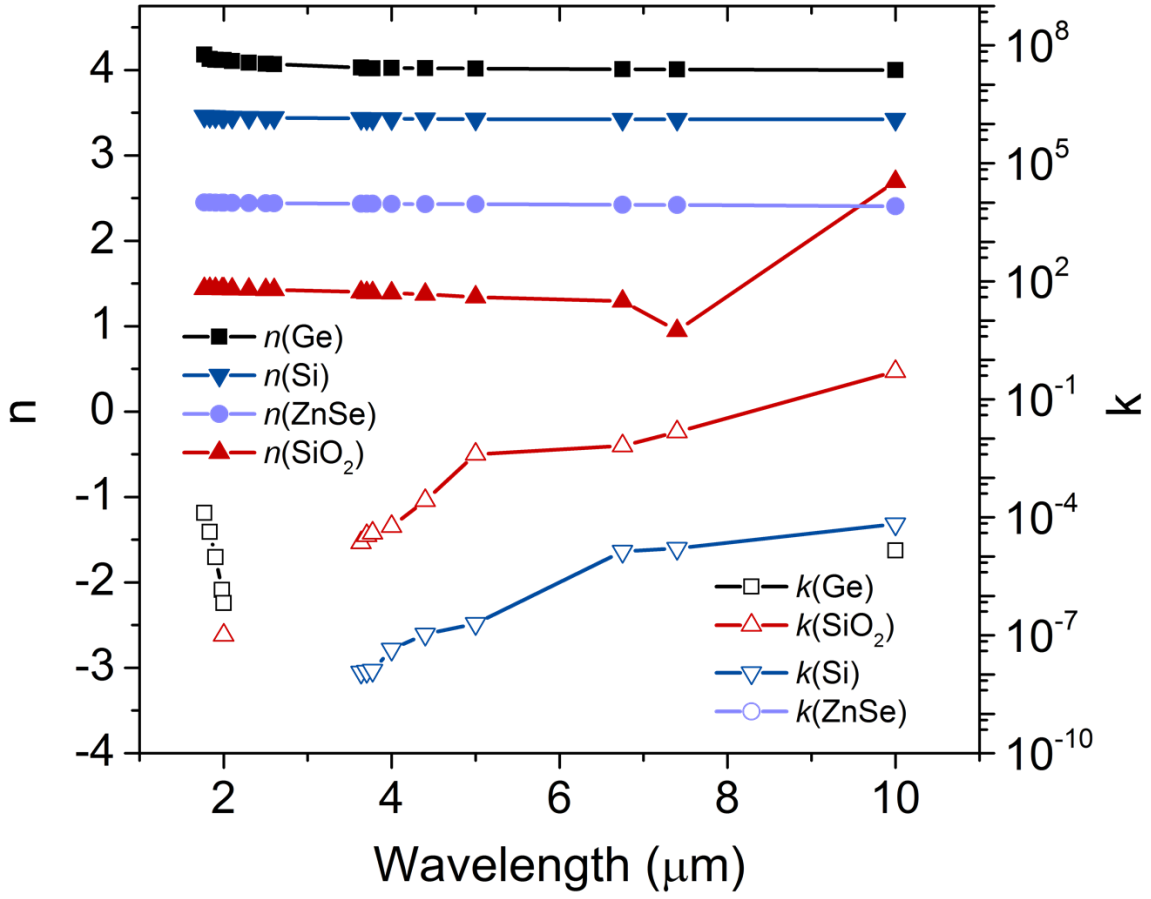


λ=2.3 μm

λ=10 μm

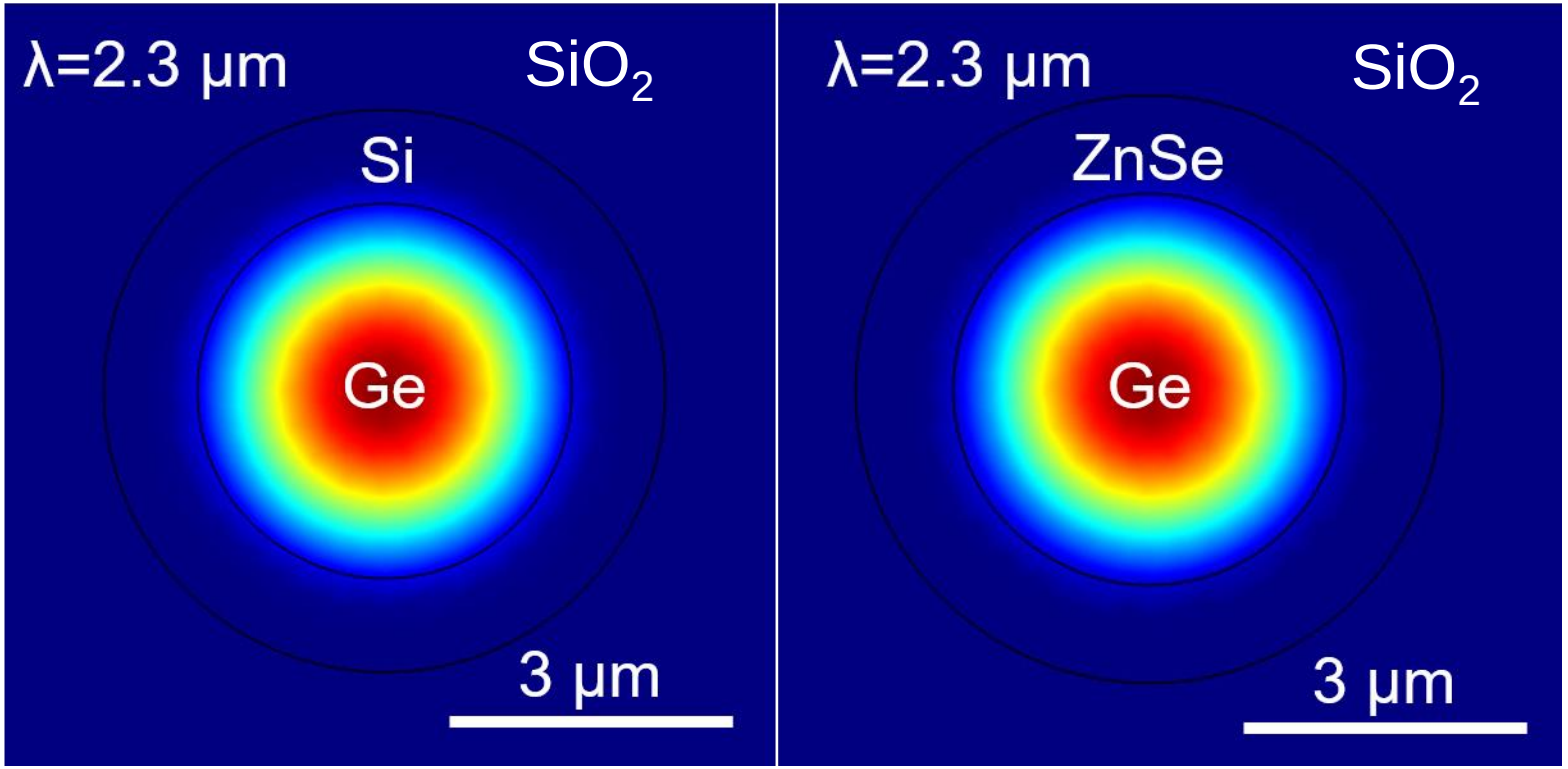
How to further reduce loss without sacrificing core size?

SECOND LOOK AT MATERIALS PROPERTIES



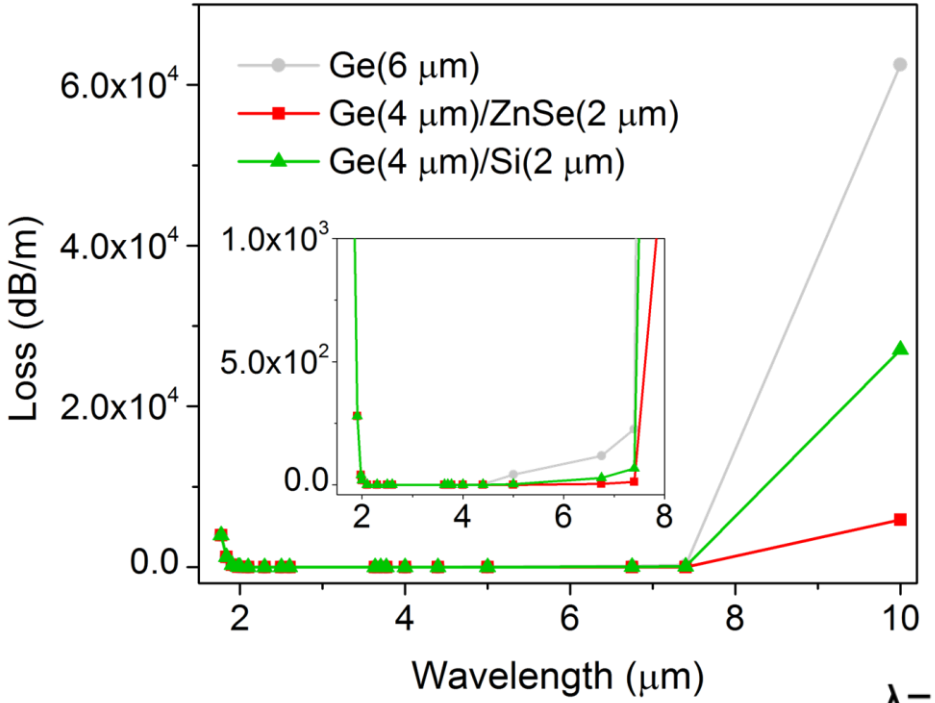
Palik. Handbook of optical constants of solids

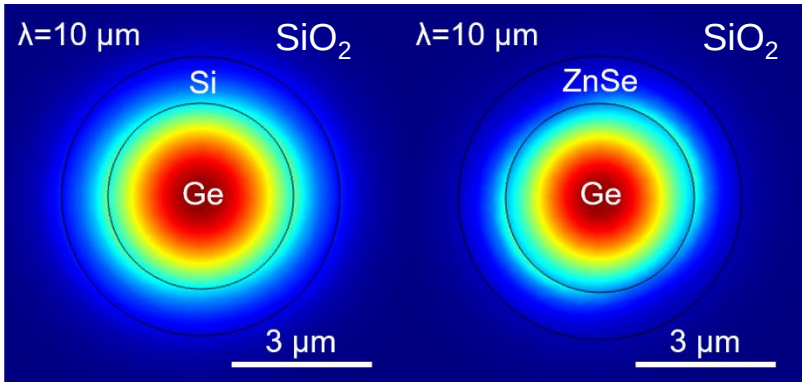
RESULTS

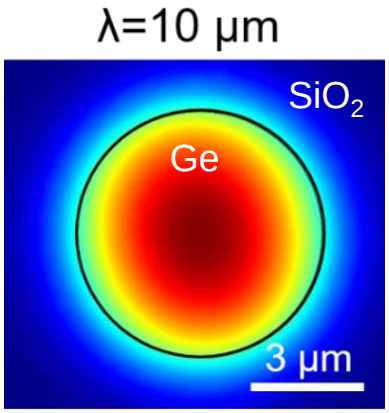


$n_{Ge} > n_{Si}$, $n_{Ge} > n_{ZnSe}$

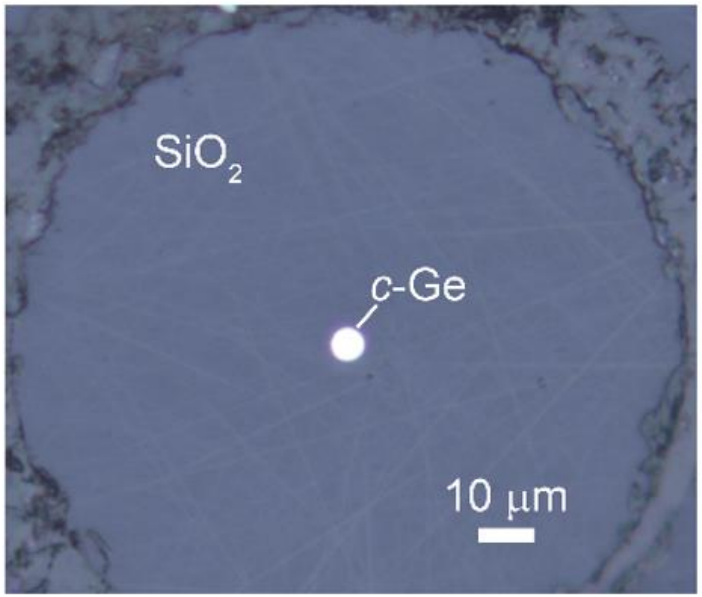
WAVELENGTH DEPENDENCE

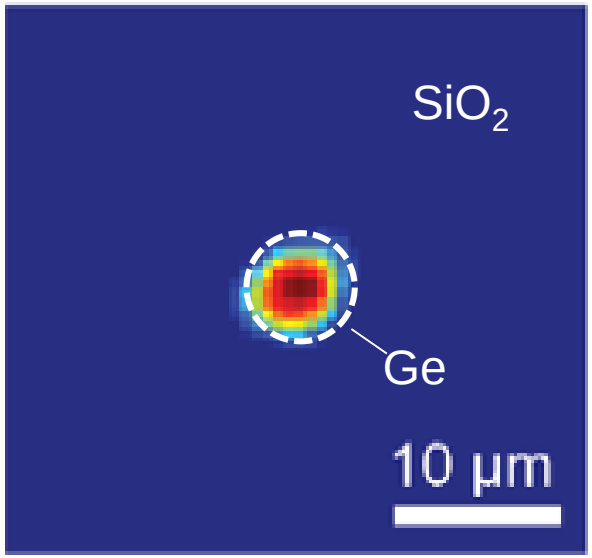






EXPERIMENT





Ji et al. Adv. Optical Mater. (2016)

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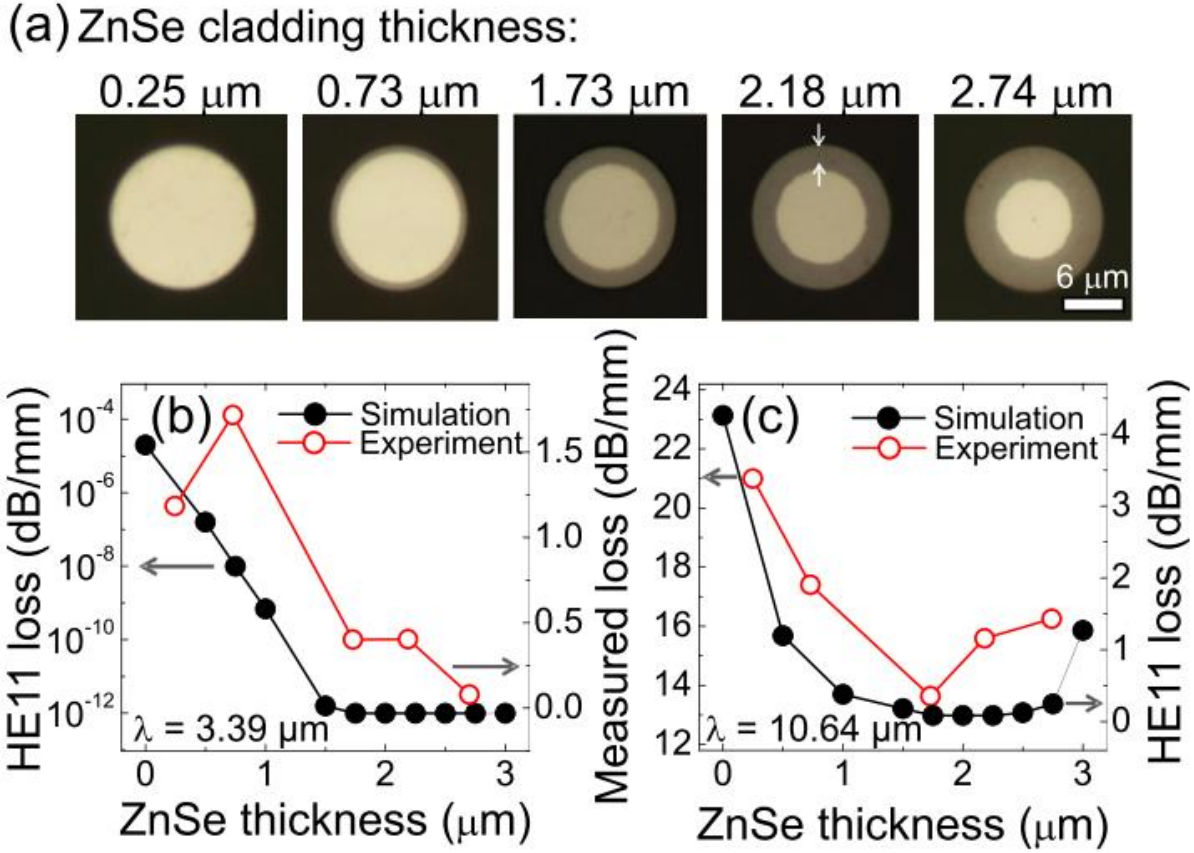

(a) ZnSe cladding thickness:
0.25 μm
0.73 μm
1.73 μm
2.18 μm
2.74 μm
6 μm
(b)
Simulation
Experiment
HE11 loss (dB/mm)
λ = 3.39 μm
ZnSe thickness (μm)
Measured loss (dB/mm)
(c)
Simulation
Experiment
HE11 loss (dB/mm)
λ = 10.64 μm
ZnSe thickness (μm)

CONCLUSIONS

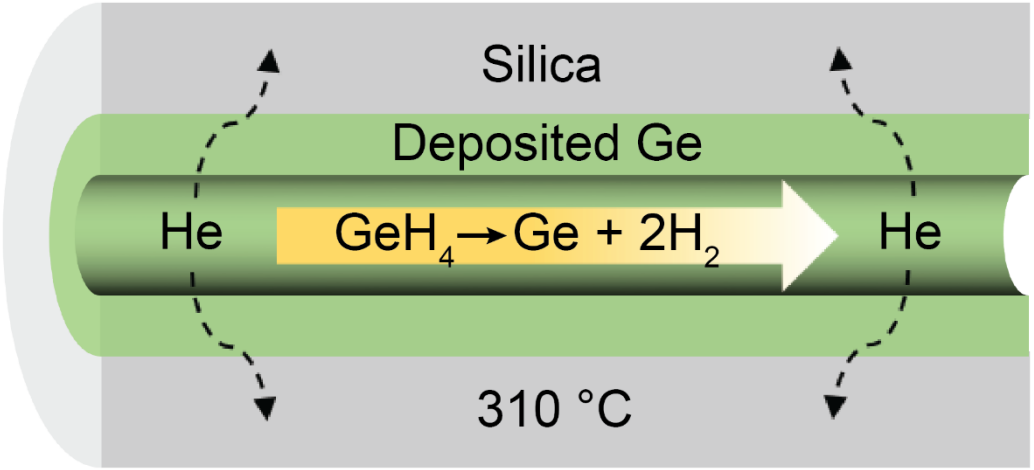
- Mode analysis was performed with the RF module for electromagnetic waves
- Parameters such as wavelength, core diameters, and interfacial layer materials were varied
- Potential application of these semiconductor core optical fibers as mid-infrared waveguides

Fund: NSF No. DMR-1420620

THANK YOU FOR YOUR ATTENTION!

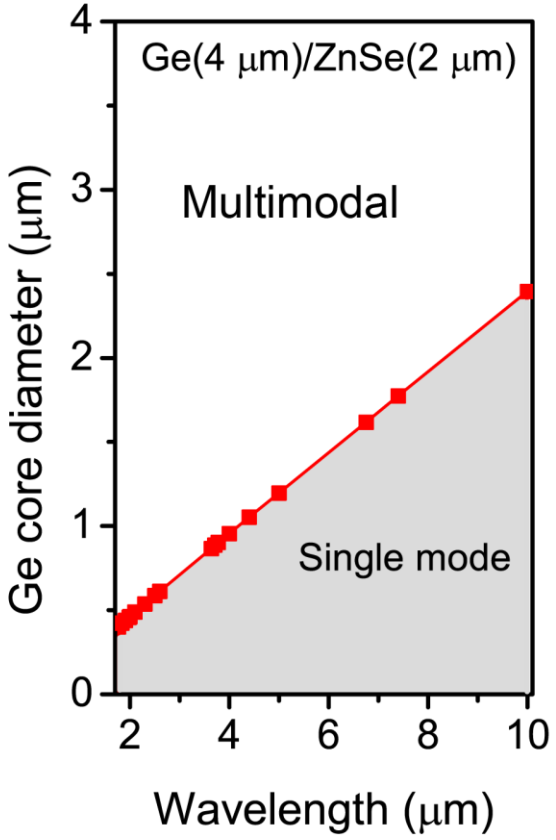
BACKUP SLIDES

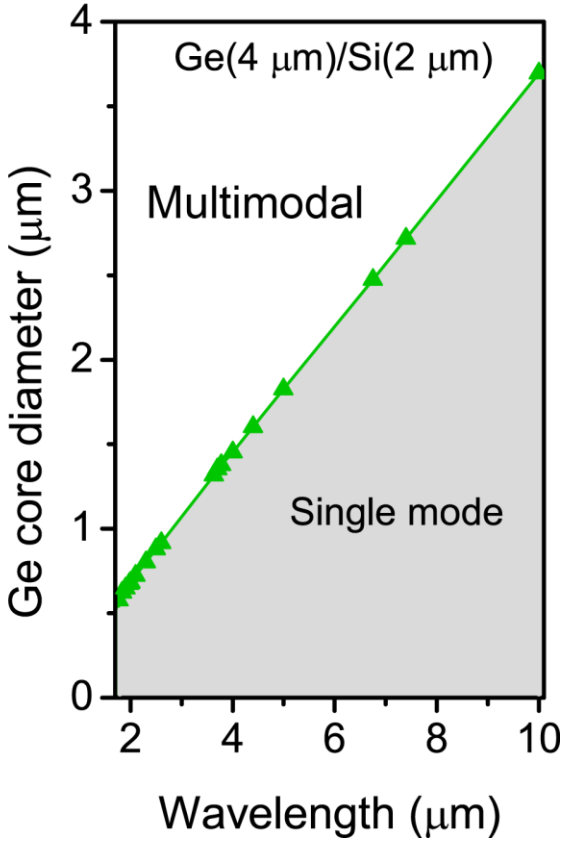
HIGH PRESSURE CHEMICAL VAPOR DEPOSITION (HPCVD)



Ji et al. Adv. Optical Mater. (2016)

SINGLE MODAL REQUIREMENT





$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2} \begin{cases} \leq 2.405 & \text{Single mode} \\ > 2.405 & \text{Multimode mode} \end{cases}$$