2018 Graduate Student Showcase

Graduate Student Showcases

April 2018

A Novel High Temperature Sensor Architecture for Harsh Environments

Bahareh Badamchi
Boise State University

Nirmala Kandadai
Boise State University

Al-Amin Ahmed Simon
Boise State University

Miria Mitkova
Boise State University

Harish Subbaraman
Boise State University

A Novel High Temperature Sensor Architecture for Harsh Environments

Abstract

High temperature sensors capable of operating in harsh environments and providing real-time information on hot spots and temperature profile play a critical role in preventing disasters and improving safety within nuclear reactors. A method widely employed in existing nuclear reactors is the melt wires technique, which suffers from being an after-effect sensor and lower resolution. Our work is focused on the design and fabrication of low power consuming, small size, reversible sensors by combining phase change properties of chalcogenide glasses and compactness of radiation hard optical waveguides to create a highly accurate and real-time temperature sensing system.

A Novel High Temperature Sensor Architecture for Harsh Environments

BOISE STATE UNIVERSITY
B. Badamchi, N. Kandadai, A. Simon, M. Mitkova, H. Subbaraman
Department of Electrical and Computer Engineering
harishsubbaraman@boisestate.edu

I. Abstract

To improve the stability and functionality of the reactor monitoring the exact condition due to high temperature, neutron irradiation, corrosive condition to is very important.

Methods to monitor temperature:

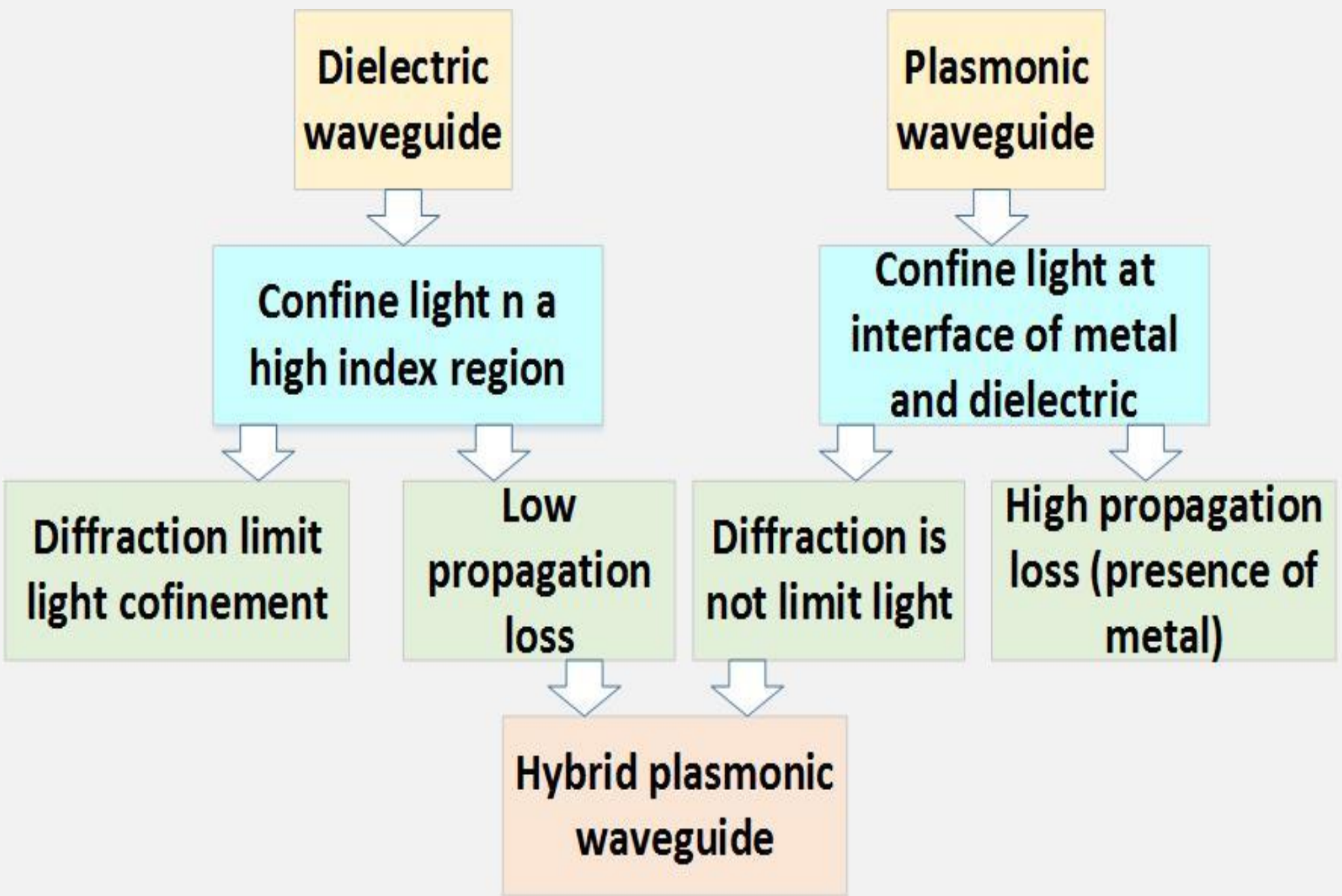
- Thermocouples: unreliable after short time exposer to radiation.
- Melt wires techniques: lower resolution.
- Optical waveguide sensor: high accurate measurement result, multi-use.

Fig. 1. Melt wire techniques [1].

II. Motivation and Method

❖ **Objective:** Design small size, highly accurate, real-time and reversible temperature sensor at 1550 nm wavelength.

❖ **Hybrid plasmonic waveguide:**



Dielectric waveguide

Confine light n a high index region

Diffraction limit light cofinement

Low propagation loss

Plasmonic waveguide

Confine light at interface of metal and dielectric

Diffraction is not limit light

High propagation loss (presence of metal)

Hybrid plasmonic waveguide

Fig. 2. Hybrid plasmonic waveguide properties.

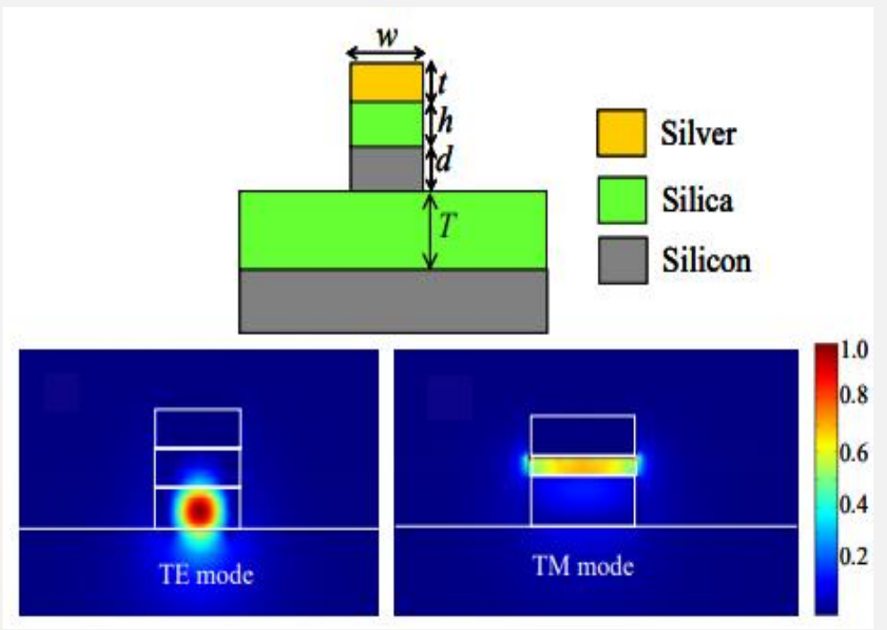


Fig. 3. Basic structure of Hybrid plasmonic waveguide.

❖ **Chalcogenide glass (GhG):**

A glass containing one or more chalcogens (sulfur, selenium and tellurium)

- Temperature sensitive:
  - Switch between an amorphous (dielectric) and a crystalline (metal) state by controlling heating and annealing (cooling) [2].

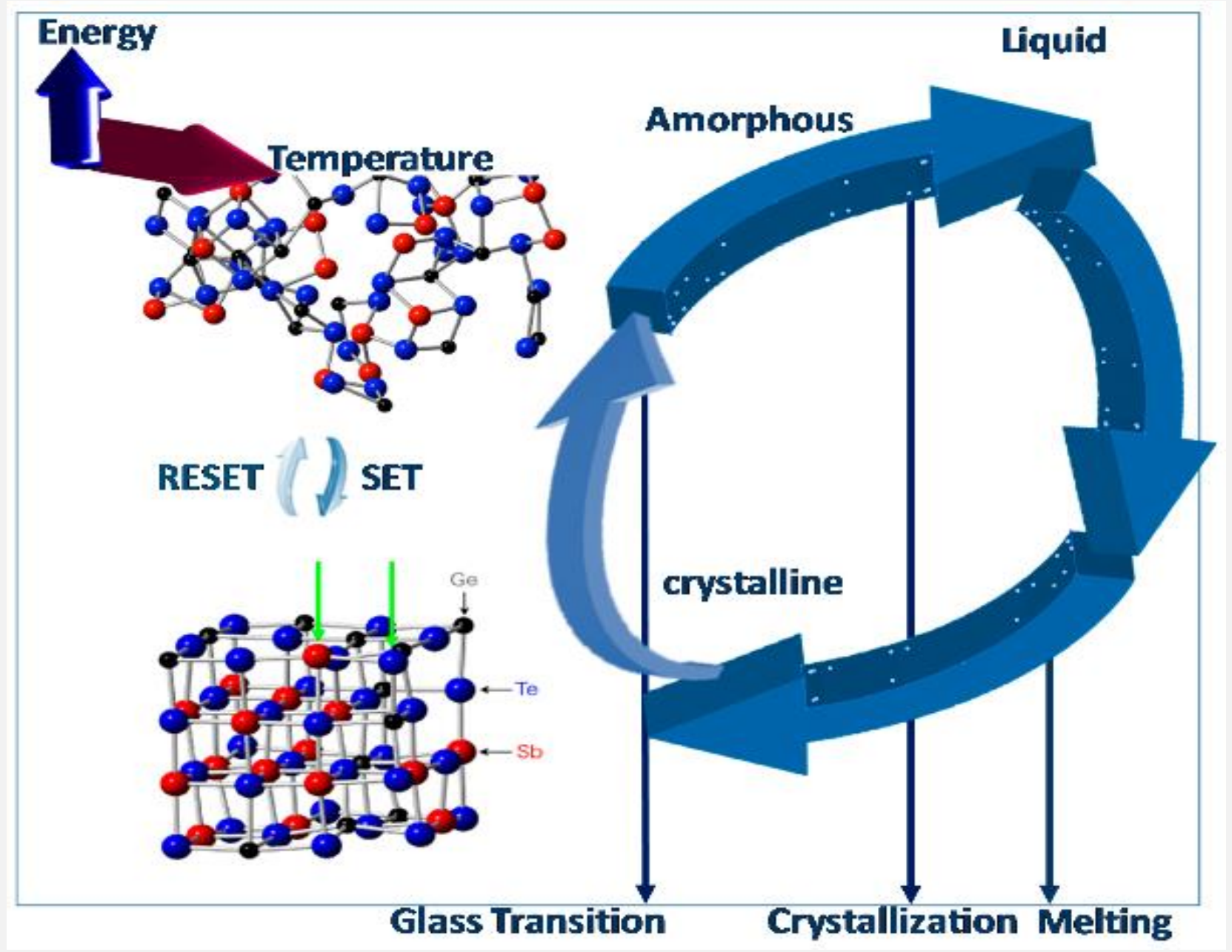


Fig. 4. Phase transition of GhG.

III. Design and Results

- Combining phase change properties of chalcogenide glasses and compactness of radiation hard Si waveguide.
- Place ChG placed on silicon [3].

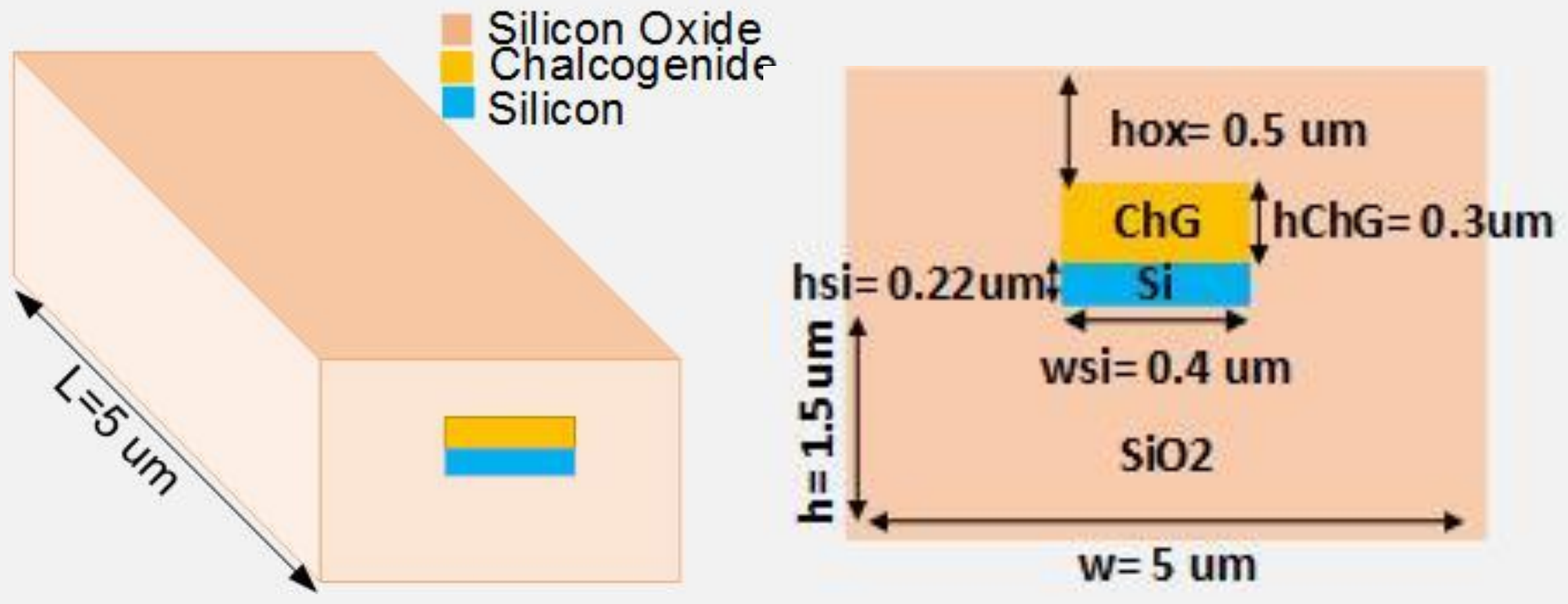


Fig. 5. Proposed hybrid plasmonic waveguide

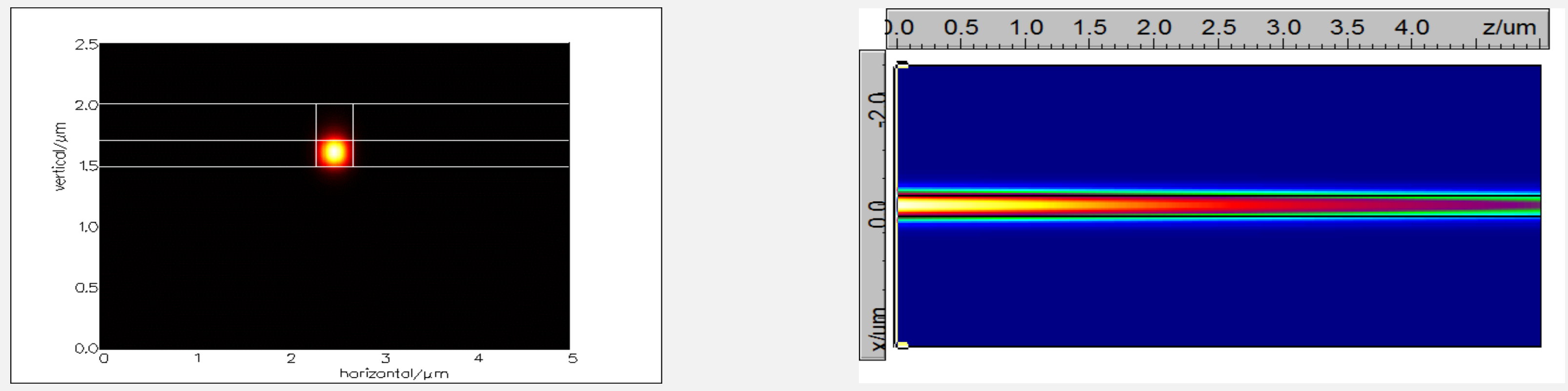
TABLE I.
Refractive index of proposed design

Material	Refractive index (n)	Extinction coefficient (k)
ChG (amorphous)	2.14	0.17
ChG (crystalline)	2.62	2.11
Si	3.47	0
SiO2	1.45	0

❖ **Amorphous phase**

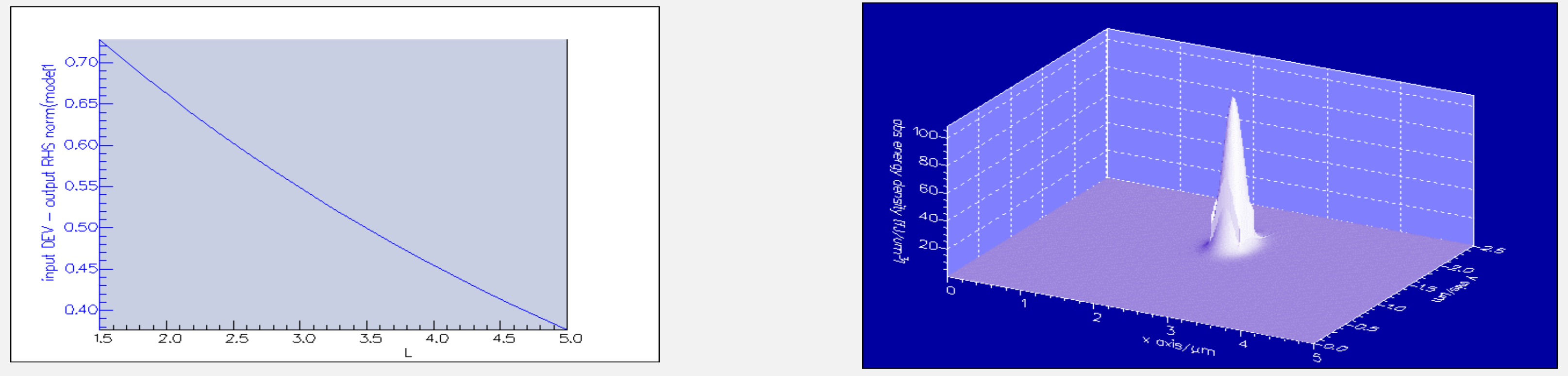
- Fundamental TE and TM modes confinement of propagating light is in Si.
- Fundamental TE and TM propagate along with waveguide with minimum loss and low absorption in near infrared.

Transverse electric mode (TE)



TE Field distribution

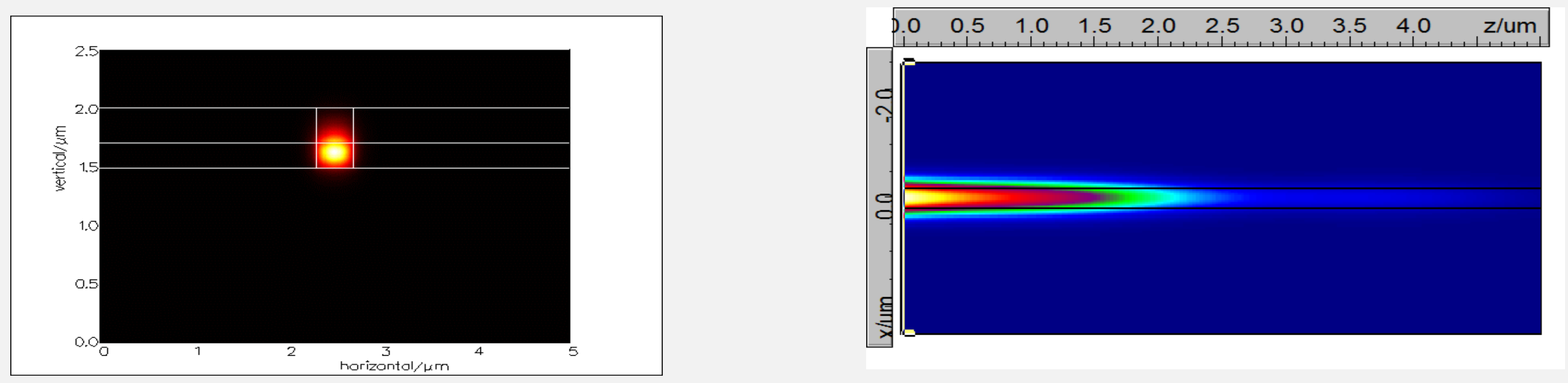
TE output power



TE output power versus length

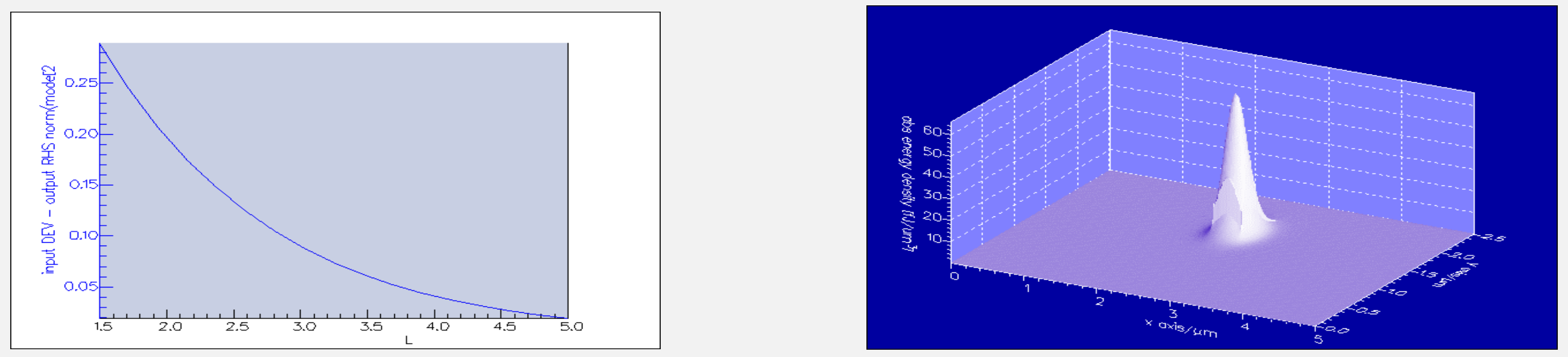
3D TE Field distribution

Transverse magnetic mode (TM)



TM Field distribution

TM output power



TM output power versus length

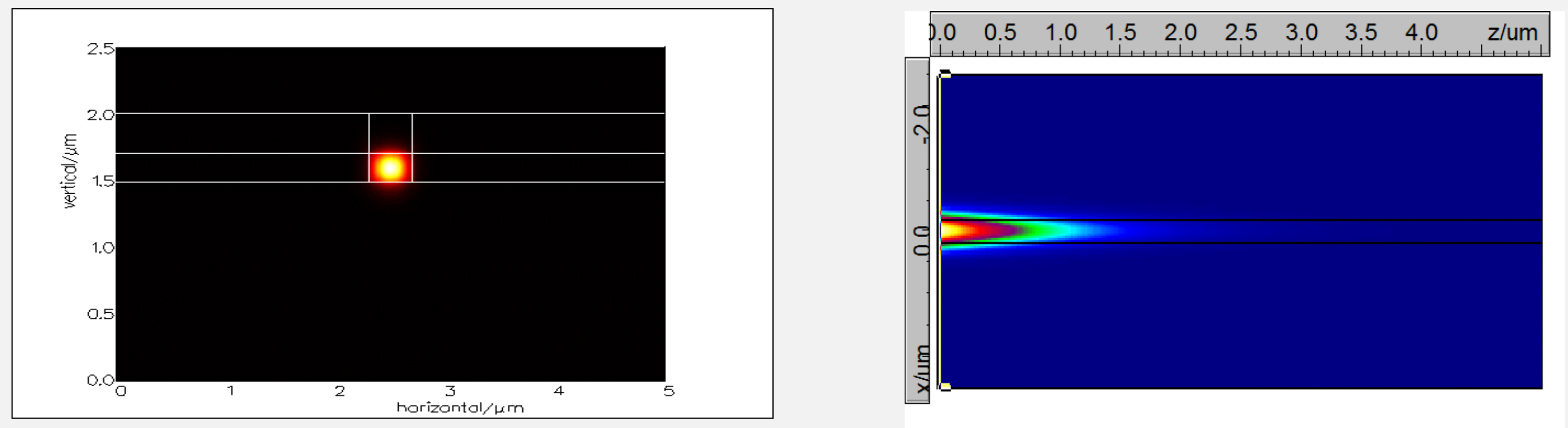
3D TM Field distribution

Fig. 6. TE and TM modes in amorphous phase.

IV. Results Cont'd

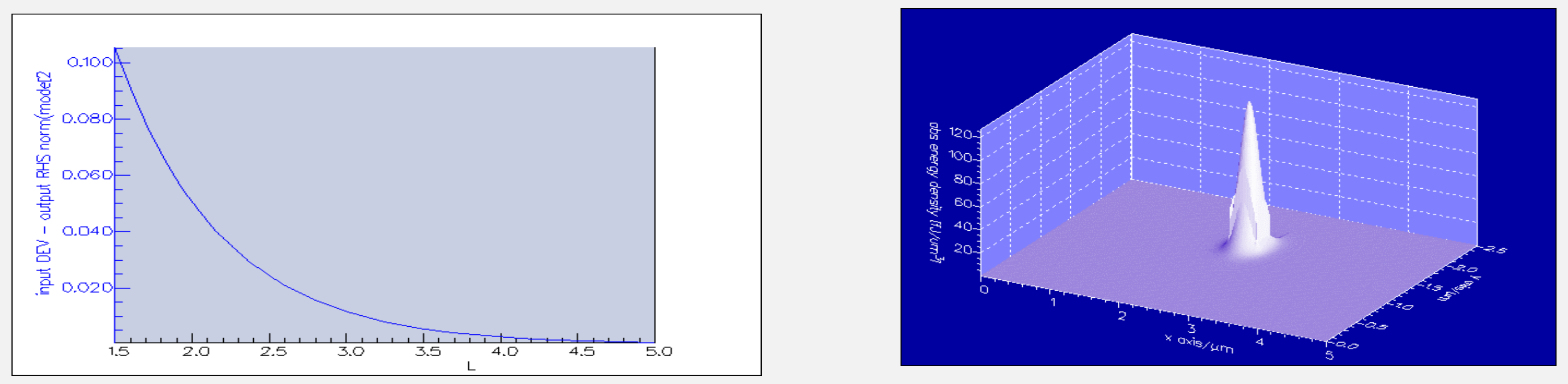
- Plasmonic mode appears at interface between silicon and metal.
- Electrical field of the excited SP wave decays exponentially at Both sides of the interface.
- Plasmonic mode in crystalline phase have higher propagation losses (~1dB/µm) than amorphous phase.

Transverse electric mode (TE)



TE Field distribution

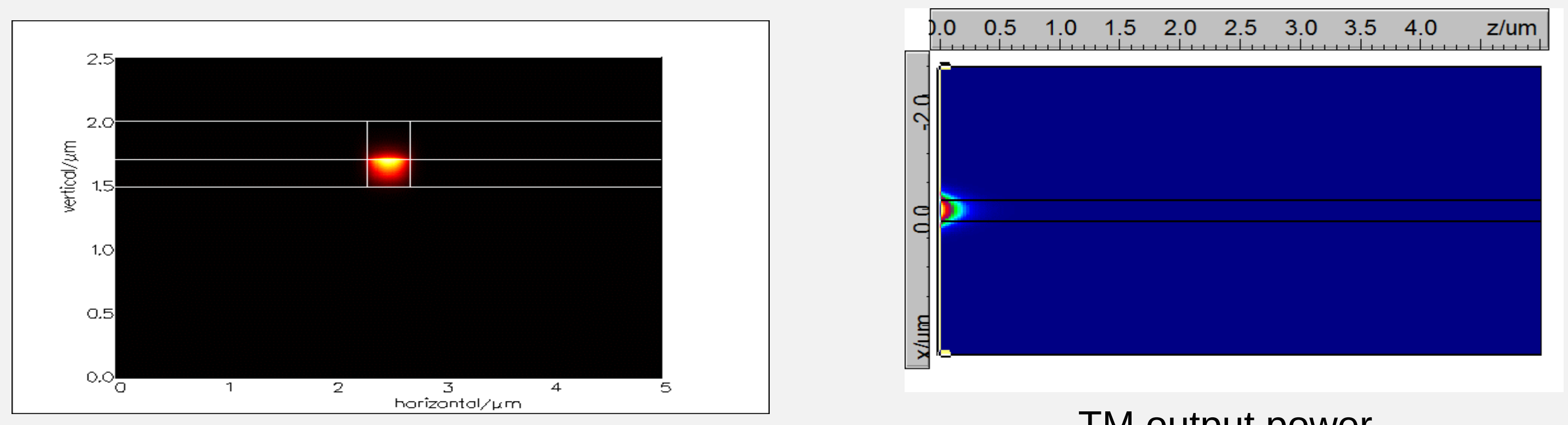
TE output power



TE output power versus length

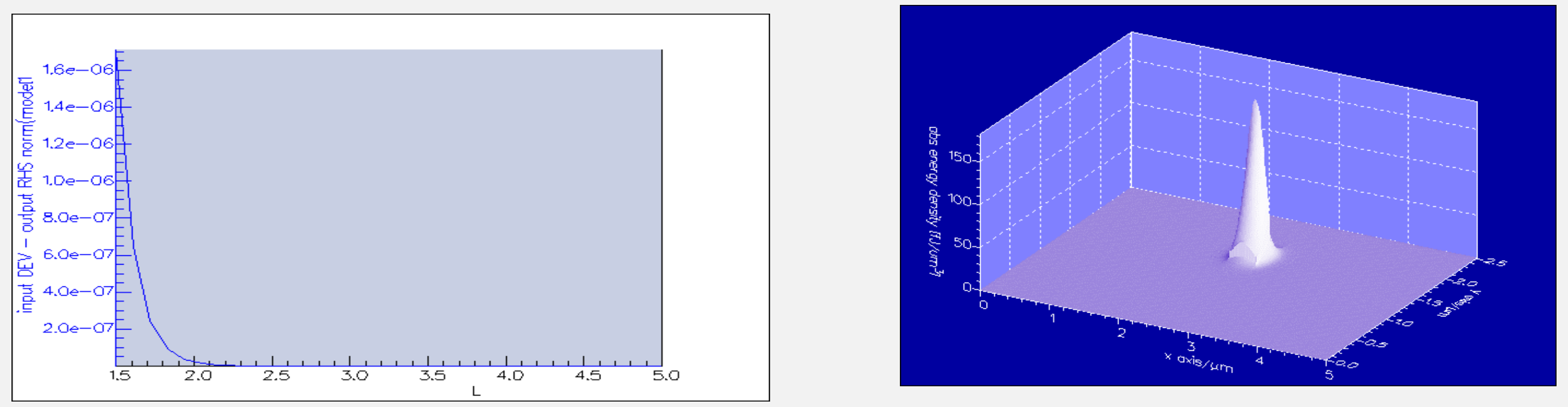
3D TE Field distribution

Transverse magnetic mode (TM)



TM Field distribution

TM output power



TM output power versus length

3D TM Field distribution

Fig. 7. TE and TM modes in crystalline phase.

V. Conclusion

- Transforming the phase of ChG in specific crystallization temperature changes the confinement and propagation loss of the waveguide.
- Crystalline to amorphous phase change of ChG facilitates multiple time use of the sensors.
- Different crystallization temperature based on composition of active ChG generates a temperature sensors in desire applications.

ACKNOWLEDGEMENTS

This work was supported by DOE under Award Number DE-NE008691.

NEUP Nuclear Energy University Program
U.S. Department of Energy

REFERENCES

[1] J. E. Daw *et al.*, “Temperature monitoring options available at the Idaho national laboratory advanced test reactor,” 2013, pp. 970–975.
[2] B. J. Eggleton, B. Luther-Davies, and K. Richardson, “Chalcogenide photonics,” *Nat. Photonics*, vol. 5, no. 3, pp. 141–148, Mar. 2011.
[3] FIMMWAVE software.