Optoelectronics Research Group

Design of Integrated Phase Shifter for Breakthrough Starshot

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AIM photonics

AMERICAN INSTITUTE for MANUFACTURING INTEGRATED PHOTONICS

Why Interstellar Flight?

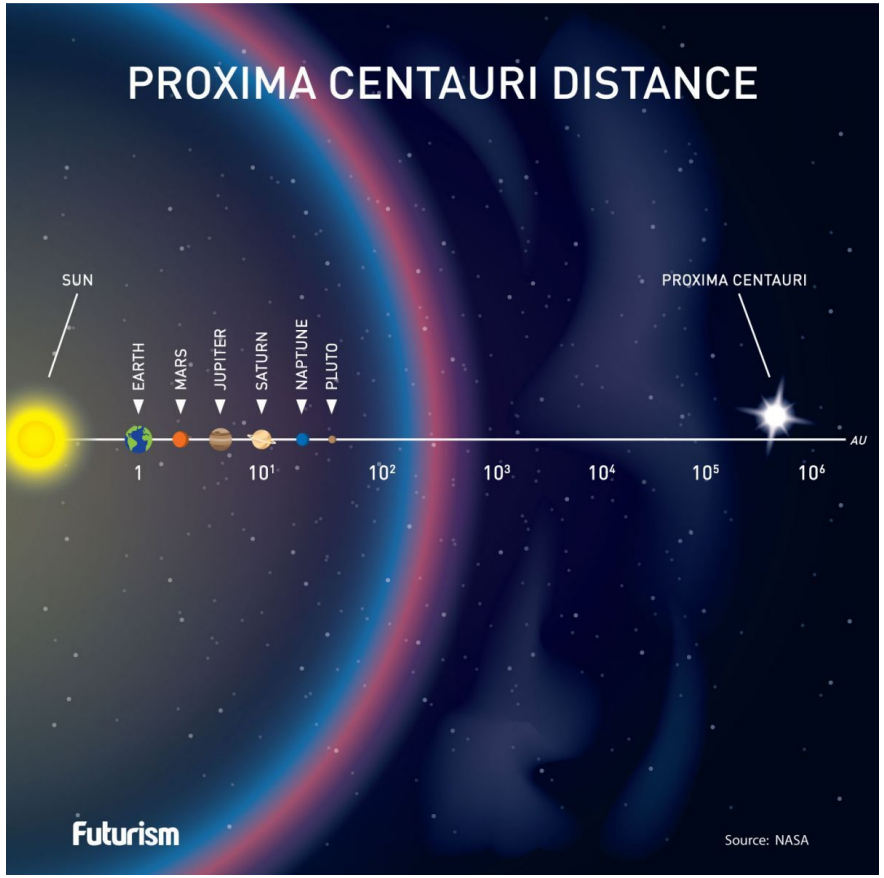
Exploration

Application of Technology

Survival

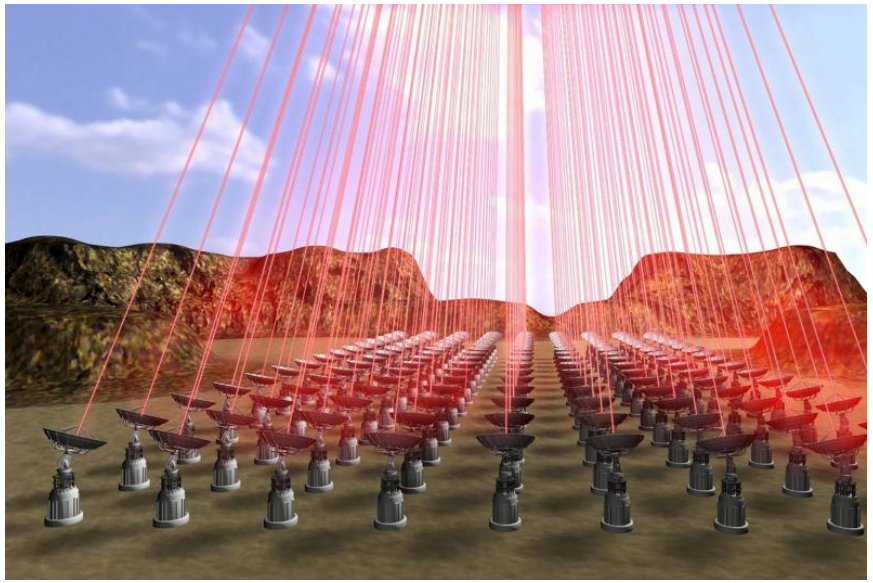
Breakthrough Starshot

Optoelectronics Research Group



Journey to Alpha Centauri

Retrieved from http://www.techort.com/the-success-of-the-breakthrough-starshot-mission-to-proxima-b-may-be-more-important-than-we-think/



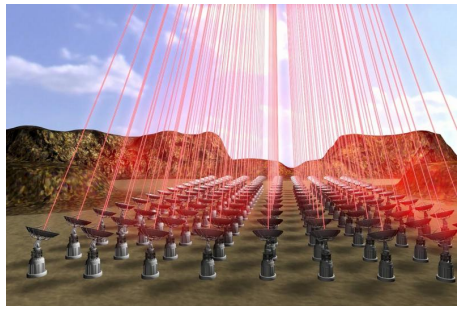
Assembly of the lasers

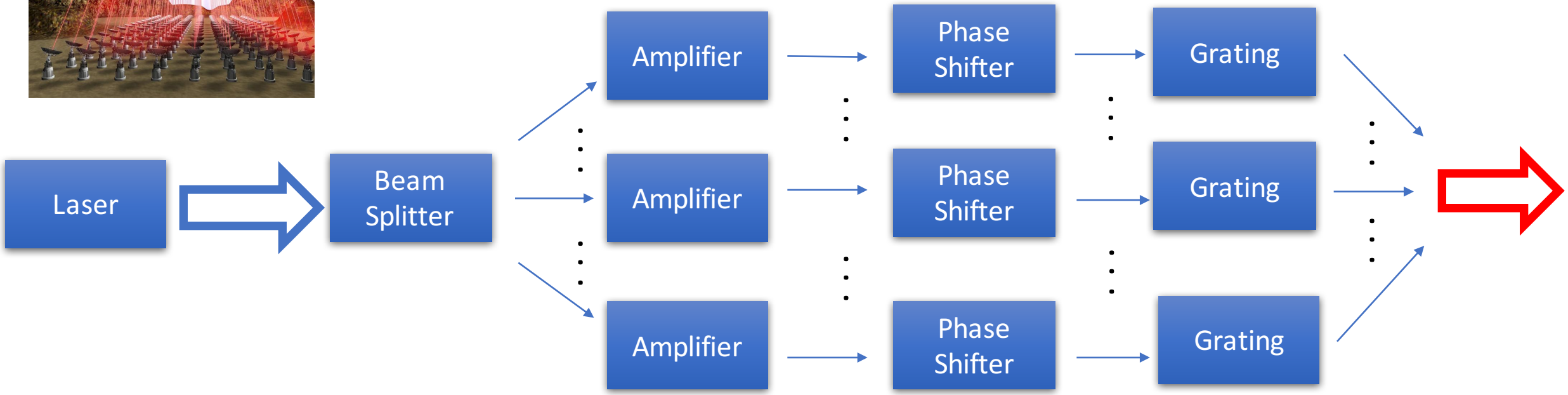
Retrieved from http://www.sciencemag.org/news/2016/05/qa-web-billionaire-describes-his-plan-shoot-stars

How the laser will propel the small spacecrafts

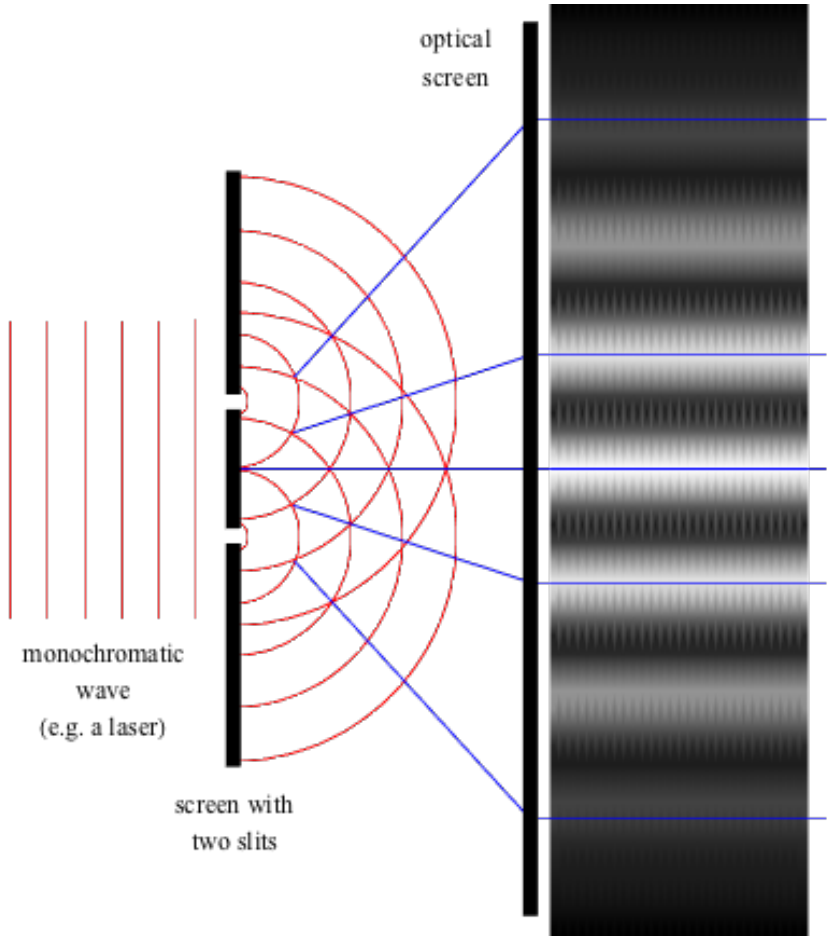
Retrieved from http://www.planetary.org/multimedia/space-images/spacecraft/breakthrough-starshot-1.html

Optical Phased Array

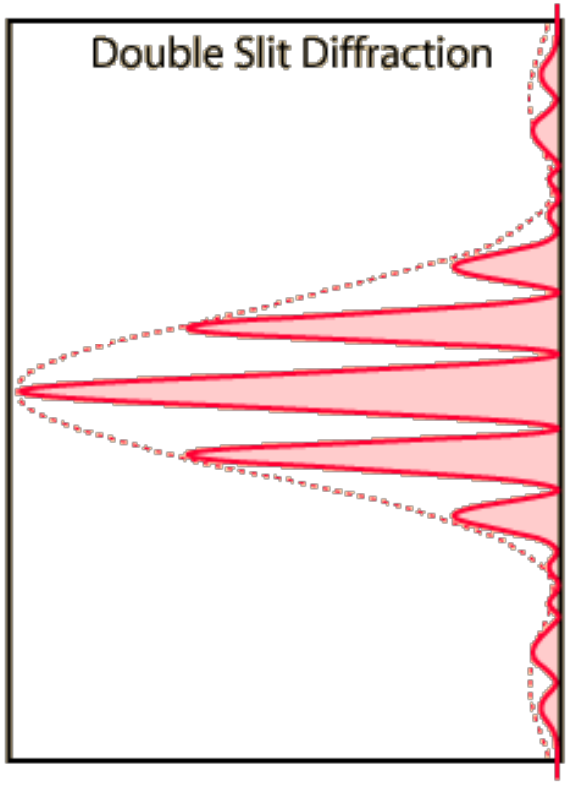




Double-Slit Experiment



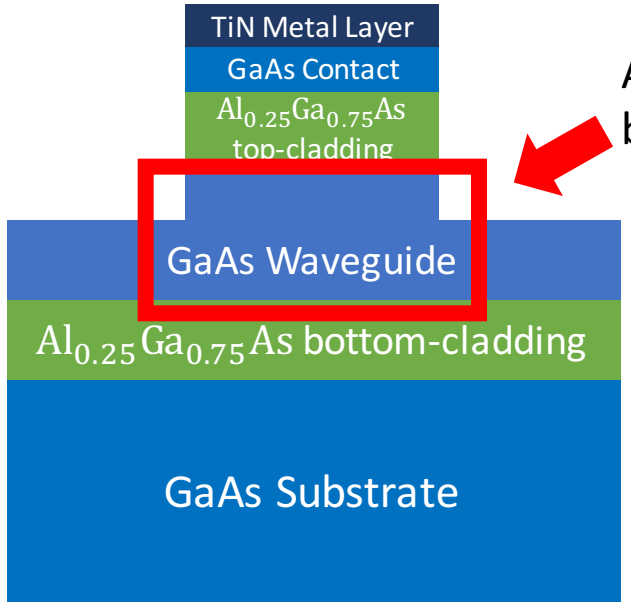
Interference Pattern



- Concentrate the intensity to one point
- Control where the maximum intensity will land

Images retrieved fromhttps://www.shmoop.com/optics/young-double-slit.html

Research Goal: Design phase shifter using integrated photonics



Area where the beam travels

Structure of the Phase Shifter

$$n = \frac{c}{v}$$

c: speed of light in the vacuum
v: speed of light in the medium

Light stays confined in the n that is bigger

$$n_{GaAs} > n_{Al_{0.25}Ga_{0.75}As}$$

Objective

- **Efficient Thermal Phase Tuning**
- **Single Mode Waveguide**

Thermal Phase Tuning

Electric Field: $E = |E|e^{-j\emptyset}$

Be able to change the phase by changing the refractive index

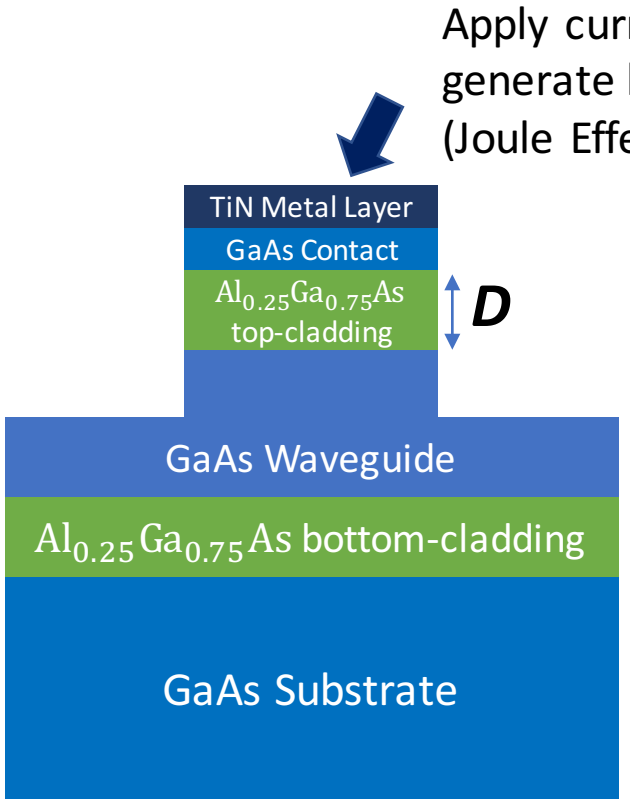
$$\Delta\emptyset = \frac{\partial n}{\partial T}\Delta T\left(L\frac{2\pi}{\lambda_0}\right)$$

$$n = \frac{c}{v}$$

Step 1: Reduce the insertion loss due to the metal (***D***)

Step 2: Find ΔT

Step 3: Find the L_{min} for shifting from 0 to 2π



Structure of the waveguide for phase shifter with metal

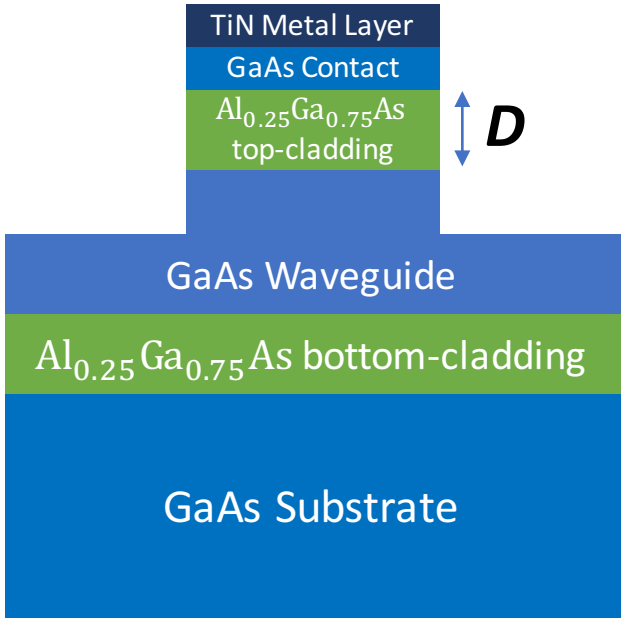
Optimize Single Mode Waveguide

- Mode: path of light propagation
  - Single mode: 1 TE & 1 TM
    - TE is horizontal light polarization
    - TM is vertical light polarization
- Determine the structure of the waveguide
  - Etch Height(**E**) = Height (H) – Slab Thickness (ST)
  - Width (***W***)

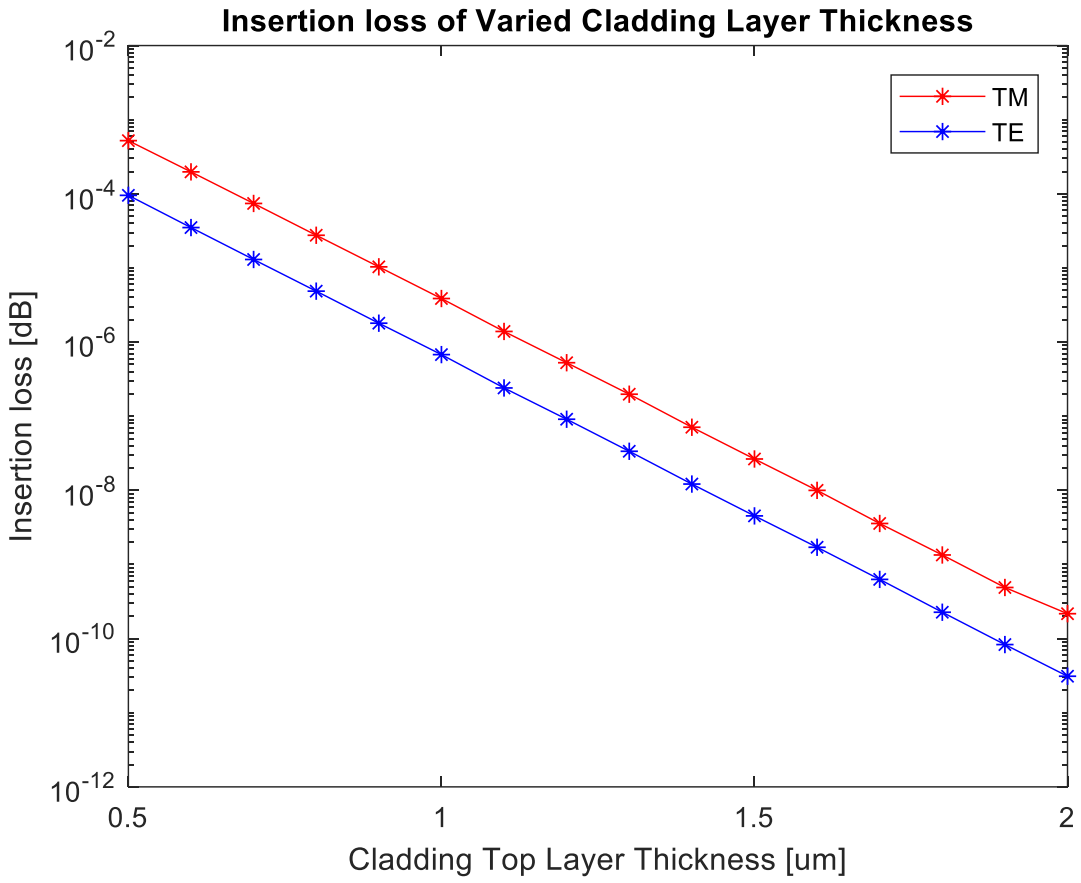
Number of Modes					
W(um) / E(um)	0.8	1.5	2.0	2.5	3.0
0.4	1 (TM)	2	2	2	2
0.6	1 (TM)	2	2	2	3
0.9	2	2	2	3	4
1.2	2	2	4	6	6

Step 1: Determination of Loss Due to Metal

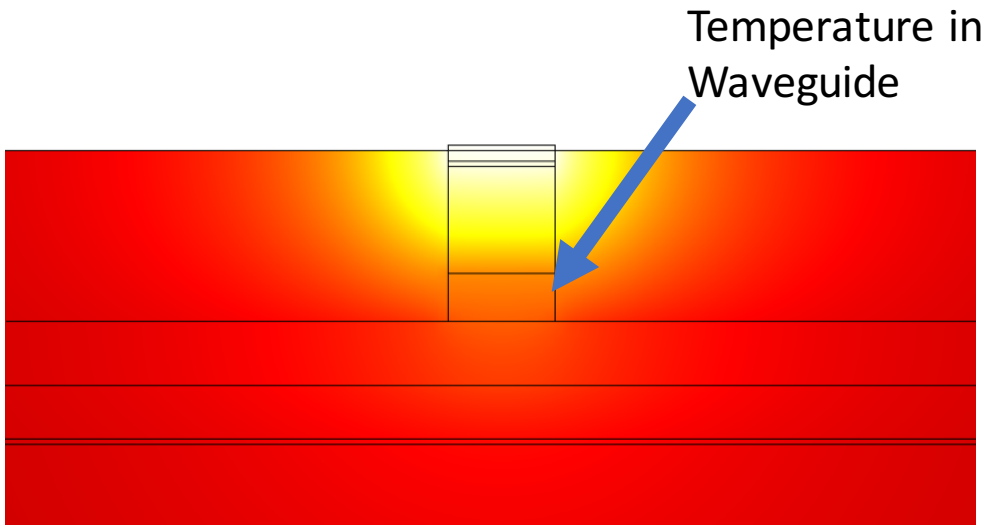
- Metal Induced Loss vs. *D*

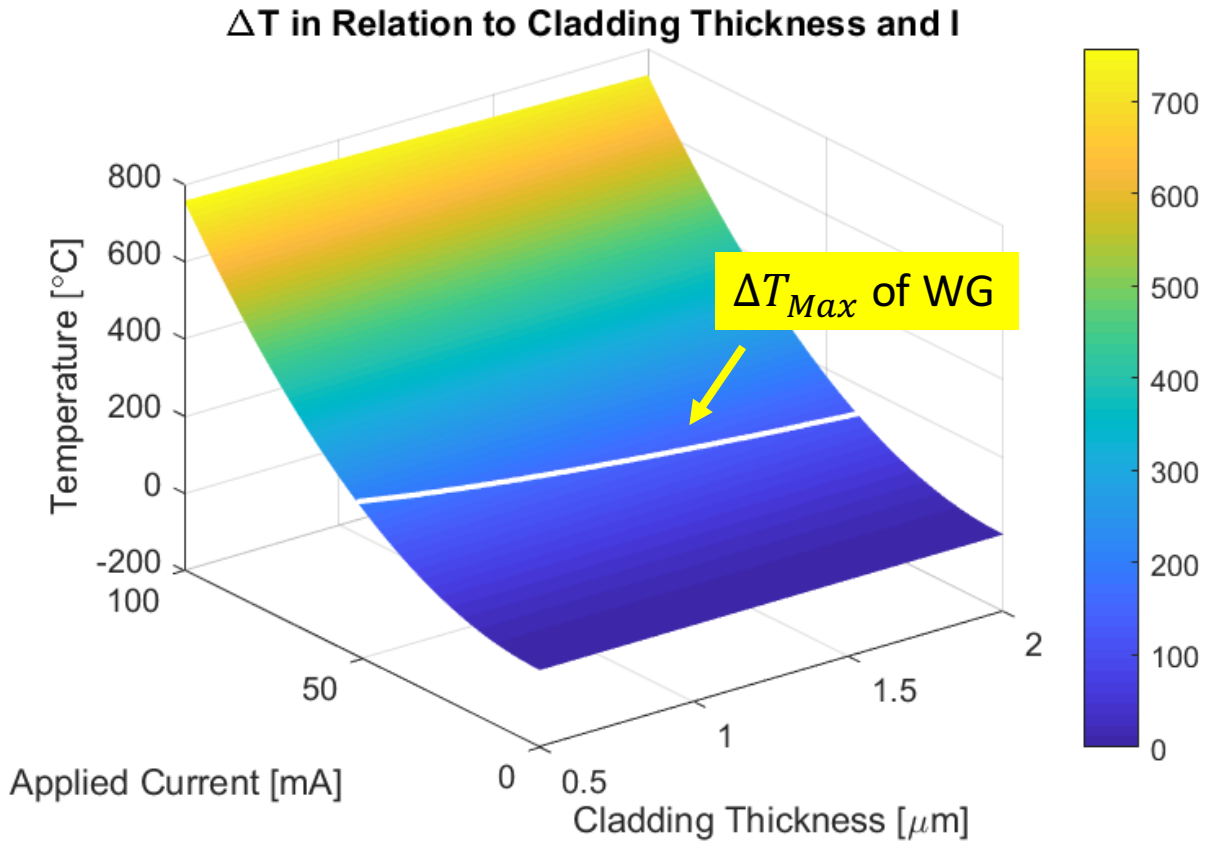


Structure of the waveguide with metal



Step 2: Relationship between the Temperature and Current





- Apply different current values and collect the temperature of the waveguide **(ΔT)**
- ΔT_{Max} of TiN = 330°C [1]

[1] Y. Cheng, W. Chang, B. Wei, F. Lu and Y. Wang, "Electrical and Reliability Characterization of Ti/TiN Thin Film Resistor", *ECS Transactions*, vol. 45, no. 6, pp. 81-90, 2012.

Step 3: Determine L_{min}

- Desire phase shift from 0 to 2π

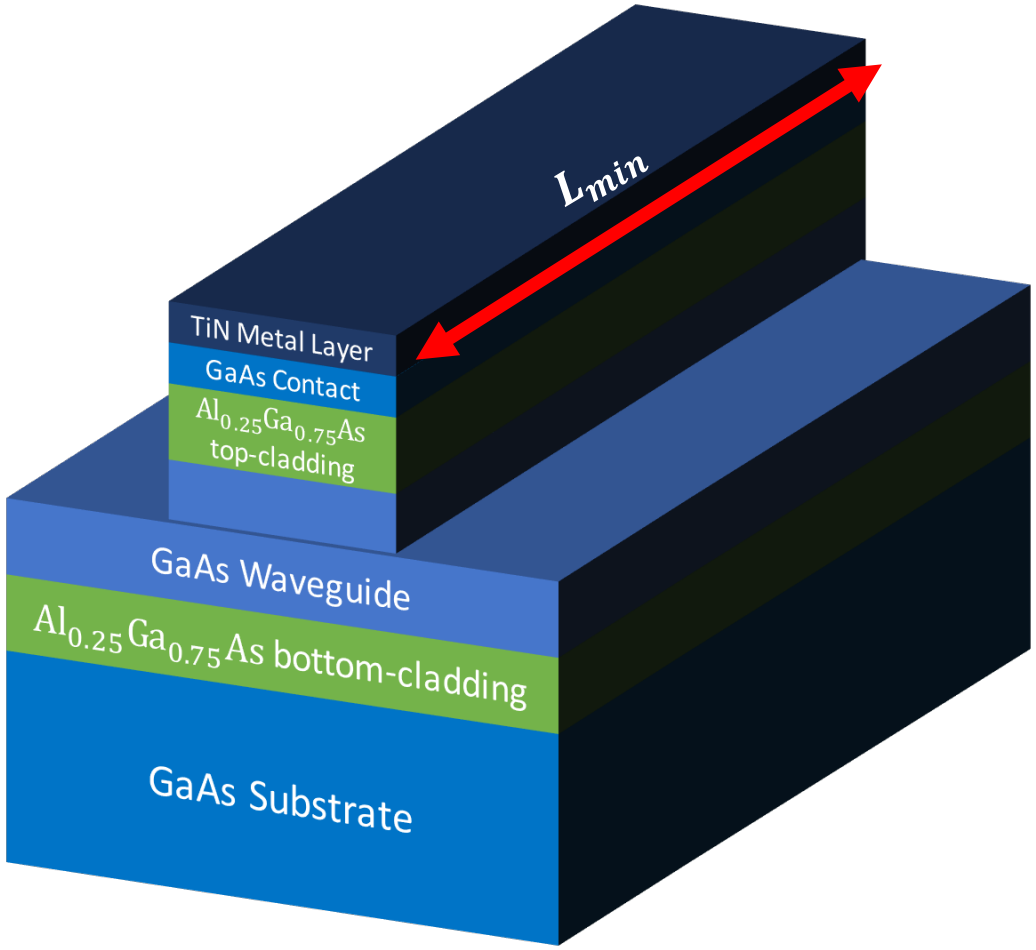
$$\Delta\emptyset = \frac{\partial n}{\partial T}\Delta T\left(L\frac{2\pi}{\lambda_0}\right)$$

$$\Delta\emptyset_{max} = 2\pi$$

$$L_{min} = \frac{1}{\frac{\partial n}{\partial T}}\frac{\lambda_0}{\Delta T_{max}}$$

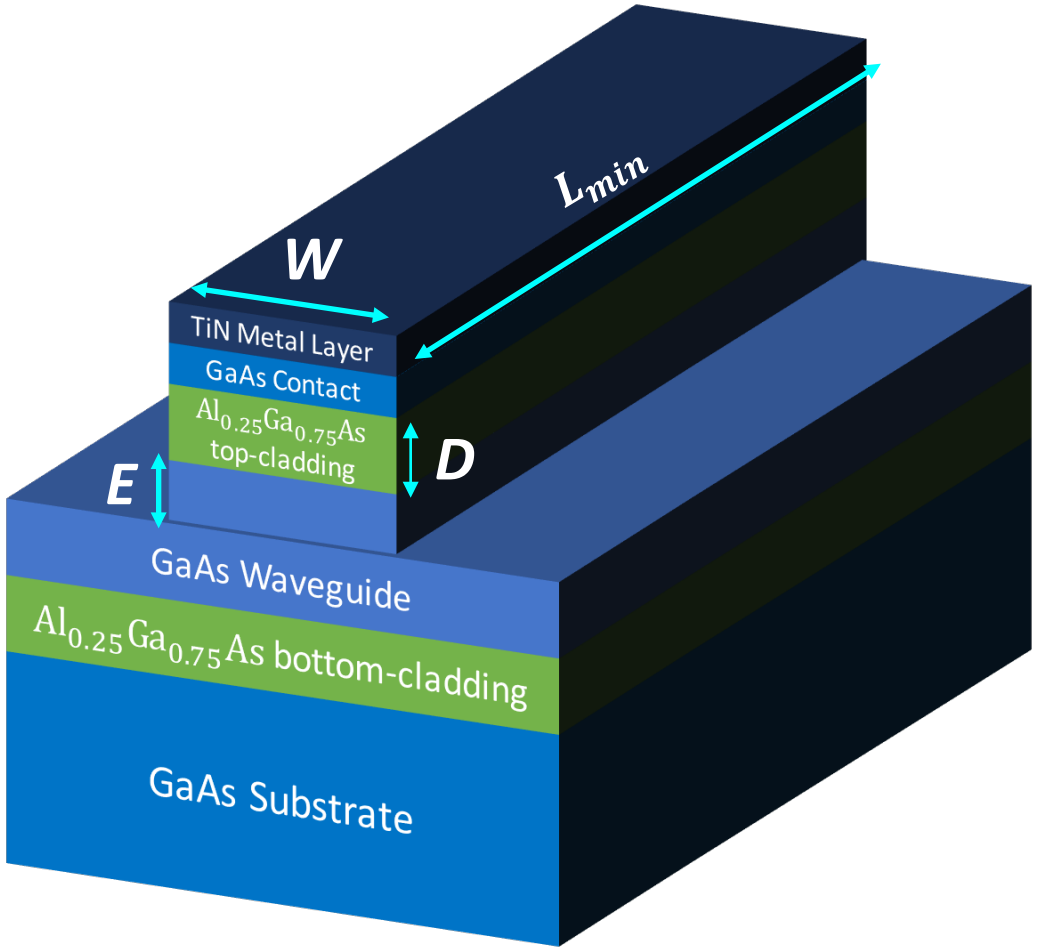
$\frac{\partial n}{\partial T}$ = 2.67e-4 for GaAs[2]

- **We find L_{min} to be 21 um**

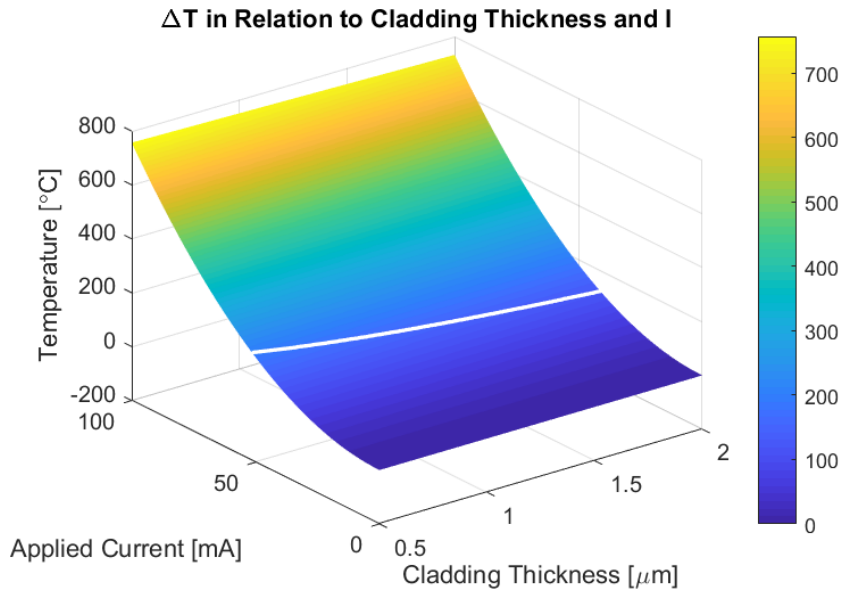


[2] F. Della Corte, G. Cocorullo, M. Iodice and I. Rendina, "Temperature dependence of the thermo-optic coefficient of InP, GaAs, and SiC from room temperature to 600 K at the wavelength of 1.5 µm", *Applied Physics Letters*, vol. 77, no. 11, pp. 1614-1616, 2000.

Structure and Thermal Phase Tuning



- E = 0.9 um
- W = 2.0 um
- L_{min} = 21 um
- D = 1.0 um



Future Plans

- Fabrication and testing
- Can be used for LIDAR application

Acknowledgement

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