Integrated optics in III-V Semiconductors

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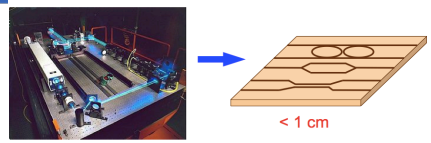
What is integrated optics and semiconductors ?

Integrated optics is a technology which aims at constructing so-called integrated optical devices or photonic integrated or photonic integrated circuits or planar light wave circuits containing several or many optical components; semiconductors are relies on quantum physics to explain the movement of electrons and holes in a crystal lattice..



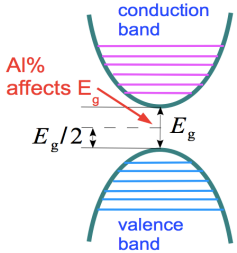
What are we looking at? Still silicon?

We compared two semiconductors: Arsenic Trisulfide (As_2S_3) and Aluminum Gallium Arsenide ($Al_xGa_{1-x}As$). Previous comparisons among some properties hove been obtained:

	Silicon	As_2S_3	$Al_xGa_{1-x}As$
Low material absorption?	√	√	√
Control over index?	X	X	√
Large Kerr nonlinearity?	√	√	√
Small nonlinear absorption?	X	√	√
Monolithic integration?	X	X	√

We were seeking for the the materials matching all the properties, apparently the Aluminum Gallium Arsenide (Alx Ga1-x As) is the one of the best ingredients for the materials

Aluminum Gallium Arsenide



Low intensities:

$E_{photon} < E_g$ - no loss

$E_{photon} > E_g$ - absorption

$E_{photon} \simeq E_g$ - emission

High intensities:

$E_{photon} < E_g/2$ - no loss

$E_{photon} > E_g/2$ - two-photon absorption

18% Al yields $E_{photon} < E_g/2$ at $\lambda \simeq 1.55\ \mu m$

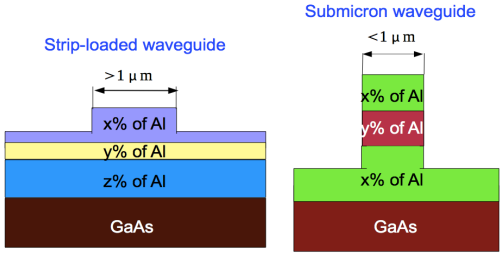
J. S. Aitchison, *et al.*, IEEE J. Quantum Electron. **33**, 341-348 (1997).

When the energy of the photon is larger than energy of the gap, electrons from the valence band can absorb such photon and can get emitted from valence band to the conduction band.

Two different types of the waveguides below, strip-loaded waveguide apparently takes more space in the optical fibers. Noticed that same percentage of the Aluminum in the first and third layer of the submicron waveguide.

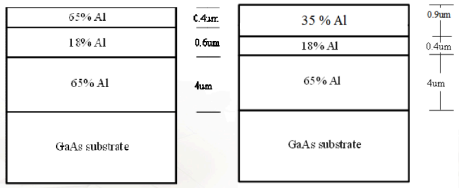
Aluminum Gallium Arsenide

III-V semiconductor, same as InP -> can be active



Proposed wafer designs

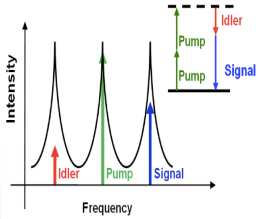
- Effective modal area as low as 0.4 μm²



Wafer design for nanowire and half core-etched WG

Wafer design for strip-loaded WG

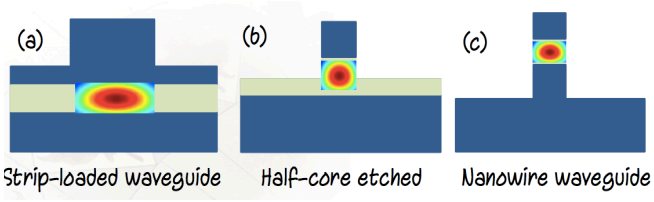
Four Wave Mixing

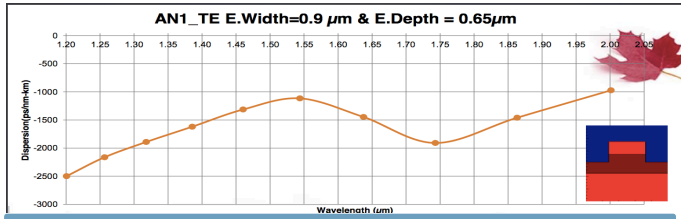


- Nonlinear process that transfers energy from pumps to signal and idler waves

Brief of Four Wave Mixing (FWM)
WM is an intermodulation phenomenon in non-linear optics producing two extra wavelengths by interacting between two wavelengths in the signal.

Nonlinear FWM affects high speed processing of optical signals, we focused on Strip-loaded Waveguide and ran different combination of width and depth in terms of E model and T model.





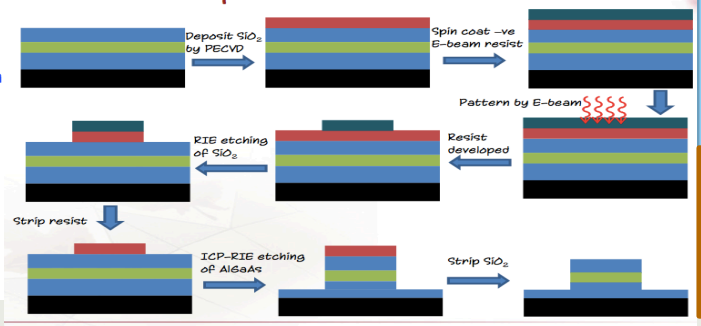
Strip-loaded waveguide
- **Embedded Core**
- **Lower Losses**
- **Easier Fabrication**
- **No Dispersion Management**

Con:
& **Low confinement**

Half-core etched:
- **Compromise Solution**
- **Good Confinement**
- **Reasonable Losses**
- **No Deep Etch Required**
- **Dispersion is controllable**

Nanowire waveguide:
- **Core is etched through**
- **High confinement**
- **Circular mode shape**
- **Dispersion is controllable**

Fabrication process



DISCUSSION:

Summary:1. Lowest losses for strip-loaded waveguide but least confinement; 2 Highest losses for nanowire waveguide but maximum mode confinement; 3 Then choice of the fair and proposed compromise would be half-core etched.

The brief of my job: Experimental work of the three different types of improved wafer compositions , ie: Strip-loaded waveguide, half-core etched and nanowire waveguide. Some of our group members have done their simulations and theoretical calculations, but we are still waiting for samples that currently at research lab of University of Sherbrooke, which caused the suspension of experimental demonstration.

Fabrication status and plan: E-beam design files and etch files along with two wafers provided to INRS, after patterning these maples will be shipped to University of Sherbrooke cleanroom and etched. Once devices are back, we plan on doing linear and non-linear characterization and start work on in-house E-beam lithograph recipe.

What I learned from this research? I learned from the strip-loaded and other configurations, this research opportunity improved my capability of studying on scientific research especially in the area of physics and photonics engineering, also gained my knowledge of semiconductors, microwaves and electronics materials. Moreover, Collaborating with gentle and hard working colleagues in such tremendous research group remarkably enhanced my on-campus research experience.

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