NAVOLCHI 1st Review Meeting

November 27th 2012, Brussels

SEVENTH FRAMEWORK PROGRAMME

FP7-ICT-2011-7
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Work Package 3 Presentation

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NAVOLCHI

Nano Scale Disruptive Silicon-Plasmonic Platform for Chip-to-Chip Interconnection

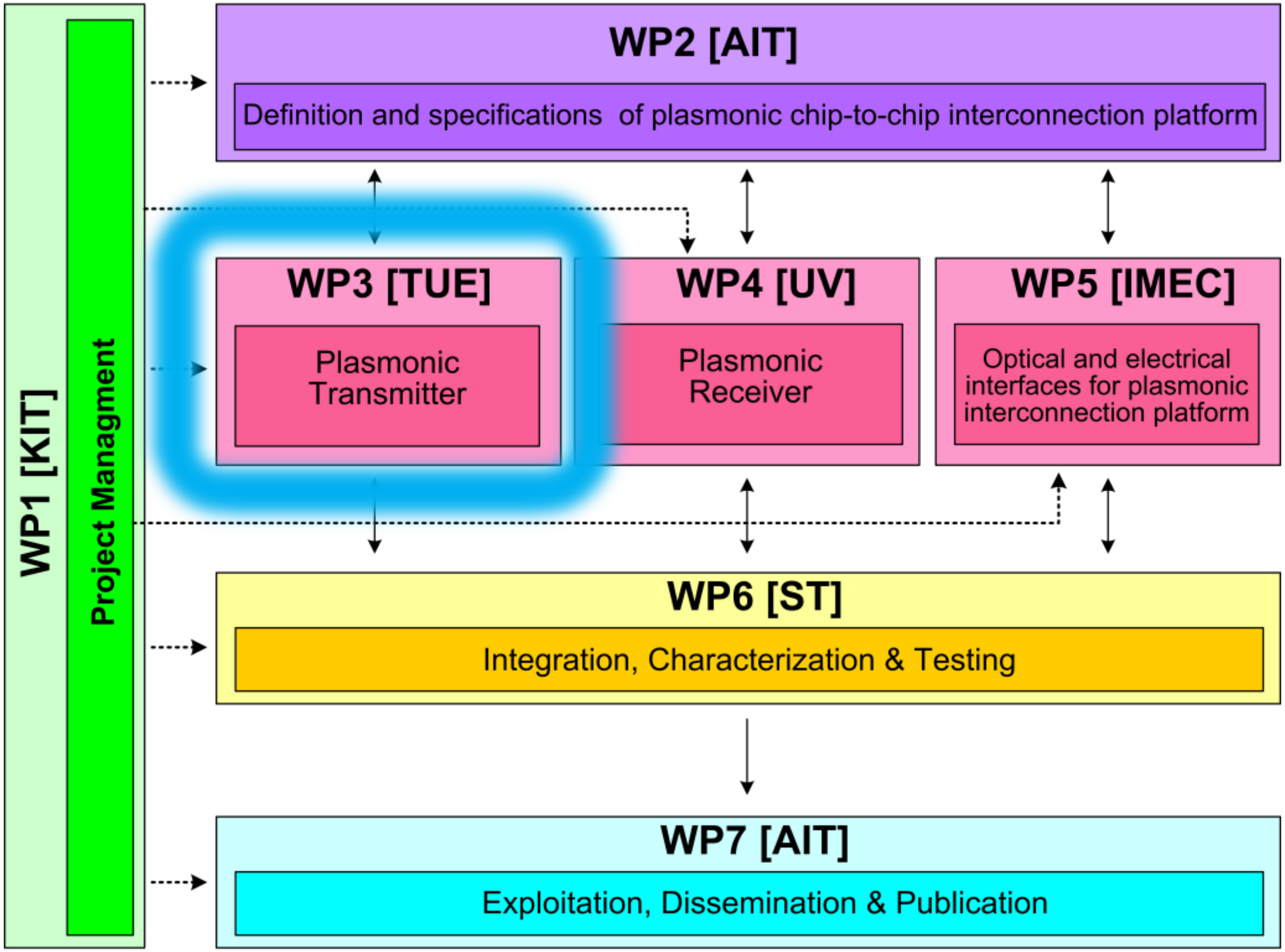
www.navolchi.eu

Outline

SEVENTH FRAMEWORK PROGRAMME

1. WP3 Position in Project
2. WP3 Objectives
3. Milestones and Deliverables
4. Status of Work: Achievements
   I. Plasmonic/Metallic Laser
      - Status of Work
      - Summary and Outlook
   II. Plasmonic Modulator
      - Status of Work
      - Summary and Outlook
5. Resources: Budget and Manpower

WP3 Position in Project



Contributors:

TU/e

KIT Karlsruhe Institute of Technology

imec

WP3 Objectives

- **Simulation studies** to optimize
  - Plasmonic/metallic nanolaser
  - Plasmonic modulator
- **Fabrication**
  - Electrically pumped plasmonic/metallic nanolaser
  - Electrically driven plasmonic modulator
- **Performance targets**
  - Laser: active region < 1 μm^2, output power > $100\ \mu W$
  - Modulator: extinction ratio $> 10\ dB$ for length $< 10\ \mu m$, and modulation speed $> 40\ Gbit/s$

Milestones

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Nanolaser (TU/e)

	Name of milestone	Month
MS8	Decision on an optimized structure for metallic/plasmonic nanolaser and its coupling to a Si-waveguide	6
MS10	Grown wafer structure for plasmonic lasers	12
MS13	Initial characterization of unbonded plasmonic lasers	18
MS15	Initial testing of bonded plasmonic lasers	24

Milestones

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Plasmonic Modulator (KIT)

	Name of milestone	Month
MS9	Decision on an optimized structure for plasmonic modulator	6
MS11	Fabrication of plasmonic modulator on a SOI platform	15
MS12	Decision on an optimized structure for plasmonic modulator with a maximum loss of 20dB	18
MS14	Initial testing and characterization of plasmonic modulators	21

Deliverables

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Nanolaser (TU/e)

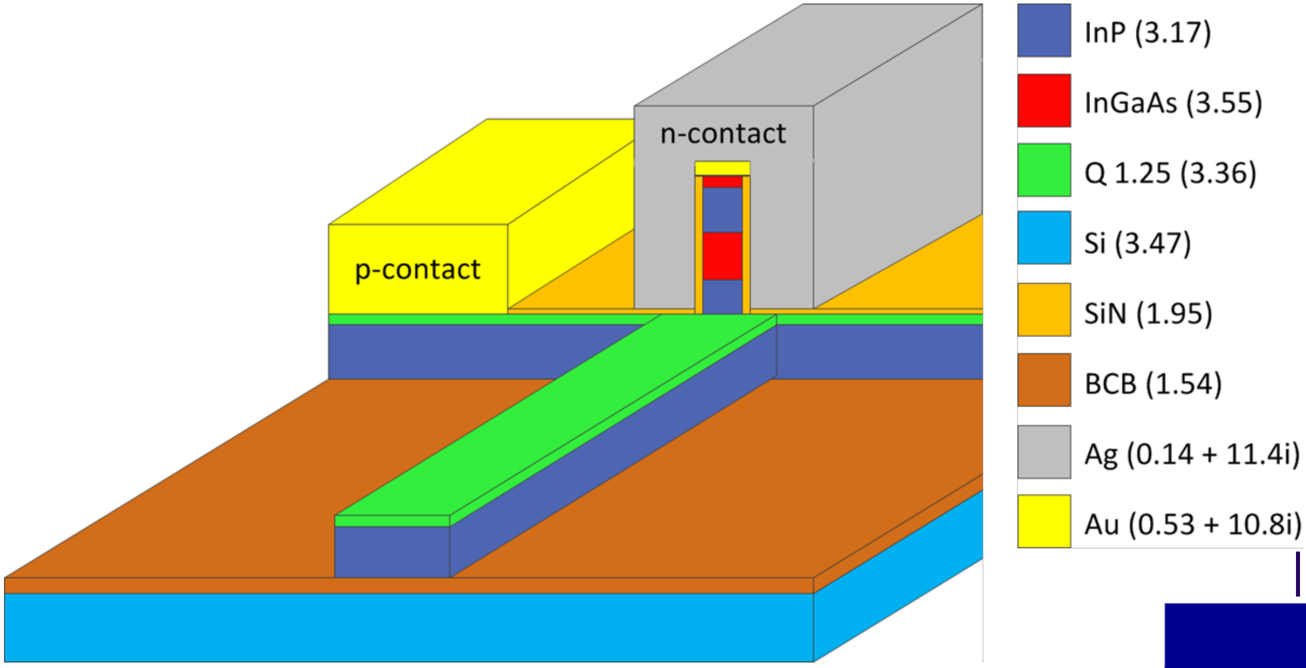
	Name of deliverable	Month
D3.1	Report on studies of optimized structure for metallic/plasmonic nanolaser and its coupling to Si-waveguide	12
D3.3	Fabrication of plasmonic laser device	24

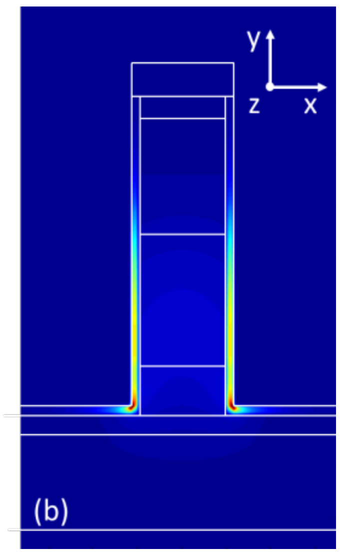
Plasmonic modulator (KIT)

	Name of deliverable	Month
D3.2	Report on modelling of the modulator structure	12
D3.4	Report on fabrication of modulators	24

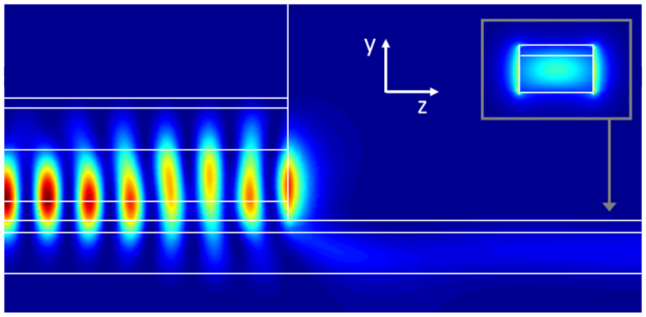
Status of Work: Nanolaser

- **Plasmonic laser design**





$|E|^2$, TE mode (along x)



Main issues:

- High propagation loss ($0.16\ dB/\mu m$)
- Poor confinement factor

Status of Work: Nanolaser

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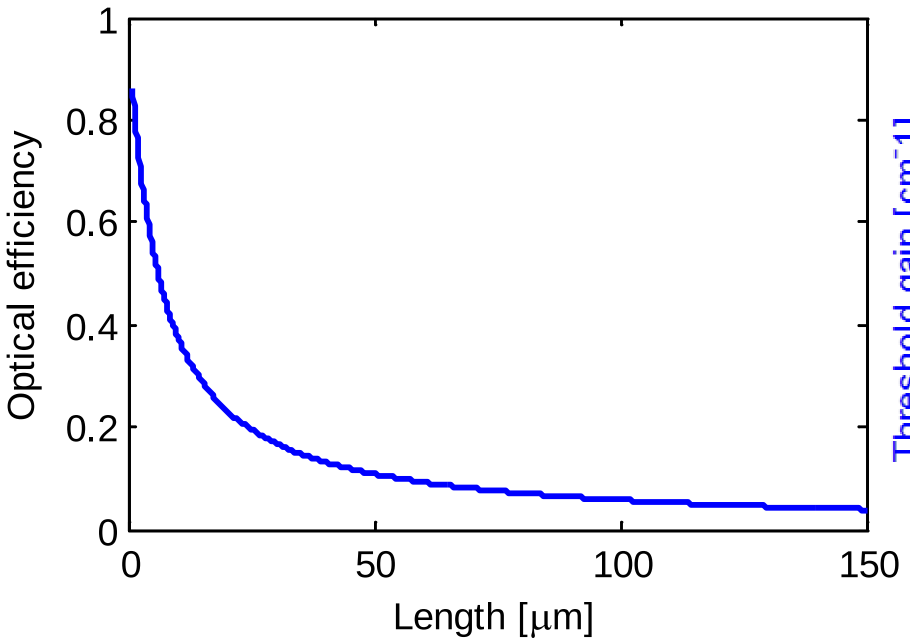
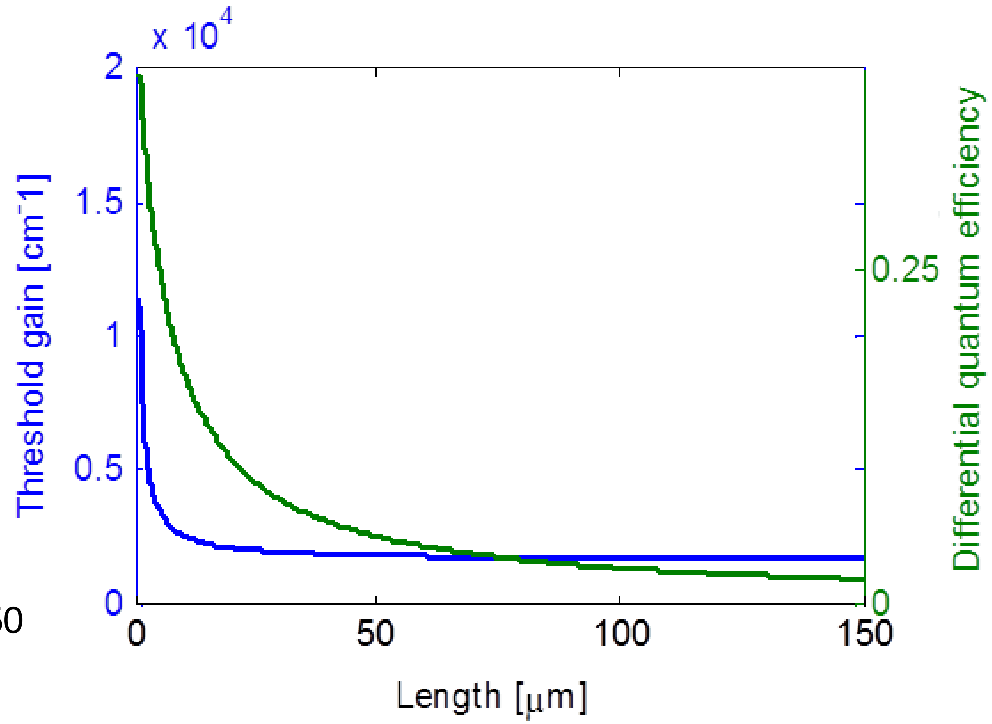
- **Threshold gain and efficiency**



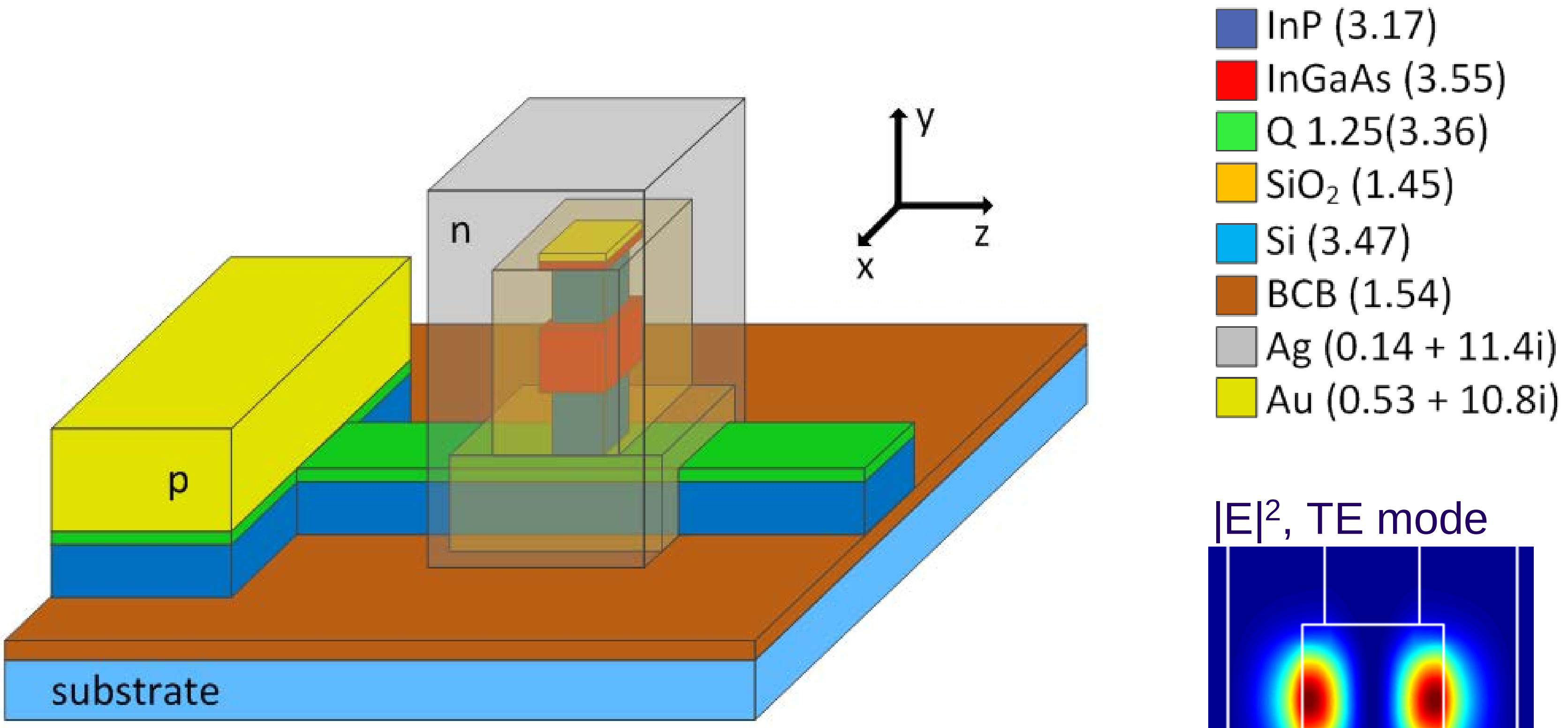


For room temperature operation ($g_{th} < 2500\ cm^{-1}$):

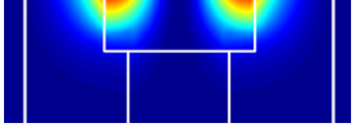
- Long devices (> 50 μm)
- Low efficiency

Status of Work: Nanolaser

- **Metallo-dielectric nanolaser**

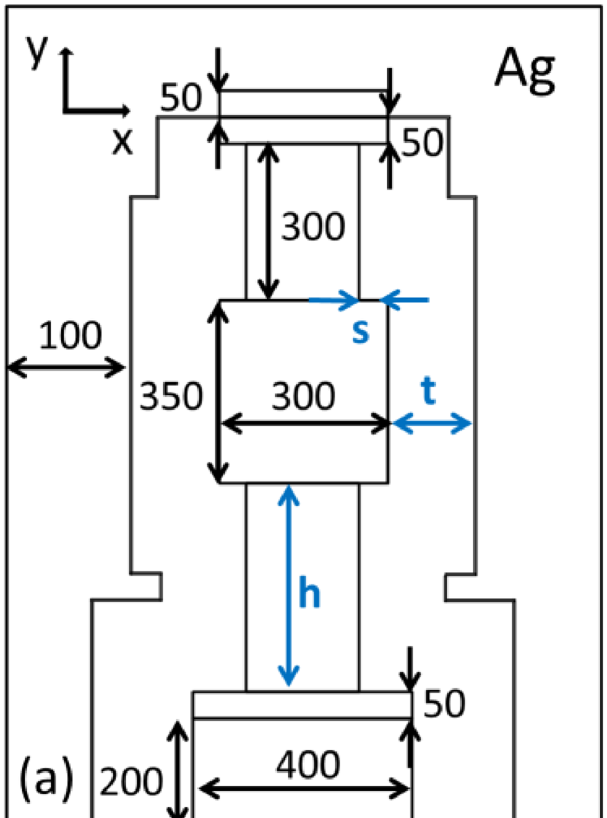


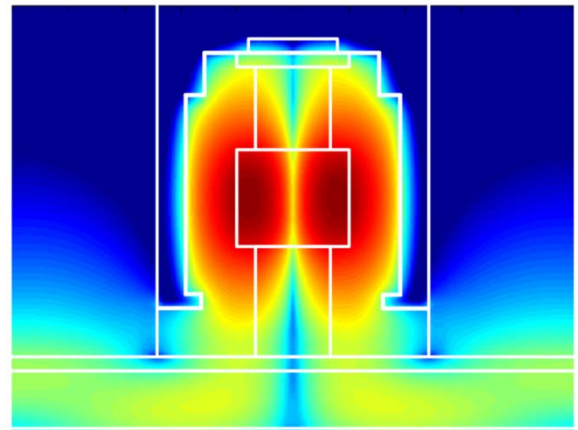
$|E|^2$, TE mode



Status of Work: Nanolaser

- **Optimization for high Q-factor and high coupling efficiency**





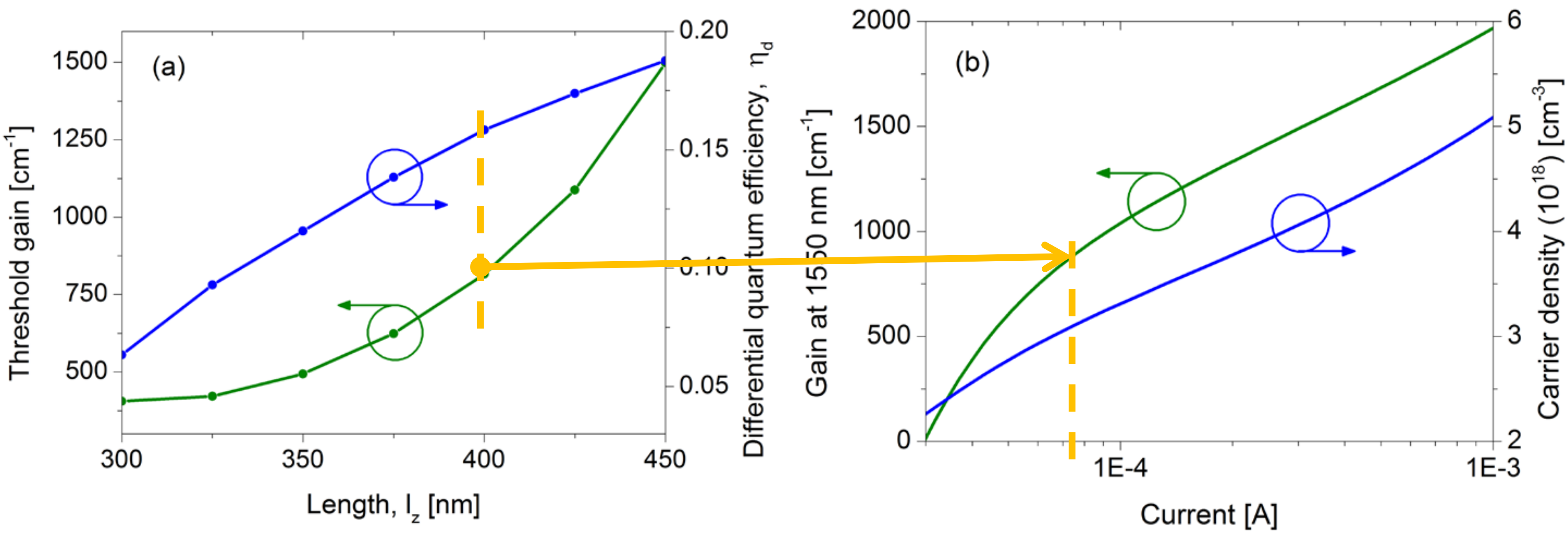
log($|E|^2$)

- Q-factor mainly depends on undercut s, bottom post h and insulation thickness t

- Coupling efficiency depends on device length l_z

Status of Work: Nanolaser

- **Calculated threshold gain and current**

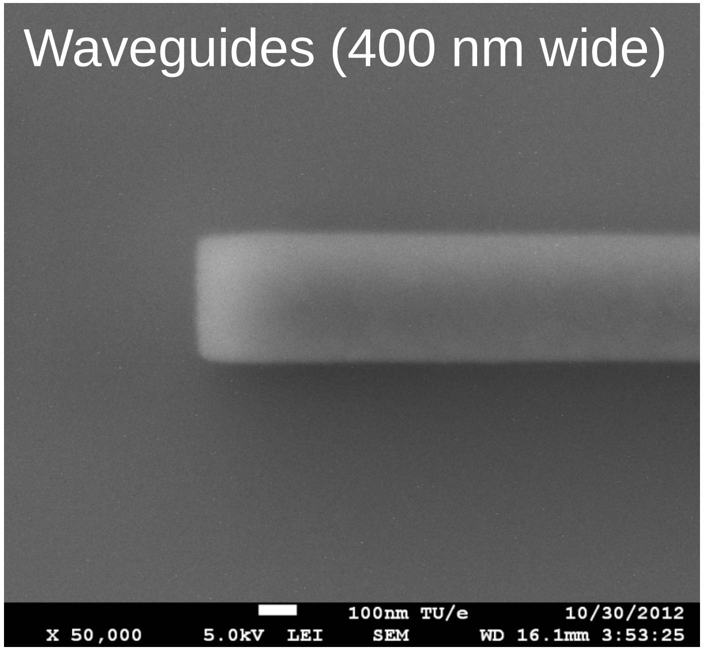


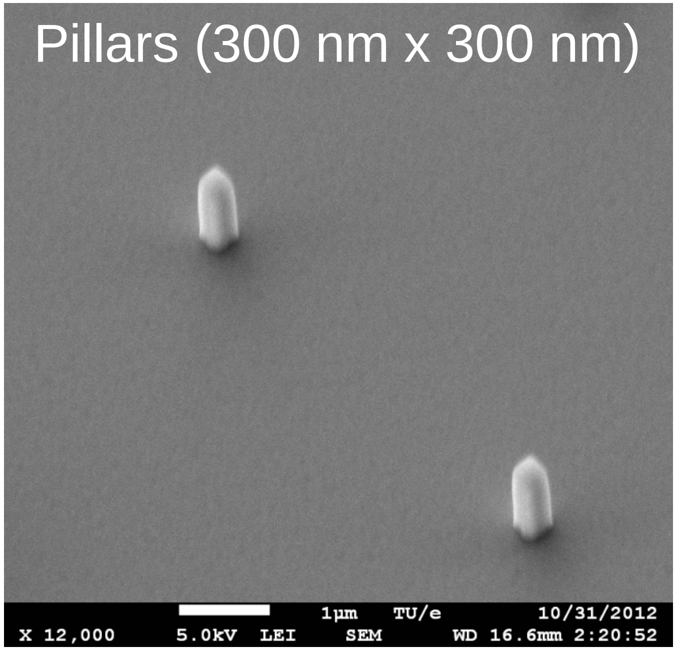
For length = 400 nm

- Threshold current ~ $70\ \mu A$
- Differential efficiency ~ 0.16
- Expected power: $50\ \mu W$ for $0.5\ mA$

Status of Work: Nanolaser

- **Fabrication started**





Summary and Outlook: Nanolaser

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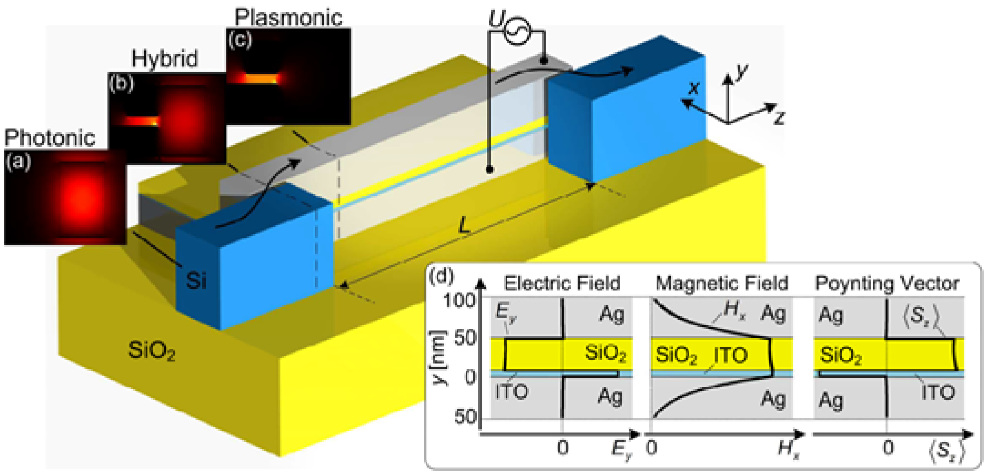
- **Summary**
  - A Fabry Perot plasmonic laser and a metallo-dielectric nanolaser have studied and optimized for operation near $1.55\ \mu m$
  - The metallo-dielectric laser has found to offer a better performance
  - Fabrication of the metallo-dielectric laser has started First etched individual pillars and waveguides

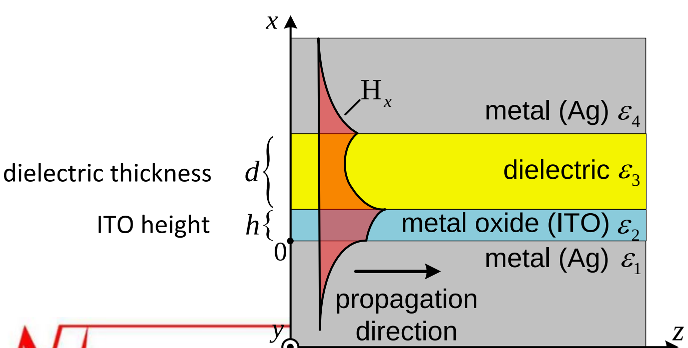
- **Outlook**
  - Further study of metallo-dielectric lasers with length of few micrometers to get higher output power
  - Bonding of InP wafers to Si wafers by IMEC
  - Continue fabrication activities
  - Characterization of nanolasers

Status of Work: Modulator

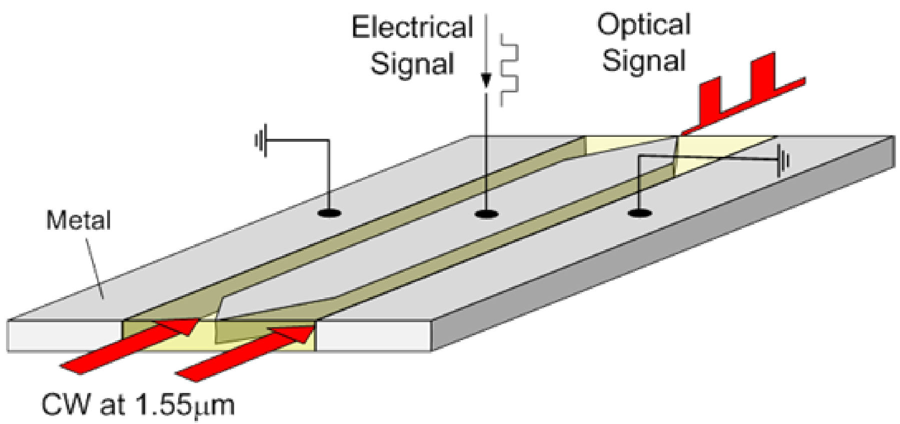
- **SPP Absorption Modulator**



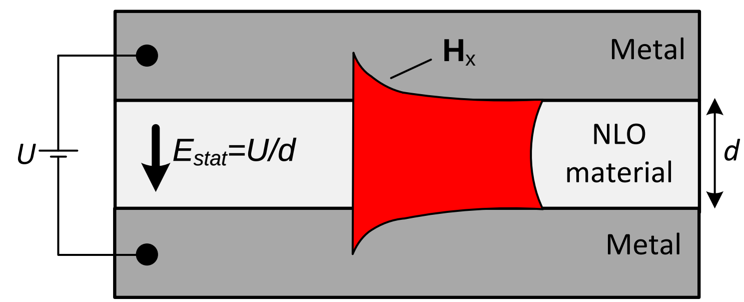
Active area:
Metal – metal oxide – insulator – metal



- **SPP Phase Modulator**

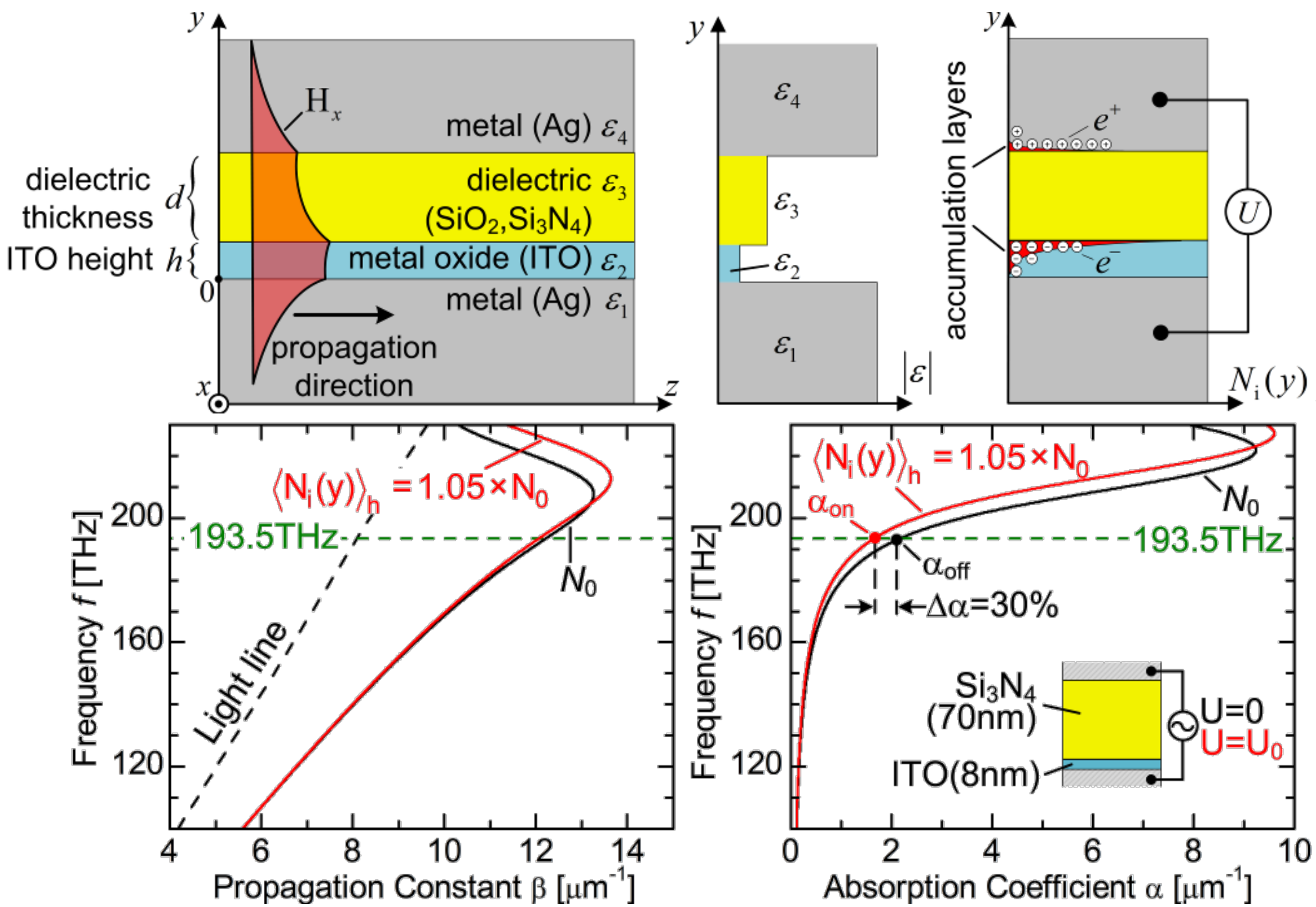


Active area:
Metal – polymer – metal



Status of Work: Modulator

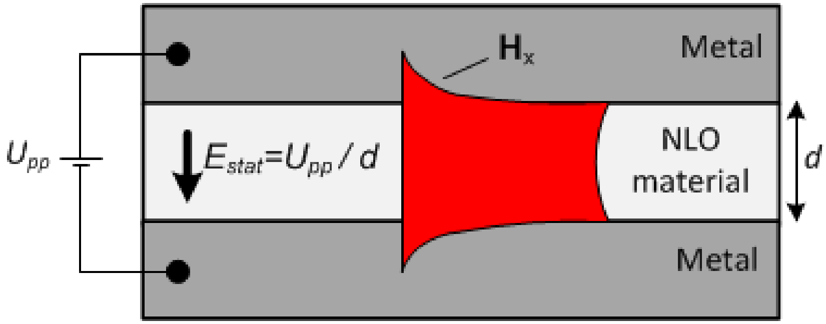
- **SPP Absorption Modulator**



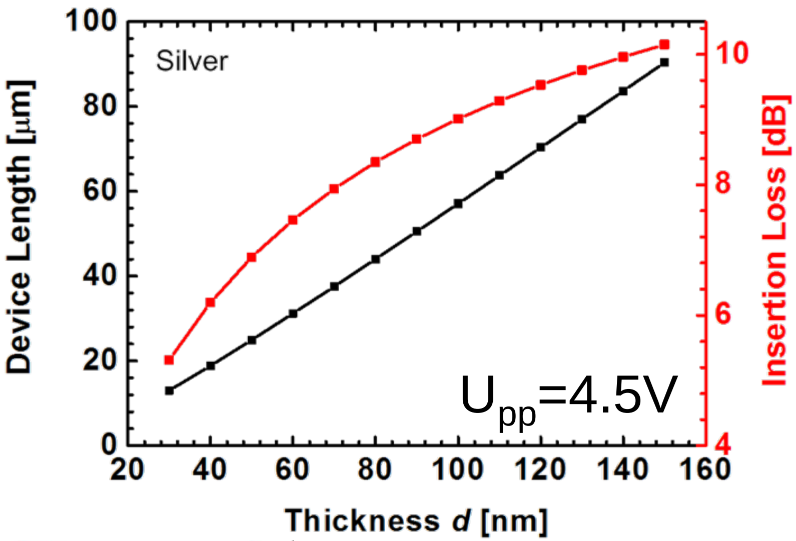
A Melikyan, N. Lindenmann, S. Walheim, P. M. Leufke, S. Ulrich, J. Ye, P. Vincze, H. Hahn, T. Schimmel, C. Koos, W. Freude, and J. Leuthold, “Surface plasmon polariton absorption modulator.,” *Optics express*, vol. 19, no. 9, pp. 8855–69, Apr. 2011.

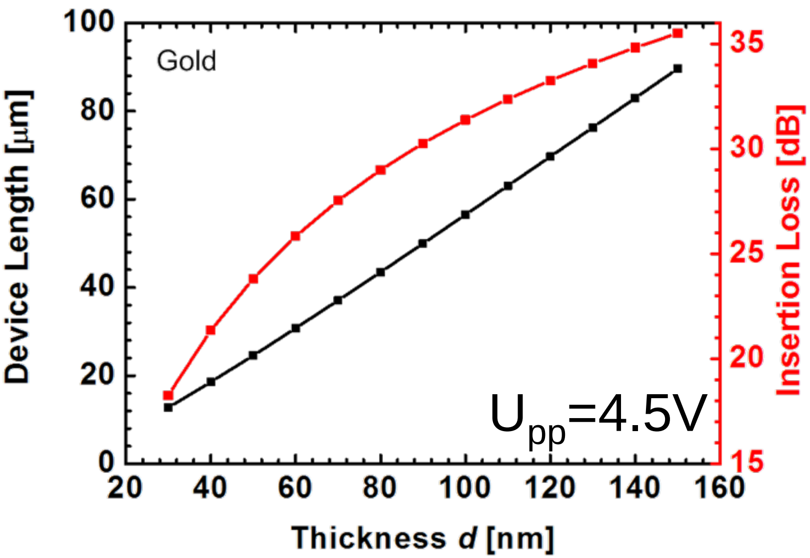
Status of Work: Modulator

- **SPP Phase Modulator**

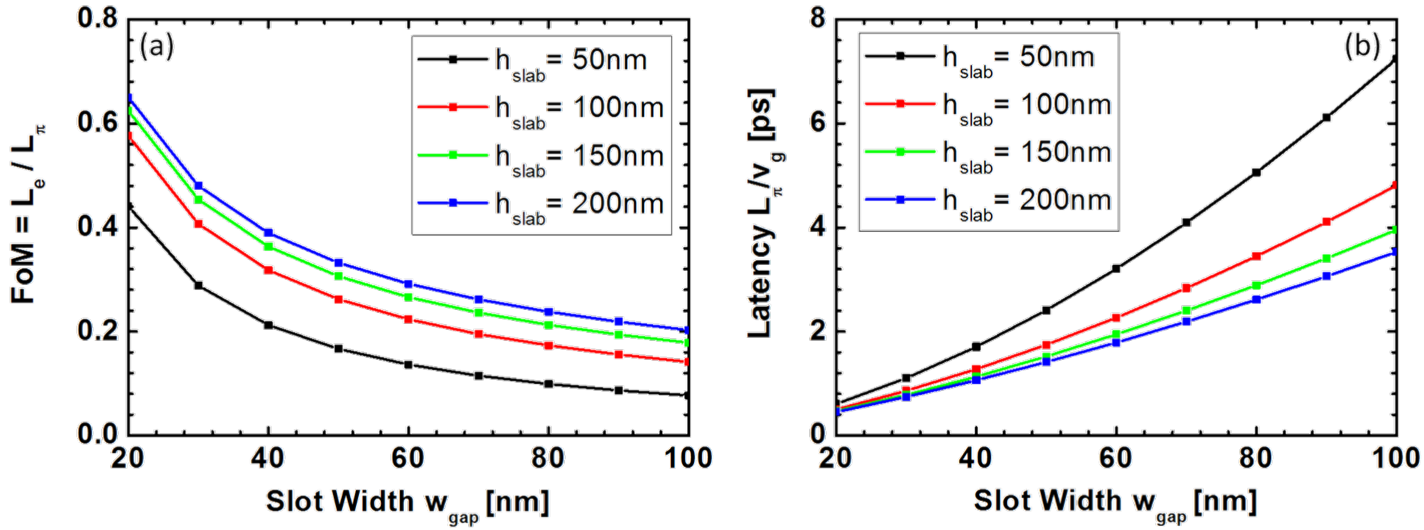


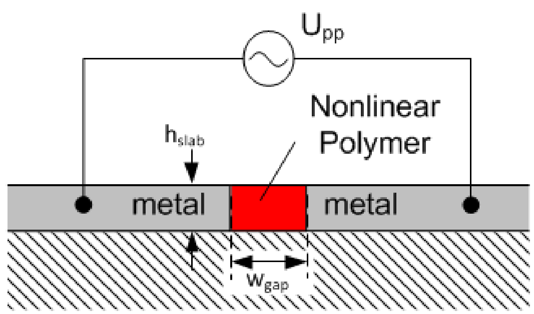
- Large figure of merit
- Easy coupling structure
- Easier fabrication

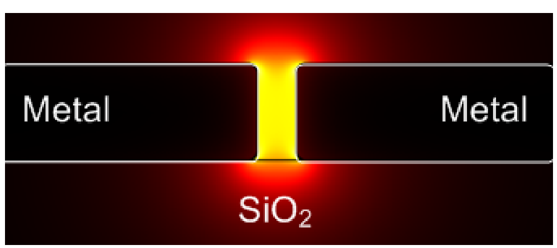




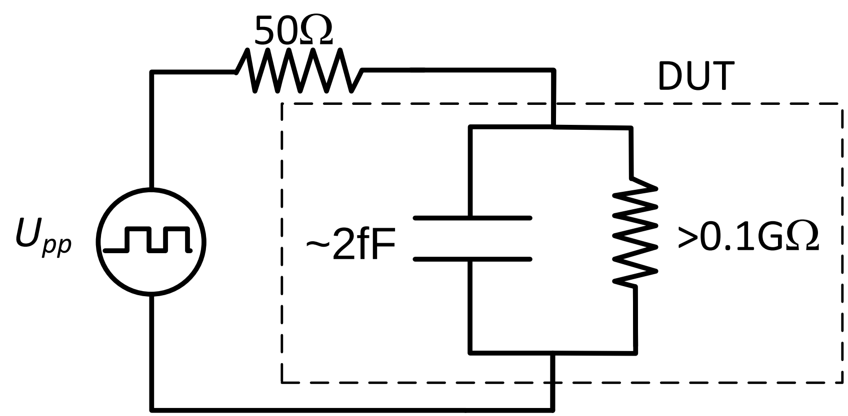
Status of Work: Modulator







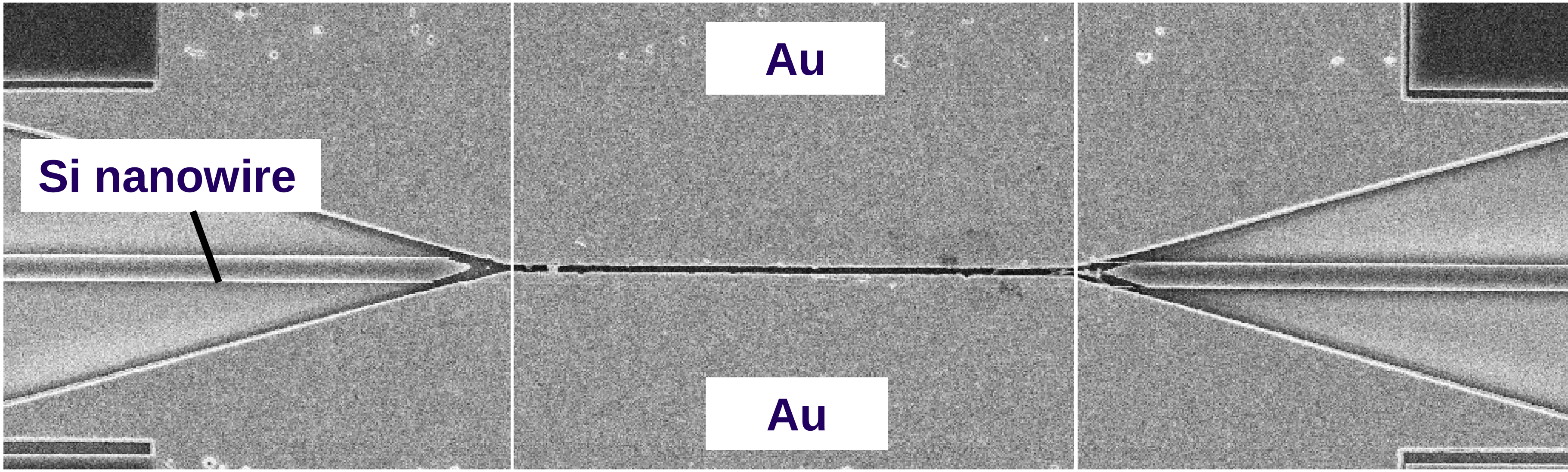
Electrical Properties

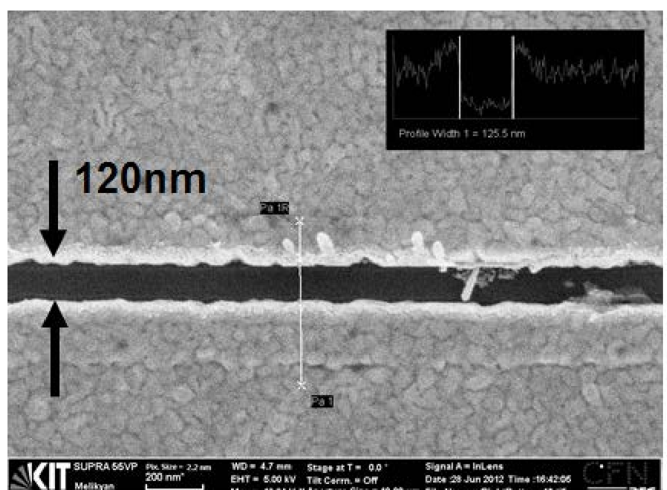


Cutoff frequency of the low pass > 1THz

Status of Work: Modulator

- **SEM image of the device**

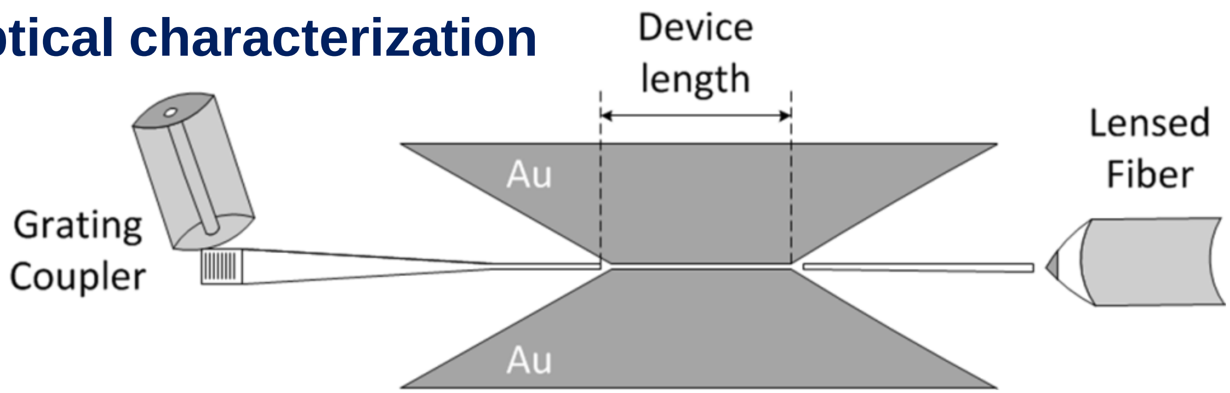


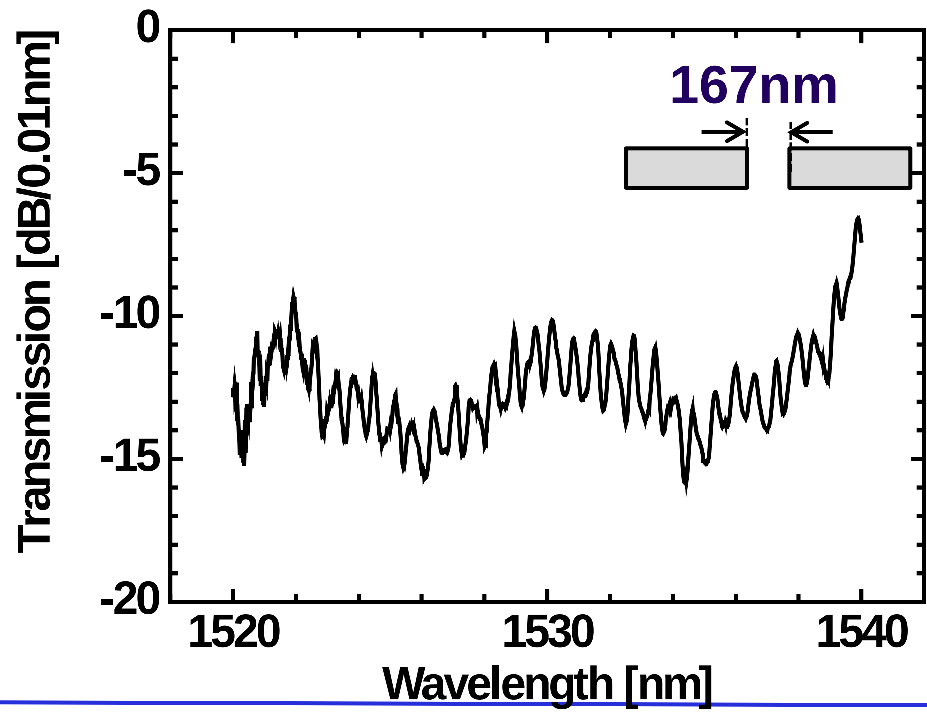


Fabrication by KIT and IMEC

Status of Work: Modulator

- **Optical characterization**





Summary and Outlook: Modulator

- **Summary**
  - Absorption and phase modulators are optimized for $\lambda = 1.55\ \mu m$ operation. It has been decided to fabricate the phase modulator
  - One wafer has been processed by IMEC and post-processed by KIT
  - First optical characterizations have been carried out

- **Outlook**
  - Further optimization of fabrication process
  - Next post-processing is being carried out by KIT
  - Coating with electro-optic polymer
  - Characterization of modulators

Resources: Budget and Man Power

- Not yet available…

Issues

1) Should we present only the details of selected devices (laser and modulator) in order to shorten the presentation?

2) Should we merge MS13 and MS15? Is it important to decide this before the review meeting?

- MS13: characterization of unbonded lasers (Month 18)
- MS15: characterization of bonded lasers (Month 24)