Integrated graphene plasmonic waveguide modulators

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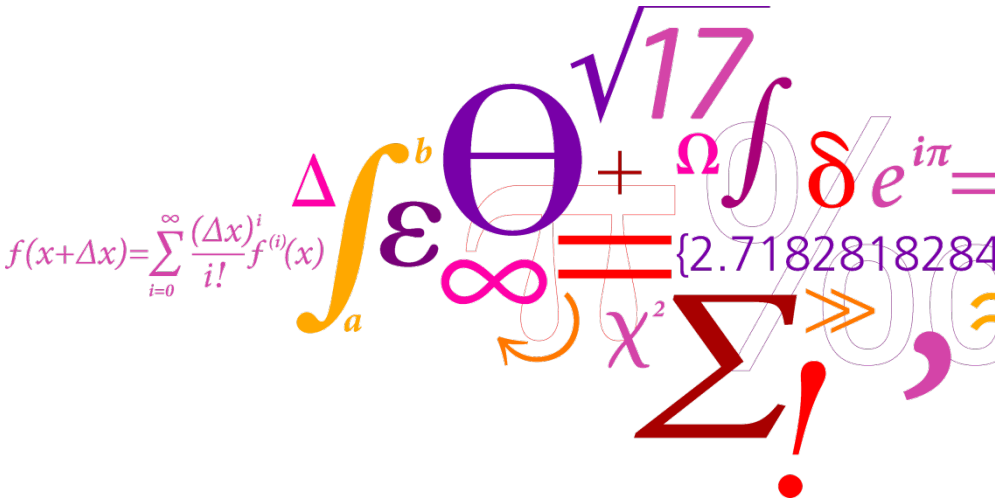


Center for Nanostructured Graphene

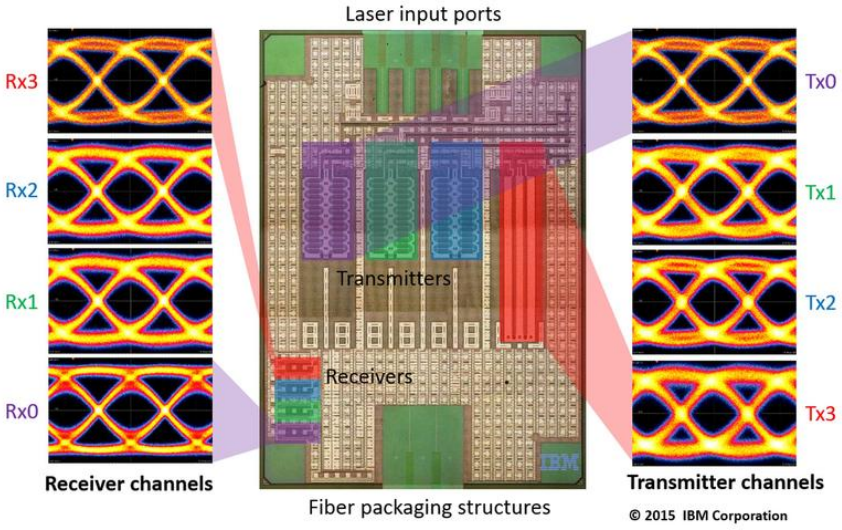
Optical interconnects: large bandwidth and low power consumption

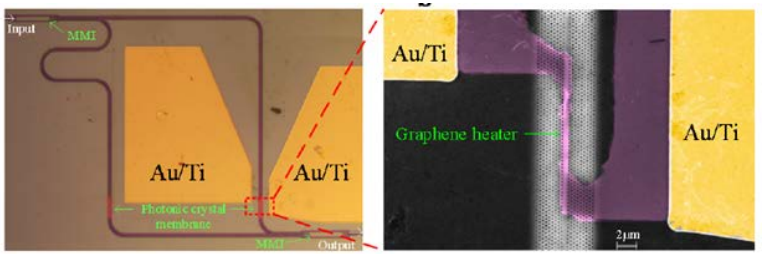
Challenges (electrical interconnets on chip):

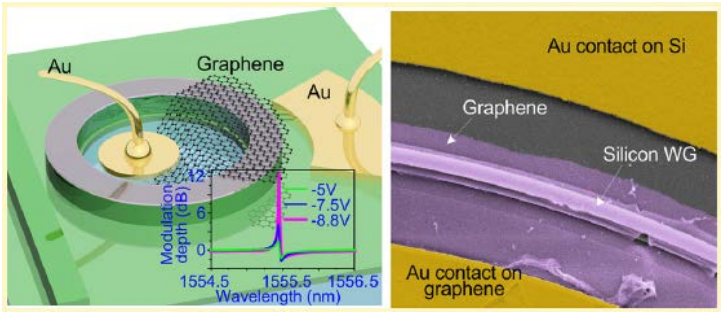
responsible for 50% of the power consumption.

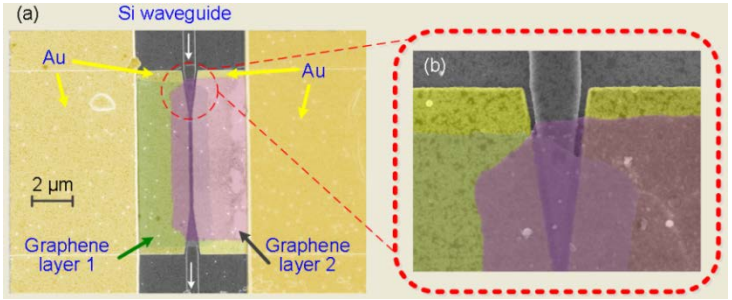
insufficient bandwidth

Silicon Photonics



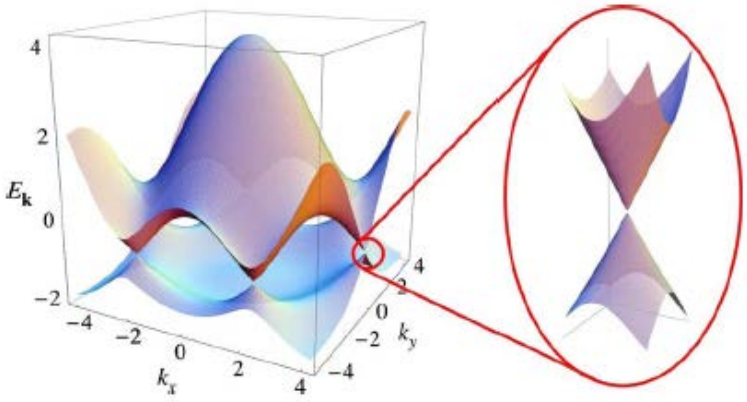


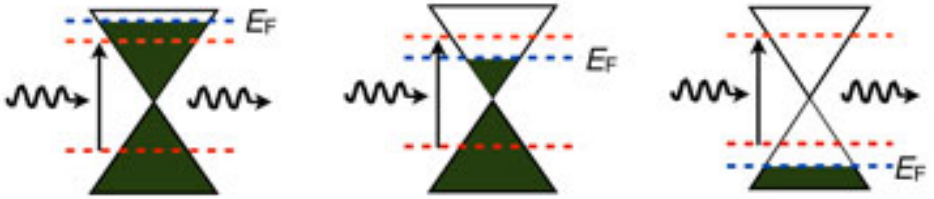


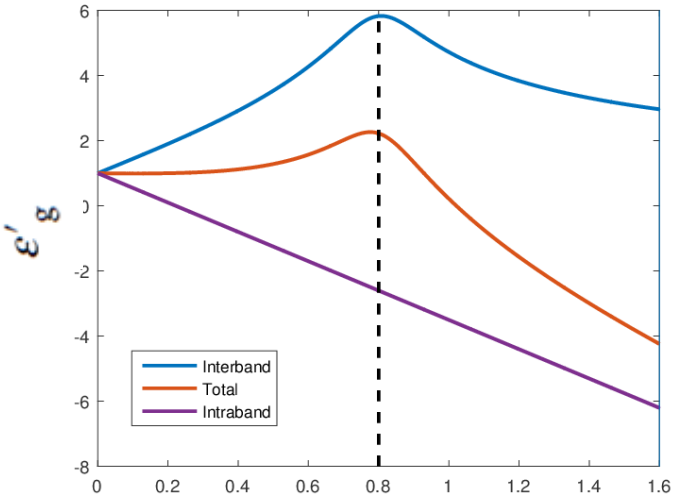


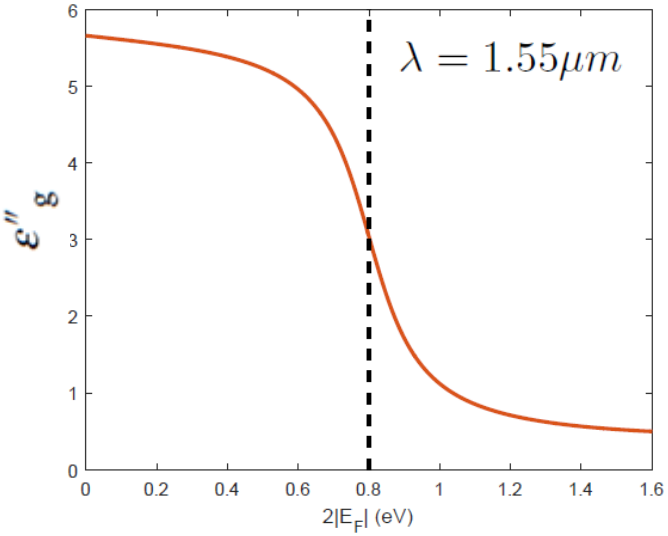
Nature Commun. 8, 14411(2017).
Nano Lett. 15, 4393(2015).
arXiv:1610.05352.

Optical properties of graphene – tunable

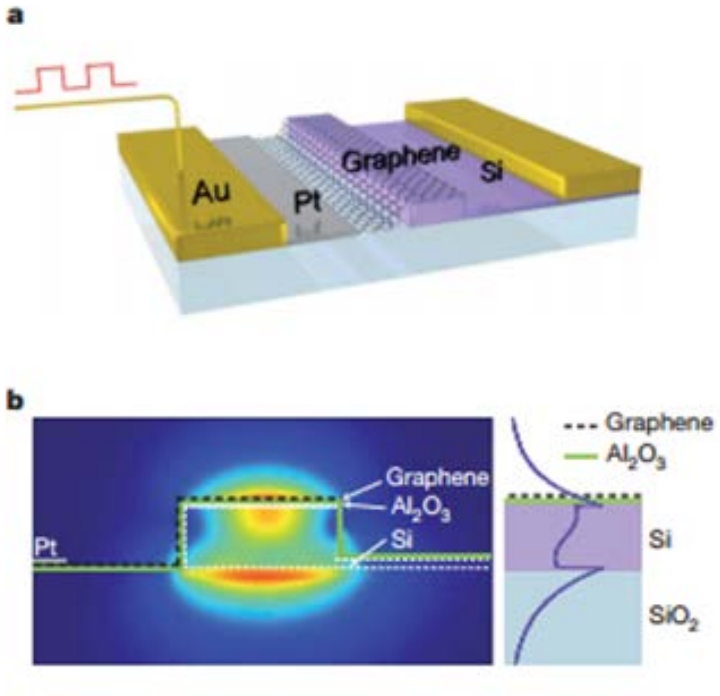


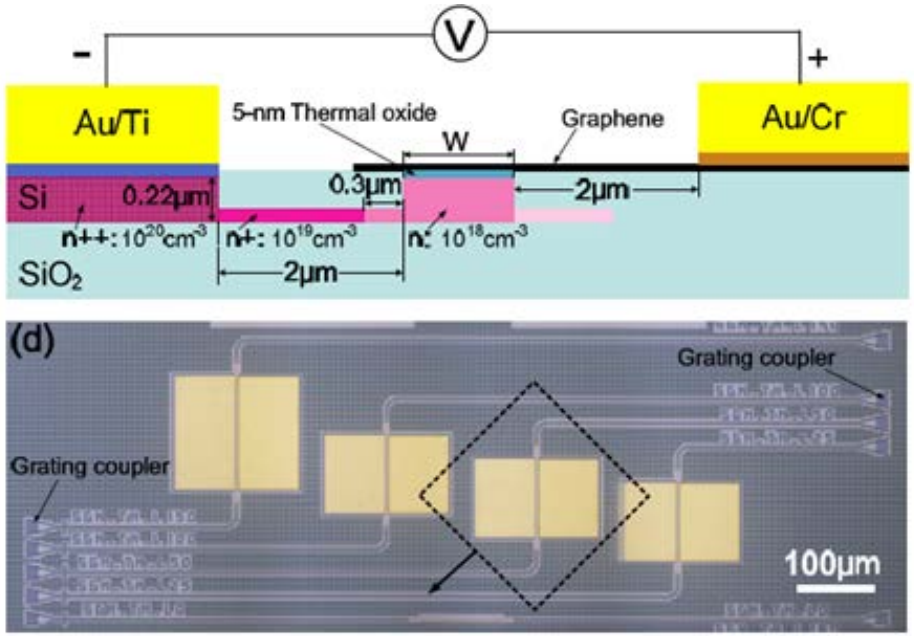






Graphene silicon waveguide electro-optic modulations





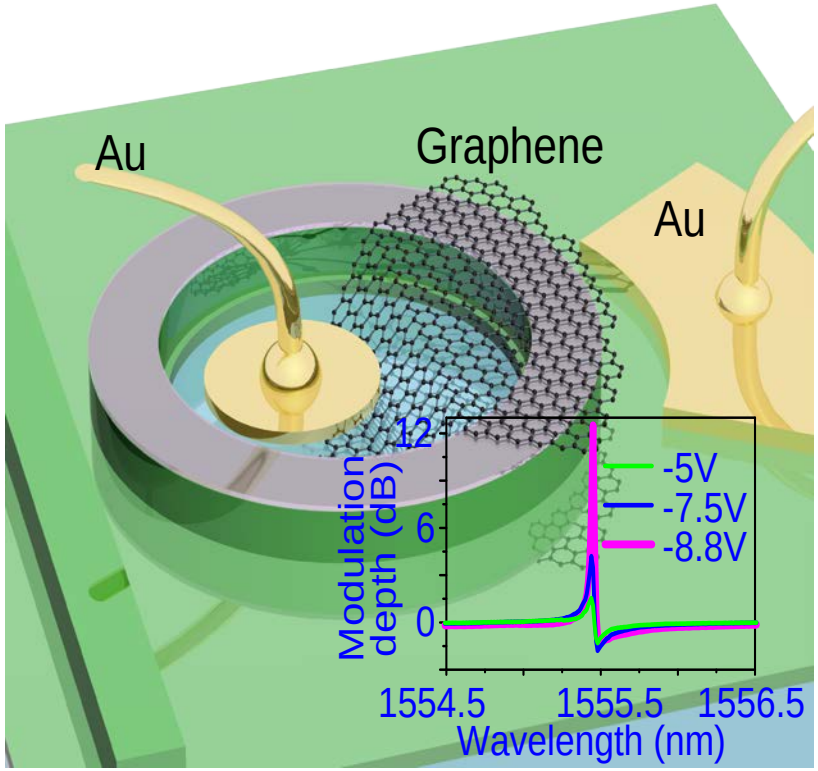
1GHz, broad operations sepctrum, tunability 0.09dB/um

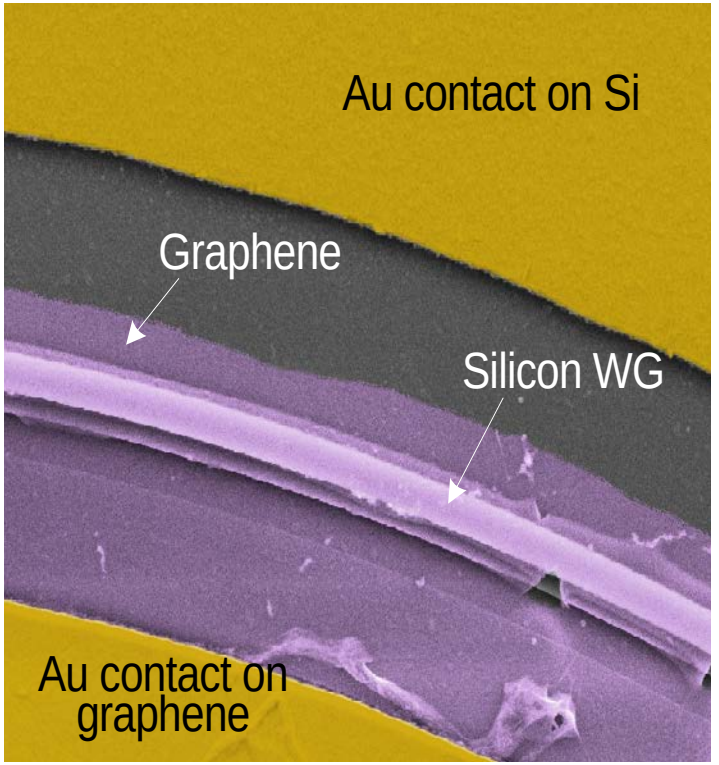
10GHz, broad operations sepctrum

Liu et. al., Nature, 474, 64 (2011).

Hu et.al., from IMEC

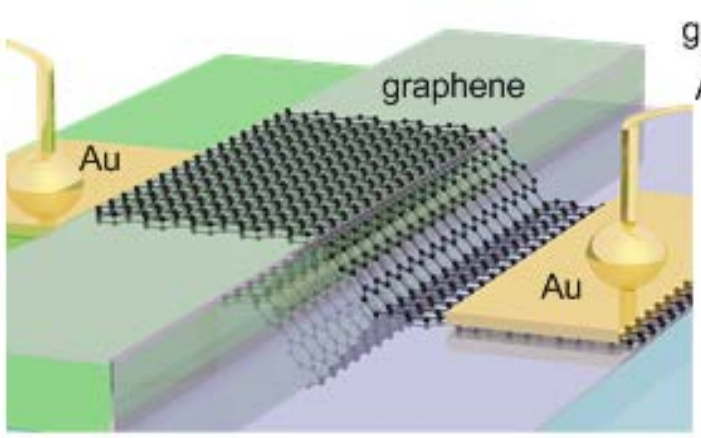
Graphene silicon microring resonator hybrid modulator

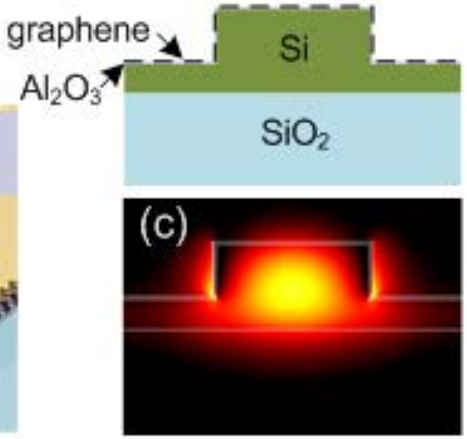


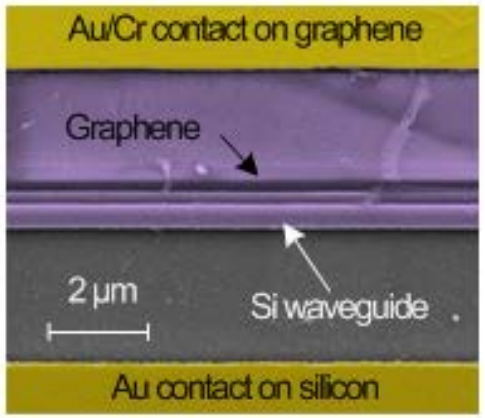


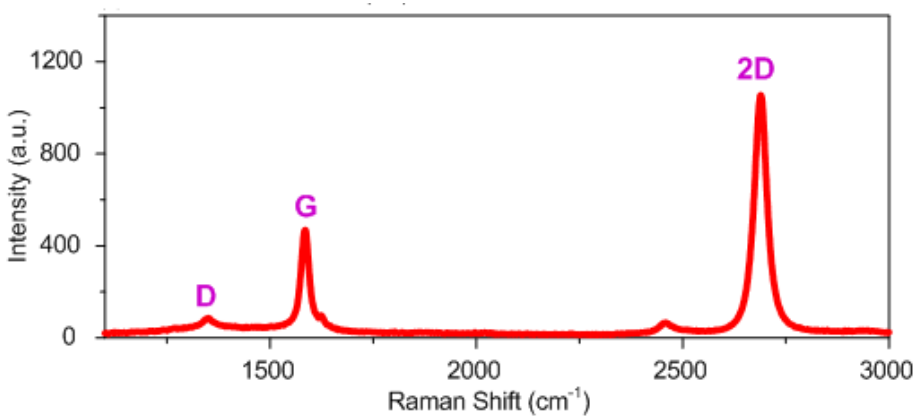
Y. Ding, et.al., Nano Lett. 15, 4393 (2015).

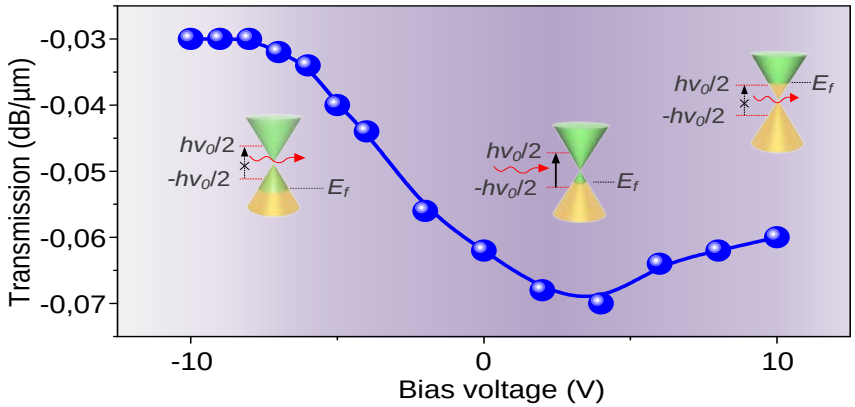
Graphene silicon waveguide modulator



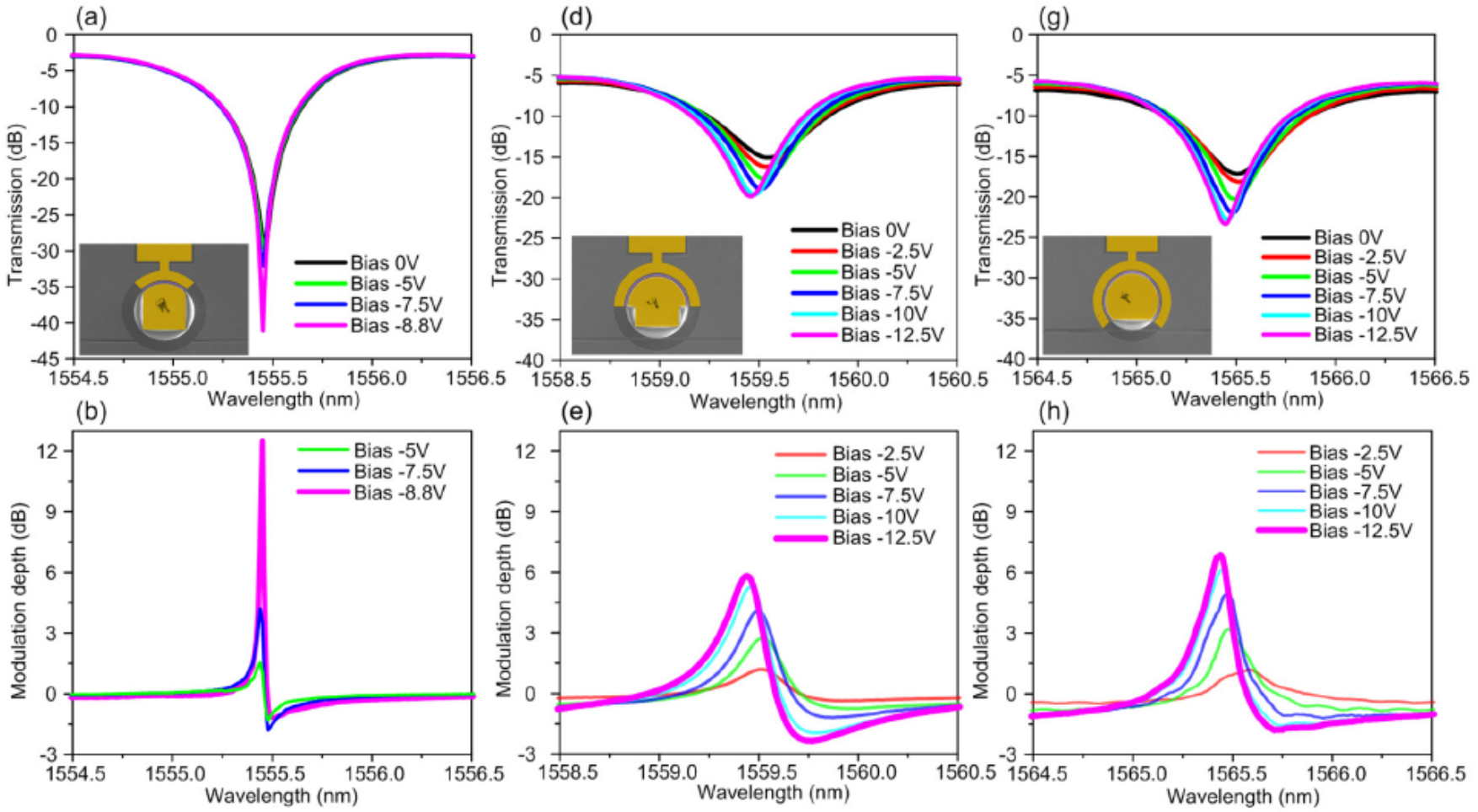








Graphene silicon microring resonator hybrid modulators



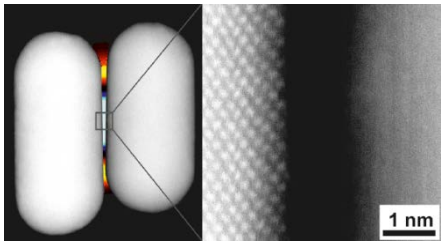
Y. Ding, et.al., Nano Lett. 15, 4393 (2015).

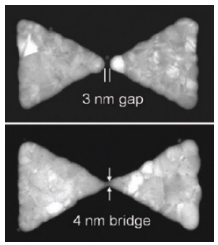
Plasmons in metal and plasmonic circuits

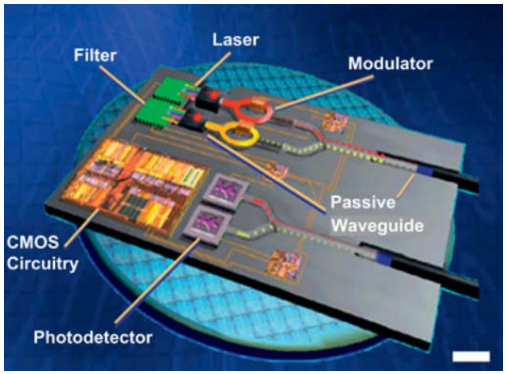
- **Plasmons:** Oscillation of free electron density, e.g., in a metal.

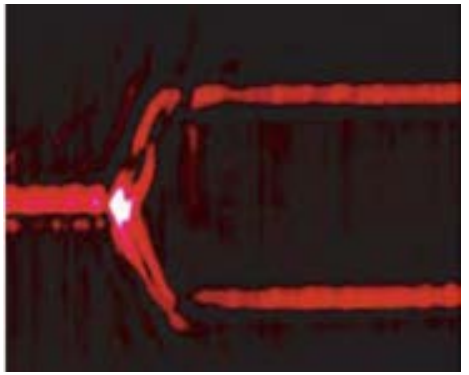
The LycurgusCup (glass; British Museum 4th century A. D.)

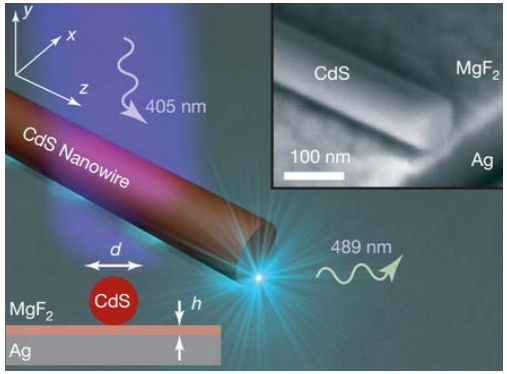
- **Plasmonics on the nanoscale**

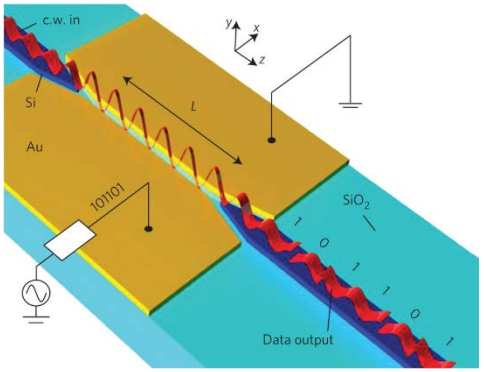








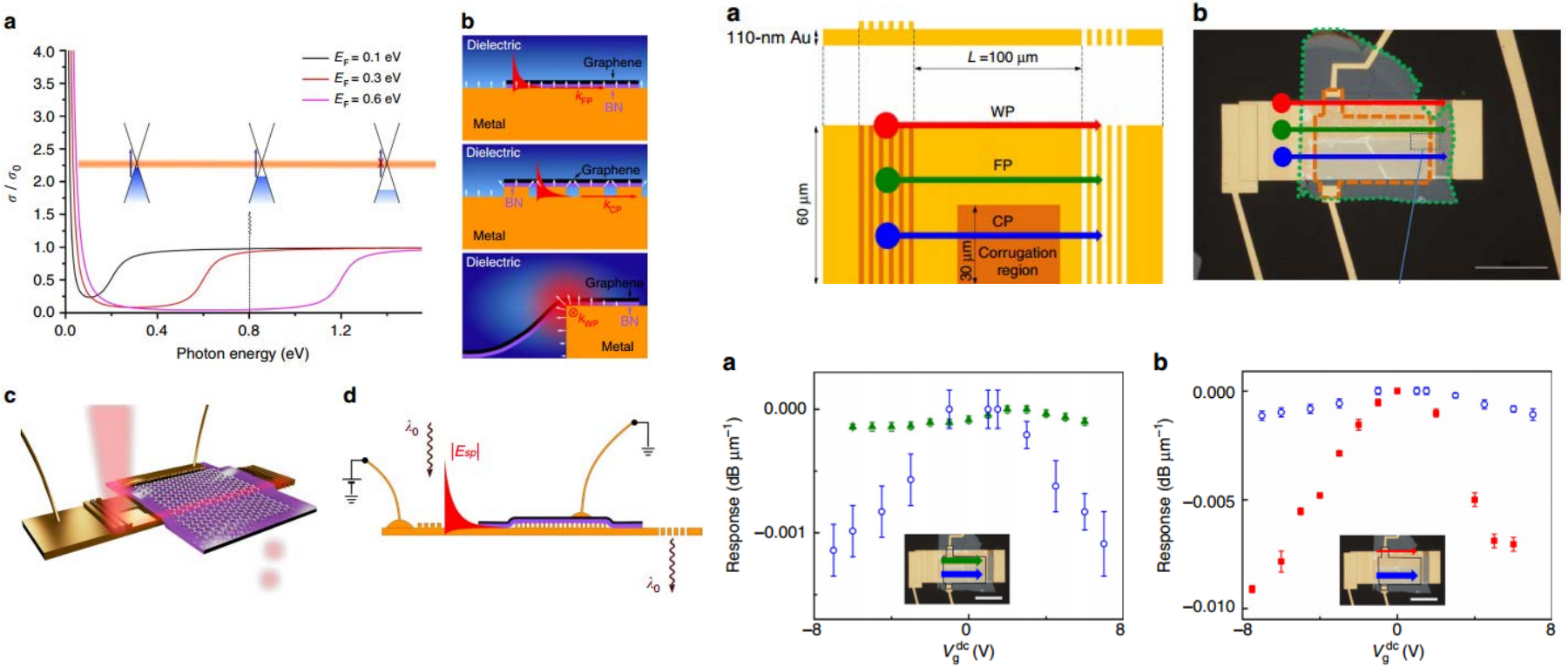




Kern et al., Nano Lett. 12, 5504 (2012).
Duan et al., Nano Lett. 12, 1683 (2012).

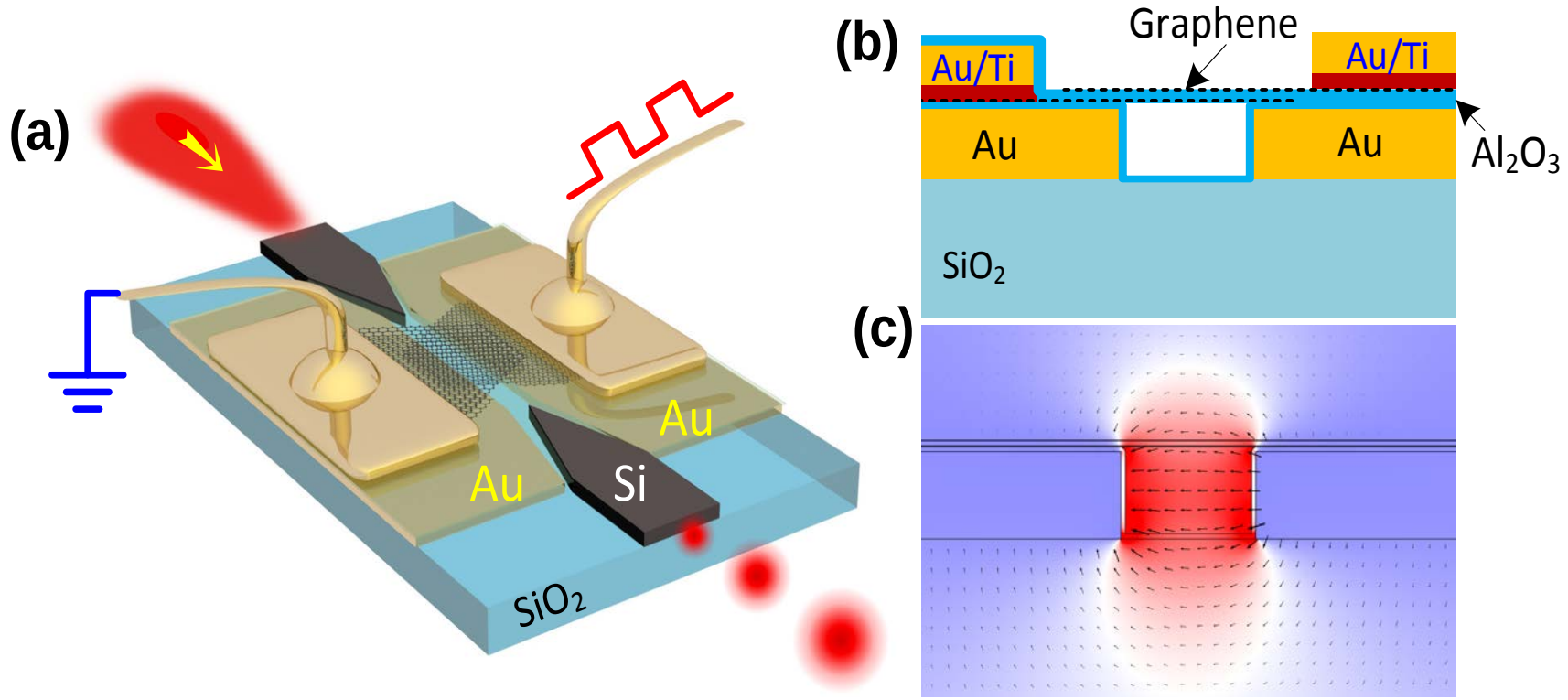
V. J. Sorger, et.al., MRS Bulletin, 37, 728 (2012).
Bozhevolnyi *et al.*, Nature, 440, 508 (2006).
R. F. Oulton, et.al., Nature Photon., 461, 629 (2009).
A. Melikyan et.al., Nature Photon., 8, 229 (2014).

First domenstration of graphene plasmonic modulators



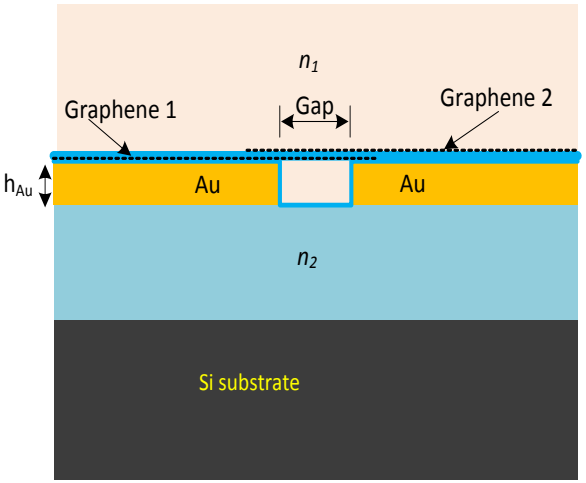
D. Ansell, et.al., Nature Common., 6, 8846 (2015).

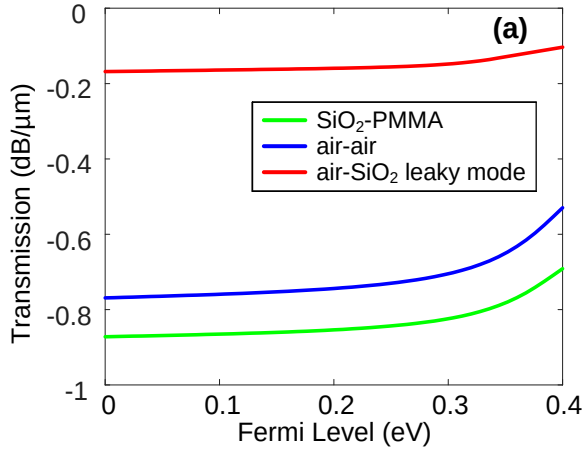
Graphene plasmonic waveguide modulator: Fully integrated with SOI platform

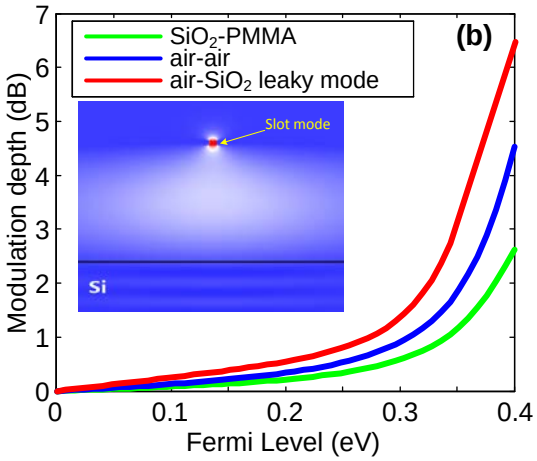


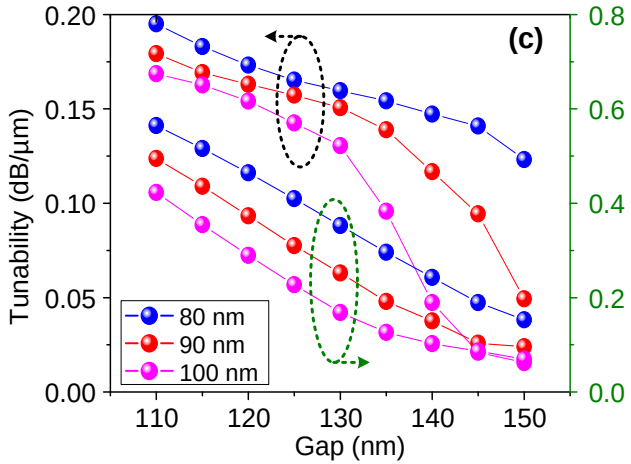
Y. Ding, et. al., arXiv:1610.05352

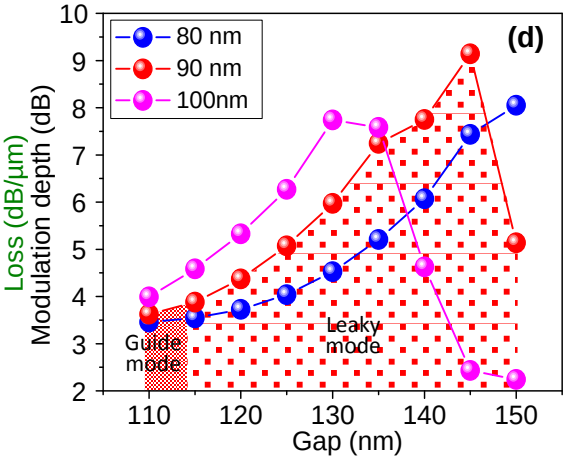
The leaky-mode slot waveguide gives largest modulation depth



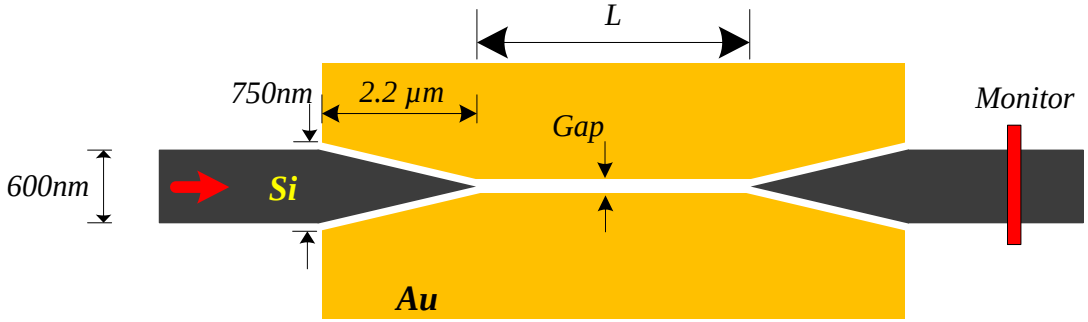


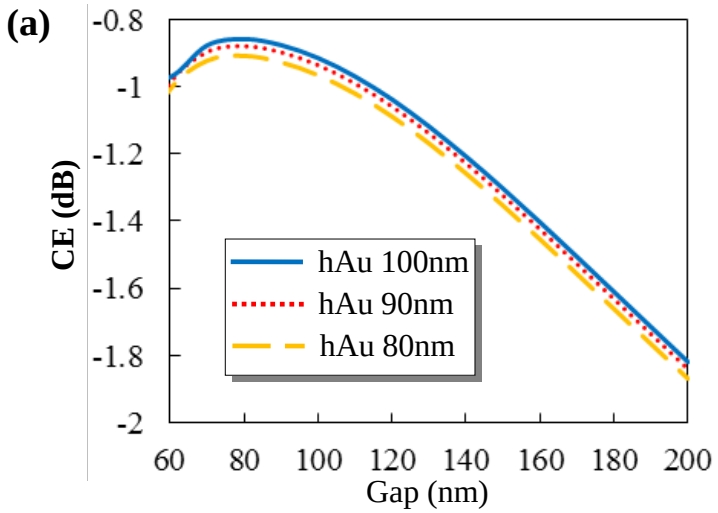


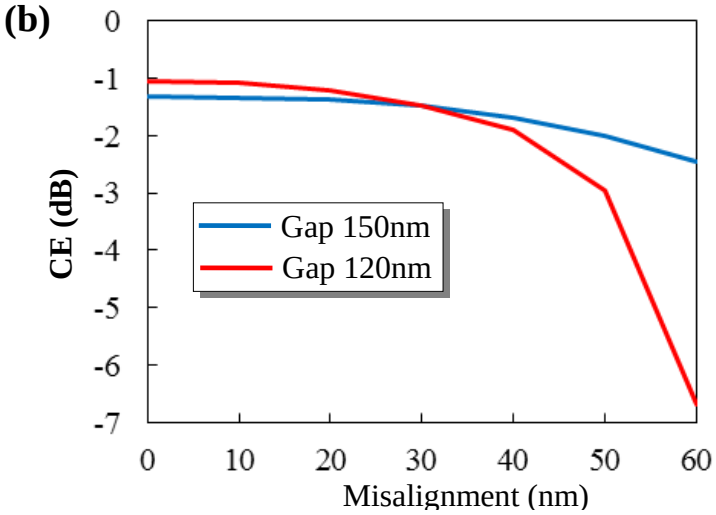




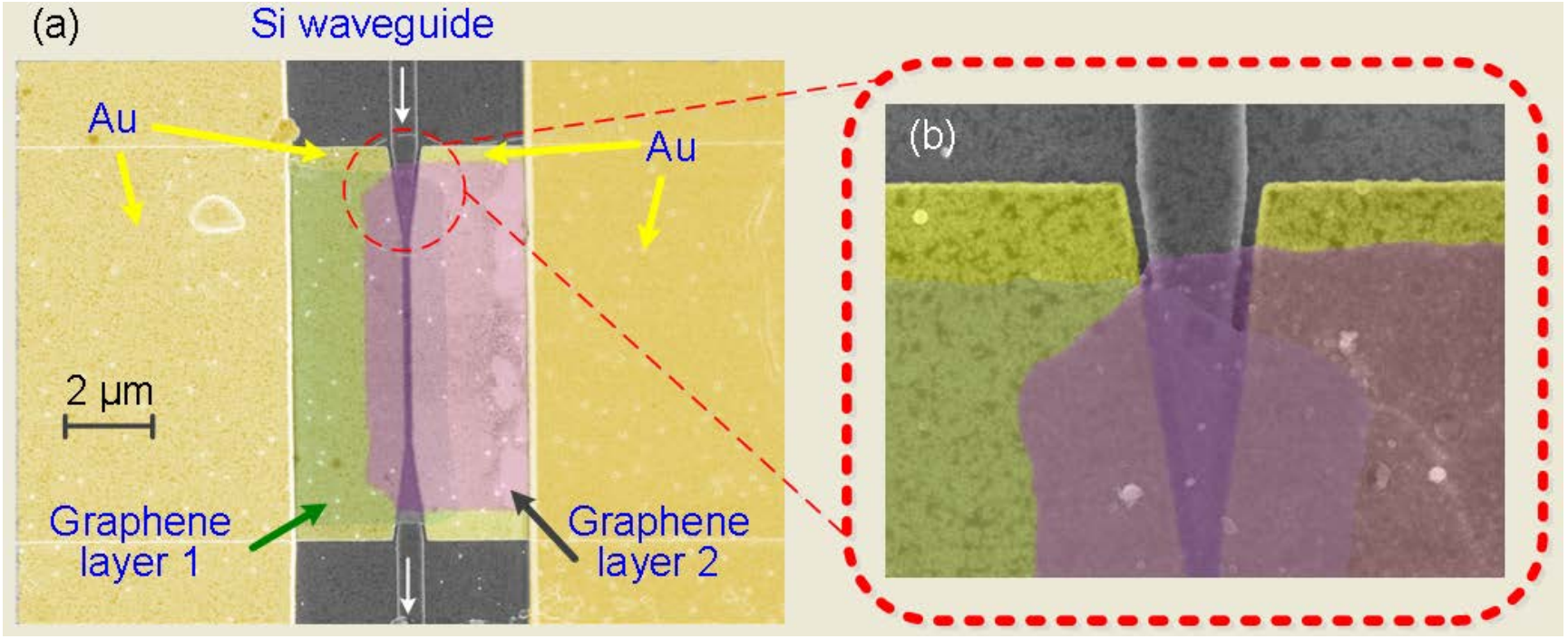
Optimization of coupling efficiency between Si and plasmonic waveguides





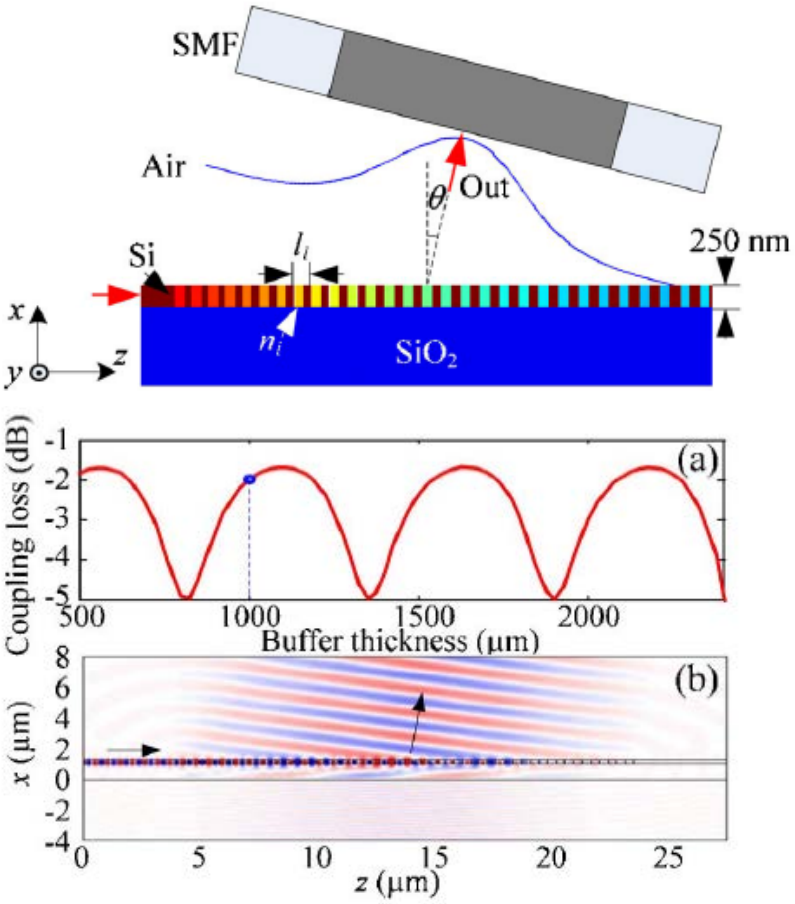


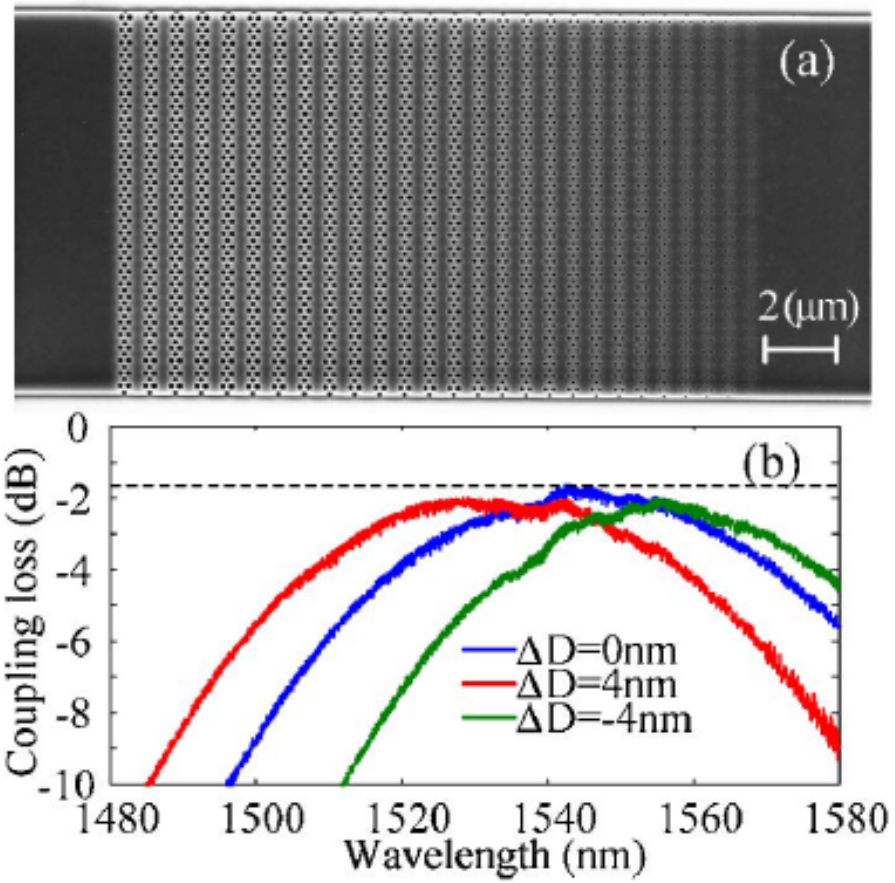
Graphene plasmonic waveguide modulators



Y. Ding, et. al., arXiv:1610.05352

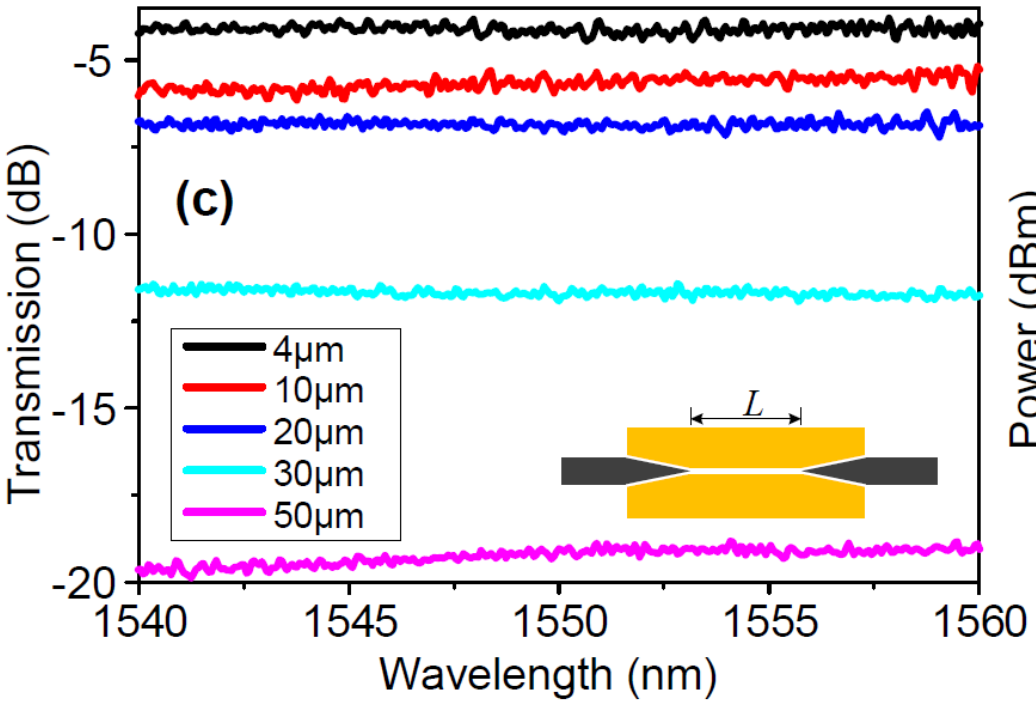
Photonic crystal grating coupler to Si waveguide

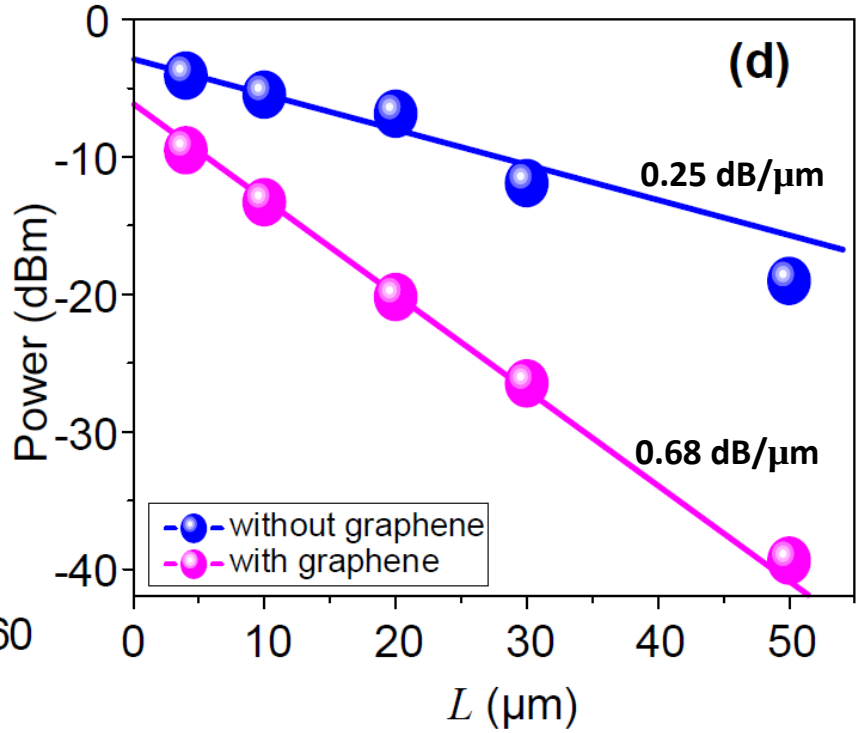




Y. Ding, et.al., OL. 38, 2732 (2013).

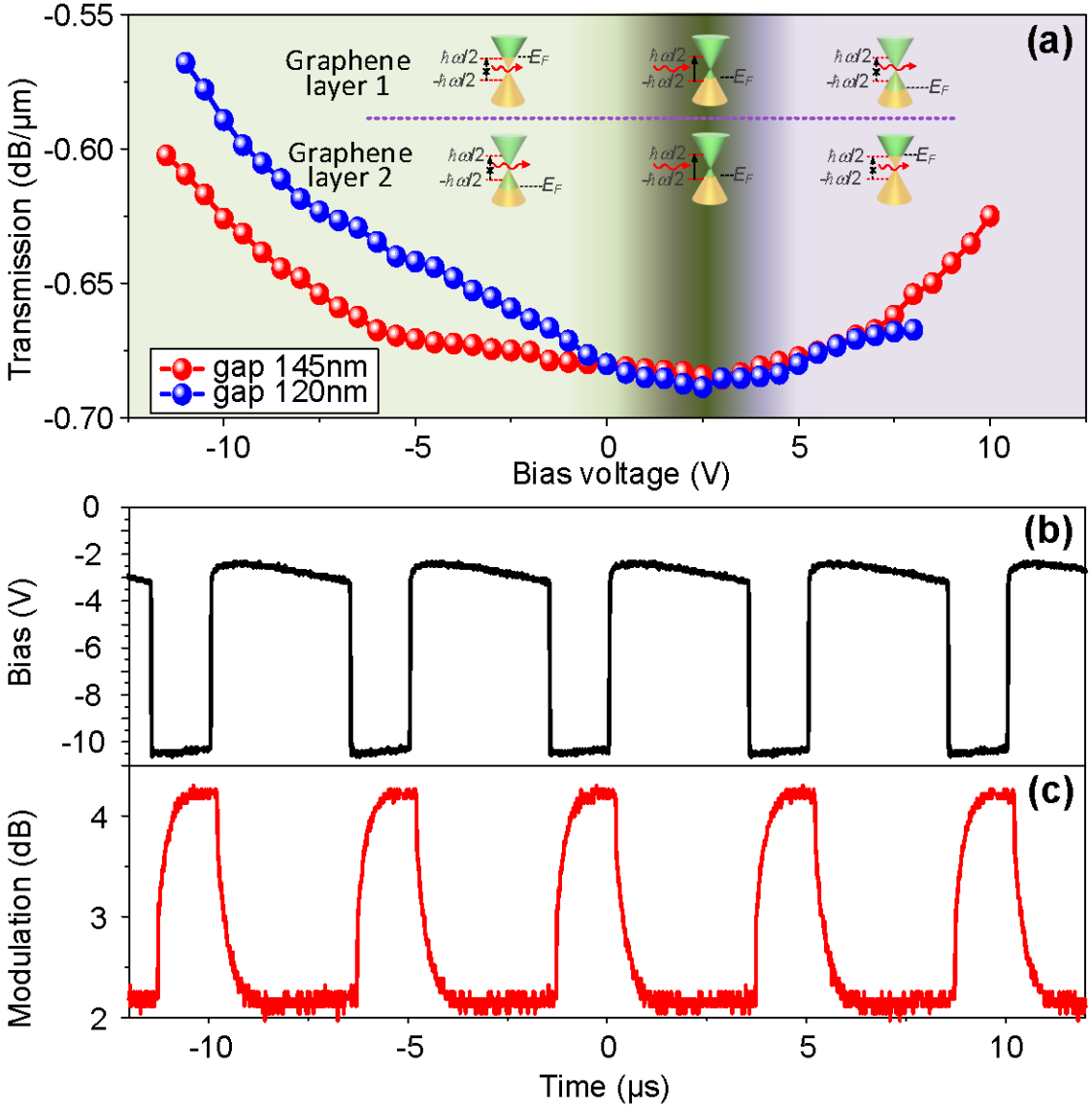
Plasmonic slot waveguides with low loss





Y. Ding, et. al., arXiv:1610.05352

Graphene plasmonic waveguide modulators

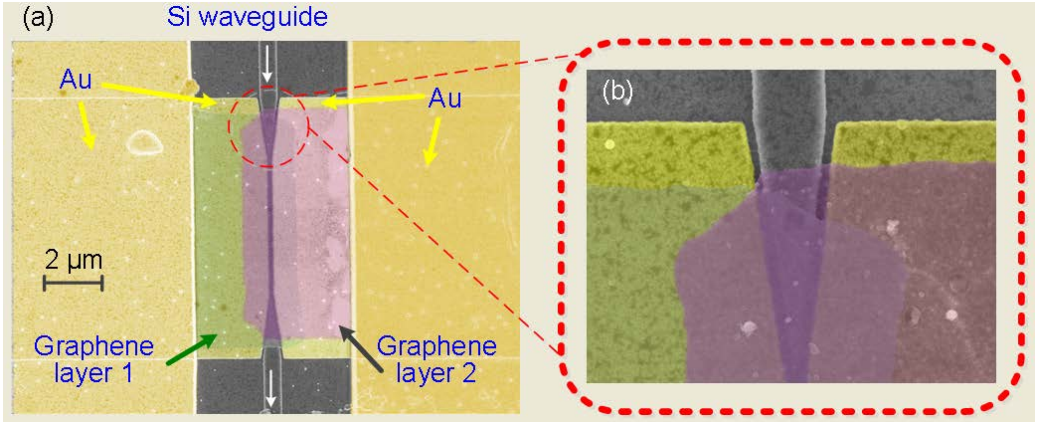


Summary

- Graphene-plasmonic waveguide modulators

  High modulation depth
  Low insertion loss
  Fully integrated with the SOI platform

  Leaky plasmonic waveguide for new applications



Y. Ding, et. al., arXiv:1610.05352

Acknowledgement

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Prof. Leif K. Oxenløwe
Dr. H. Hu
Dr. Y. Ding
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DTU Nanotech

Dr. Xiaolong Zhu

SDU (Odense), Denmark

Prof. Sergy I. Bozhevolnyi

Center for Nanostructured Graphene

Danmarks Grundforskningsfond
Danish National Research Foundation

Thanks for your attention