Ultrafast graphene photonics for futuristic generation of datacoms

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Ultrafast Graphene Photonics for Futuristic Generation of Datacoms

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SPIE.

BACKGROUND

Silicon Modulators

- Require large scale → sufficient modulation depth (due to a relatively weak high-order electro-optical effect).

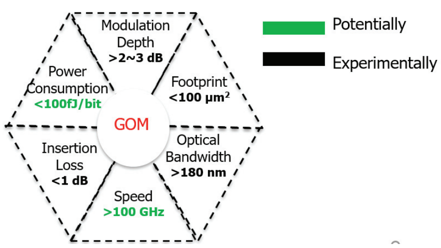
Modulators based on Germanium and other Compounds

- Have severe problems to be integrated with current complementary metal-oxide-semiconductor (CMOS) techniques.

Modulators with Resonators

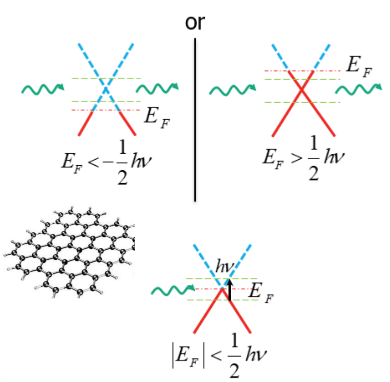
- Narrow modulation bandwidth with stringent fabrication requirement and thermal instability limits their development.

Graphene Optical Modulators



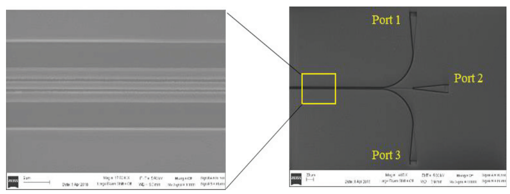
Mechanism of Absorption with Electrical Gating in Graphene

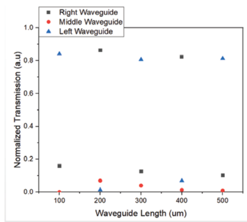
A monolayer of graphene – Noble prize winning material can be used to control the optical absorption in a silicon-based waveguide, inspiring a new category of optical modulators.

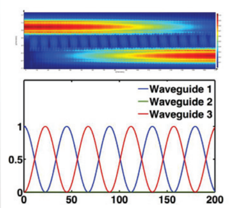


When Graphene is positively charged, fermi level is lowered ($E_f < -h\nu/2$), transmission is allowed.
When $-h\nu/2 < E_f < h\nu/2$, transmission is attenuated and the incident light can excite electron.
When Graphene is negatively charged ($E_f > h\nu/2$), there is no state available for the electrons to be excited to. Therefore absorption in this case is zero[1].

ADIABATIC ELIMINATION

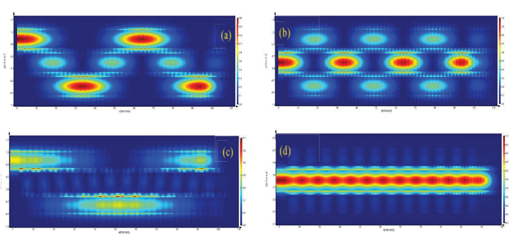






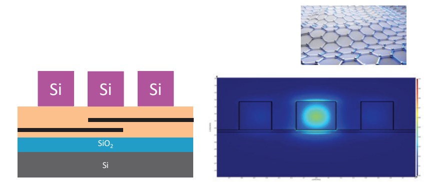
The expected results at waveguide's outputs while injecting the light through one of the outer waveguides.

Light is coupled to an outer waveguide in an AE configuration. The preliminary results agree with simulation results (absence of light in the middle waveguide).
Measurement is done at **λ**= 1550 nm with different waveguide's lengths (ranging from 100-500 um). Error bars are obtained for 3 different measurements.
The transmission is normalized with fabricated single waveguide to compensate the waveguide's loss.

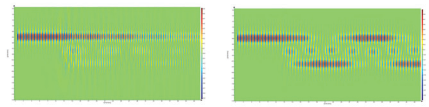


Due to the coupling between the directional waveguides, light appears in all waveguides along the propagation, regardless if the input tunable light source is injected to (a) the outer or (b) the middle waveguide. (c) and (d) observation of **AE configuration** with a wider middle waveguide. (c) Light is coupled to an outer waveguide in an AE configuration. The simulation confirms the absence of light in the middle waveguide along the entire propagation. (d) Light is coupled to the middle waveguide in an AE configuration. Only the middle waveguide emits light at the output without coupling into nearby outer waveguides and no light leaks out from the middle waveguide.

MODULATOR



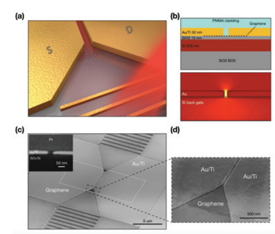
TM mode at 1550 nm



Graphene in Off condition	Graphene in ON condition
Chemical potential near zero	Chemical potential ~ 0.5 ev
Temperature: 300 K	Temperature: 300 K

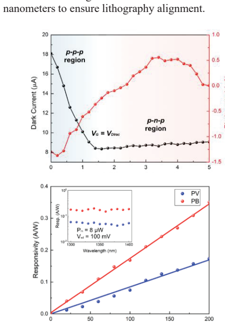
The applied voltage to graphene is enough to do the modulation.

PHOTO-DETECTOR



(a) 3-dimensional representation of the photodetector. (b) Cross sectional schematic of the device, where the Ti/Au metallic structures are in close proximity to each other for forming the plasmonic slot waveguide, as well as serving as the source-drain contact, while the p-doped SOI device layer silicon is used for back gate with a thin silica layer in between. (c) SEM image of fabricated photodetector, graphene is underneath the metal structure and the cross-sectional image as inset, here is a slot with slot gap width W = 30 nm and length L = 5 µm. (d) Zoom in view of the tapered region and slot, note that the graphene layer is slightly extended out from the slot region for a few hundreds of nanometers to ensure lithography alignment.

(Top) Measurement of photocurrent and dark current (I_{sd}) from the photodetector (V_{sd} = 0.1V), the photocurrent changes sign when the photovoltaic effect is stronger than bolometric effect. 8 µW optical signal at 1310 nm wavelength was coupled into the plasmonic slot structure, and the source-drain current and photocurrent under different gating voltage was measured with a static bias voltage of 0.1 V (Bottom) Measured responsivity vs. bias voltage, a linear fit of **1.71A/WV** and 0.85A/WV for PB and PV effect is retrieved, respectively. Inset shows a broadband responsivity from 1300 to 1400 nm. The measurement is mainly limited by metallic grating coupler operating wavelength.



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