Waveguide integrated MoS_2 photodetectors

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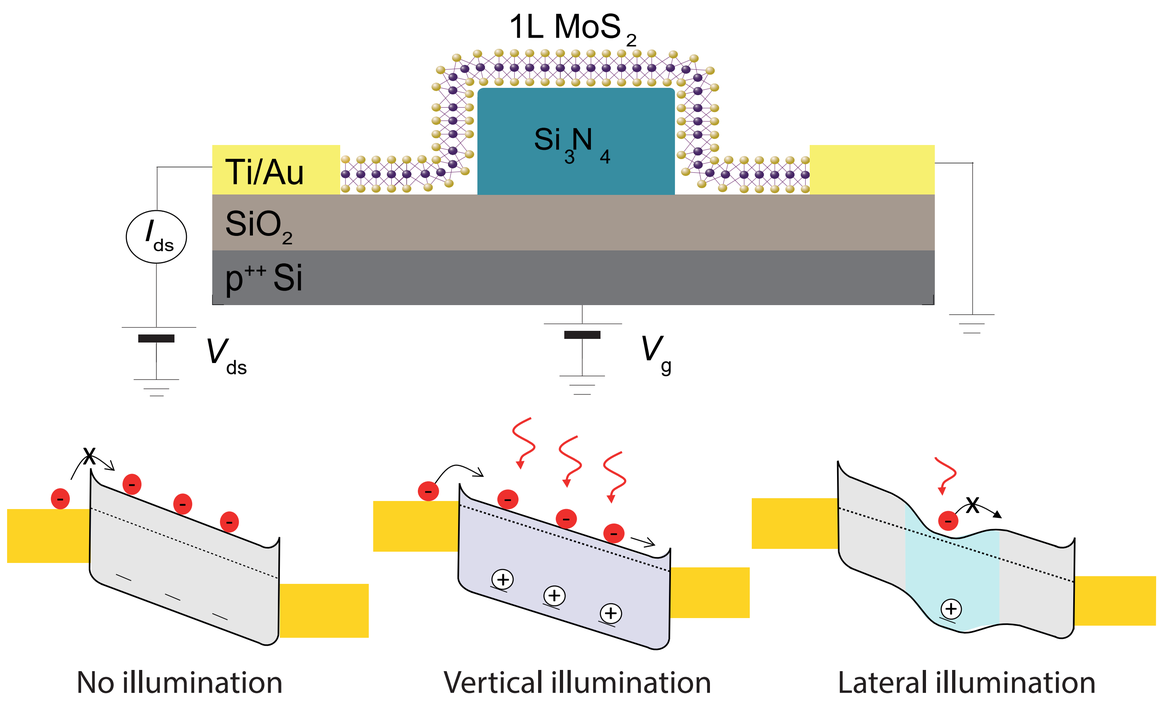
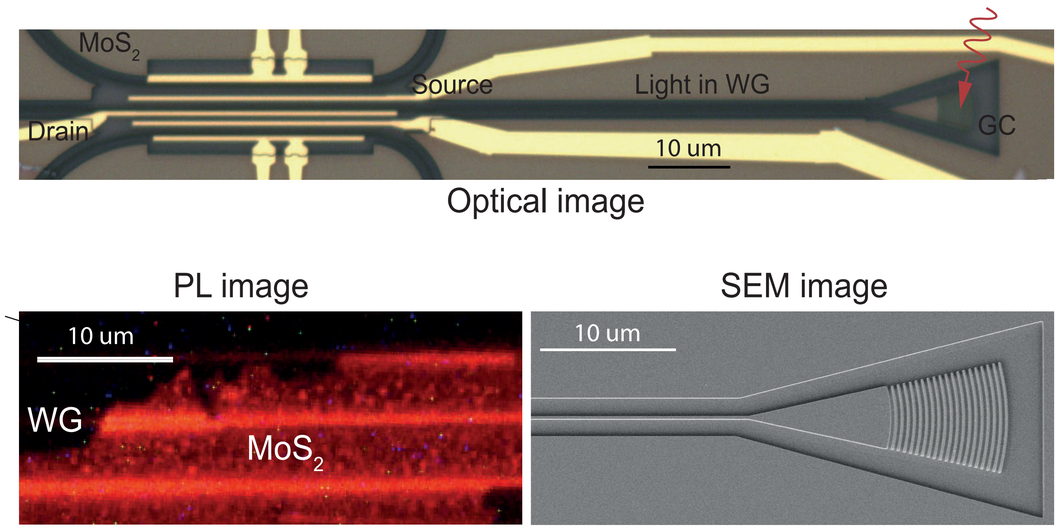
1. Introduction. Schematics

We present MoS_2 photodetectors integrated in SiN waveguides, for increased lateral absorption and responsivity. Light is coupled into the waveguide with diffraction gratings, and generates e-h pairs in the monolayer by excitation through the evanescent field. By applying a constant bias in the phototransistor, the external light excitation is transformed in electrical current.



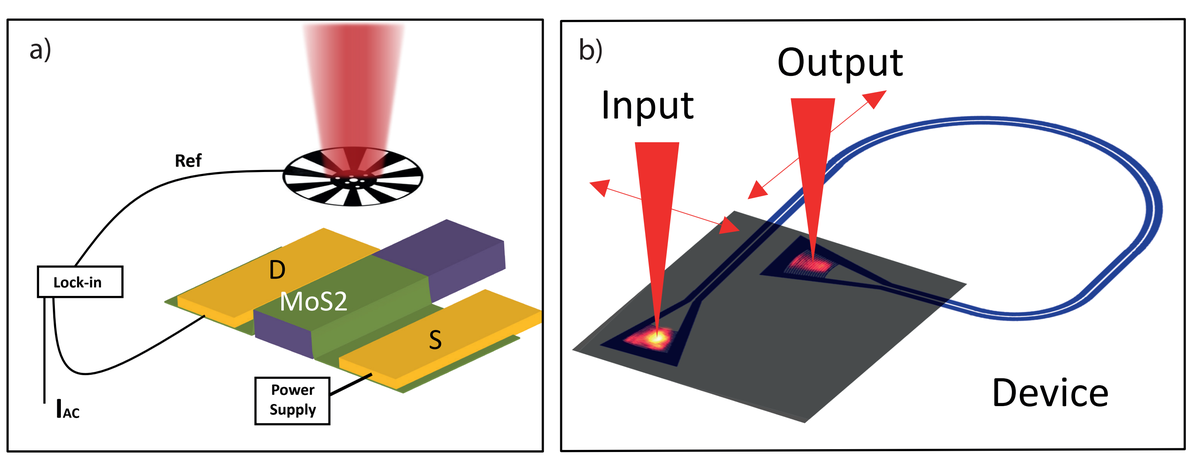
2. Device fabrication

Photonic structures are fabricated by dry etching of SiN layers grown by LPCVD. The dimensions are optimized for wavelengths at the bandgap of MoS_2. Waveguide sidewalls are smoothened by KOH wet etching, after which MoS_2 monolayers are transferred. Ti-Au contacts are deposited close to the waveguide to increase photocurrent, but far enough to avoid optical losses.



Photoluminescence image shows the transferred flake on top of the waveguide. Quality of diffraction gratings and waveguides is confirmed by SEM and AFM.

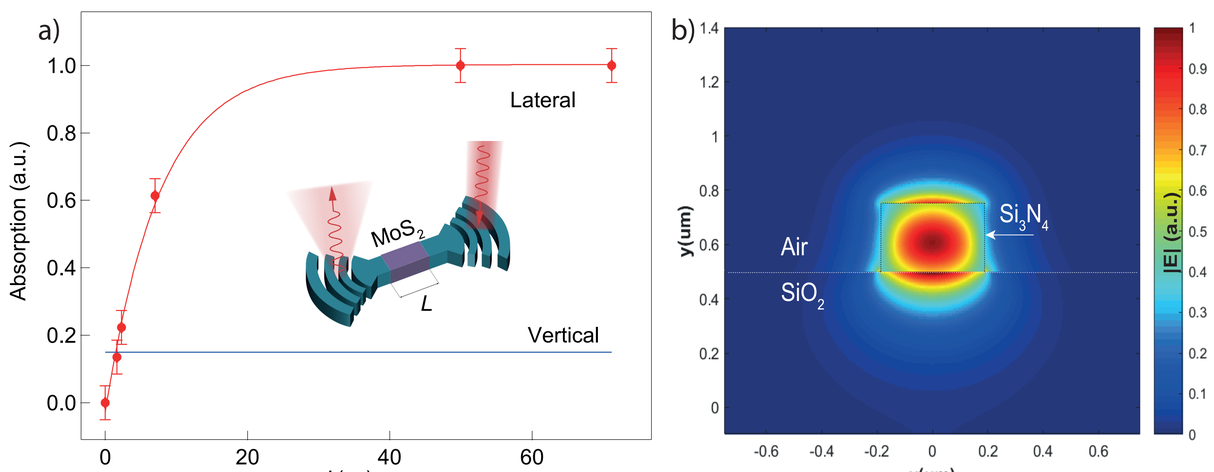
3. Measurement set up



a) Schematics of photocurrent measurements with light modulated by a chopper

b) Schematics of cross polarized measurements for characterization of photonic structures

4. Control of light absorption

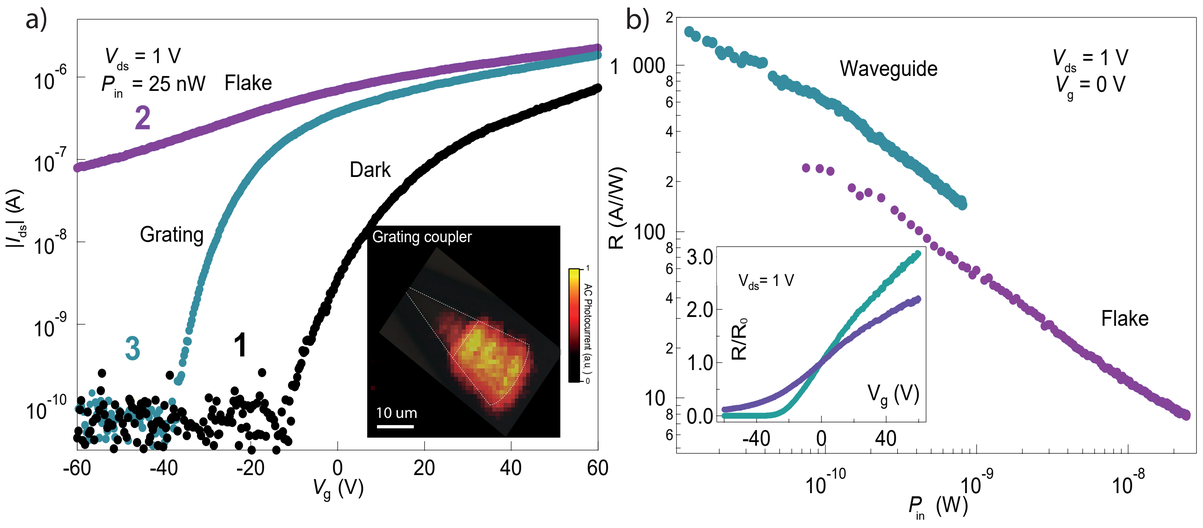


a) Light absorption of MoS_2 as a function of flake length for lateral and vertical illumination

b) Calculated TM field magnitude for light propagation in the waveguide

5. Enhanced photoresponse

Photocurrent generation upon light excitation on the grating coupler is enhanced due to the increased overlapping area between the monolayer and the waveguide. The particular device geometry allows the photoresponse to be switched on and off with the back gate.

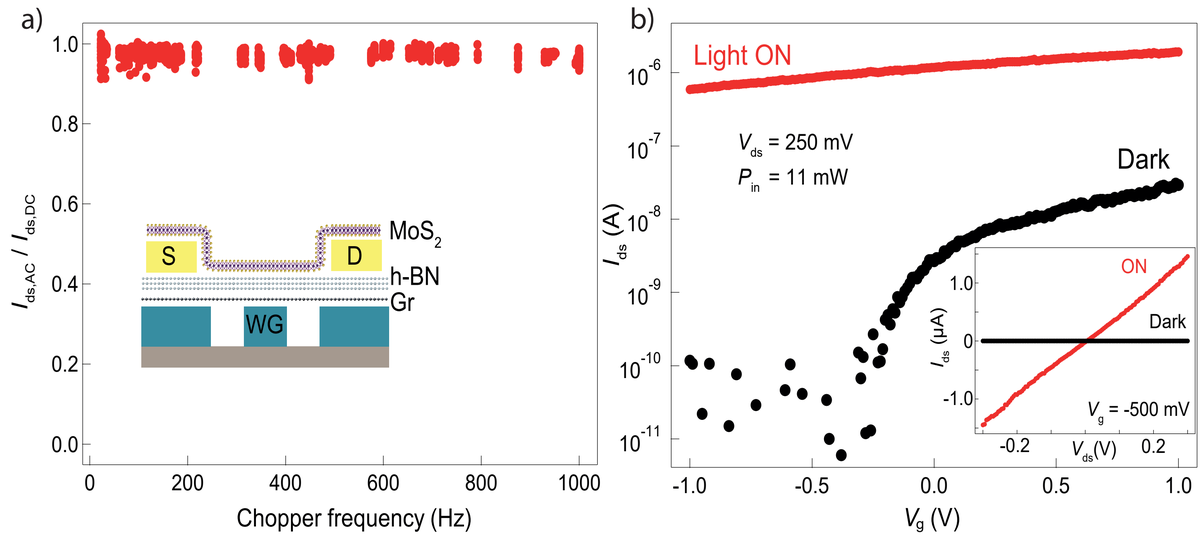


a) Drain-source current dependence on applied back gate voltage for three illumination regimes

b) Photoresponsivity as a function of incident power. Inset shows modulation with gate voltage

6. Improved response time

By combining a MoS_2 semiconducting channel with hexagonal boron nitride dielectric and a graphene local gate, we further achieve fast photoresponse and low power operation of the optoelectronic device.



a) AC photocurrent dependency on chopper frequency proving response times below 1 ms

b) Low voltage operation of MoS_2/hBN/Gr photodetector fabricated on the waveguide

7. Conclusions

- We demonstrate integration of MoS_2 photodetectors on photonic structures and present device architectures for practical optoelecctronics circuits.
- Large photoresponsivity is observed for lateral illumination at wavelengths close to bandgap
- Diffraction gratings provide homogeneous and large coupling area for external light sources
- The use of a graphene back gate with thin h-BN as dielectric reduces the voltage range needed to operate the phototransistor and increases operation speed below 1 ms

Acknowledgement

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