A wavelength-scale black phosphorus spectrometer

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Introduction: On-chip spectrometers with a compact footprint are being extensively pursued due to their promising future in critical applications such as sensing, surveillance and spectral imaging. Most existing miniaturized spectrometers use a large array of photodetection elements to capture the different spectral components of incident light, from which its spectrum is reconstructed⁵-⁷.

The operational principle of the single-detector black phosphorus (BP) spectrometer

Device mechanism: Tunable Stark effect in a single BP photodetector, with a footprint of 9×16 µm².⁶,⁷

Steps of the spectroscopy: 1. learning, 2. sampling, 3. reconstruction

Mathematical tools: Adaptive regressions with regularizations⁸,⁹

Characterizations of the tunable BP photodetector

- The dual-gate BP photodetector consists of a graphene/hBN/BP/hBN heterostructure on a SiO₂/Si substrate.
- The photocurrent is maximized along the charge-neutrality line, and the displacement field is given by $D = \varepsilon_{BN} (V_G - V_D)/d_{BN}$.
- The photoresponsivity of BP as a function of $D$ and wavelength $\lambda$ is inferred based on its photoresponse to a blackbody source.

Spectroscopy demonstrations

- By fitting the measured photocurrents as a function of $D$, including the data measured at $D_1$, $D_2$, and $D_3$, the unknown spectrum can be reconstructed.
- The spectrum of an infrared laser is reconstructed and compared with the standard reference spectrum. The resolution is 90 nm at mid-infrared.
- The spectral feature of carbon dioxide can be identified using this single-detector spectrometer.

Reference:

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