

## Giant Photo-induced Valley Hall Conductivity Driven by Twist-Engineered Quantum Geometry in a Moiré Superlattice

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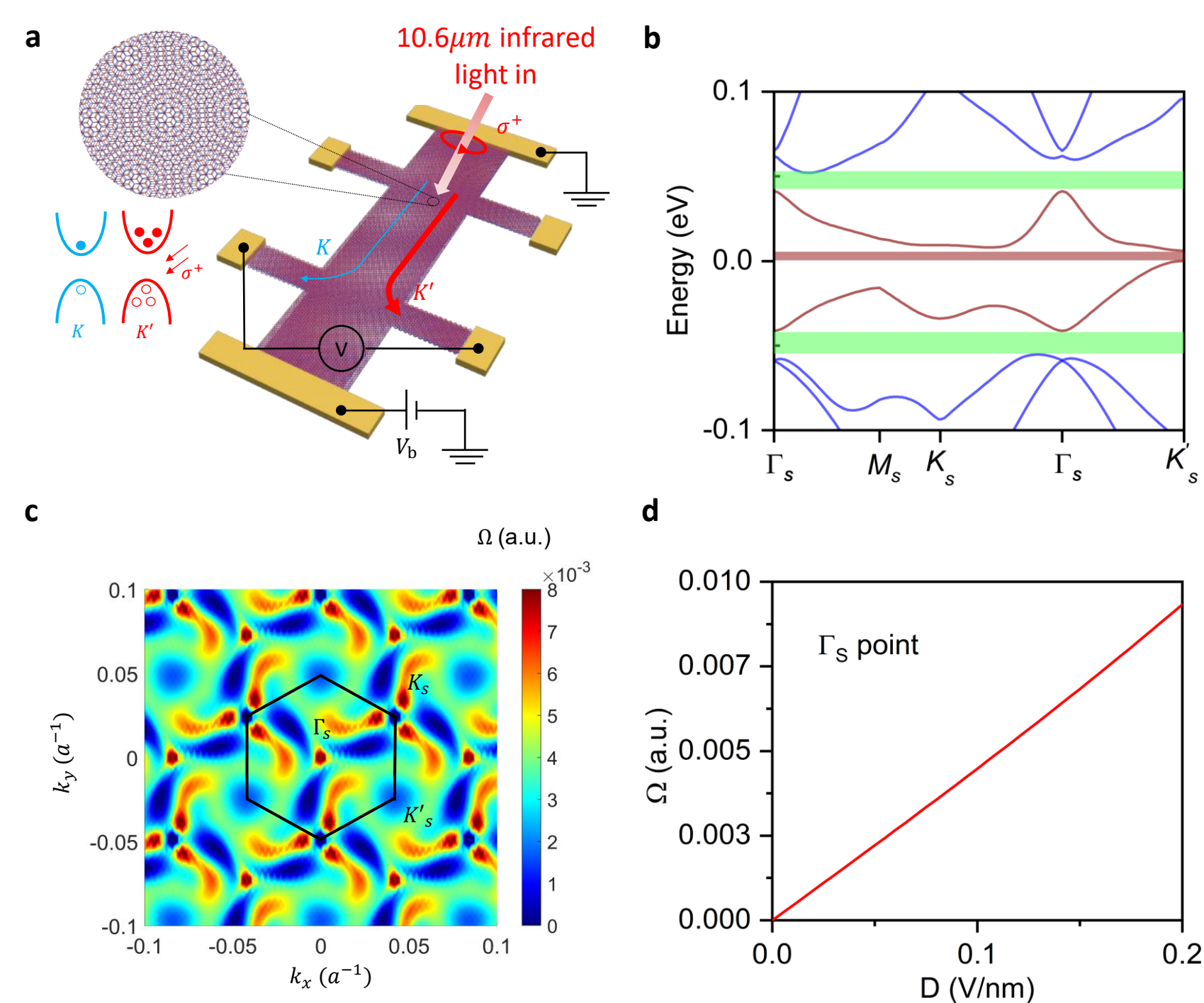
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### Abstract:

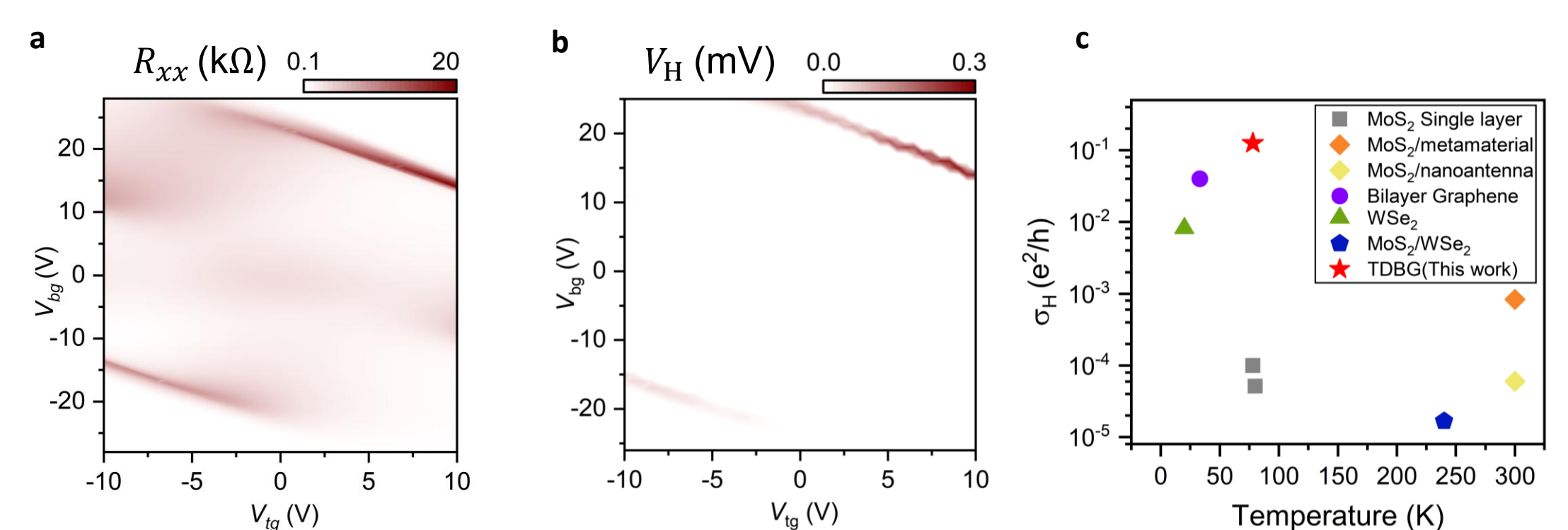
Moiré superlattices, formed by twisting two-dimensional atomic crystals, provide a powerful platform for engineering the underlying quantum geometry of electrons, particularly the Berry curvature. This capability opens new avenues for exploring and harnessing the valley degree of freedom. Here, we report the direct observation of a giant photo-induced valley Hall effect in twisted double bilayer graphene. Using mid-infrared optical pumping, we generate and detect a valley-polarized photovoltage, achieving an ultra-high valley Hall conductivity up to  $0.125 e^2/h$  at 78 K—orders of magnitude larger than that observed in transition metal dichalcogenides-based systems. This substantial response originates from a massively enhanced Berry curvature, induced by symmetry breaking via the moiré potential. Combined experimental and theoretical analyses reveal the evolution of this valley Hall conductivity with an external displacement field, demonstrating its full electrical tunability. Furthermore, the valley Hall measurement geometry effectively suppresses additional noise voltage under a longitudinal bias, yielding an exceptionally low noise voltage floor of  $29.7 \text{ nV}/\sqrt{\text{Hz}}$  at 105 Hz. With outstanding responsivity and inherent low-noise configuration, our devices enable circular-polarization-resolved mid-infrared imaging, offering unique advantages over commercial thermal detectors at  $10.6 \mu\text{m}$ . Our findings establish moiré engineering as a powerful route to harnessing the valley degree of freedom and point towards new architectures for ultra-low-noise optoelectronic and valleytronic devices.

### Berry Curvature driven VHE (Valley Hall effect) in TDBG



➤ Berry Curvature hot spot at  $\Gamma_s$  point enabling a notable VHE in TDBG.

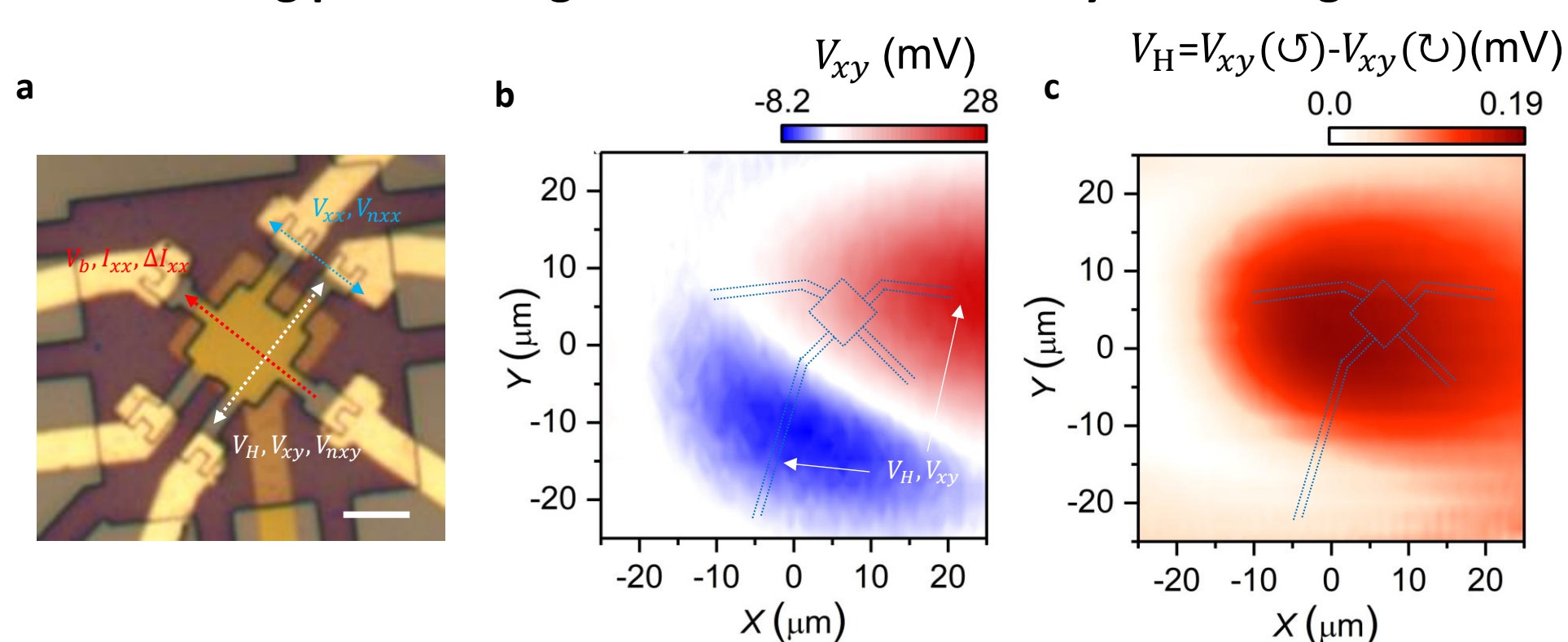
### Giant Photo-induced Valley Hall Conductivity



➤ The valley Hall conductivity in TDBG reaches  $0.125 e^2/h$ , which is orders of magnitude higher than other 2D materials.

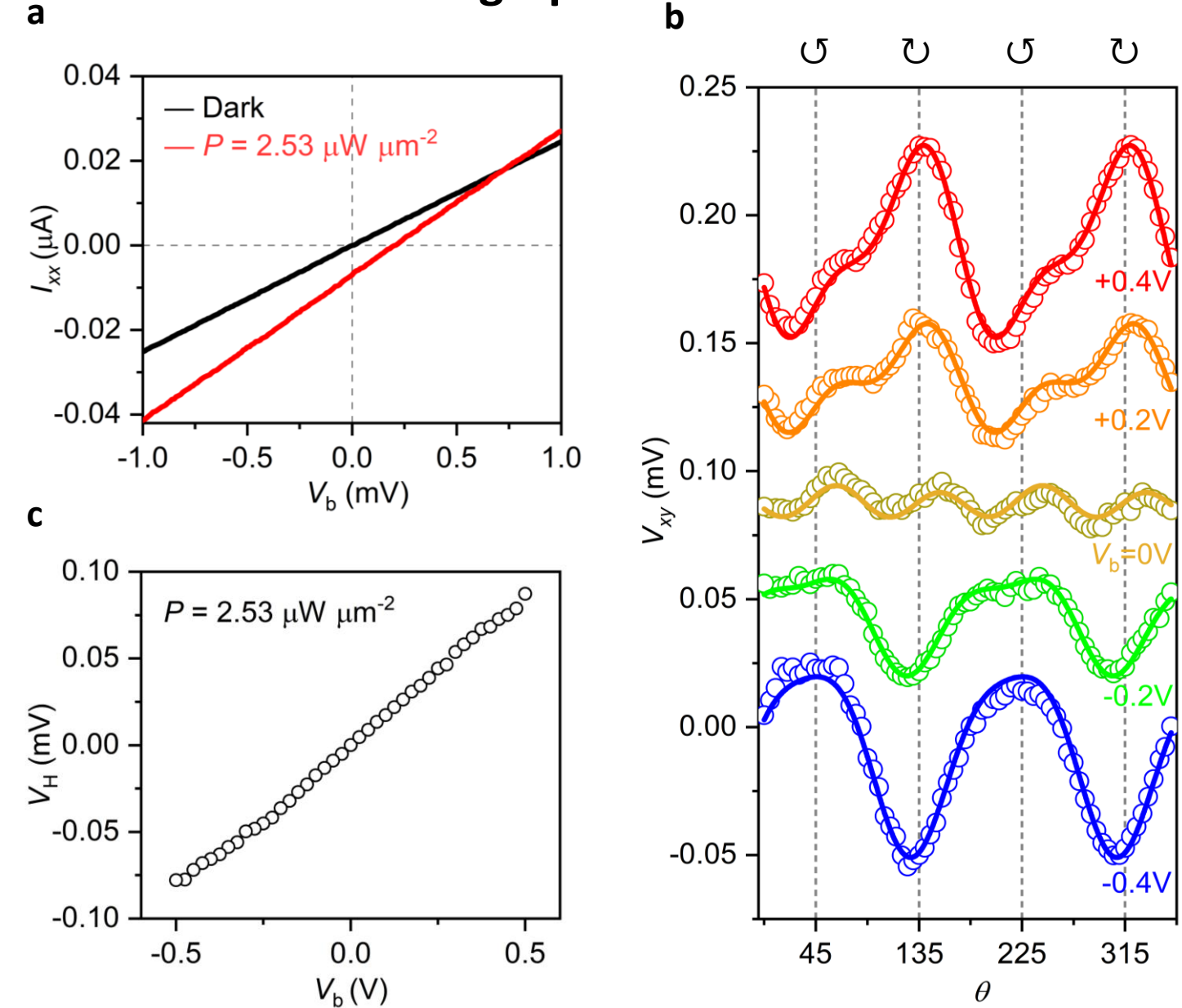
### Direct Observations of VHE

#### Scanning photovoltage measurement of valley hall voltage



➤ The observed valley hall voltage  $V_H$  originates from a solid bulk response.

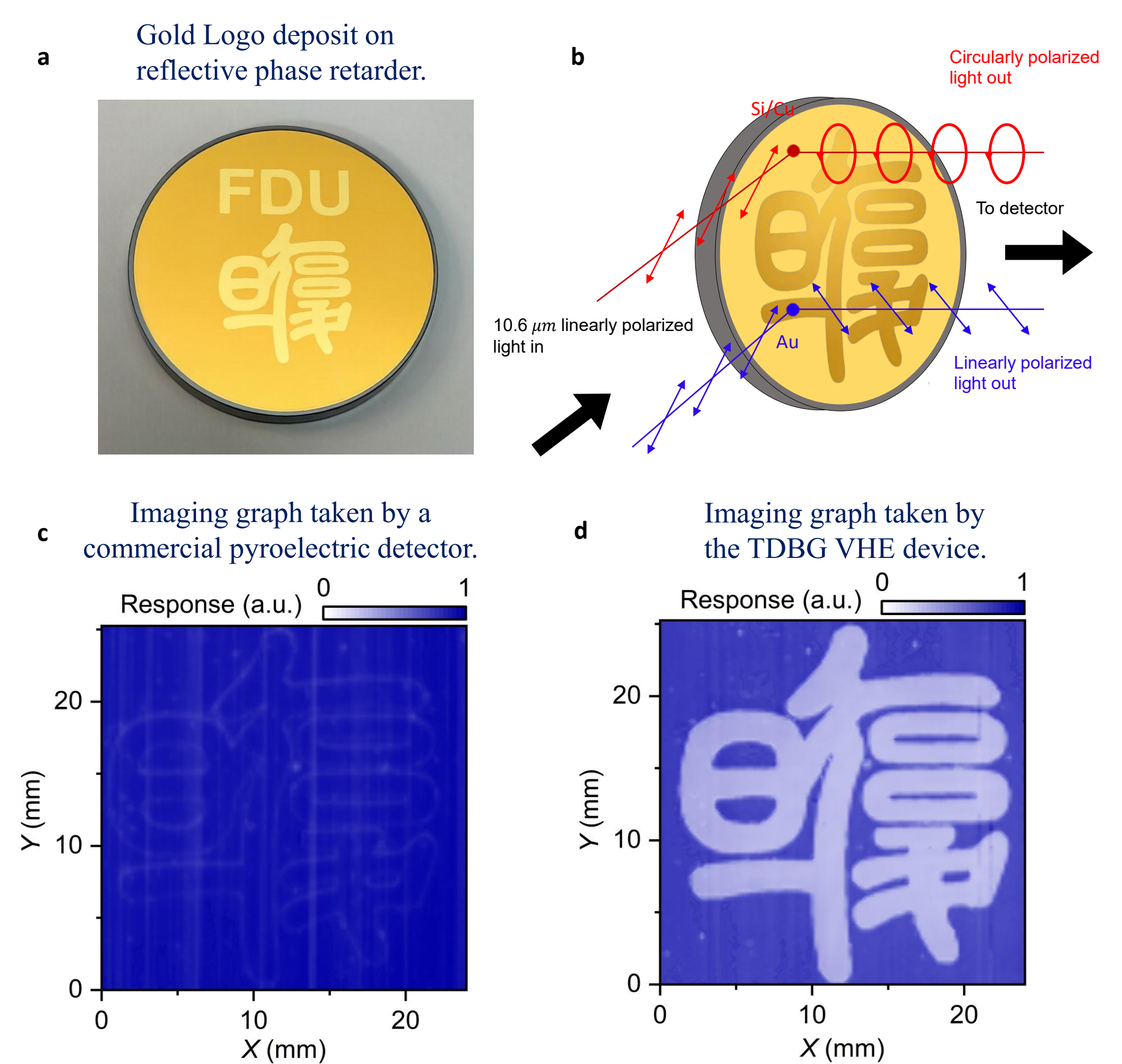
#### Fingerprints of VHE



➤ Hall voltage  $V_{xy}$  shows a dependency on helicity of incident light.

➤ The valley hall voltage shows a linear dependency on longitudinal bias  $V_b$ .

### TDBG VHE for circular-polarization-resolved mid-infrared imaging



### Highlights

- Berry curvature driven strong VHE in TDBG, with record-high valley Hall conductivity.
- The VHE is fully tunable through gating. A large displacement field  $D$  enhance the berry curvature, leading to the observed colossal VHE response.
- VHE in TDBG offers a unique approach for mid-infrared polarization-resolved imaging, which surpasses conventional thermal detectors at corresponding wavelength.