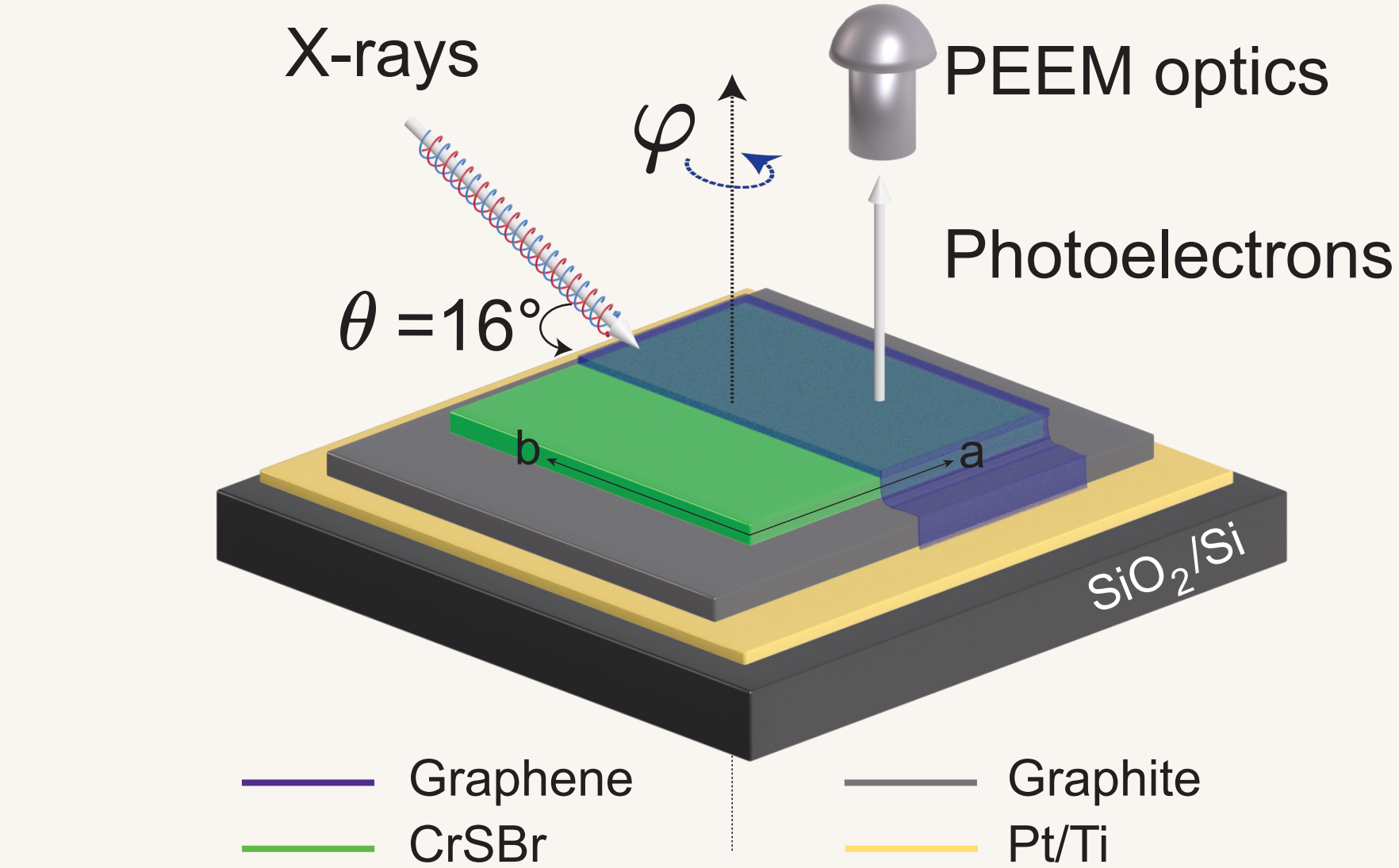
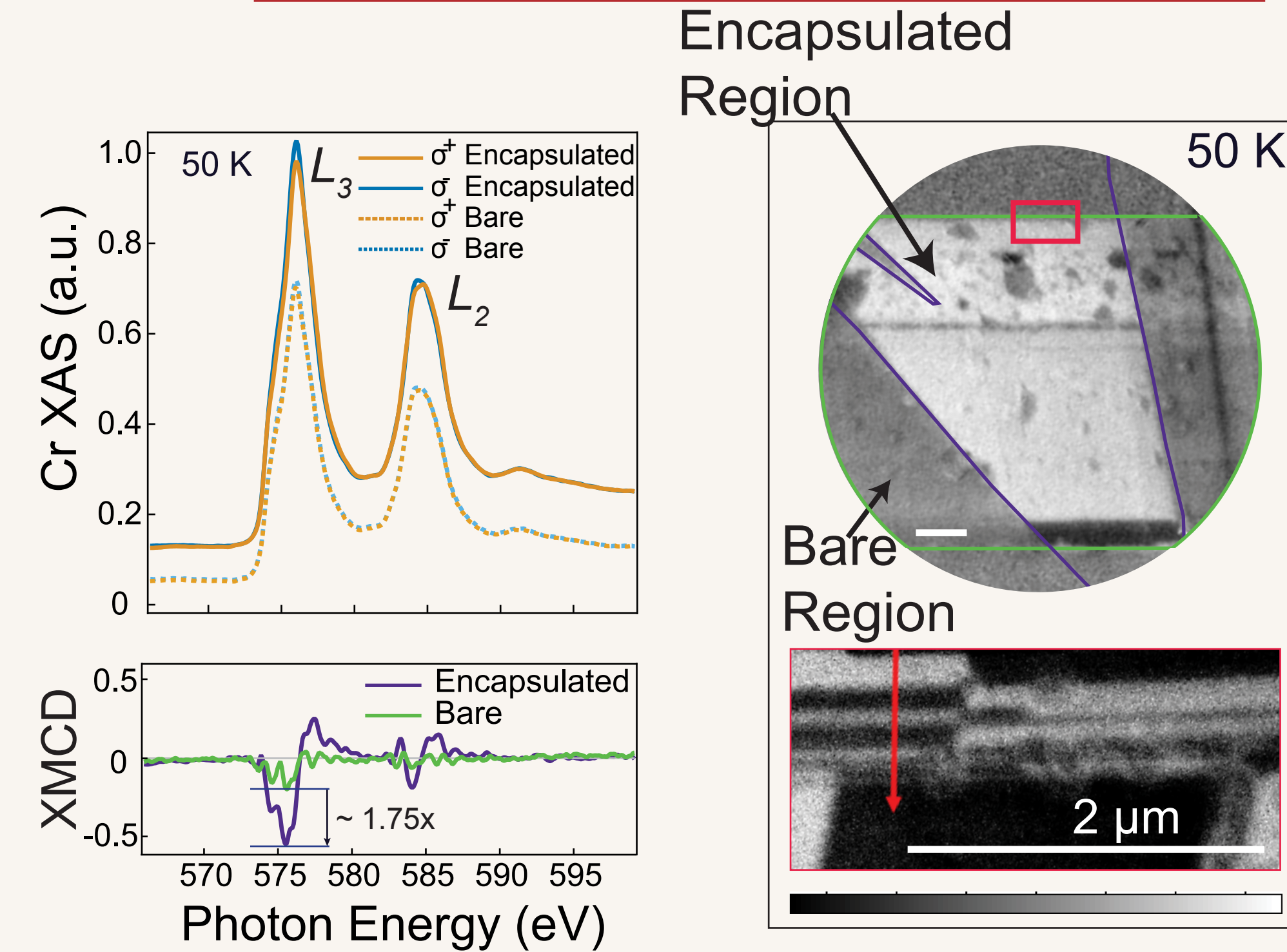


Motivation: Van der Waals (vdW) based magnets are an ideal platform for probing and understanding emergent spin phenomena. However, element-specific nanoscale characterization of the spin structure in these systems is crucial for both fundamental insight into low-dimensional magnetism and the rational design of spintronic devices based on these materials, remains elusive. Here, we utilize X-ray magnetic circular dichroism paired with photo emission electron microscopy (X-PEEM) to resolve the magnetic order in atomically thin CrSBr and Fe_3GeTe_2 (FGT)/ WTe_2 heterostructures. Our comprehensive measurements reveal CrSBr magnetic structure at the nanoscale and its dependence on layer-parity and twist angle, additionally directly capturing all-electrical, spin-orbit torque (SOT) driven domain dynamics in FGT.

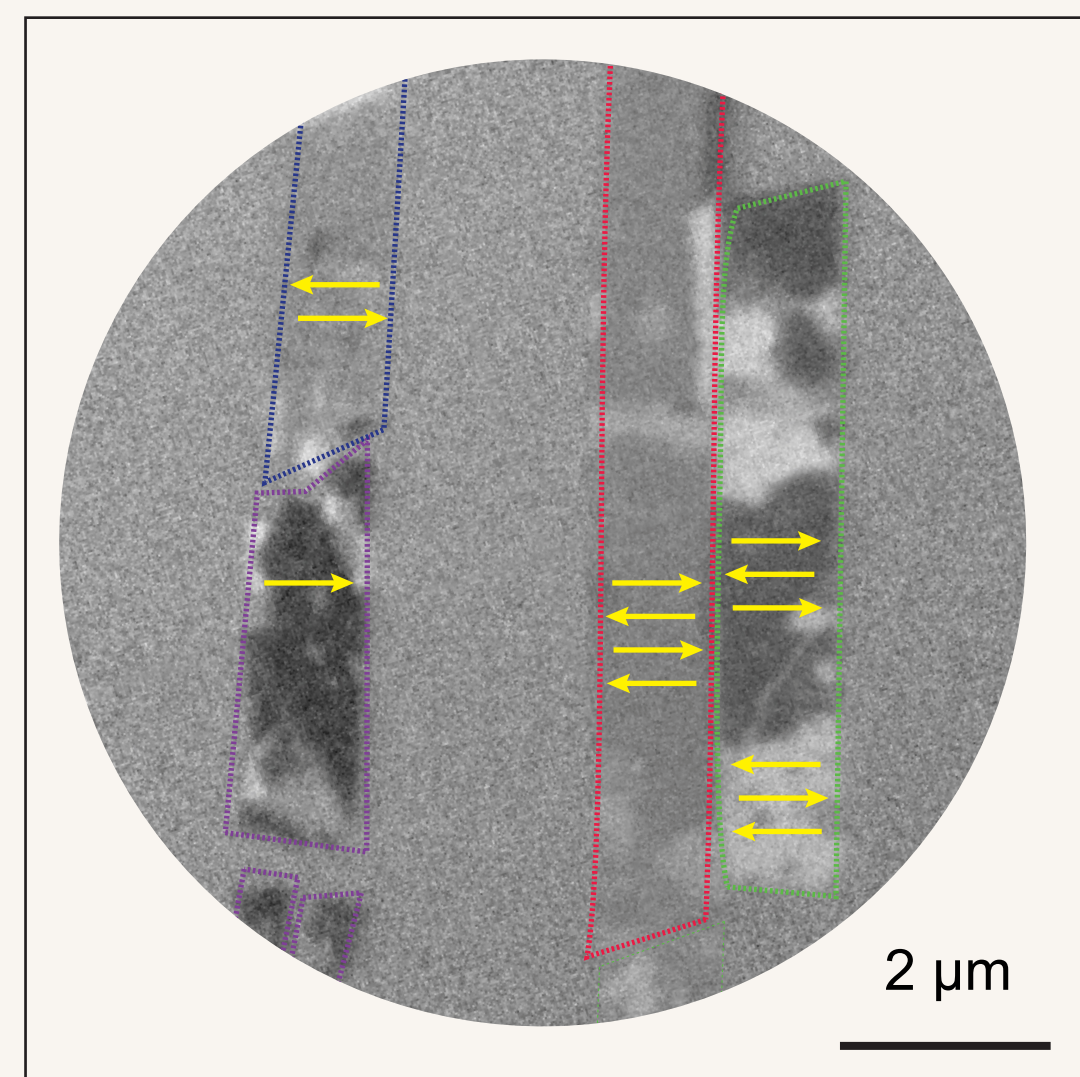
Layer-Parity and Twist-Dependent Magnetism in CrSBr

Multilayer CrSBr Heterostructure



The XMCD signal is proportional to the projection of local magnetization onto the X-ray propagation direction ($\mathbf{m} \cdot \mathbf{k}$).

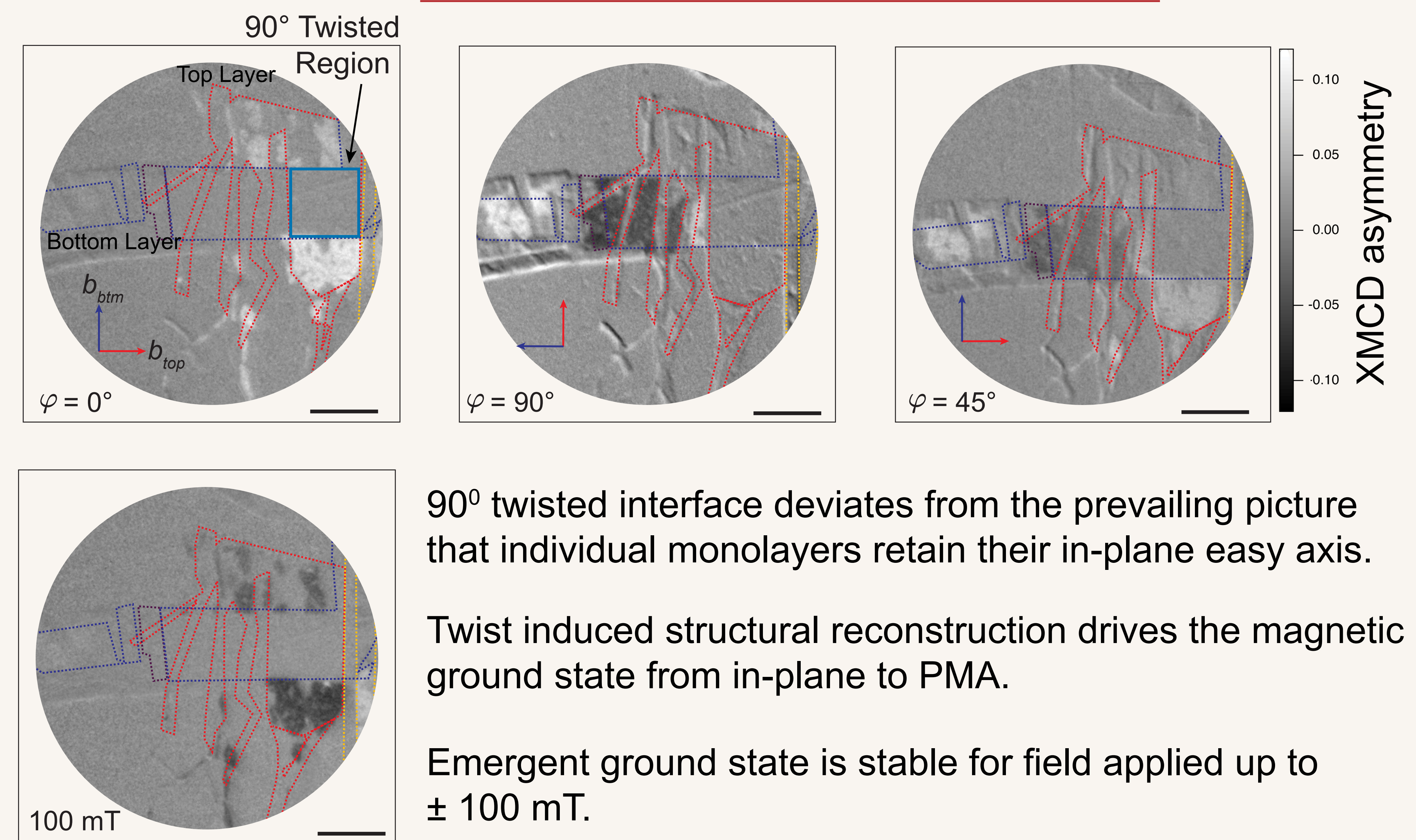
1L-4L CrSBr Heterostructure



Graphene encapsulation enhances XMCD signal.

Layer-parity-dependent magnetization set by surface termination, persisting down to monolayer.

Orthogonally Twisted CrSBr monolayers



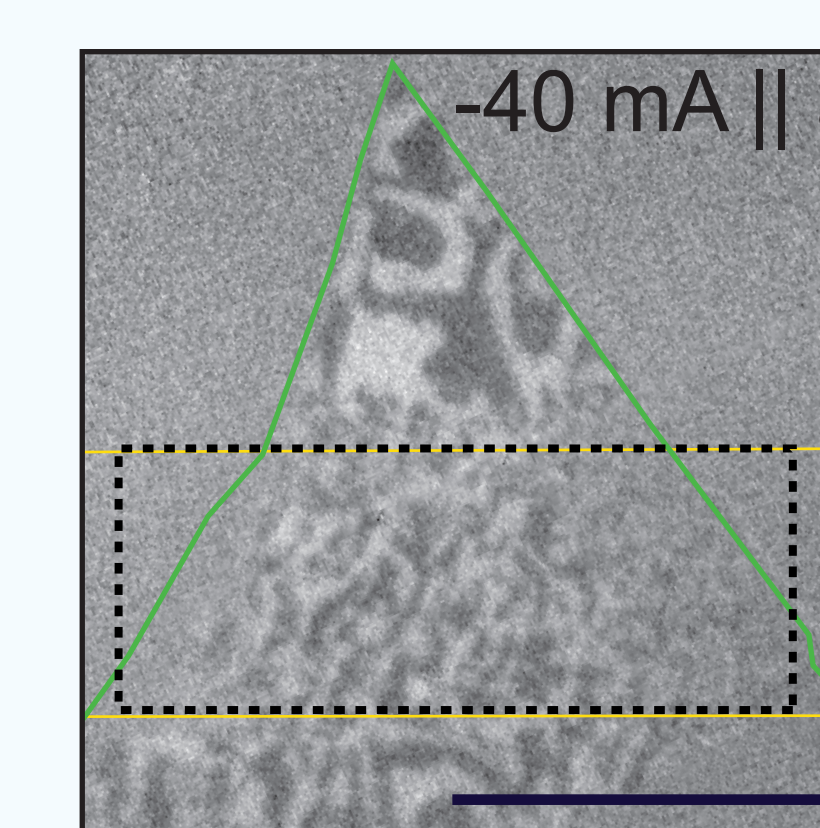
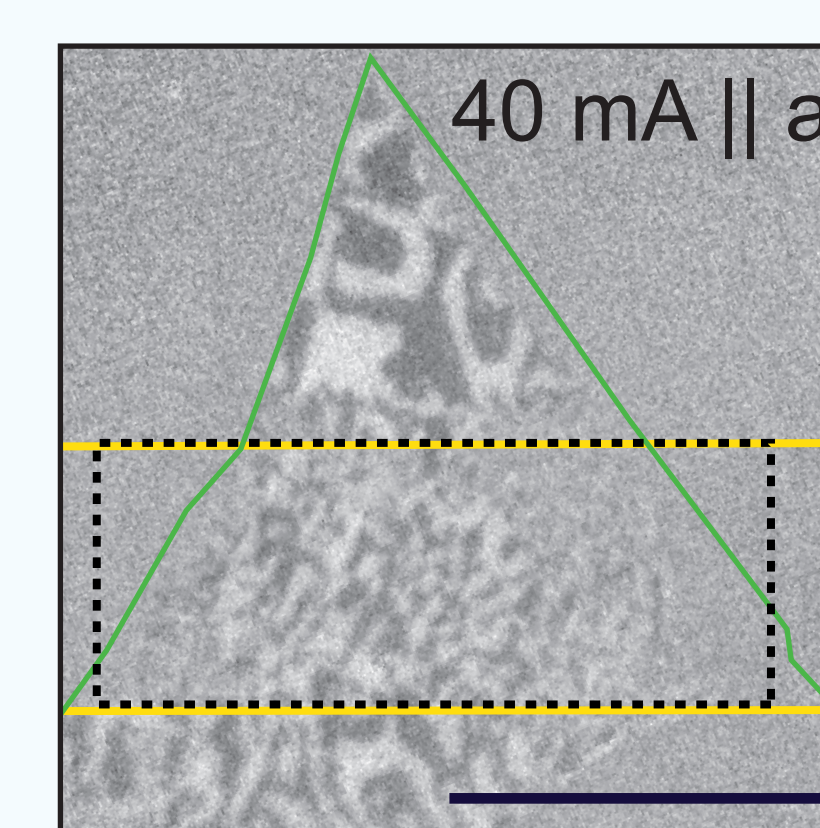
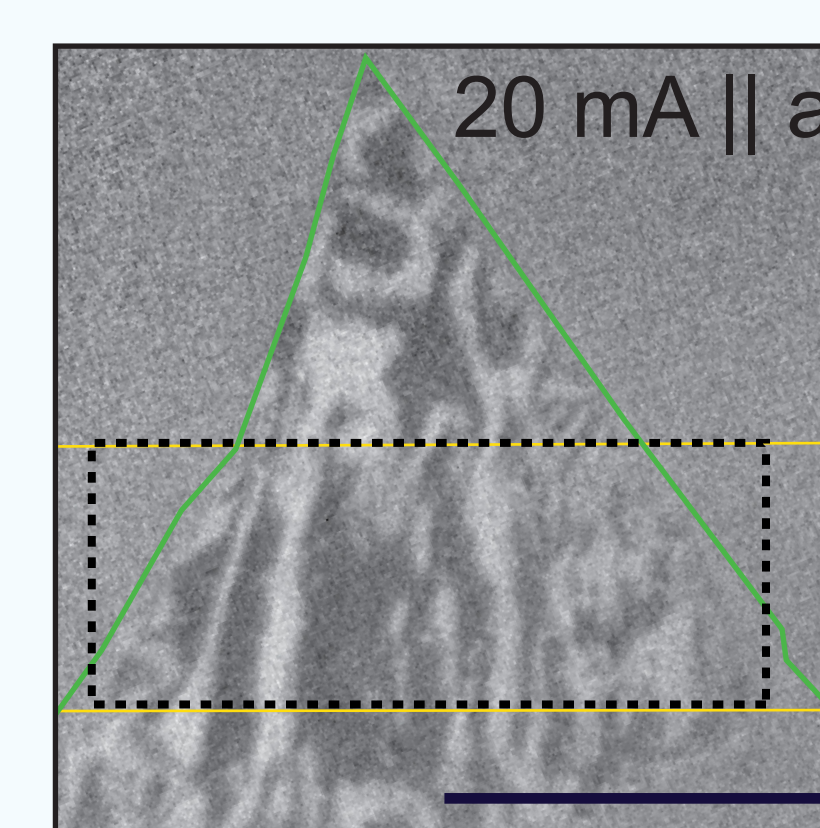
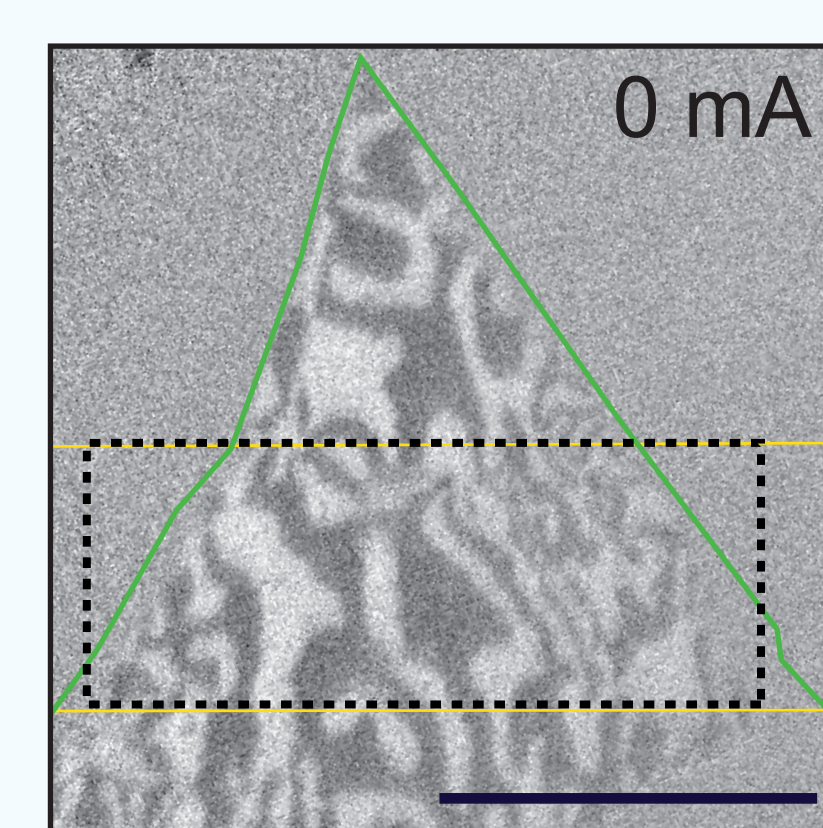
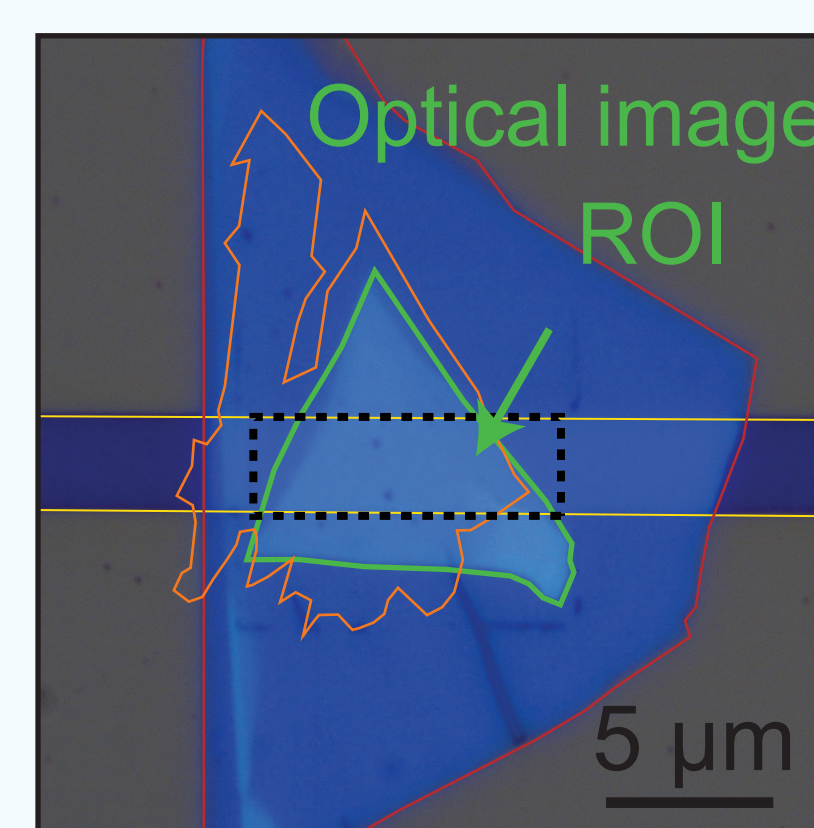
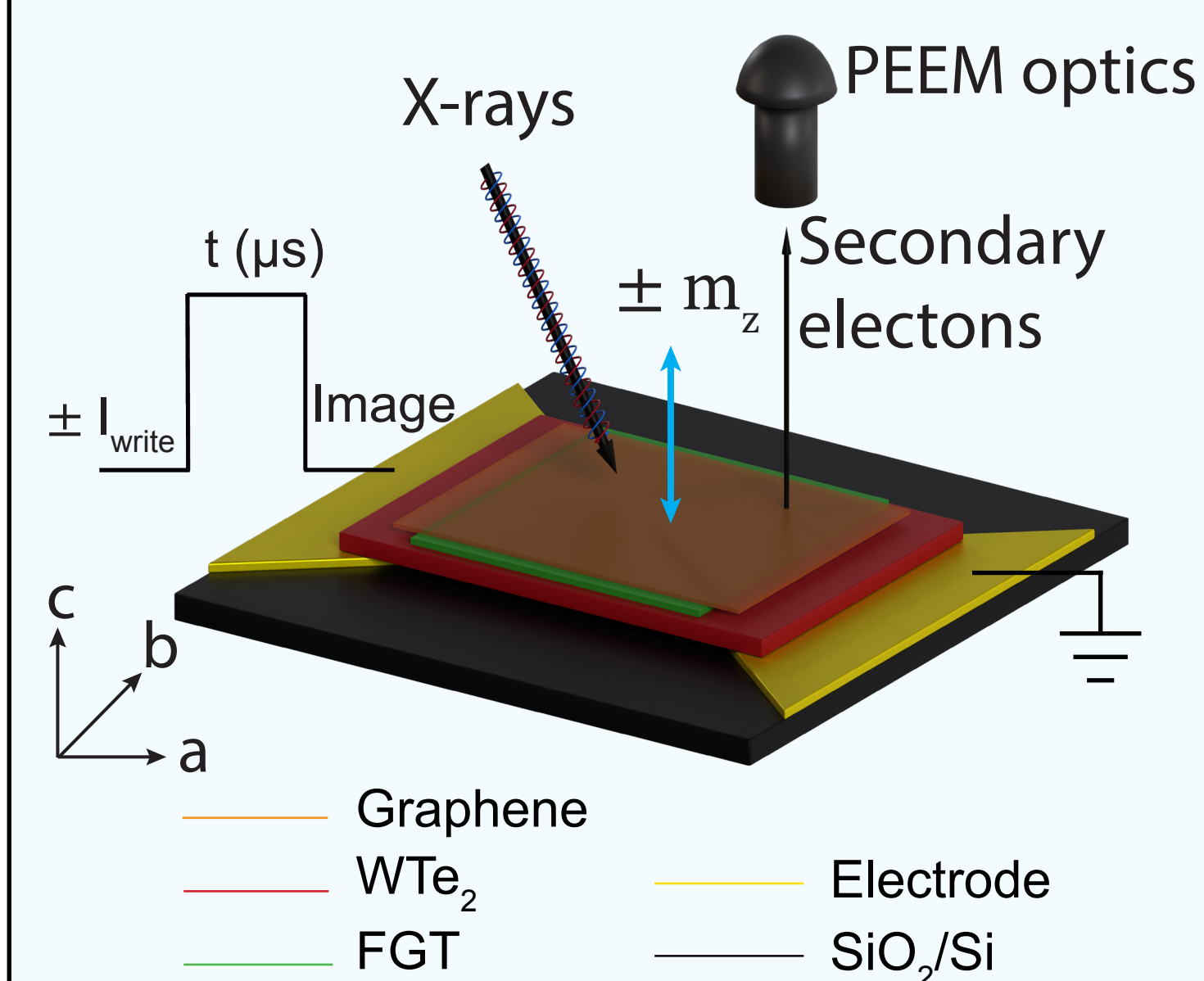
90° twisted interface deviates from the prevailing picture that individual monolayers retain their in-plane easy axis.

Twist induced structural reconstruction drives the magnetic ground state from in-plane to PMA.

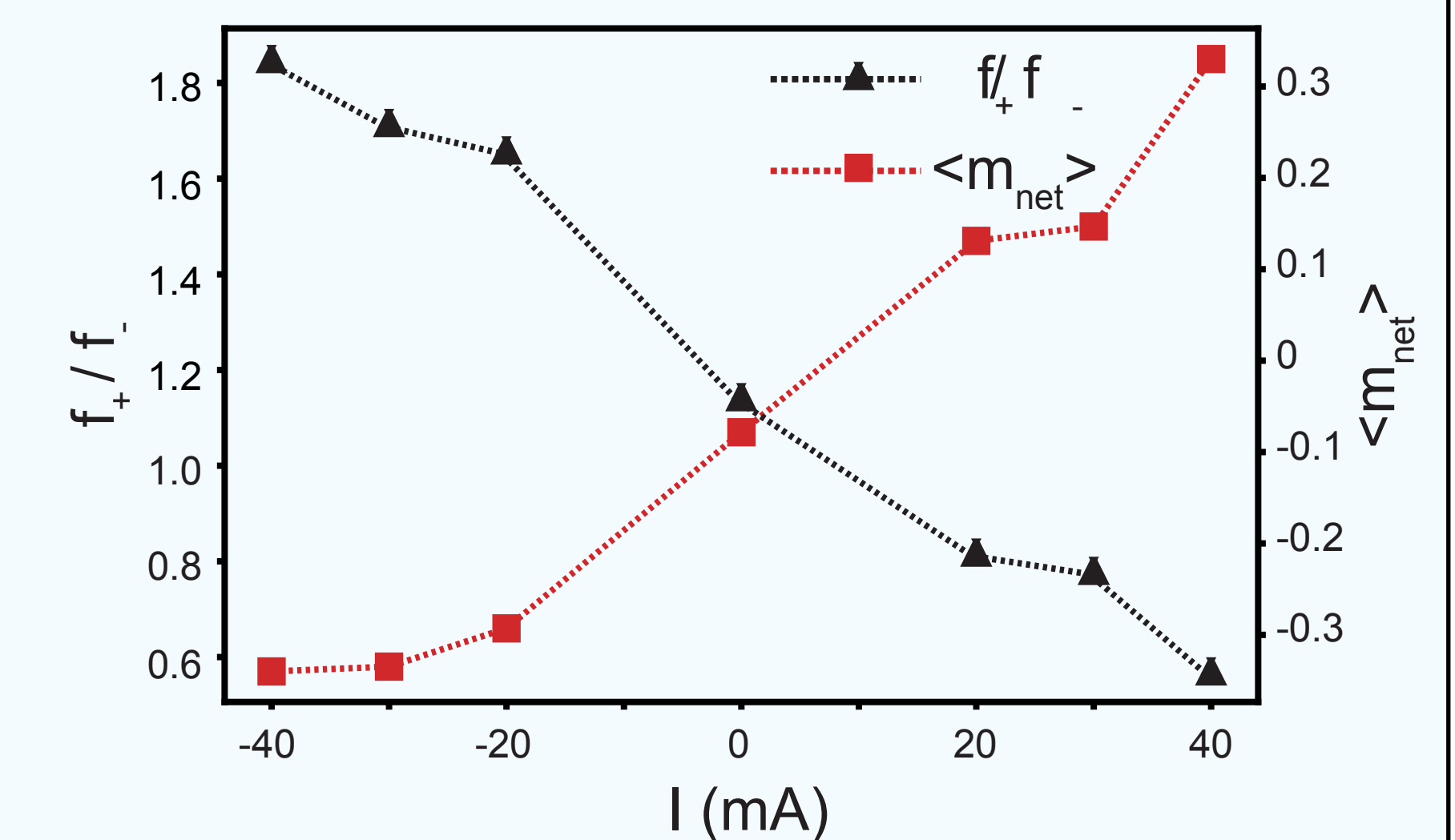
Emergent ground state is stable for field applied up to ± 100 mT.

FGT/ WTe_2 in SOT architecture

SOT driven magnetic domain dynamics in FGT/ WTe_2



A writing current pulse applied along the WTe_2 a -axis changes net magnetization of the ROI



Evolution of ratio of up/down areal domain density and average magnetization in the ROI

- References:**
1. Element-Specific Visualization of Layer-Parity and Twist-Dependent Magnetism in CrSBr (to be submitted for peer-review)
 2. Magnetic Domain Evolution of a Ferromagnet in Spin-Orbit-Torque device Architecture (to be submitted for peer-review)

Acknowledgements: We acknowledge financial support from the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, through Award No. DE-SC0002549; from the U.S. Office of Naval Research (ONR) under Award No. N00014-23-1-2751; from the Center for Emergent Materials at The Ohio State University, an NSF MRSEC, through Award No. DMR-2011876; from an NSF-CAREER Award under Grant No. DMR-2339309; from the National Science Foundation (NSF) through Grants No. DMR-2210510 and ECCS-2531211; and from an NSF-CAREER Award under Grant No. ECCS-2339723.