Interfacial Magnetotransport as an Electrical Probe of Helical Antiferromagnetism in a van der Waals NiI_2/Graphene Heterostructure

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Van der Waals multiferroics host coupled magnetic and electric order and have attracted growing interest in spintronics research, but their behavior is often challenging to access electrically due to their high resistivity. The transition metal halide NiI_2 has recently been established as a van der Waals type-II multiferroic with multiple magnetic phase transitions and a noncollinear helical spin texture [1]. Here we demonstrate that interfacial magnetotransport in graphene provides a sensitive electrical probe of magnetic phase evolution in NiI_2 via proximity-mediated coupling.

Graphene/NiI_2 heterostructures were fabricated on Hall-bar devices, enabling transport measurements dominated by the graphene channel while remaining strongly coupled to NiI_2. Temperature-dependent measurements reveal pronounced features in the first, second-, and third-harmonic longitudinal resistances that coincide with the known magnetic transition temperatures of NiI_2, including the onset of the multiferroic helical phase. In-plane magnetoresistance measurements exhibit large, anisotropic peak structures centered at zero field that vanish above the multiferroic transition temperature, inconsistent with intrinsic graphene magnetotransport and indicative of an interfacial magnetic origin. Harmonic analysis of the magnetoresistance further uncovers reproducible, field-dependent features consistent with field-driven reconfiguration of the helical spin texture.

Current-dependent measurements and quantitative scaling analysis show that the observed nonlinear transport responses cannot be explained by Joule heating alone, implying additional interfacial contributions linked to the magnetic state of NiI_2. These results establish graphene as an effective electrical transducer of complex magnetic order in insulating antiferromagnets, extending transport-based magnetic proximity approaches previously demonstrated in conventional conductor–magnetic insulator systems [2] to van der Waals helimagnets.

References:

[1] Song et. al., Nature **642**, 64-70 (2025)
[2] Huang et. al., Phys. Rev. Lett. **109**, 107204 (2012)

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