Developing a Quantitative q-EELS Framework for Probing Collective Electron Dynamics

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ABSTRACT

With a background in applied physics and materials science, I am motivated to develop experimental techniques that quantitatively probe how electrons respond to external perturbations. Momentum-dependent electron energy-loss spectroscopy (q-EELS) is particularly well suited for this purpose because it directly measures the loss function $\mathrm{Im}[-1/\varepsilon(\omega,q)]$ and reveals the energy–momentum dispersion of collective excitations. This capability enables the extraction of key electronic parameters such as the effective mass m^*, Fermi velocity v_F, and carrier density n—quantities that fundamentally govern screening, transport, and dynamical behavior in solids. To establish a reliable analysis workflow, I first applied q-EELS to silicon as an illustrative benchmark, demonstrating that plasmon dispersion fitting yields m^* and v_F values consistent with the literature. In a separate example, I prepared and structurally verified monolayer and bilayer WSe_2 using substrate transfer and atomic-resolution STEM, providing representative low-dimensional samples for potential future studies. While these materials demonstrate the versatility of q-EELS, they are not the focus of the research itself; rather, they serve as practical test cases supporting the development of a broadly applicable technique. Moving forward, my primary objective is to refine q-EELS into a robust, general framework for extracting electronic dynamical parameters across diverse material systems, with optional extensions toward 2D materials when appropriate. Ultimately, I aim to establish a quantitative methodology that links atomic structure to collective electron dynamics through plasmon dispersion analysis.

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