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Locality as a Design Variable at Interfaces

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Interfacial function is often attributed to the few atomic layers at a boundary. For mixed-dimensional interfaces, however, how far that influence extends depends strongly on direction. The same boundary can act locally along one crystallographic direction and nonlocally along another, reaching tens to hundreds of nanometers into adjoining materials. While theory has long recognized such nonlocality, directly resolving it at functioning interfaces has remained challenging. I argue that the locality of an interface, the distance over which its influence reaches, is not a fixed material property but a design variable revealed by resolving the interfacial response in momentum, space, and time. My group achieves this using momentum-resolved electron energy-loss spectroscopy, transient absorption spectroscopy, and time-resolved photoemission microscopy. I will discuss two case studies. In $MoOCl_2$, an anisotropic van der Waals crystal, the interface extends far along one in-plane direction while remaining confined along the orthogonal one, making a single boundary simultaneously local and nonlocal. In cobalt and iron oxides, the balance is set instead by the material: regions of local bonding and defect trapping can dominate in one oxide, while strain and interfacial fields carry influence across buried interfaces in another. Together these examples show that the role of locality at an interface can be tuned by direction, structure, and composition, providing a route to engineer light-matter interactions for photocatalysis and quantum emitters.

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