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Extending Bragg Interferometry for the Study of Magic Angle Trilayer Graphene

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Moiré superlattices of trilayer graphene allow an array of novel correlated electronic phases to be engineered by controlling rotation and translation between stacked layers. By controlling the stacking in bilayer graphene (BLG), in particular, by rotating layers to a “magic angle”, novel quantum phenomena have been observed that originate from extremely flat electronic bands [1-3]. Adding a third layer makes even more stacking configurations available, and recent work has begun to examine how rotation and translation impacts the electronic structure and correlated phases of moiré trilayer graphene (TLG) [4-9]. Structures of interest include ABC stacked TLG on hexagonal boron nitride (hBN) [4], alternating twist TLG (also known as magic angle TLG or MATLG) [5-7], twisted trilayer graphene (TTLG) [8] and twisted monolayer-bilayer graphene TMBG [9]. Each of these structures has demonstrated novel correlated electron states [4-9] and MATLG samples, in particular, have demonstrated robust superconductivity [5,6].

However, much of the present understanding and theoretical calculations of these multilayer moiré materials is based on idealized structural models that do not take into account the structural relaxation and inherent strain of these elastic graphene sheets. To date, relaxation and strain have been quantitatively measured only in twisted bilayer graphene; recent work from our group enabled determination of the local structure of these moiré lattices using Bragg interferometry, thus shedding critical new light on the origin of these physical phenomena [11]. Bragg interferometry is a 4D-STEM technique in which the intensity in the overlapping Bragg disks from the azimuthally misoriented graphene layers allows determination of the displacement vector between layers [11]. By obtaining the displacement vectors it is possible to determine the extent of structural relaxation, disorder, and strain of the material, and this structural information can then be correlated to the local variations in electronic states [11].

Up to this point, however, Bragg interferometry, as outlined in previous work [11], has only been demonstrated for bilayer graphene. We are developing methods to extend Bragg interferometry to the multilayer case. As layers are added, solving for the intralayer displacements becomes increasingly difficult because the relation between overlapping Bragg disks influences the ability to solve for displacement vectors. Due to the multiple displacements, we introduce a new fitting procedure to identify different overlap regions in order to calculate the multiple displacement vectors. The challenges associated with this are well illustrated by the MATLG structure, where the alternating twist angles result in two of three peaks being completely overlapped as demonstrated in Figure 1. Bragg interferometry of the MATLG structure is deeply needed to understand how displacement between layers influences superconductivity, as has been theorized [12-13]. Our work toward being able to retrieve the displacements and intralayer strain in MATLG expands the abilities of Bragg interferometry and illustrates key features of the MATLG structure which may help explain its unique electronic properties. [14]

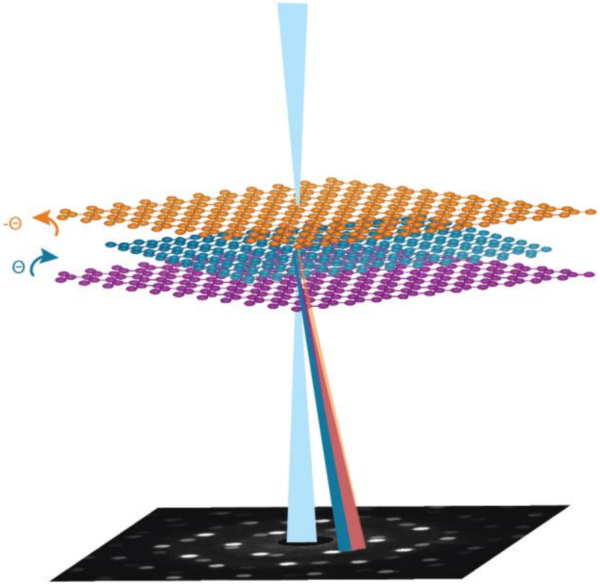

Figure 1. Diagram of a collecting a single diffraction pattern during a 4D-STEM experiment on magic angle trilayer graphene.

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