

### Comment on “Motional Ordering of a Charge-Density Wave in the Sliding State”

A recent Letter [1] reports x-ray diffraction evidence for motional ordering of a charge-density wave (CDW) in quasi-one-dimensional NbSe<sub>3</sub>. The width of a CDW superlattice diffraction peak is, with corrections for instrumental resolution and crystal mosaicity, inversely related to the CDW’s phase-phase correlation length. Reference [1] reports that when the CDW is depinned at a current  $I = I_T$ , the longitudinal width of the CDW peak abruptly narrows by about 45% and then remains nearly constant for  $I/I_T > 2$ . The pinned and sliding-state peak widths yield CDW correlation lengths of  $0.8 \pm 0.1 \mu\text{m}$  and  $1.6 \pm 0.1 \mu\text{m}$ , respectively. In contrast to the longitudinal ordering, the transverse CDW peak widths increase by 80% to  $\sim 0.047^\circ$  just above  $I_T$  before narrowing at higher currents.

Pinned-state CDW correlations have been measured [2,3] in undoped NbSe<sub>3</sub> samples having the same source and purity as in Ref. [1]. The pinned-state longitudinal CDW peak widths in [2] were resolution limited to  $3.2 \times 10^{-4} \text{ \AA}^{-1}$ , smaller than the pinned-state peak width in Ref. [1]. In [3], resolution-limited widths were again obtained but this time with a longitudinal resolution of  $0.8 \times 10^{-4} \text{ \AA}^{-1}$ . This resolution yields a lower bound on the longitudinal pinned-state correlation length that is a factor of 3 longer than the motionally ordered length in Ref. [1].

Longitudinal peak broadenings in excess of resolution were observed in Ref. [2] for heavily Ta-doped crystals and yielded CDW correlation lengths of  $\sim 0.4 \mu\text{m}$ . This is only a factor of 2 smaller than the pinned-state correlation length reported in Ref. [1], even though the impurity concentration is roughly 30 times larger. Furthermore, the longitudinal pinned-state correlation length in Ref. [1] is comparable to the transverse correlation lengths for undoped crystals measured in Ref. [2]. This implies that CDW correlations are essentially isotropic, which is inconsistent with NbSe<sub>3</sub>’s highly anisotropic electronic structure and transport properties.

In collective transport systems including CDWs, vortex lattices, and Wigner crystals, the sliding-state behavior is extremely sensitive to sample and contact perfection. In NbSe<sub>3</sub>, extrinsic CDW shear corrupts transport properties [4,5] and broadens transverse diffraction peak widths [6]. These ribbonlike crystals exhibit steps in thickness transverse to the direction of CDW motion. These produce transverse variations in the local CDW depinning current density [5] so that thicker regions of the crystal cross section depin first. CDW elasticity couples the resulting shear deformations to longitudinal deformations and produces longitudinal peak broadening. Furthermore, boundary conditions at current contacts produce current density-dependent longitudinal CDW peak shifts [7], and shear translates these shifts into longitudinal peak broadenings and splittings. Evaluating the intrinsic driving

force dependence of CDW correlation lengths is further complicated because correlations in the reference state  $I = 0$  are extremely sensitive to the sample’s thermal and electrical history.

Strong evidence for extrinsic shear in Ref. [1] is provided by large transverse peak broadenings above  $I_T$  of up to  $\Delta\theta \approx 0.045^\circ$ . These broadenings are twice those reported for a comparable size crystal with large transverse current inhomogeneity in which shear was directly observed by x-ray diffraction topography [6]. The longitudinal peak’s structure for  $I > I_T$  is also naturally explained by transversely inhomogeneous depinning. Reference [1]’s large  $I = 0$  longitudinal widths likely result from the method used to prepare the  $I = 0$  state.

Extrinsic shear also explains longitudinal peak narrowing when the CDW is mode locked to an external ac field [8]. Mode locking causes the CDW current density distribution to collapse and the broad-band noise amplitude to drop by orders of magnitude. CDW shear plasticity is eliminated and shear strains are reduced, reducing their effects on longitudinal diffraction peak widths.

Extrinsic CDW shear has clear signatures in electrical properties including the sharpness of the depinning threshold, the spectral sharpness of the coherent oscillations (“narrow-band noise”), and the completeness of mode locking on high-order subharmonic Shapiro steps. A benchmark for these properties in a nearly shear-free NbSe<sub>3</sub> crystal was set in [4] and reproduced in [9]. Intrinsic CDW correlation lengths—and any other property—of a depinned CDW must be evaluated using crystals that meet or exceed this standard.

Robert E. Thorne,<sup>1</sup> Joel D. Brock,<sup>2</sup> and Mark Sutton<sup>3</sup>

<sup>1</sup>Physics Department, Cornell University  
Ithaca, New York 14853, USA

<sup>2</sup>Department of Applied and Engineering Physics  
Cornell University  
Ithaca, New York 14853, USA

<sup>3</sup>Physics Department, McGill University  
Montréal, Quebec, Canada H3A 2T8

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