Clarke and Merlin Reply: Gay and Clemens[1] have questioned our claim that the robustness of the diffraction pattern of an imperfect Fibonacci superlattice is a special feature of quasiperiodic ordering.[2] They quite correctly remind us of the well-known result for periodic superlattices in which peaks occurring near principal reciprocal-lattice points are largely unaffected by discrete layer fluctuations. In reply, we expand on some subtleties associated with quasiperiodic ordering which were the basis of our original remarks on the role of growth fluctuations in this system.

The effects of disorder in quasiperiodic systems are conveniently discussed in terms of the projection construction of Elser.[3] A systematic study was presented recently by Horn *et al.*[4] The key point is that *two* distinct types of displacement field are required to describe disorder in quasiperiodic or incommensurate systems. One represents the "phononlike" displacements familiar from periodic superlattices. The other is specific to incommensurate systems and relates to the *phase* of the nonperiodic ordering sequence.[5]

The relative magnitudes of these two distortion fields are revealed by high-resolution measurements of the x-ray diffraction peak widths as illustrated in Fig. 1. The relevant parameter here is the perpendicular, or "phason," wave vector $G_\perp$ rather than the diffraction vector Q.[4] Note that there is no systematic trend in peak width as a function of Q in our data; for example, the peaks labeled (1,1) and (2,1) in Fig. 1 are neighboring peaks in Q space, but their widths differ by a factor of $\simeq 3$.

The linear dependence on $G_\perp$ (≥ 1 Å^{-1}) shown in Fig. 1 reveals that the growth defects in our sample have a small but measurable phason component. From the data we infer an rms phase fluctuation of order 0.1%, roughly 20 times smaller than the phononlike displacements of the interfaces. The latter cause the divergence in FWHM of large-Q peaks occurring in the region $G_\perp \leq 1$ Å^{-1}. Note that atomic mobilities in these superlattices are extremely small at ambient temperatures and so the fluctuations referred to here are static.

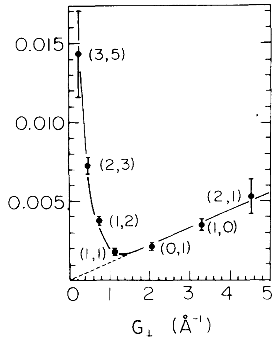

FIG. 1. X-ray diffraction peak width (FWHM) for GaAs-AlAs Fibonacci superlattice as a function of perpendicular wave vector, $G_\perp$. The indices (m,n) refer to peaks with diffraction vectors $Q=2\pi(m+n\tau)/(\tau d_A+d_B)$, where $d_A=59$ Å and $d_B=37$ Å (Ref. 2).

To conclude, we maintain that the survival of components in the power spectrum of the imperfect Fibonacci superlattice is more complex than simple extensions of the periodic case would imply. In particular, neighboring low-Q peaks (near reciprocal-lattice points) are observed to suffer less broadening at smaller values of $G_\perp$. These peaks also tend to be the most intense features of the diffraction pattern. Such considerations may be important in determining whether the unusual consequences of quasiperiodic ordering can be observed experimentally.[6]

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[1] J. G. Gay and B. M. Clemens, preceding Comment [Phys. Rev. Lett. **59**, 2236 (1987)].

[2] J. Todd, R. Merlin, R. Clarke, K. M. Mohanty, and J. D. Axe, Phys. Rev. Lett. **57**, 1157 (1986).

[3] V. Elser, Acta Crystallogr. Sect. A **42**, 36 (1986), and references therein.

[4] P. M. Horn, W. Malzfeldt, D. P. DiVincenzo, J. Toner, and R. Gambino, Phys. Rev. Lett. **57**, 1444 (1986).

[5] D. Levine, T. C. Lubensky, S. Ostlund, S. Ramaswamy, P. J. Steinhardt, and J. Toner, Phys. Rev. Lett. **54**, 1520 (1985).

[6] Y. Liu and R. Riklund, Phys. Rev. B **35**, 6034 (1987).