Toward Difficult Phonon Measurements using Inelastic X-Ray Scattering: The Example of $YBa_2Cu_3O_{7-\delta}$

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Inelastic X-Ray scattering (IXS) with meV resolution is a technique, that, in principle, can offer some advantages for phonon measurements [1], as compared to inelastic neutron scattering (INS). However, this potential is limited by a count-rate problem: the *scattering* cross sections for x-rays and neutrons are roughly similar, but the *absorption* cross-section for x-rays is generally several orders of magnitude larger than for neutrons. Then, for IXS, one is almost always doing an experiment on a sample that is, effectively, only a few tens of microns thick, leading reduced rates. However, this also leads to an interesting corollary: if you can do the experiment at all with x-rays, you can probably do it using samples of size ~0.1 mm or smaller. When the potential to measure small sample using IXS is combined with other aspects of the method, including very small backgrounds, well defined and relatively good momentum resolution, and good (meV) resolution at large energy transfer (see [1]), one can consider applying IXS to experiments that, by the standards of INS, are rather difficult, assuming a strong source is available.

Over the past 7 years, the Materials Dynamics Laboratory of the RIKEN SPring-8 Center has spearheaded an effort to make a very high flux beamline for IXS [2]. This facility, the RIKEN Quantum NanoDynamics Beamline, BL43LXU, is now commissioning. It will use 3 tandem insertion devices and a large, 42 element, analyzer array to perform particularly difficult measurements of phonons (also electronic excitations), and, while presently operating at reduced strength, it is already allowing exceptionally good quality data to be collected on samples of interest. We demonstrate this by showing essentially background free spectral measurements of the rather weak bond-stretching phonon mode of de-twinned, optimally doped, $YBa_2Cu_3O_{7-\delta}$. The data quality is good enough to allow extraction of the linewidth, which shows a huge temperature dependence: increasing by 6 meV and 13 meV in a* and b* directions, respectively, below T_c. This demonstrates there is extremely strong electron-phonon coupling in this material. Meanwhile symmetry considerations suggest the coupling has limited bandwidth, so might result from some sort of electronic excitation or perhaps (dynamic) stripe order [3].

[1] A.Q.R. Baron, X線非弾性散乱による結晶中フォノンの研究, 分光研究 **54** (2009) 205-214, Available in English as arXiv 0910.5764

[2] A.Q.R. Baron, *The RIKEN Quantum NanoDynamics Beamline (BL43LXU): The Next Generation for Inelastic X-Ray Scattering*, SPring-8 Information Newsletter **15** (2010) 14-19, http://user.spring8.or.jp/sp8info/?p=3138

[3] A. Q.R. Baron, D. Ishikawa, H. Uchiyama, T. Fukuda, T. Masui, N. Murai, R. Heid, K.-P. Bohnen, K. Tsutsui, S. Miyasaka, S. Tajima, *et al.*, *In preparation.*