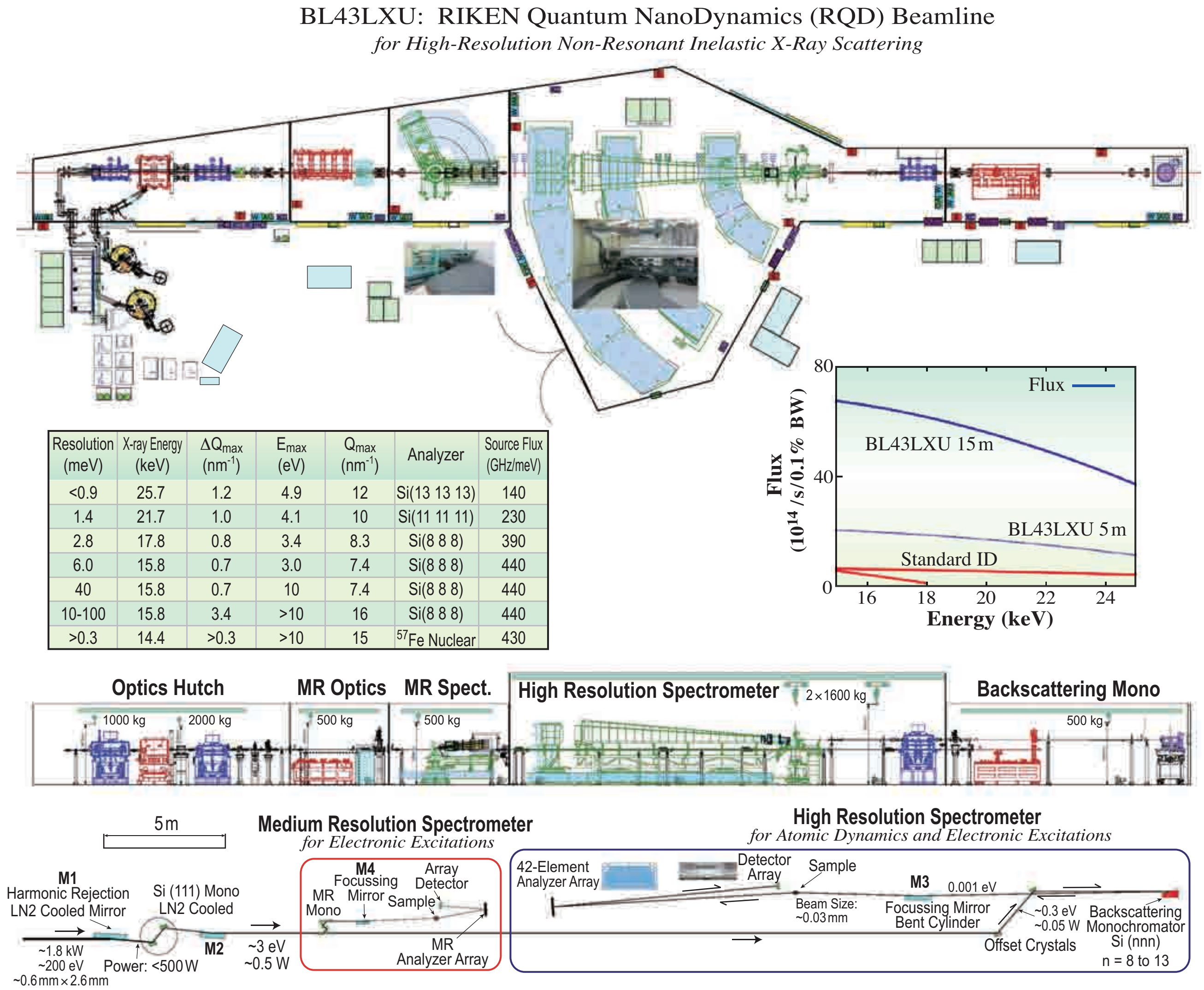
A high-flux undulator beamline for high-resolution inelastic X-ray scattering

Non-resonant, high-resolution, hard-X-ray, inelastic scattering is, *in principle*, a nearly ideal tool for the condensed matter scientist. The technique directly probes the electronic density-density correlation function, the dynamic structure factor, S(**Q**, ω), over correlation lengths comparable to unit cell sizes, with resolution that can be at the meV level. These scales are interesting as they are the energy scales of phonons, and low-lying electronic excitations, and also because it is the interplay between low-energy excitations that governs the behavior of many of the most interesting and technologically relevant materials. When one also notes that the brilliance of a third generation synchrotron radiation source allows micron-scale beam sizes to be achieved, one has, again in principle, a very powerful probe of the dynamical behavior of condensed matter systems.

The above optimistic picture, however, lasts only until the count-rate limitations of real experiments are encountered. While modern synchrotron radiation sources provide huge fluxes (~10^{13} or even ~10^{14} hard X-ray photons/s after a typical monochromator), the first thing an IXS experiment does is reduce this flux by several orders of magnitude to achieve the necessary resolution. Thus, while straining to take full advantage of modern third-generation sources, the final flux on the sample in a high-resolution IXS experiment is more characteristic of a first generation source, and the experiments are correspondingly limited. A survey of published data will show that



Resolution (meV)	X-ray Energy (keV)	ΔQ_{max} (nm^{-1})	E_{max} (eV)	Q_{max} (nm^{-1})	Analyzer	Source Flux (GHz/meV)
<0.9	25.7	1.2	4.9	12	Si(13 13 13)	140
1.4	21.7	1.0	4.1	10	Si(11 11 11)	230
2.8	17.8	0.8	3.4	8.3	Si(8 8 8)	390
6.0	15.8	0.7	3.0	7.4	Si(8 8 8)	440
40	15.8	0.7	10	7.4	Si(8 8 8)	440
10-100	15.8	3.4	>10	16	Si(8 8 8)	440
>0.3	14.4	>0.3	>10	15	^{57}Fe Nuclear	430

Fig. 1. BL43LXU layout.

essentially all work to date using non-resonant IXS with better than ~100 meV resolution, investigates only the very strongest excitations, phonons, and, even then, experiments are often count-rate limited.

On this basis, discussions began some years ago about creating a very intense beamline for high resolution IXS. The essential idea was to take advantage of SPring-8's strengths – the 8 GeV electron energy, in-vacuum undulator technology and the availability of long straight sections – to make a uniquely powerful beamline, with extremely high flux on the sample. This beamline, the RIKEN Quantum NanoDynamics (RQD) beamline was funded by MEXT, through RIKEN beginning in 2009. In October of 2011, RIKEN allocated funds to largely complete it.

The target of the beamline is the investigation of dynamics with ~1 to ~100 meV energy resolution, with particular emphasis on high-resolution measurement of electronic excitations, and, then, studies of atomic dynamics of difficult systems. The beamline (see the Fig. 1) is expected to provide about 1 order of magnitude more flux onto the sample than a standard ID and will increase parallelization of data collection by about a factor of 3. It will operate at energies between 15 and 25 keV, with resolutions between 1 and 100 meV. A new design for the medium-resolution spectrometer will allow ~20 meV resolution with while a collecting large solid angle and with comfortable space for sample environment.

The RQD is now in the first stages of commissioning. The initial 1/3 of the insertion device has been installed, and, at the end of 2011, the mechanics for the first, high resolution, spectrometer was installed. Commissioning is expected to extend into the spring, with first experiments taking place in the summer. Thanks to the additional funding from RIKEN, the completion of the insertion device is planned for early in 2013. Commissioning of the medium resolution spectrometer will begin late in 2012.

The initial targets for the beamline are, the extension of high-resolution studies into the field of electronic excitations, for example, to investigate the excite states of orbital order, and several problems in atomic dynamics, including phonons in high-temperature superconductors.

Additional details can be found at:
http://user.spring8.or.jp/sp8info/?p=3138

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