BL43LXU
RIKEN Quantum NanoDynamics

1. Introduction

The bulk of the beamtime at BL43LXU [1] in 2024/2025 was for user experiments, but also included some testing, installation, and commissioning of new equipment (see below). The present report will, as usual, emphasize both the changes and problems at the beamline to provide a record of progress and useful information to others working to develop SR instrumentation.

Work at the experimental stations has largely been done by members of the Materials Dynamics Laboratory, with assistance on some projects by members of JASRI and RIKEN. K. Taguchi retired from BL43LXU work early in 2025. BL43LXU also had occasional help from full-time members of the engineering team on specific tasks, including the standard start-up of the LN_2 cooling for the mirror and monochromator, and, sometimes, setting up sample refrigerators.

2. Upstream of the Optics Hutch

The upstream components (electron orbit, IDs, mirrors, and HHL mono) were stable during this period. The orbit-correction protocol operated smoothly, and there were no issues with the IDs.

3. High-Heat-Load Mono

The nitrogen flow rate showed a steady decrease that was corrected by careful pumping and flowing hot, dry nitrogen through the system during shutdown. The Y2 encoder failed. The reason is not clear but it was possibly radiation damage.

4. High-resolution Spectrometer

This operated well over the year. It seems that the granite plates remain stable, and no realignment has been necessary for >5 years.

5. New 4 K Closed-cycle Cryostat

The main BL closed-cycle cryostat system died during this period, with an unrepairable leak in the compressor. Considering that it had been in frequent use for more than 20 years, this is considered relatively good performance. Since the manufacturer (APD) had gone out of business, it was replaced. The new system (ARS/Sumitomo) seems to be performing well, with a 3.5 K base temperature in off-line tests and 4.4 K measured with a sample at the beamline.

6. Persistent Failure of the Joule–Thomson Cryostat

We attempted to use a combined closed-cycle and Joule–Thomson cooling system that, on initial delivery about 12 years ago, provided robust operation to $T < 2$ K. However, it failed to cool below 6 K during tests. Even after being sent out for repair, where several issues were fixed, the system failed again at the beamline in multiple tests (including some with factory technical help present). It has been returned to the factory for further work.

7. Investigation of Backscattering Crystals

There have been persistent issues with the nonuniform resolution obtained on different parts of the backscattering monochromator crystals—variation by 0.1 to 0.3 meV in the resolution is not unusual. While we always carefully optimize the position to attain the best available resolution, this sensitivity has been irritating. In particular, as we have been attempting to work with ~0.3 meV total resolution, this has been especially irritating. Therefore, more systematic studies were undertaken. Whereas previously we had moved to different positions on the crystal and measured the resolution, this time we tried an approach that was easier, faster and simpler, namely, just measuring the reflected beam intensity from the backscattering crystal as a function of position. If one uses an incident beam that having a broad bandwidth (e.g., ~0.2 eV) compared to the width of the backscattering reflection (<0.001 eV), regions of increased strain lead to higher reflected intensity. This makes it easy to map the strain, and, of special note, makes the measurement relatively insensitive to temperature or angular variation.

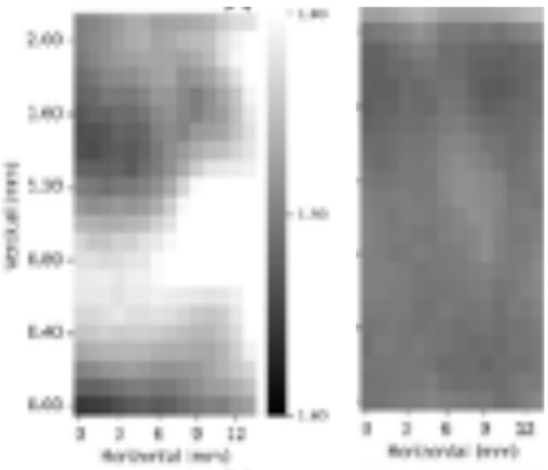

Fig. 1. Uniformity scans of a backscattering crystal. The grey scale shows the reflected intensity as the meV resolution crystal is moved through a ~200-meV-bandwidth beam. The left panel shows the results for typical (or even slightly poor) mounting of the sensors, while the right panel is after improved mounting. The improvement was stepwise: first poor response, then removing grease and sensors to show that the intrinsic quality was good, and then adding the grease and then the sensors again, but more carefully to preserve the response, and checking after each step.

In particular, it is then possible to map the strain over the backscattering crystal under a greater variety of conditions—e.g., both with and without the attachment of the temperature sensors, or with and without the grease used to

Si(nnn)	X-Ray Energy (keV)	Calculated							Measured (meV)
		Abs. Length (mm)	Ext. Length (mm)	Single Reflection (meV)	Autocor. (meV)	R^2 (Peak) (2 xtals)	ppb	mK	
9	17.793	0.70	0.17	1.97	2.72	0.56	153	59	2.75
11	21.747	1.24	0.40	0.83	1.17	0.46	54	21	1.25
12	23.725	1.59	0.44	0.76	1.06	0.53	45	17	1.12
13	25.702	1.99	0.96	0.35	0.51	0.32	20	7.6	0.61
15	29.656	2.94	2.41	0.15	0.23	0.16	8	3.1	0.32

Table 1. Properties of backscattering reflections in silicon. Notably, with recent improvements to the setup at BL43LXU, the measured resolution is almost as good as the theoretical value: compare the two shaded columns. For n=9, 11, 12, and 13, spherical diced analyzers were used, while for n=15, a flat analyzer was used. Energy resolution is given as the full width at half maximum (FWHM).

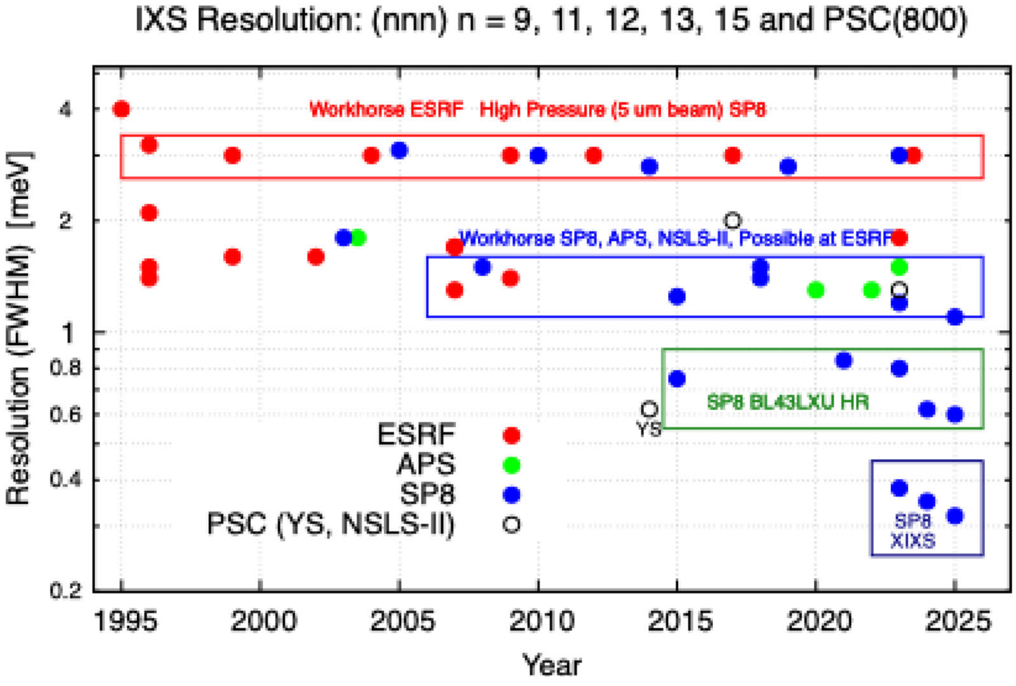

Fig. 2. IXS resolution vs year. The points indicate representative results from the indicated facilities. Of special note is that the 0.6 meV setup at SPring-8 is relatively robust. The post-sample collimation (PSC) setups tend to have much lower flux and—in the case of the result from 2014—have not been reproduced.

promote thermal contact with the holder. The result was very clear: the mounting of the temperature sensors, even some 30 mm or more from the beam spot, could introduce residual strain (see Fig. 1). Changing the mounting of the sensors reduced this strain and allowed an improvement of ~0.1 meV in the resolution relative to previous best cases at both Si(12 12 12) and Si(13 13 13). Thus, on the best analyzer crystals, using a combined T-gradient and dispersion compensation [2–4], we are now achieving (to better than 0.1 meV) essentially theoretical resolution (see Table 1).

8. IXS Resolution on the World Stage

With the improvements in the resolution made possible by the temperature gradient analyzers, dispersion compensation, and the improved sensor mounting mentioned above, SPring-8 has taken a firm lead in providing the best resolution for IXS worldwide. This is shown in Fig. 2. The very long time, about 20 years, between the operation at ESRF with 1.4 meV resolution and the obviously desirable development of sub-meV resolution is an indication that this is a difficult problem requiring parallel improvements in multiple aspects of instrumentation to be successful. In particular, it has been made possible by our T-control setup, which provides ~0.2 mK rms stability over week time scales [3], our care in detector setup [4], our efforts to improve the measurement of the resolution function [5], and significant work to mitigate the impact of power load and to improve beamline stability [6,7]. We are now in the process of (or have already been) transferring many aspects of these development programs to BL35XU.

9. Toward Sub-meV Analyzer Fabrication

Following the other improvements in BL operation, we are now beginning to focus again on analyzer fabrication. This is because, after the combined T-gradient/dispersion compensation and the new sensor mounting, the main limit to resolution is the analyzer quality. Analyzer fabrication has always been somewhat variable - at *all* IXS facilities - as the fabrication process, which involves the dicing, etching, and urad-level alignment of ~10000 silicon blocks while keeping the local strain at the ppb level, is extremely challenging. At this point, roughly 10 of the 28 analyzers at BL43LXU provide resolution that is within 0.1 or 0.2 meV of theoretical values, with the others being worse. Therefore, we are revisiting the analyzer fabrication process. The first test results obtained by a new procedure using anodic bonding appear promising, though we still need to investigate many detials further.

10. Other Activities: Summer School, Tours

As usual, there was a 1-day practical for the summer school run primarily by H. Fukui, D. Ishikawa, and T. Manjo. Also, there were multiple times when BL43LXU was shown, and activities were described to both international and Japanese groups visiting SPring-8. Baron also helped organize a session on the meV scale dynamics at the 10th International Discussion Session on Relaxations in Complex Systems (10IDMRCS), which took place in Barcelona.

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