BL43LXU
RIKEN Quantum NanoDynamics Beamline

1. Introduction

The bulk of the beamtime at BL43LXU [1] in 2023/2024 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 the problems at the beamline to provide a record of progress and to provide useful information to others working to develop SR instrumentation. We note that during the period of 2 April – 17 June, there was only one scientific staff person working at BL43LXU.

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 also provided part-time help. BL43 also had occasional help from full-time members of the engineering team on specific tasks including standard start-up of the LN_2 cooling for the mirror and mono, and, sometimes, setup of sample refrigerators.

2. Upstream of the Optics Hutch

The upstream components (electron orbit, IDs, mirrors, 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

There were no changes in this period.

4. Medium-Resolution Spectrometer

Most work during the year used the high-resolution spectrometer.

5. High-Resolution Spectrometer

This operated reasonably over most of the year. There was one period when the temperature readout became slightly noisy as was traced to a loose connector. This has been replaced and the noise appears to be gone.

6. Extreme Resolution

The extreme resolution setup operated with resolution that was as good as 0.35 meV. It is now expected that the degradation from the theoretically expected ~0.23 meV and the 0.26 meV observed with a small beam, is probably mostly due to residual strain in the backscattering monochromator crystal. This crystal will be replaced.

7. A position-sensitive detector for IXS

We installed the lambda flex detector into the IXS setup (see figure 1), after extensive tests during the previous year. As noted in last year's report, there were issues with the detector: the relatively slower (1ms) readout time and the small (55 um) pixel size made it more difficult to reduce backgrounds without losses as compared to the previously tested DECTRIS detectors (see [2]). However, after careful understanding of the "summing mode" of the detector based on published papers, it was decided to use that mode.

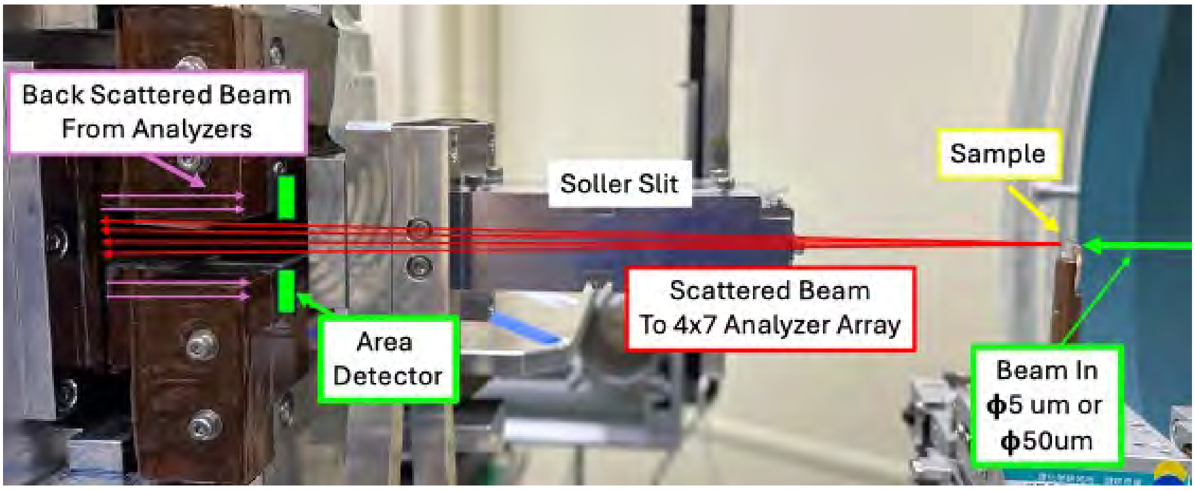

Fig. 1. Sample area of the IXS spectrometer showing the boxes with the newly installed area detectors.

The summing mode for the Medipix-3 essentially selects the only one pixel with the largest deposited charge in each 9x9 region of the detector to fire for any one event. This effectively prevents multi-hits due to charge sharing. In normal operation (no summing) when the threshold is set to half the x-ray energy the effective efficiency of the detector is reduced by ~20% (depending on details). However, in summing mode, one can set the threshold lower, and (see figure 2) the detector becomes nearly 100% efficient, without double counting (measured double counting rate is < 1% for a 6 keV LLD and a 30 keV x-ray energy in a GaAs detector). Further, in such a mode the ULD can be set to prevent counting high energy background events. This makes a relatively straightforward effective setup possible for IXS experiments.

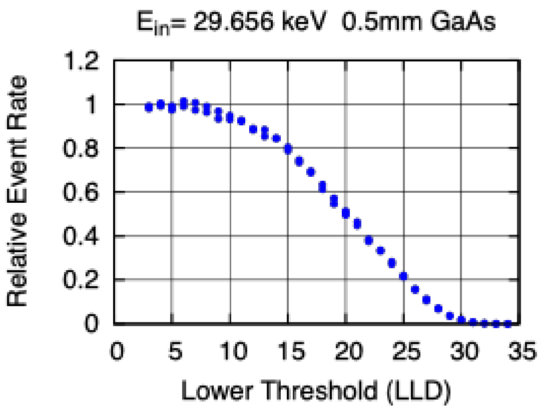

Fig. 2. Event Rate vs Discriminator Threshold. Note setting the threshold at half the X-ray energy costs about 20% detection efficiency.

The material, 0.5 mm thick GaAs, for the detector sensor was deliberately chosen. While it is there is always fluorescence for energies above 10 keV, the reduced stopping power for >50 keV photons (relative to 1 mm thick CdTe) is expected to reduce backgrounds. Further, as BL43LXU operates sometimes at 30 keV, using GaAs avoids the reduction in efficiency that occurs if one exceeds the Cd K-edge at 26.7 keV.

8. Improved resolution & Si (12 12 12)

The use of the position sensitive lambda flex detector in conjunction with analyzer temperature gradients (see discussion in [3] and [4]) allowed a noticeable improvement of resolution, especially for the analyzers further from backscattering. In particular, using the Si(12 12 12) it was possible to achieve resolution of 1.2 – 1.3 meV on most analyzers (the best analyzer was 1.1 meV). Note that in all cases, the quoted resolution is the full width at half maximum, FWHM. The Si(12 12 12) offers slightly better resolution than the Si(11 11 11) but actually has similar intensity since the reflectivity of the Si(12 12 12) is a bit higher (calculated 73% vs 68% for the (11 11 11)). Further, the Si (12 12 12) does not exhibit the multibeam peak at about 9 meV energy transfer that can appear with the Si(11 11 11) reflection.

9. Robust sub-meV resolution

While the extreme resolution setup mentioned above allows ~0.35 meV resolution, that setup works with only a single flat analyzer. Given the success of using the flex detector for improved resolution using the spherical analyzer array at the Si (12 12 12), we then tried also the Si (13 13 13). That setup had previously exhibited best case resolution of 0.75 meV [4] but the theoretically expected value is ~0.51 meV while the measured value in real experiments was >0.8 meV and, on most analyzers, >0.9 meV [5]. Thus, given the success with the new Si(12 12 12) setup, we tried the Si(13 13 13). This worked nicely with the best case resolution 0.61 meV, and with many analyzers having 0.7 to 0.8 meV resolution, a notable improvement relative to the previous operation. It is expected that this setup, with lower, but still mostly comfortable, rates, and with the large (28 element) analyzer array will be a valuable tool for high-resolution investigations of atomic dynamics, especially of liquids. We note that the analyzers will be re-arranged to more effectively take advantage of this setup in the summer of 2024.

10. Other Activities: IXS2024 & Summer School

As SPring-8 is supporting the IXS2024 meeting in Himeji (A. Baron, chair) significant effort was also involved in preparing this meeting. Also, as usual, there was 1-day practical for the summer school run primarily by H. Fukui and D. Ishikawa.

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References:

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[3] D. Ishikawa and A. Q. R Baron,. (2010). *J. Synch. Rad.* **17**, 12–24. https://doi.org/10.1107/S160057752100179X

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