BL03XU
Advanced Softmaterial

1. Introduction

The main methods performed at BL03XU are small-angle X-ray scattering (SAXS), wide-angle X-ray scattering (WAXS), ultrasmall-angle X-ray scattering (USAXS), μ-beam SAXS/WAXS, grazing-incident SAXS/WAXS (GI-SAXS/WAXS), and X-ray photon correlation spectroscopy (XPCS). Switching times between experiments were minimized to increase the effective beam time while enhancing the throughput. The control system and the beam monitor system for beam tuning were improved.

Improvement of Control System

The control system of the beamline is organized into multiple functional layers, as illustrated in Fig. 1. These layers comprise (1) a device control layer, which directly interfaces with the hardware; (2) a control sequence layer, responsible for executing predefined operational sequences of devices; and (3) a user interface (UI) layer, through which measurement conditions are defined by the operator.

The legacy system had been implemented as a monolithic software package that tightly couples all three layers, with the software architecture heavily reliant on the specific characteristics of the underlying hardware. Consequently, any hardware failure or upgrade necessitated extensive modifications to the software, resulting in high maintenance costs and limited system flexibility.

To address these limitations and enhance maintainability, a modular control system architecture was introduced. For hardware-level control, the BL-774 system [1], developed by RIKEN, was adopted to facilitate device abstraction, thereby decoupling device operations from hardware-specific commands. The control sequence layer was restructured into two sublayers. The lower sublayer consists of individual command scripts for each hardware component, implemented in Python and executed on the BL-774 system. These scripts are used to manage the low-level control logic, while device status information is recorded and stored using Redis, an in-memory data structure store. The upper sublayer enables the coordinated operation of multiple devices by invoking the lower-layer commands. This upper-layer software resides on the operator's PC and communicates with the lower layer through the XML-RPC protocol. Measurement parameters defined in the UI are transmitted in JSON format to the upper layer using the same protocol. Status updates and data retrieval in the graphical user interface are also mediated through Redis, and the GUI does not directly interface with the BL-774 system. Device coordination is implemented via asynchronous control, with timing synchronization achieved using standard 5V TTL signals. This modular system architecture significantly improves maintainability and scalability. System components can be updated independently, allowing for rapid adaptation to hardware modifications or changes in experimental procedures without requiring extensive revisions to the overall control software.

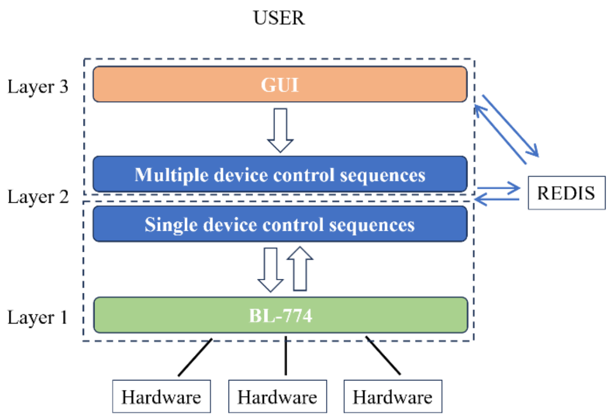

Fig. 1. Schematic diagram of the layered architecture of the control system.

Development of High-resolution Beam Monitor

Microbeams are employed for localized structural analysis. At BL03XU, microbeams generated using compound refractive lenses (CRLs) are utilized. Beam monitors are typically used for the coarse alignment of the optics. However, given that the microbeam size is on the order of 1 μm, a high-resolution beam monitor is required. Since the focused X-ray beam size is a few micrometers, the beam monitor must achieve a sub-micrometer spatial resolution. Furthermore, because of the limited space available near the sample position, the system must be compact. To meet these requirements, a high-resolution beam monitor was developed using a 10-μm-thick LuAG scintillator, a 20× magnification telecentric lens, and a CMOS camera. The CMOS camera (C11440-36U) has a pixel size of 5.86 μm, resulting in an effective resolution of approximately 0.3 μm. While the actual spatial resolution is lower, the performance is sufficient for optical alignment purposes. Figure 2 shows a beam image captured with the developed monitor. During optical alignment, the beam monitor is inserted into the optical path to identify the focal distance at which the beam size is minimized. As the sample position is fixed owing to the constraints of the measurement system, the position of the CRLs is adjusted to place the focal point at the sample location, followed by the fine adjustment of the CRLs. The beam shape at the sample position is then verified using the beam monitor, and the beam size is determined by wire scanning. Previously, multiple wire scans were required to locate the focal point, which made the alignment process time-consuming. With the introduction of the high-resolution beam monitor, the optical alignment can now be completed within approximately 1 h.

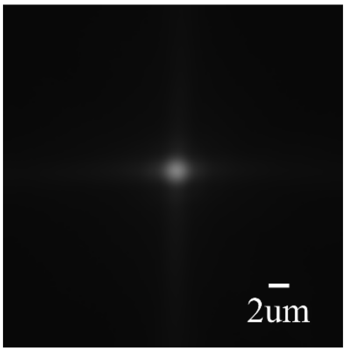

Fig. 2. Image of a focused X-ray beam. The wire scan had a full width at half maximum of 1.2 μm.

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Reference:

[1] Motomura, K. Yasuda, N. Imai, Y. Nakajima, K. & Joti, Y. (*2024*). *SPring-8/SACLA/NanoTerasu Information* **29**, 19–27.