BL09XU
HAXPES I

1. Introduction

BL09XU is an X-ray beamline with a 32-mm-period standard linear undulator. In FY2021, BL09XU was reorganized as a beamline dedicated to HAXPES [1]. In this upgrade, all optics except for a liquid-nitrogen-cooled double-crystal monochromator (DCM) with Si 111 reflection were upgraded to state-of-the-art equipment specialized for HAXPES experiments for conducting more advanced HAXPES applications, such as resonant HAXPES [2], and three-dimensional spatially resolved chemical bonding analysis [3]. For example, two pairs of double channel-cut crystal monochromators (DCCMs) with Si 220 and Si 311 reflections were introduced to realize HAXPES analyses with a total energy resolution below 300 meV at any incident photon energy in the range of 4.9–12 keV while satisfying a fixed-exit condition. X-ray phase retarders (XPRs) with two diamond crystals enable us to control the polarization state with a high polarization degree above 90% in a wide energy range of 5.9–9.5 keV. In FY2024, (1) a nonevaporable getter (NEG)/ion pumping system and (2) the improvement and expansion of a web application software program for beamline control were introduced.

2. NEG/ion pumping system

Recent studies on semiconductor and catalyst materials have been paying a lot of attention to the electronic states, chemical bonding, and atomic structures in localized regions. Localized three-dimensional measurements can be conducted in an angle-resolved setting with a wide-angle analyzer, and an extremely small beam focused to 1 μm in EH2. However, recently, the vibrations caused by the turbo molecular pump (TMP) and the dry pump (DP) themselves, mainly used for vacuum pumping in the main chamber, and by the cooling fan of the TMP, have caused the sample position to vibrate vertically, resulting in the vertical beam size on the sample appearing to expand to a few micrometers.

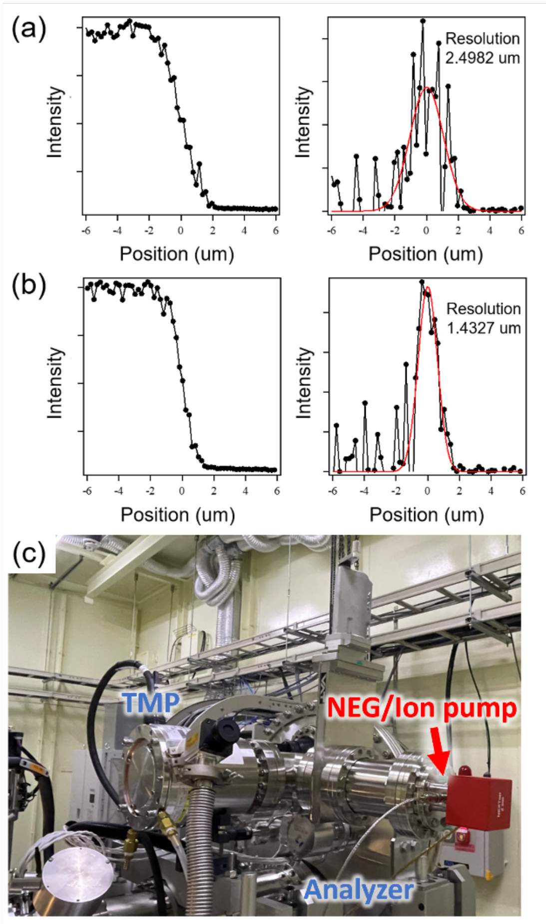

Fig. 1 Vertical beam profile with TMP and DP (a) in operation and (b) stopped. (c) NEG/ion pumping system installed at HAXPES analyzer part.

Figures 1(a) and 1(b) show the vertical beam profiles with TMP and DP in operation and stopped, respectively. It is obvious that the beam size was estimated to be largely deteriorated from 1.4 μm to 2.5 μm when TMP and DP are in operation. To reduce vertical vibration, we installed the NEG/Ion pumps at the main chamber part and the analyzer part, as shown in Fig. 1(c), since this NEG/Ion pump can create an ultrahigh-vacuum condition equivalent to that of TMP without vibration. With these pumps, it has become possible to conduct experiments with a beam equivalent to that shown in Fig. 1(b) in an ultrahigh-vacuum state suitable for HAXPES measurements.

3. Improvement and expansion of web application software for beamline control

As reported last year, we developed new web application software for controlling optical instruments and the sample position adjustment of HAXPES devices [4]. Its main feature is that key functions, such as collaborative operation between multiple beamline devices, are built into the BL-774 framework to take advantage of the excellent task management capabilities of BL-774 [5], and that the load on the device control server PC can be greatly reduced by using a web application. Furthermore, for future remote experiments managed from outside of SPring-8, multiple web applications can be switched and used in a single browser. The software had been developed for use only in BL09XU but its usefulness was recognized, and its expansion to other beamlines, especially BL46XU (HAXPES II), which provides the same HAXPES applications, was expected. Therefore, the software was improved to be more expandable, taking into consideration its use in other beamline environments. In addition, support for various measurement techniques was added.

To enhance expandability, the following improvements were made: (i) registration to a database of information regarding stage position adjustment and optical system control, reducing input effort when repeating the same adjustments and control; (ii) enabled stage position adjustment using any stage and detector. These improvements allow immediate control of equipment on other beamlines and make expansion to other beamlines more convenient.

Furthermore, the following measurement techniques are now supported:

Energy scan: X-ray absorption spectroscopy (XAS) measurements are performed using the count intensity output from a counter-timer and the photoelectron intensity. This enables XAS measurements such as partial fluorescence yield (PFY) measurements using a silicon drift detector (SDD) and total electron yield (TEY) measurements using drain current from the sample, as well as the acquisition of constant initial state (CIS) spectra using Auger electron or core electron intensity.

Time scan: The temporal variation of the count intensity can be acquired from a counter-timer. This is mainly used to record the incident beam intensity variation during resonant HAXPES or polarization-controlled HAXPES measurements utilizing XPRs.

The upgraded software with the above improvements and additional functions has been installed not only on BL46XU but also on the new public beamline BL06U of NanoTerasu, which is a beamline that specializes in soft X-ray angle-resolved photoelectron spectroscopy (ARPES) [6,7]. The beamline equipment control uses BL-774, and Scienta-omicron PEAK has been introduced for photoelectron measurements and photoelectron-analyzer control, the same as for BL09XU. In this way, the control environment is almost the same as that of BL09XU, although the measurement technique differs. For example, Fermi-surface mapping measurements require control technology combining sample manipulator position control, the adjustment of the incident-beam energy condition, and photoelectron measurement. This is common with the three-dimensional spatial-resolved chemical bonding analysis and resonant HAXPES conducted at BL09XU and can be achieved using the above software. The developed software system is not only applicable to the photoelectron technique but also to other spectroscopic measurements, and we expect its use to expand further in the future.

Fig. 2. Captured image of “Energy scan” software.

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