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Abstract

Combined systems for photoelectron spectroscopy using synchrotron radiation (SR) and laser have been constructed at BL5A and BL6A2 in the UVSOR facility, Okazaki. The systems consist of photoelectron spectrometers with high performance, mode-locked lasers, and timing electronic circuits. The laser pulses with repetition frequency of 90 MHz are synchronized with the SR pulses. An upgrade project to install a micro-ESCA at BL6A2, which is now in progress, is also reported.

Keywords: Photoelectron spectroscopy; Synchrotron radiation; Laser; Time-resolved spectroscopy; UVSOR

1. Introduction

Since the first report by Saile [1], several groups have been developing new spectroscopy based on a combination of synchrotron radiation (SR) and laser. The combined spectroscopy is very attractive and interesting, since both SR and laser are useful light sources with quite different characteristics; e.g., SR provides high-energy photons capable of investigating the core states, while laser light is very intense and can produce the excited valence states with high density. Various combinations of two powerful light sources may open up new scientific achievements. For example, non-equilibrium electronic states on semiconductor surfaces have recently been studied by combined SR–laser experiments [2]. Furthermore, photo-induced phase transitions in crystal structure, magnetism, and optical properties are also interesting and promising subjects. Therefore, new beam-line systems for photoelectron spectroscopy using SR and laser have been constructed in the UVSOR facility, Okazaki. In this paper, we will report the beam-line systems at BL5A and BL6A2 for pump-probe photoelectron spectroscopy. An upgrade project to install a micro-ESCA at BL6A2 is also introduced.

2. SR-laser system at BL5A

The BL5A consists of an SGM-TRAIN monochromator, a spin- and angle-resolved photoelectron spectrometer, a high-resolution photoelectron spectrometer, and a laser complex. The SGM-TRAIN monochromator covers the spectral range from 5 to 300 eV with three gratings. Higher order radiation is successfully eliminated using laminar-type gratings and materials coated on the plane mirror [3]. Both SR from a dipole bending magnet and circularly polarized light from a helical undulator are available in this station [4]. Higher order radiation is also suppressed in the operation mode of circular polarization. The laser complex is composed of a femtosecond mode-locked Ti : sapphire laser (Coherent, Mira 900 F/P), a regenerated amplifier (RegA9000A), and an optical parametric amplifier (OPA9400A). The frequency of Mira 900 F/P is set at 90.1 MHz that fits well to the RF frequency of the storage ring. The phase locked electronics (Synchro-Lock) always follows the external signal from the master oscillator of the storage ring, resulting in the best coincidence between SR and laser pulses. RegA9000A can provide intense pulses of about 10 μJ with repetition frequency from 10 to 300 kHz. Signal and idler light from OPA9400A can cover a wide spectral range from violet to near infrared. Since the pulse widths of laser and SR are about 160 fs and 1.5 ns, respectively, an optical fiber of 50 m in length is introduced to expand the laser pulse up to 300 ps width. There are two photoelectron spectrometers in the main chamber. A spin- and angle-resolved photoelectron spectrometer is of hemi-spherical type with radius of 50 mm. A spin detector is a type of low energy diffused scattering, which has four sectors [5]. Another analyzer is an OMICRON high-resolution photoelectron spectrometer EA-125HR, which has five channel detectors. The timing circuit consisting of a time-to-amplitude converter (TAC), delay lines, timing gate, and multi-channel scalers makes it possible to observe time-resolved photoelectron spectra.

3. SR-laser system at BL6A2

The BL6A2 consists of a plane-grating monochromator (PGM), a hemi-spherical photoelectron analyzer, and a sub-nanosecond mode-locked Nd : YAG laser. The PGM can provide high photon flux of about 10^{11} photons/s and covers the spectral range from 2.5 to 150 eV with two gratings. Higher order radiation is suppressed by choosing one of several collecting mirrors with different angles. The laser pulses have good coincidence to the SR pulses under multi-bunch operation, because the 8/16 signal from the RF master oscillator is used for an acoustic modulator in the laser cavity. Experimental setup for the investigation of photo-voltage effects on semiconductor surfaces is shown in Fig. 1. A mechanical shutter cuts the laser light every other second for a period of one second. Photoelectron signals with and without laser light are separately stored in two channels. It is important for the surface photo-voltage experiments to confirm the spatial

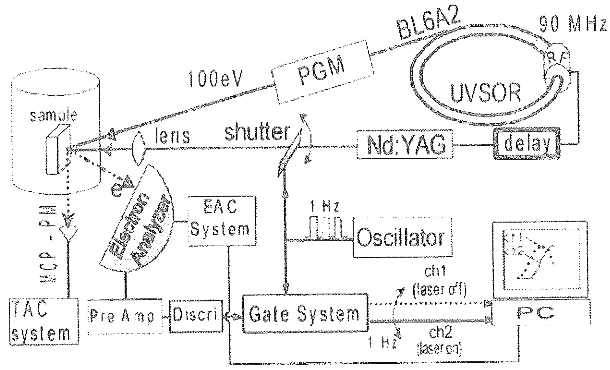

Fig. 1. Schematic experimental setup for SR-laser combined photoelectron spectroscopy at BL6A2.

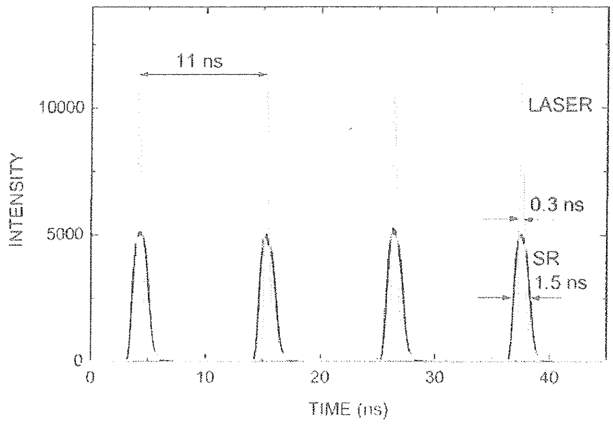

Fig. 2. Temporal coincidence of SR and laser pulses under multi-bunch operation.

and temporal overlaps of SR and laser pulses. The temporal overlap is checked by observing the zeroth-order light from the monochromator and the laser light with a TAC technique, as shown in Fig. 2. The pulse widths of SR and laser are 1.5 and 0.3 ns, respectively. The pump-probe technique allows us to observe time-resolved photoelectron spectra in the time range of 1.5–11 ns, which is limited by the pulse width and repetition of SR under multi-bunch operation.

4. Upgrade project at BL6A2

A new program to improve the performance of photoelectron spectroscopy at BL6A2 is going on. The homemade hemi-spherical electron analyzer system will be replaced by a micro-ESCA system (FISONS ESCALAB220i-XL), which is a powerful instrument for microscopic photoelectron spectroscopy with high performance. It consists of multi-channel detectors, flow-type helium cryostat, and various components for conducting both XPS and UPS. The optics in the post-mirror system is upgraded in order to obtain the best fit of the PGM output to the micro-ESCA system. A main upgrade of the optics is to obtain a demagnified spot on sample surfaces for investigating photo-induced phase transitions of various kinds of materials with small size. The optical layout is shown in Fig. 3. Since there are five mirrors (two spherical M0 and M1, one cylindrical

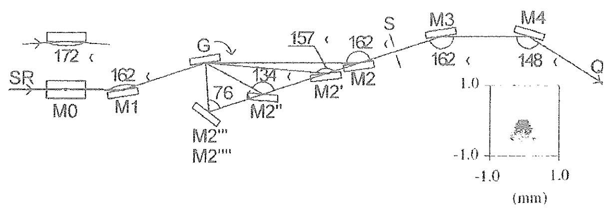

Fig. 3. Optical layout of BL6A2. The inset shows the ray tracing calculation at the sample position.

M2, one plane M3, and one toroidal M4) and one plane grating (G) in the light path, the spot is not exactly round, but will be focused in a small area of 0.5 mm in diameter. The inset shows the expected spot size on the sample position, which is derived from the ray-tracing calculation. Since the micro-ESCA has a good electrostatic and magnetic lens system, it is possible to measure photoelectron spectra in a small area of about 20 μm in diameter and observe microscopic pictures with spatial resolution of about 2 μm [6]. For this system, mode-locked Ti:sapphire and Nd:YAG lasers are available with and without an optical fiber, respectively

Acknowledgements

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