Status of spin- and angle-resolved photoelectron spectroscopy with laser light at Laser and Synchrotron Research Laboratory

Spin-and angle-resolved photoelectron spectroscopy (SARPES) is a powerful technique to investigate the spin-dependent electronic states in solids. This has been used for studying exchange splitting of ferromagnetic materials over 50 years. Recently, spin textures have been intensively studied in strongly spin-orbit coupled materials, such as Rashba spin-split systems and topological insulators. We have been developing a SARPES apparatus using vacuum-ultraviolet (VUV) lasers at Laser and Synchrotron Research Laboratory in the Institute for Solid State Physics, named LOBSTER (Laser-Optics-Based Spin-vecTor Experimental Research) machine. The LOBSTER machine is currently utilized to obtain precise information on spin-dependent electronic structures near the Fermi level in solids. We started a project to construct the LOBSTER machine from FY 2014 and joint researches at this station have started from FY2015.

Figure 1 represents an overview of the LOBSTER machine [1]. The apparatus consists of an analysis chamber, a carousel sample-bank chamber connected to a load-lock chamber, and a molecular beam epitaxy (MBE) chamber, which are kept in an ultra-high vacuum (UHV) environment and are connected with each other via UHV gate valves. The hemispherical electron analyzer is a

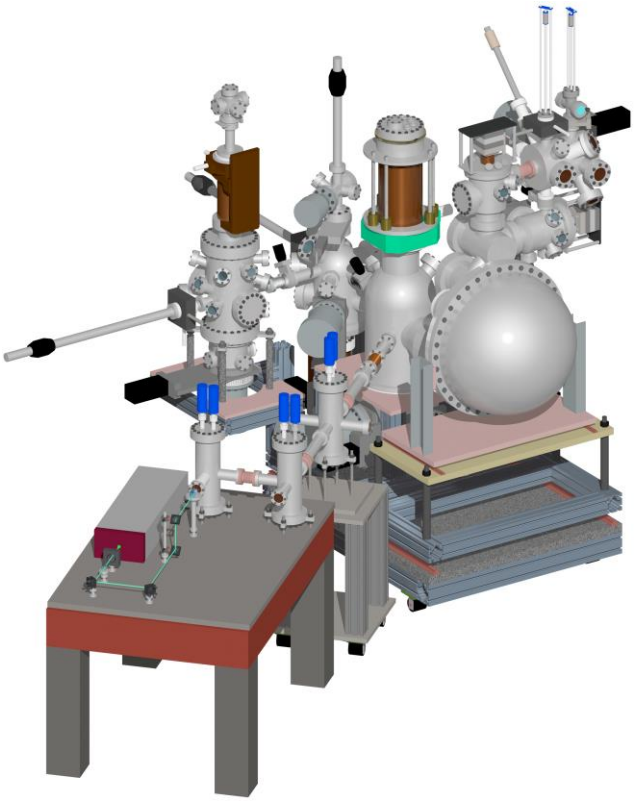

Fig. 1. Overview of the LOBSTER machine developed at the Laser and Synchrotron Research Laboratory at the Institute for Solid State Physics [1].

custom-made ScientaOmicron DA30-L, modified to attach the very-low-energy-electron-diffraction type spin detectors. The electrons are currently excited by 6.994-eV photons, yielded by 6th harmonic of a Nd:YVO_4 quasi-continuous wave laser with repetition rate of 120 MHz. A helium discharge lamp (VG Scienta, VUV5000) is also available as a photon source. At the MBE chamber, samples can be heated by a direct current heating or electron bombardment. The surface evaluating and preparing instruments, such as evaporators, low energy electron diffraction, sputter-gun and quartz microbalance, can be installed. At the carousel chamber, 16 samples can be stocked in the UHV environment.

In FY2019, eleven research proposals from outside of the institute were accepted and conducted. Spin-polarized states were investigated in both bulk and surface of various topological materials including magnetic and superconducting ones, atomic layers, and ferromagnetic compounds. For extending the use of laser-SARPES to time-resolved study, we have been developing a new laser beamline of 10.7 eV femtosecond laser pulses based on the Yb-doped fiver with the high repetition rate (1 MHz) [2].

References

[1] K. Yaji, A. Harasawa, K. Kuroda, S. Toyohisa, M. Nakayama, Y. Ishida, A. Fukushima, S. Watanabe, C.-T. Chen, F. Komori and S. Shin, Rev. Sci. Instrum. **87**, 053111 (2016).

[2] Z. Zhao and Y. Kobayashi., Opt. Exp. **25**, 13517 (2017).