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. For example, one looks at the exchange splitting of ferromagnetic materials. Also, recently, strongly spin-orbit coupled materials, such as Rashba spin-split systems and topological insulators have been intensively studied. We developed a SARPES apparatus with a vacuum-ultraviolet (VUV) laser 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 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 FY 2015.

Figure 1 represents an overview of the LOBSTER machine [1]. The apparatus consists of an analysis chamber, a 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

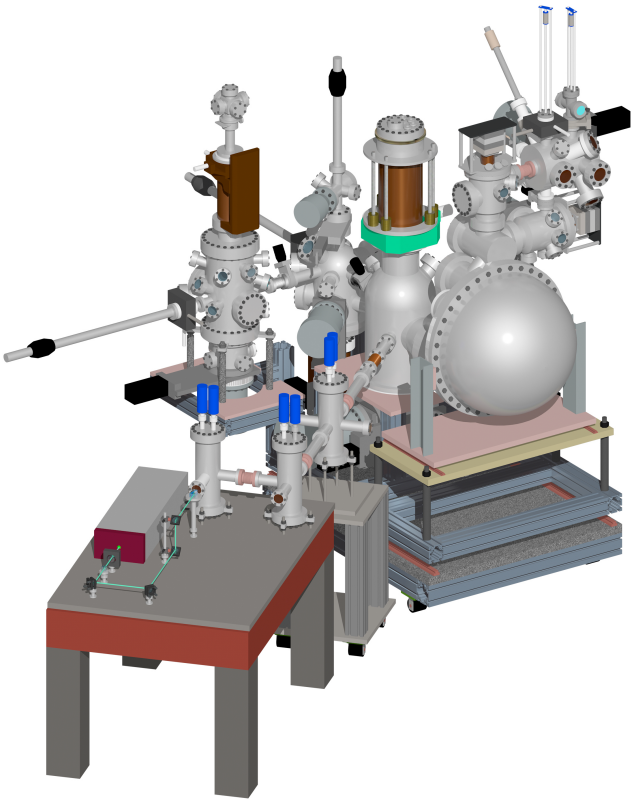

Fig. 1. Overview of the LOBSTER machine developed at the Laser and Synchrotron Research Laboratory at the Institute for Solid State Physics [1].

connected with each other via UHV gate valves. The hemispherical electron analyzer is a custom-made ScientaOmicron DA30-L, modified to attach the very-low-energy-electron-diffraction type spin detectors. The electrons are 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 FY 2017, seven research papers were published. Among these, one of the most significant papers is the observation of topological surface states of an iron-based superconductor $FeTe_{0.55}Se_{0.45}$, reported by Prof. Shin group [2]. In this study, the authors were performed high-resolution SARPES measurements using the VUV laser to demonstrate the spin polarization of a Dirac-cone–type surface state in a superconducting gap of $FeTe_{1-x}Se_x$. They found that the spin polarizations of the surface states are reversed with respect to the Γ point, which is consistent with the spin-helical texture. The authors concluded that the observed spin polarizations of the surface states are the direct evidence of the topological surface states. The results opened a new pathway for realizing Majorana bound states on solid surfaces at high temperature.

Reference

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