Performance of laser-based SARPES with micrometer spatial and vector spin resolution at HiSOR

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Angle-resolved photoemission spectroscopy (ARPES) is a powerful tool to directory observe the electronic structure of solids. In recent years, micro-ARPES [1] which is combined with a micro-focused light source has attracted much attention, since it is found to very useful to explore the electronic states in newly topological materials [2], phase-separated correlated systems [3] and transcription samples [4].

Spin-resolved ARPES (SARPES) [5] enables us to detect not only the energy and momentum but also the spin of photoelectrons owing to recent development of the spin detectors. However, micro-SARPES measurement has never been reported so far, because of the difficulties of the spin detection and its combination technique. Synchrotron Radiation is a conventional light source used for SARPES. Although there are some synchrotron radiation based micro- (or nano-)ARPES systems, the use of special optical elements (such as Fresnel zone plate) attenuate intensity of light and the need for a mechanism to control the optical system under ultrahigh vacuum condition make micro-SARPES a difficult and still developing technology.

In this context, we employed a high-photon flux ultraviolet laser with 6-eV of photon energy instead of synchrotron radiation to realize micro-SARPES. In addition to high photon flux, the advantage of the 6-eV laser is the flexibility of its optical system due to high atmospheric transmission. Since SARPES requires an intense light source to perform high resolution measurements, we considered a laser to be the best light source for micro-SARPES. Therefore, we combined a high-intensity 6-eV laser with a high-efficiency spin detector at HiSOR to develop micro-SARPES machine that can perform high-efficiency spin-resolved experiments while maintaining micro-focusing.

In this presentation, we will describe the performance of the-state-of-the-art micro-SARPES machine combining 6-eV laser source and the photoelectron analyzer equipped with the electron deflector function and two VLEED type spin detectors [6]. We evaluated spatial resolution and long-time stability using an Au polycrystalline letter pattern ("μ-SARPES") sample, which is fabricated on a Si substrate using photo lithography (Fig. 1). We performed not only 3D spin-resolved experiment to Bi_2Te_3, which is a typical topological insulator as a test sample, but also spin- and spatial-resolved experiment to $PbBi_4Te_4S_3$ [7], which has two Dirac-cone-like dispersions derived from two distinct terminations (Fig. 2).

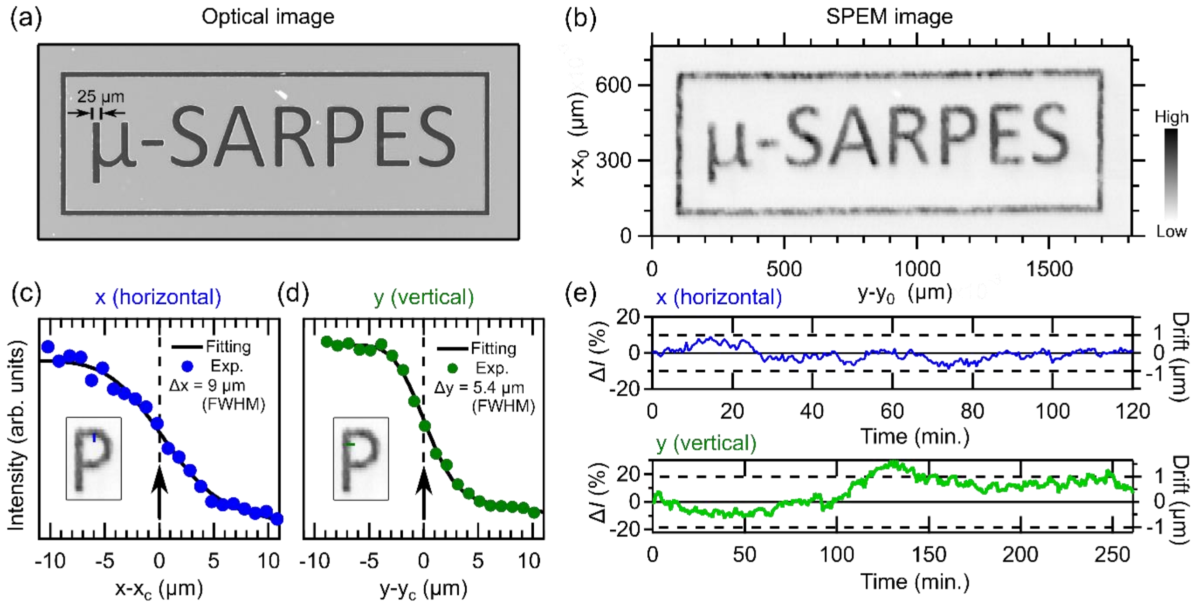

FIGURE 1. Characterization of the spatial resolution. (a) The optical microscope image of the Au pattern on the Si (001) substrate. (b) The image of the scanning photoelectron intensity map (SPEM) taken in the Au pattern. (c) and (d) Photoelectron intensity profiles at the edges of the Au pattern along the *x* (horizontal) and *y* (vertical) axes, respectively (green and blue lines in the insets). (e) Plots of the intensity deviation $\Delta I(x)$ and $\Delta I(y)$ as a function of time to evaluate possible long-term drifts of the laser and the sample stage. The data was recorded at the intensity edge at x_c and y_c denoted by arrows in (c) and (d). The 1~µm of the drift along *x* (*y*) axis can correspond to 19% (10%) of $\Delta I(x)$; [$\Delta I(y)$] guided by dashed lines.

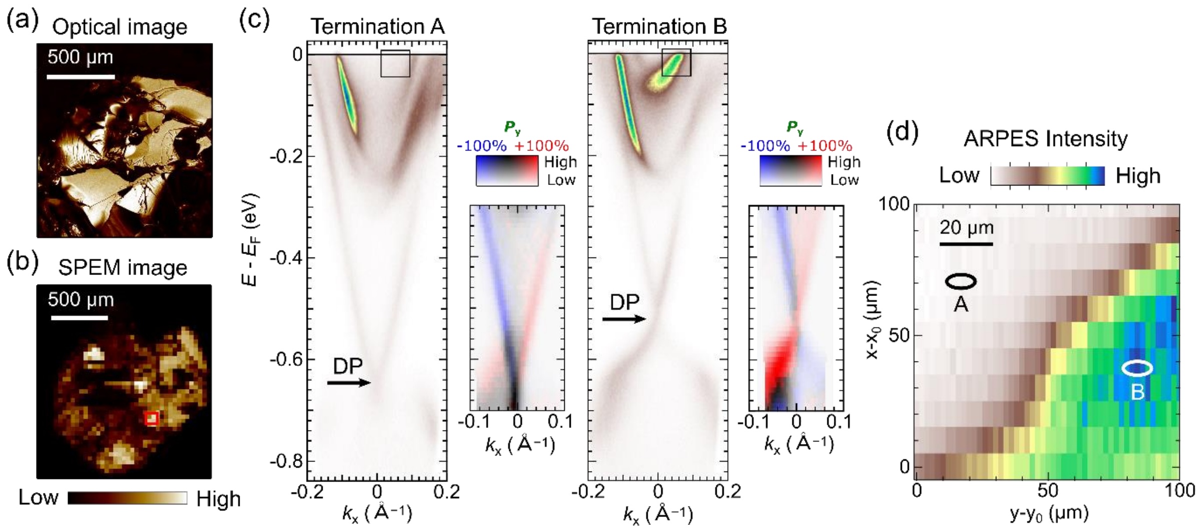

FIGURE 1. Demonstration of spatially-resolved SARPES measurements on $PbBi_4Te_4S_3$ (a) Optical microscope image of a cleaved surface of $PbBi_4Te_4S_3$. (b) SPEM image taken with a 50 µm step. (c) Spatially-resolved ARPES images acquired at different surface terminations [7]. (d) Scanning ARPES intensity map measured at the 100×100 µm marked by the red square in (b). The map is taken by scanning 2 µm and 10 µm steps along *x* and *y* axes, respectively.

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