Application Note
Ultra high resolution photoelectron spectroscopy

Photoemission (PES) has the ability to detect very small features in the band structure crucial for understanding the function of e.g. superconductivity, where it is of utter importance to determine the gap symmetry and positions of the nodes. This is illustrated by a study of the KFe_2As_2 iron-pniptide superconductor presented by K. Okazaki et al. in Science 337 (2012) 131. The data is recorded using a state of the art setup at Professor Shin's lab at the Institute of Solid State Physics, University of Tokyo, including a Scienta Omicron R8000 hemispherical analyser, an upright helium-impounding cryostat and a laser system. This setup holds the world record in instrumental resolution of 70 µeV.

The Scienta Omicron R8000 analyser is a 200 mm mean radius analyser equipped with a lowest pass energy of 0.5 eV and a smallest slit of 50 µm width, which result in a best theoretical resolution of 62.5µeV. The photons of the light has a minimum of 25 µeV, which make the total instrument theoretical broadening to be 67.5 µeV. Figure 1 shows a Fermi level spectrum of gold with a total resolution of 0.5 meV, which is totally dominated by the temperature broadening. From this spectrum the instrumental broadening of 70 µeV is derived.

This high resolution instrument is used for studying superconductors. The KFe_2As_2 iron-pniptide superconductor electronic structure is presented in Science 337 (2012) 131. The experiments reveal that KFe_2As_2 is a nodal s-wave superconductor with a highly unusual Fermi surface (FS)-selective multi-gap structure. The FS map along with one of the measured I(E,k) spectrum and a momentum distribution curve (MDC) cut is displayed in Figure 2. The MDC cut shows three FSs (denoted outer, middle and inner) for this particular superconductor. ... →

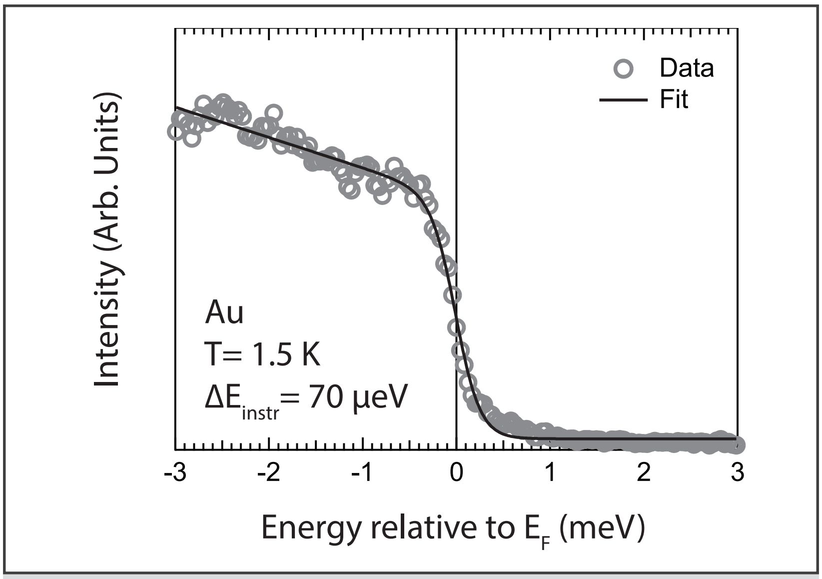

Figure 1: Fermi surface map of the Au(111) including the surface state (bottom left corner) and the bulk Fermi surface. Recorded in scan mode using angular mode 30.

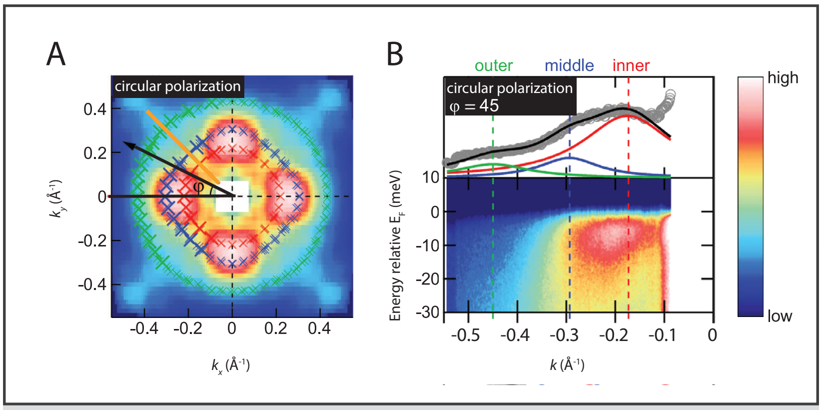

Figure 2: Figure 2: A typical second generation ARPES spectrum of the Au(111) surface state at the θx, =± 7, θy= 0 degrees position.

... → Energy distribution curve (EDC) measurements were performed for a set of different positions to verify the gap structure (see Science 337 (2012) 131). The gap structure around ϕ =0° is only in the order of tenth of µeV and to resolve this gap the power of the high resolution instrumentation comes at hand. Figure 3 show high resolution energy distribution curve (EDC) measurements and symmetrized EDCs for ϕ=8.9°, 4.0° and -0.5°.
As seen, the 8.9° and -0.5° spectra show small but finite superconducting gaps, whereas the 4.0° spectra does not, instead showing closing of the gap at this position.

This application note was written in collaboration with Professor Shik Shin at the Institute for Solid State Physics at the University of Tokyo / Japan.

For more information please see: K. Okazaki et al. in Science 337 (2012) 131 or contact shin@issp.u-tokyo.ac.jp.

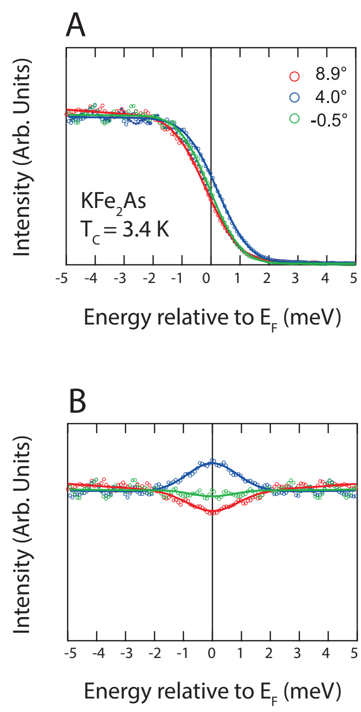

Figure 3: A) High resolution EDC measurements around ϕ =0 for the middle FS. B) Symmetrized EDC spectra from A.