Design and construction of a side beamline of BL12XU at SPring-8 dedicated to HAXPES

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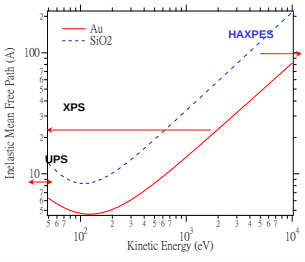
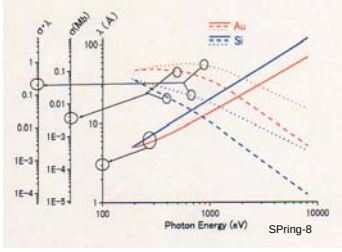
Introduction

There has been growing interest in utilizing the increased bulk sensitivity of hard X-ray photoemission spectroscopy (HAXPES) to tackle the electronic structure of bulk materials and buried interfaces. We design and construct a side beamline of BL12XU at SPring-8 dedicated to HAXPES.

Why hard x-rays

Electron IMFP (probing depth) and Cross section





Higher Ek for deeper probing depth or more bulk sensitivity, for strongly correlated systems and interface properties.
Photoemission signal (σ·λ) decreases rapidly > 1 keV.
Need photon source of higher flux/brightness (modern SR), efficient BL design and good electron analyzers.
HAXPES is a low count rate, photon hungry experiment!
(except at a grazing incident angle)

Design considerations

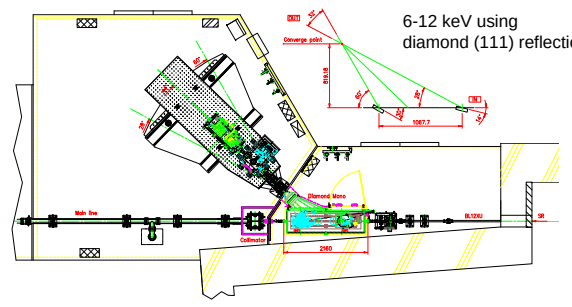
1. Scan of photon energy is not considered.
2. Focusing on photon energies to have reasonably large IMFP of photoelectrons while reasonably good signal rates.
3. Range of photon energy thus the kinetic energy of photoelectrons should match the range of available electron energy analyzers (Scienta or MBS).
4. Minimizing photon flux loss by minimal numbers of reflection and diffraction and putting the whole beamline under vacuum, with few Be windows. Beam spot size at the sample position should match the electron optics of the analyzer to maximize detection efficiency.
5. Using the existing hutches of BL12XU at SPring-8, must install the first optical element after front end to intercept the strong white beam from undulator.
6. Sharing beamtime and even flux with the main line particularly at 10 keV, which is used heavily, and also allowing main line to use 3rd harmonic of the photon energy used at the side line.
7. Cost.

Photon energy range 6-12 keV

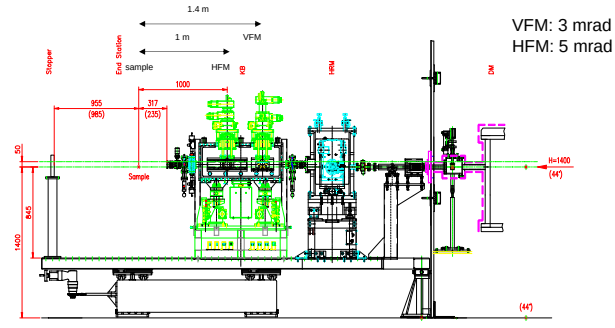
Summary of final beamline design

1. Single bounce diamond monochromator (DM). (horizontal dispersion)
   A. Diamond is the only choice.
   B. High thermal conductivity, low thermal expansion coefficient, can use a much simpler water cooling system than complicated and expensive cryogenic LN2 cooling system widely used at SPring-8 (BL12XU main line).
   C. Low absorption or high transmission of diamond enables us to share beam with the main line.
   D. Two modes are implemented:
      a. A thin diamond (100) with (111) diffraction in transmission Laue mode, fine with higher photon energy; near normal incidence, 80% transmission at 10 keV for the main line.
      b. A thicker diamond (111) with (111) diffraction in reflection Bragg mode, must be used at lower photon energy; 90% transmission at 18 keV in third harmonic for the main line.
   E. Drawback: BL after DM and end station must be rotated to match diamond scattering angle 2theta with different photon energies.
2. Single pair of Si channel-cuts as high resolution monochromator (HRM). (vertical dispersion)
   Advantage: reduced flux loss due to Si absorption using 2 pairs of channel-cuts.
   Drawback: BL and end station must change height with photon energy.
3. KB mirror system focus beam down to 30x30 um^2 to match lens optics of electron energy analyzer.

Layout of side line



Side view of side line

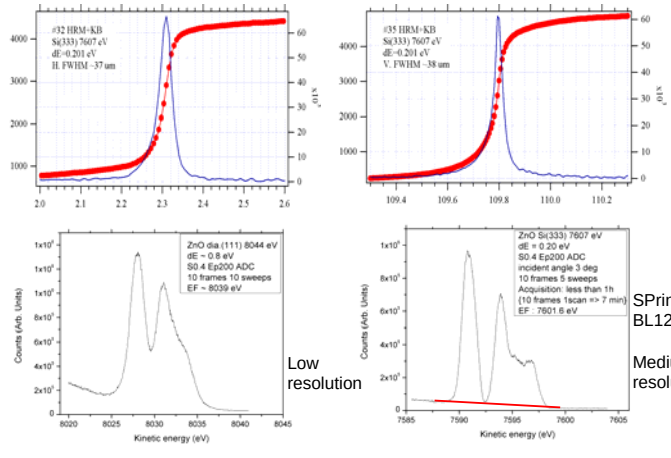


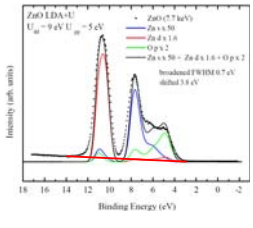
Diamond monochromator

MBS electron energy analyzer End station

Commissioning

HRM: Si(333) 7607 eV, ΔE = 0.20 eV, after KB horizontal and vertical beam size < 40 μm





Concluding remarks

HAXPES beamline successfully built and commissioned. Further commissioning with experiments are underway.