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1^2-ARPES: The ultra-high-resolution photoemission station at the U112-PGM-2a-1^2 beamline at BESSY II

Helmholtz-Zentrum Berlin für Materialien und Energie*

Instrument Scientist:
- Dr. Andrei Varykhalov, Helmholtz-Zentrum Berlin für Materialien und Energie
  phone: +49 30 8062-14888, email: andrei.varykhalov@helmholtz-berlin.de

Abstract: Article describes instrumental features of the 1^2-ARPES endstation and beamline at BESSY-II which are relevant for planning and preparation of experiments.

1 Introduction

The 1^2 angle-resolved photoemission station is the more versatile setup than the low-temperature 1^3 system. While it receives light from the same beamline and is equipped with a very high resolution electron energy analyzer, it sacrifices the ability to reach the lowest temperatures in favor of a much more flexible 6-axes manipulator allowing for better navigation in the reciprocal space of the band structure.
The endstation is equipped with Scienta R8000 spectrometer especially designed for low-kinetic energy measurements. Analyser is equipped with 2D MCP detector allowing for parallel detection of multiple emission angles of the photoelectrons and can be operated in three modes corresponding to acceptance angles of 30°, 14° and 7°. Slit of the spectrometer (slice in the reciprocal space along which the band structure dispersion is acquired) is vertical. See chamber design in Figure 1 and Figure 2 for reference. Such configuration allows to measure photoemission maps by scanning polar angle of manipulator (rotating sample around its vertical axis) with high precision. Resolutions of the analyser can go down to 0.1° (angular) and 1 meV (energy).
The endstation is equipped with LHe-cooled 6-axis manipulator "Cryoax 6" of IFW-Dresden type (Figure 3). It has three linear axes of sample translation (X,Y,Z) and three axes of sample rotation: Polar (rotation around vertical axis), Azimuth (rotation around sample surface normal), Tilt (rotation around

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horizontal axis). All axes are operated independently. Ranges and accuracies of the axes are summarized in Table 1. Manipulator is motorized and computer controlled.

Axis	Range	Accuracy
X	-25 .. +25 [mm]	0.05 [mm]
Y	-25 .. +25 [mm]	0.05 [mm]
Z	0 .. 600 [mm]	0.1 [mm]
Polar	-160 .. +160 [^{o}]	0.2 [^{o}]
Azimuth	-110 .. +110 [^{o}]	1 [^{o}]
Tilt	-5 .. +15 [^{o}]	1 [^{o}]

Table 1: Ranges and accuracies of sample manipulator axes of “Cryoax 6”.

Peculiar feature of the system is the placement of the preparation chamber on-top of analysator chamber (see Figure 1 and Figure 2). In such geometry both preparation and analysis chambers share the same manipulator. This allows not only to minimize in-vacuo sample transfers in the case of in-situ preparation, but also permits deposition from the evaporators on cold sample and subsequent ARPES measurement without warming up of the sample.
The only disadvantage of such chamber arrangements appears the situation when the samples have to be cleaved: top-posts should not fall down on the valve between chambers and hence have to be bounded to sample holders with a thin conductive wire.
As by the end of 2015 an overall energy resolution of the experiment is limited by 10 meV due to manipulator. Upgrade of manipulator for a more modern one with better mechanical, electrostatic and cryogenic performance is planned in a short term perspective.
The versatility of the system is furthered by two sample handling options: it either be used with copper sample holders (wedge-like IFW-type design) for low temperature applications (down to 25 K) or Omicron sample plates for enhanced sample preparation flexibility (down to 35 K). Switching between sample holder types requires remounting of sample handling manipulators (load-lock arm, sample transfer arm, wobblestick) which, in turn, requires venting of the preparation chamber and its subsequent bakeout. Default configuration is the one for Omicron sample plates which is also used most of the time by the majority of the user groups.
The system is permanently attached to the UE112-PGM-2a beamline which can provide photons in the energy range from 10-250 eV with very high resolution and full control over the polarization.

The station offers:

- preparative sample heating up to 2300 K (only with Omicron-type sample holders)
- moderate temperature heating up to 1000K with precise temperature control (only with Omicron-type sample holders)
- ion sputtering up to 3 keV
- gas line with leak valve for in-situ gas treatment
- a quadrupole massspectrometer
- 5x (4x DN40CF and 1x DN63CF) ports for evaporators. 3x DN40CF ports are gatable and can be used for exchangable evaporators which can be replaced without breaking the vacuum in the preparation chamber
- quarz microbalance for calibration of evaporators’ deposition rate
- deposition from evaporators with subsequent measurements at low temperature
- deposition from evaporators with subsequent measurements at low temperature
- deposition from evaporators on hot samples (only with Omicron-type sample holders)
- DN40CF port for connecting the external vacuum suit case(s) (only with Omicron-type sample holders)
- low-energy electron diffraction (LEED)

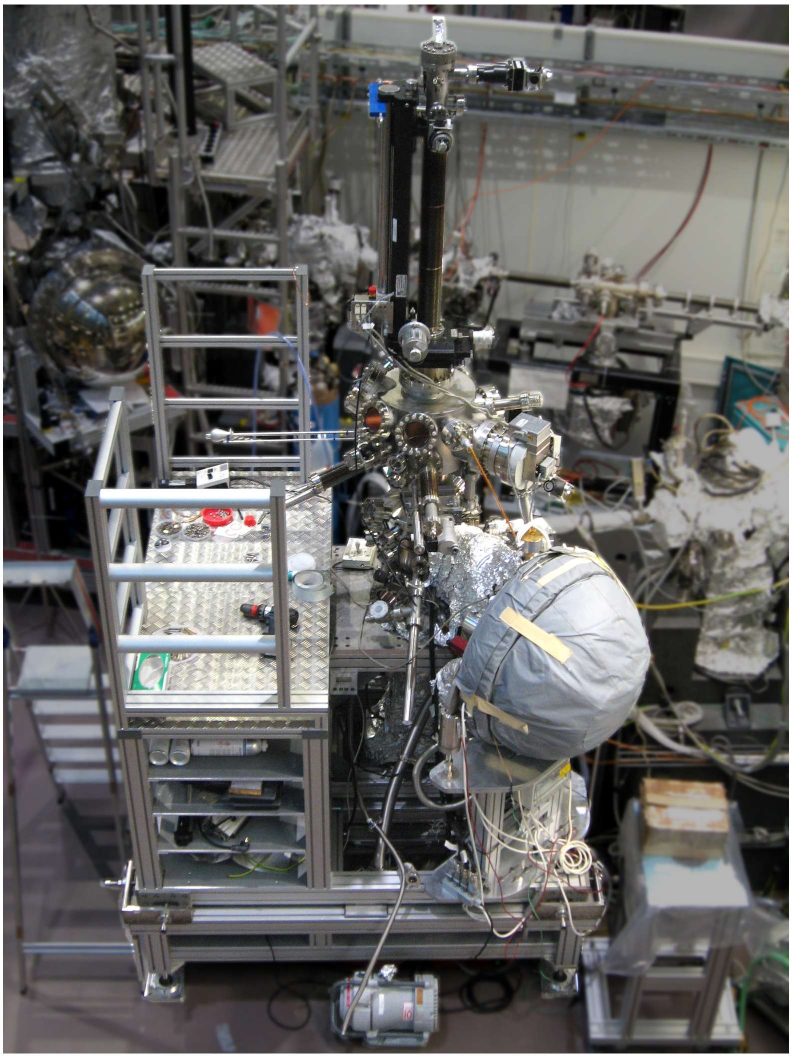

Figure 1: Aerial view of ARPES 12 endstation in experimental hall of BESSY-II.

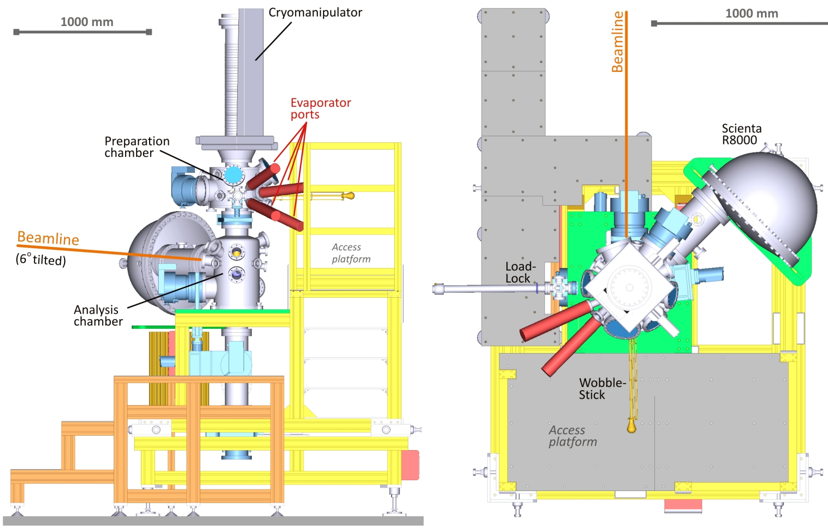

Figure 2: Technical design of ARPES 1^2 endstation. Side and top views.

Figure 3: Cryoax 6 manipulator (designed by IFW-Dresden) adapted for the operation with Omicron-type sample holders.

2 Instrument applications

Typical applications of the ARPES 1^2 Endstation are:

- Topological insulators and Rashba-type systems
- Epitaxial graphene
- High-T_c superconductors
- Metal single crystals and vicinal surfaces
- Thin films and quantum well states

Methodes:

- Angle-resolved photoelectron spectroscopy (ARPES)
- Low energy electron diffraction (LEED)

3 Source

The insertion device is the elliptical undulator UE112 with the following parameters:

Type	APPLE-II
Location	H13
Periode length	112 mm
Periods/Pols	32 n
Minimal Energy at 1,7 GeV	5.4 eV
Minimal Gap	24 mm
Polarisation	linear variable -90° ... +90° elliptical, circular

Table 2: Parameters of the insertion device UE112.

4 Optical Design

Optical design of the UE112 PGM-2a-12 beamline is shown in Figure 4. It is based on low-energy collimated plane-grating monochromator with normal incidence option. The beamline delivers photons in the energy range from 10 to 250 eV. Energy resolution for the photon energies below 100 eV can be tuned down to 1 meV. Horizontal dimension of the focal spot is about 460 μm, its vertical dimension depends on the exit slit setting but is typically about 20 μm.

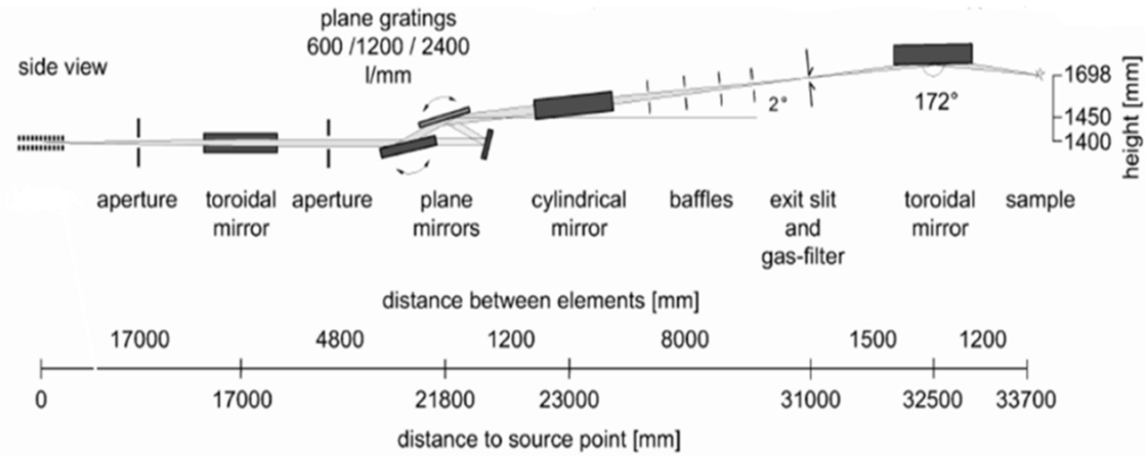

Figure 4: Optical layout of beamline UE112 PGM-2a-12 (by Dr. Rolf Follath).

5 Technical Data

UE112 PGM-2a-12 beamline	
Location	12
Source	UE112
Monochromator	PGM 2
Energy range	10 - 250 eV
Energy resolution	<1 meV for E < 100 eV
Flux	> 10^{13} (photons / s / 100 mA)
Polarisation	• Linear any angle • Circular
Divergence horizontal	1 mrad
Divergence vertical	3 mrad
Focus size (hor. x vert.)	465 x variable μm
Distance Focus/last valve	867 mm
Height Focus/floor level	1685 mm
Free photon beam available	No
Fixed end station	Yes
Phone	+49 8062 14696
1^2 ARPES endstation	
Monochromator	Low energy collimated plane-grating monochromator with normal incidence option
Experiment in vacuum	Yes, base pressure below 1E-9 mbar
Temperature range	Measurement: 25–400 K Preparation up to 2300 K
Analyser	Scienta R8000
Manipulators	Motorized 6 axes manipulator (IFW Dresden design)

Table 3: Technical data of UE112 PGM-2a-1^2 beamline and 1^2-ARPES endstation.

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