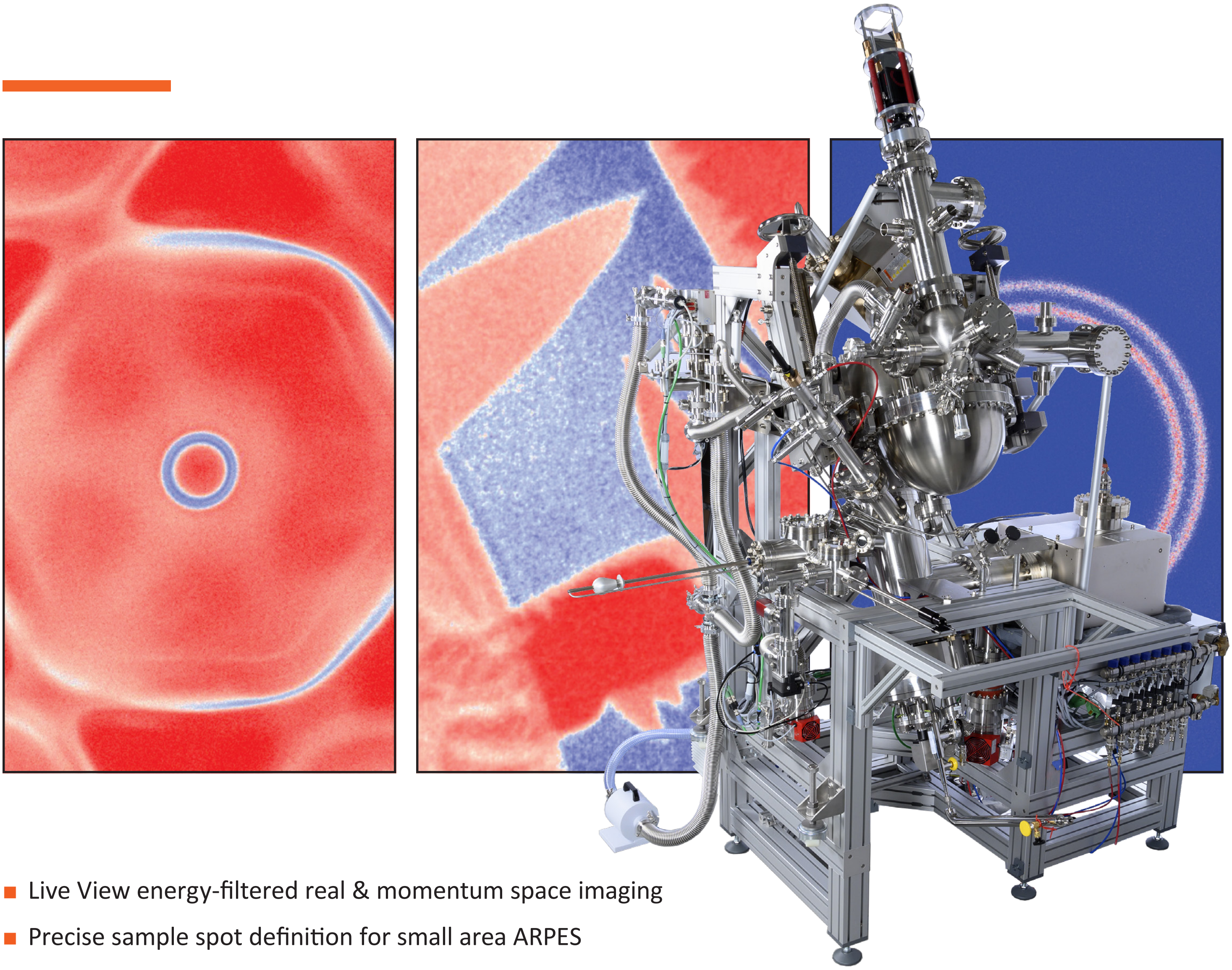
NANOESCA MARIS SYSTEM

Momentum and Real Space Imaging Spectroscopy



- Live View energy-filtered real & momentum space imaging
- Precise sample spot definition for small area ARPES
- One-shot 180° ARPES overview without sample movement
- XPEEM Chemical mapping with very high spatial resolution
- Time of flight (TOF) momentum and real space imaging spectroscopy
- 6-axis LHe cooled sample stage and dedicated light-sources

Photoemission has established itself as one of the leading techniques in material and surface science. In the last decade, 2D k-space imaging or "Momentum Microscopy" has become one of the latest and most promising developments in this field. It allows insight into the electronic band-structure of novel material systems, unveiling useful effects that can have a strong impact in future information technology. In combination with its real-space imaging capability, NanoESCA MARIS is the ideal tool for investigating the physical properties of materials at the nanoscale, thus enabling the development of next-generation nanodevices.

NanoESCA MARIS: Improved performance

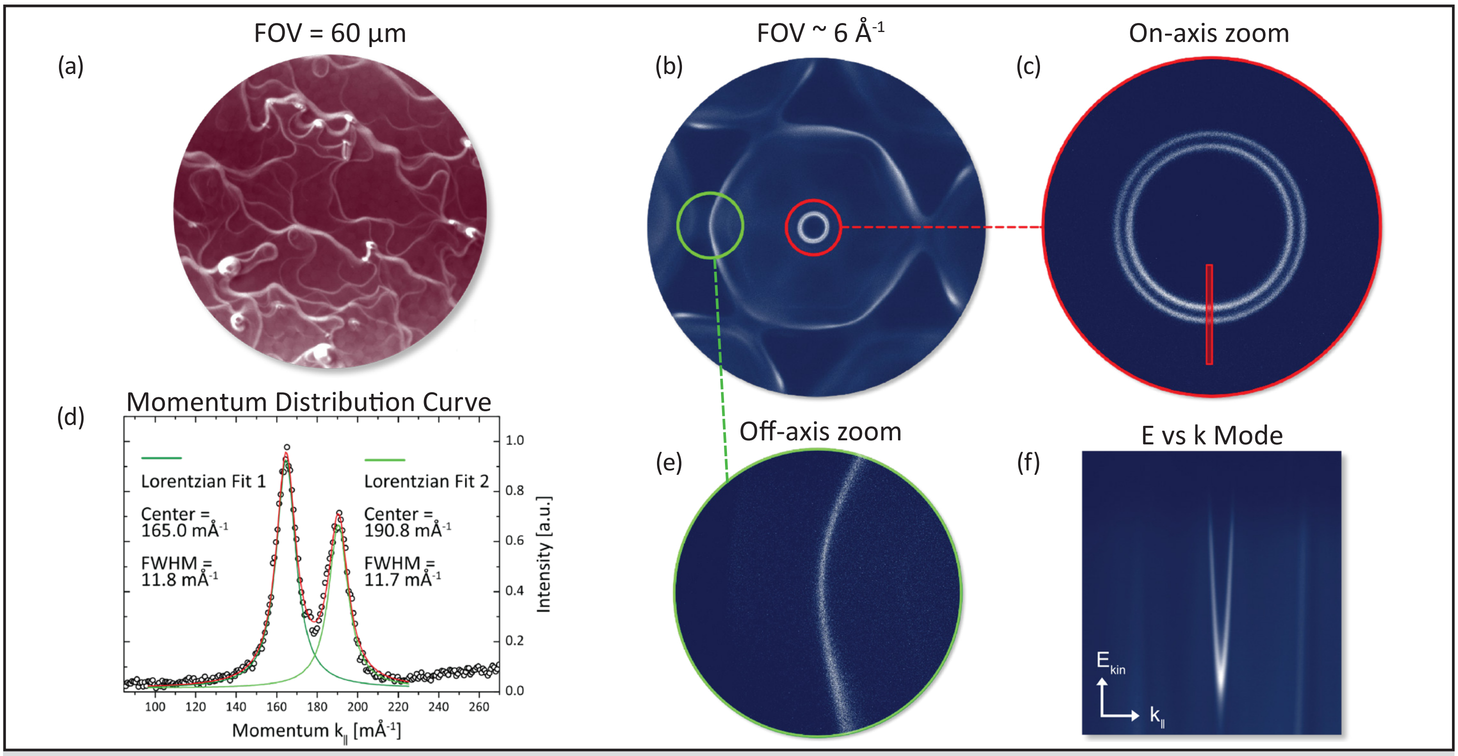


Fig. 1. (a) Real space image of Ag (111) measured in aberration corrected mode. (b) Mamomentum space image of Au (111) taken at the Fermi level. (c) On-axis zoom revealing the Rashba split bands. (d) Line profile taken along the red line in (c) fitted with two Lorentzian peaks. (e) Off-axis zoom onto the edge of the Brillouin zone. (f) Surface state of Au (111) acquired in energy dispersion mode. All band structural data are collected at a sample temperature of 45 K.

The lens system of the NanoESCA MARIS is completely modified as compared to its predecessor (NanoESCA III) in order to achieve a much improved angular/momentum resolution of 0.005 $Å^{-1}$, while keeping the same excellent lateral resolution in real space of < 35 nm. An example of a real space measurement is shown in Fig. 1a. The image is taken on an Ag (111) sample, nicely showing the terrace like structure of the surface. The performance in momentum space is highlighted in Fig. 1 (panels b to f), displaying the band structure of a Au (111) single crystal. Using the NanoESCA MARIS, a complete image of the Brillouin zone can be obtained in a single shot, as shown by the Fermi surface data of Fig. 1b. By zooming onto the zone center (on-axis zoom), the Rashba split surface state is nicely resolved (Fig. 1c). A momentum distribution curve is extracted along the red line and fitted by two Lorentzian peaks (Fig. 1d), demonstrating that the inherent broadening of the spectral bands is considerably larger than the Gaussian broadening caused by the instrumental resolution. More often than not, spectral features away from the center of the Brillouin zone are of interest in ARPES experiments. As such, the new NanoESCA MARIS system allows to zoom onto any point in momentum space and collect band structural data around a desired *k*-point with high-resolution. The off-axis zooming capability is presented in Fig. 1e. In particular instances, there may be the need for a direct measurement of the Energy Dispersion Image. A new mode in the lens system – called the Energy Dispersion Mode – enables the projection of an energy vs. momentum cut directly onto the detector as shown in Fig. 1f.

XPEEM - Chemical mapping

In addition to the standard Hg and VUV sources, a lab-based NanoESCA MARIS system can be equipped with a monochromatized Al kα Xray source. The latter is specially designed to have a focused beam spot on the sample, the size of which can be adjusted between 200 – 900 µm. By upgrading the measurable energy range of the NanoESCA to 1600 eV, chemical mapping of the sample is thus enabled in XPEEM mode. Note that for synchrotron based NanoESCA MARIS systems, the energy range can further be extended to 10 keV, giving the possibility to perform HAXPEEM experiments.

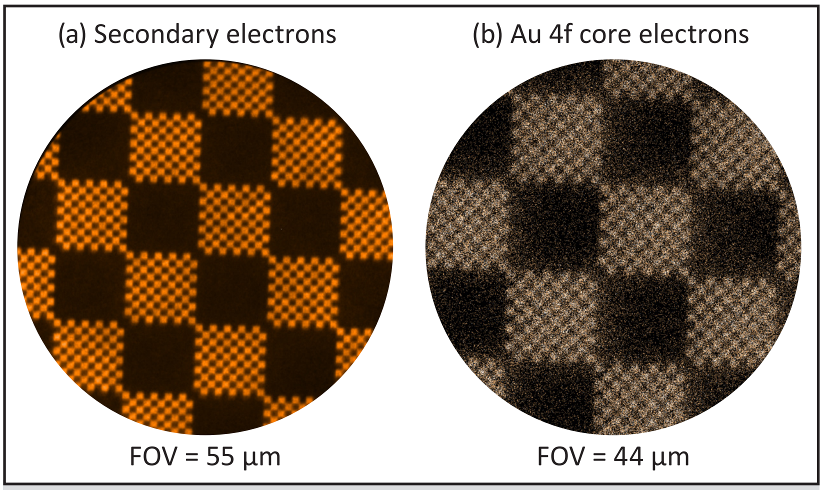


Fig 2. Chessy sample composed of 1 µm square-shaped Au islands on a Si substrate. The XPEEM images are acquired (a) using secondary electrons and (b) using Au 4f core electrons.

In Fig. 2, a "chessy" sample composed of square-shaped Au islands on a Si substrate is measured in XPEEM mode using the focused Al kα Xray source. The small Au squares measure 1 µm each. First, the microscope is focused using secondary electrons at an energy E-EF = 4.55 eV (Fig. 2a). The FOV is set to 55 µm. Then the kinetic energy is tuned to that of the Au 4f core level, i.e., $E-E_F$ = 1402.8 eV (E_{bin} = 83.9 eV), and the chemical map of the sample is measured within a FOV of 44 µm (Fig. 2b). As can be seen the small Au squares are very well resolved in the chemical map. A typical XPEEM image, as the one shown in Fig. 2b, can be acquired within two hours. Depending on the analyzer settings, the same image can also be obtained with better spatial resolution but longer integration time.

Low Temperature NanoESCA manipulator with Hexapod sample stage

For ultimate experimental resolution, it is always desired to cool down the sample. With the newly designed open cycle LHe cooled NanoESCA manipulator, a sample temperature of < 10 K is obtained. The manipulator also hosts a 6-axis hexapod sample stage, enabling a proper in-situ alignment of the sample with respect to the optical axis of the microscope. The specifications of the low temperature hexapod sample stage are given in Fig. 3.

Scan the QR-code to visit our Youtube-channel and see a video of the 6-axis hexapod stage during operation.

or visit https://www.youtube.com/watch?v=izuFVH7A3iw

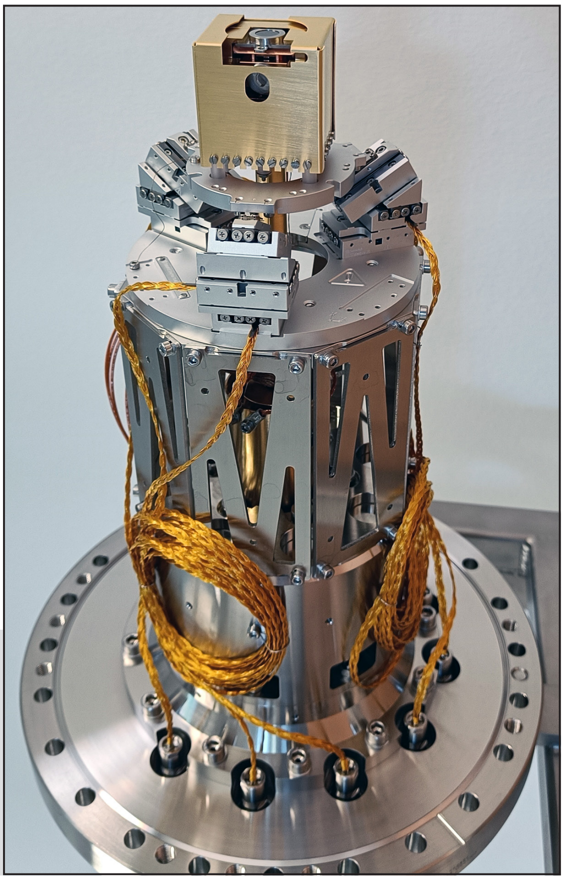


Fig. 3. Low Temperature NanoESCA manipulator with hexapod sample stage.

- Temperature range < 10 K to 400 K
- x and y motion ±5 mm
- z motion > 5 mm.
- tilt along x and y directions > ± 5°
- azimuthal rotation ± 10° (upgradeable to ± 60° with the addition of a goniometer)
- 4 electrical contacts to the sample (optional)

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MARIS TOF-PEEM:

The new MARIS lens setup can be equipped with a Time Of Flight (TOF) imaging energy filter, which is ideally suited for energy filtered low intensity applications with electrons in the low kinetic energy range. Together with a time sensitive imaging Delay Line Detector (2D DLD), a dedicated drift tube and a pulsed light source, the MARIS TOF-PEEM offers a unique detection system.

The detector allows true single electron counting with massive parallel detection and excellent signal to noise ratio. In addition to standard energy filtered TOF PEEM experiments (energy resolution < 30 meV) the detector also allows for time dependent studies with a time resolution of < 160 ps.

Fig. 4 represents a characteristic TOF-PEEM measurement, showing the complete momentum space of an Au (111) surface. During the measurement the sample was kept at room temperature and the excitation source was a pulsed 210 nm laser (80 MHz rep. rate, 200 x 200 μm^2, 17 µW).

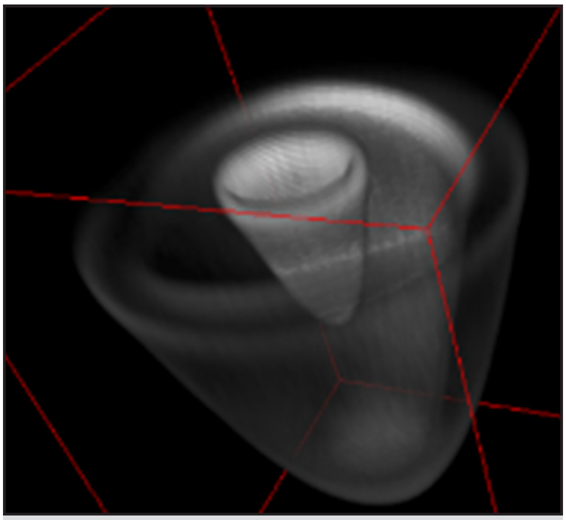

Fig. 4. 3D representation of the complete (E, k_x, k_y) data cube measured by TOF-PEEM. The data is collected from a sampling area of 25 µm at room temperature, using a pulsed 210 nm laser.

Technical Data

Property	Specification
Energy resolution	< 25 meV (15 meV achieved)
Energy range	0-200 eV (up to 10 keV optional)
Momentum resolution	< 0.005 $Å^{-1}$
Momentum space field of view	0.5 $Å^{-1}$ ...6.0 $Å^{-1}$
Angular range	± 90° (full solid angle)
Real space resolution	< 35 nm
Real-space field of view	6...800 µm
Magnetic shielded analysis chamber	Yes
Base pressure, analysis chamber	< 1x10-10 mBar
VUV photon flux density	Up to 1 x 10^{13} ph/s/mm²
VUV beam spot size	< 300 µm
VUV photon line-width	< 2 meV (He I)
Laser/synchrotron port	Available
Manipulator axis	6-axis, motorized
Manipulator temperature range	< 10 K...400 K
MISTRAL System Control	Yes
ProNanoESCA Measurement Software	Yes
Event Counting	Yes

Options:

A wide range of options allow for tailoring the system to the specific needs of individual reasearch. For example:

Light sources:

- HIS 14 HD mono: Monochromatized VUV source
- Monochromatized x-ray sources: Al Kα, 200 µm focus, for chemical imaging
- Sample stage: 4 electrical contacts
- Nano-ESCA extensions: Imaging spin filter
- Extended energy range: 0...1600 eV (for x-ray excitation)
- S-CMOS camera: 100 frames/s
- HAXPEEM energy range: > 10 keV
- Normal incidence mirror: For laser experiments
- Preparation chamber: Available
- Damping legs: Available

FOCUS

The NanoESCA MARIS technology is developed by our partner FOCUS GmbH

https://www.focus-gmbh.com

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