Microscopy with Momentum and Imaging Spin-Filter (Au/Ir)

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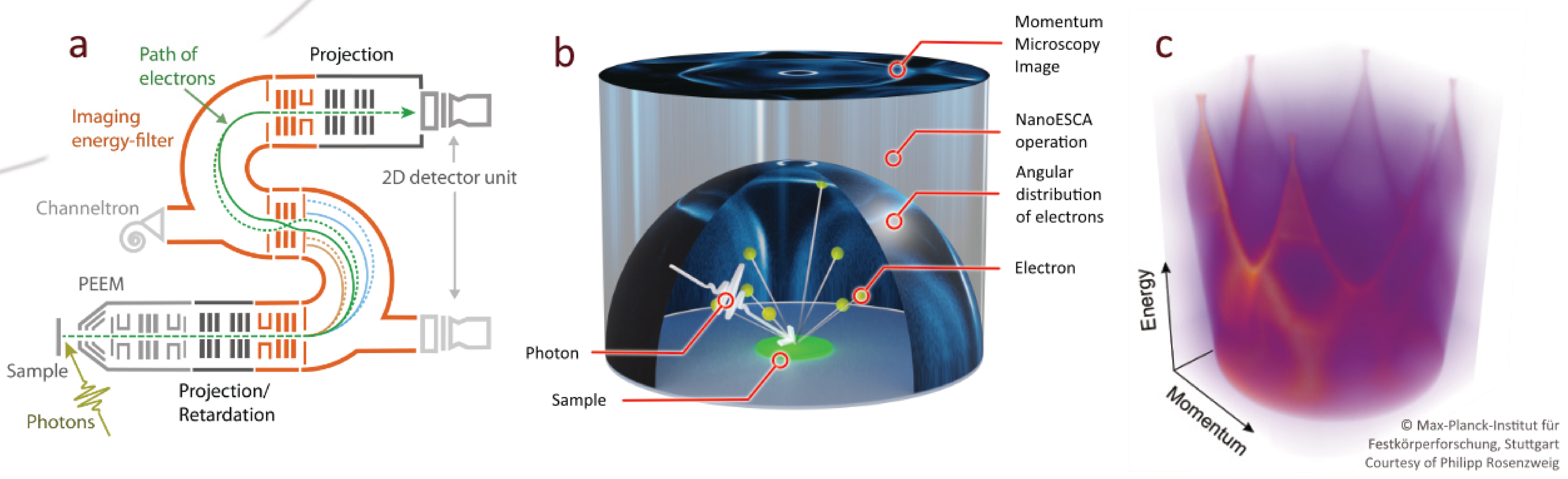
Momentum Microscopy

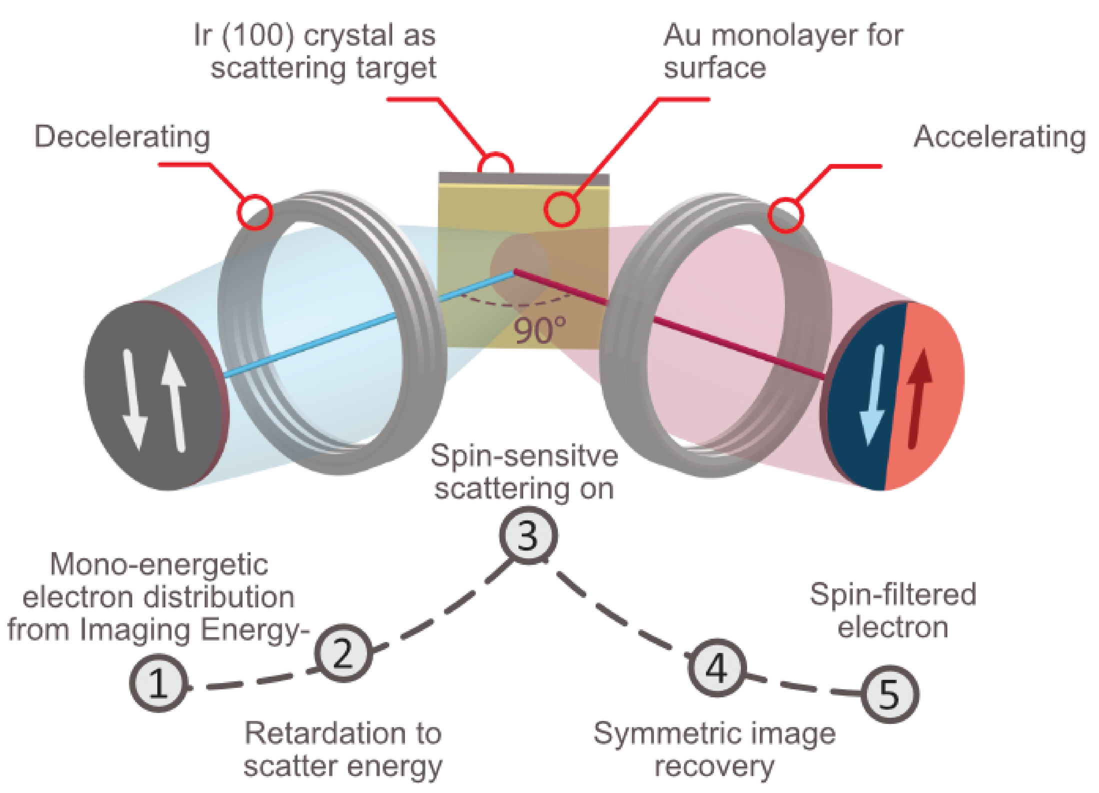


Momentum Microscopy is a new technique in surface science, in which the **momentum** (or the **real-space**) distribution of photoelectrons is projected onto an image plane (b) by using a **photoemission electron microscope** (PEEM) column. In case of momentum imaging the kx-ky plane can be energy-filtered by a double-hemispherical electrostatic analyzer (IDEA[1]) (a) to achieve a monochromatic momentum distribution. The ability of the method to map the complete angular distribution of photoelectrons is successfully used for photoemission **orbital tomography** (e.g. at the **NanoESCA in Trieste** [1]). Scanning the filter-energy of the NanoESCA allows to map the band structure of novel materials (c).

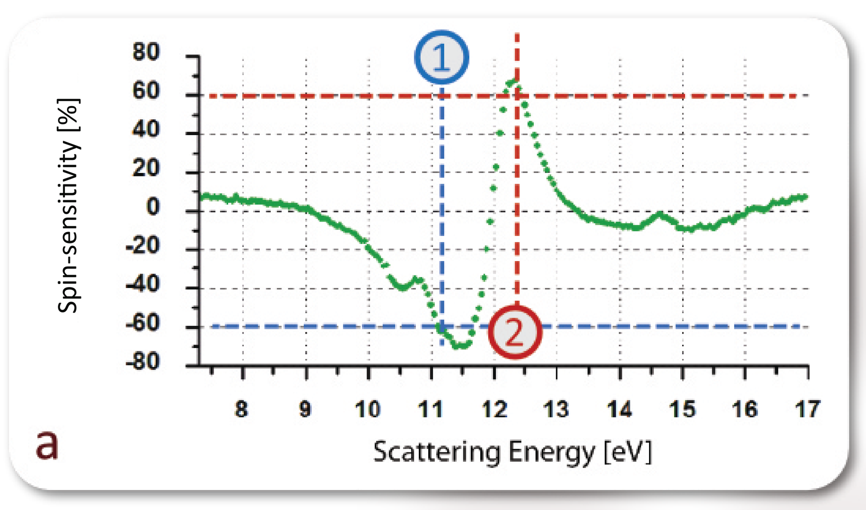
[1] M. Wießner et al., Nature Comm.5 4156 (2014)

Spin-Filter working principal

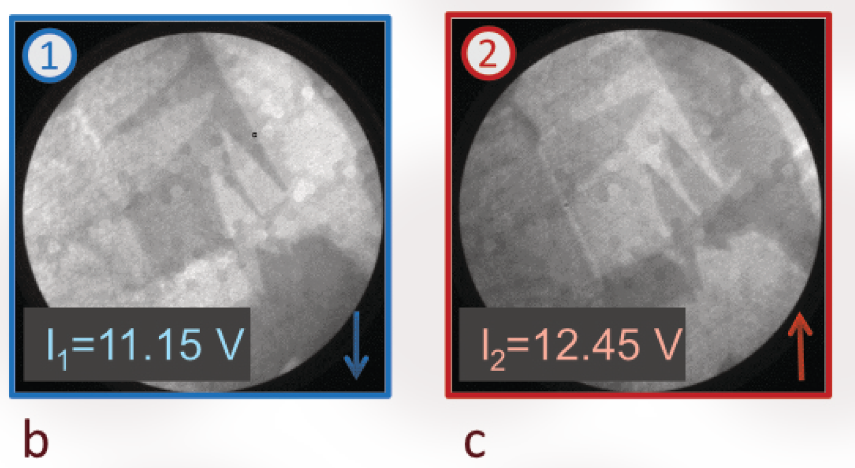
The **monochromatic image** delivered by the **Imaging Energy-Filter**[2] of the **NanoESCA** is projected onto a **Au/Ir crystal**. For specific kinetic electron energies, one **spin polarization** is strongly preferred in the scattering process due to spin-orbit coupling. The reflected image is **spin-filtered**. The **Au passivated surface** of the Ir crystal keeps the scattering conditions **stable for weeks**.



The asymmetry of IV-curves of the Au/Ir (100) crystal and optimal scattering energies

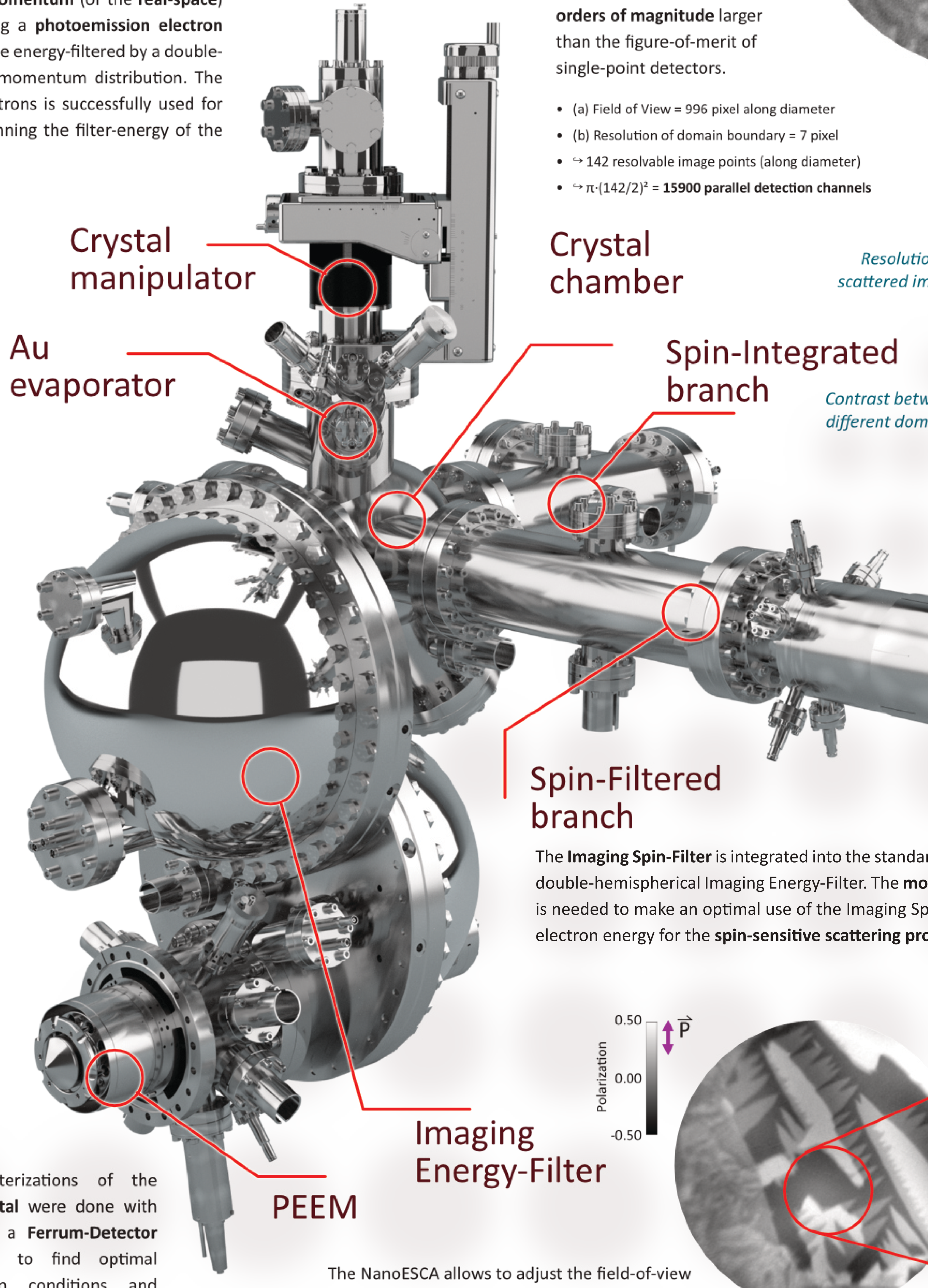


Images at both scattering energies (FoV 66 µm)



Pre-characterizations of the **Au/Ir crystal** were done with LEED and a **Ferrum-Detector** setup [1] to find optimal preparation conditions and scattering energies for a high single-point figure-of-merit (with **Spin-sensitivity >60%** and **Reflectivity >1%**) [2]. The I-V-curve in (a) was measured with the Ferrum setup and shows, at which scattering energy the **highest spin-sensitivity** can be reached. Images (b,c) are then acquired at these **two energetically sharp working points** with the **NanoESCA** and are used to calculate the spin-polarization of the complete field-of-view.

[1] Escher, et al., e-J. Surf. Sci. Nanotech. Vol. 9, 340-343 (2011)
[2] C.Tusche et al., Ultramicroscopy 159, 520–529 (2015)

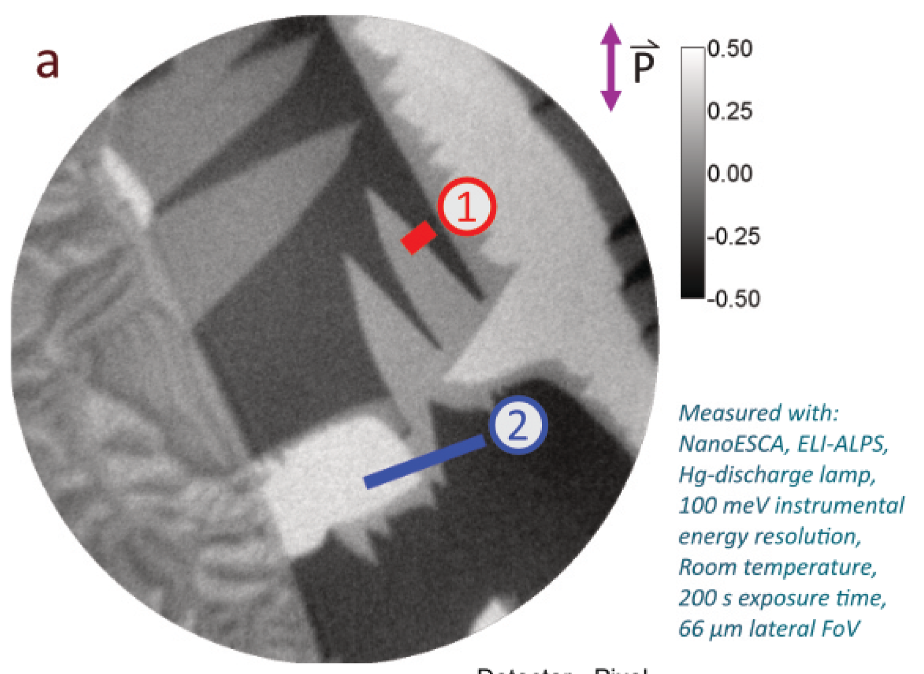


Spin-polarization imaging of magnetic domains of poly-cristalline iron

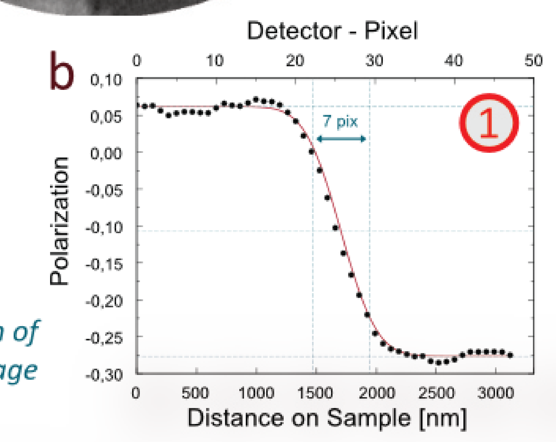
Parallel detection of spin-channels

The already high single-point figure-of-merit (Sherman function > 60% and Reflectivity > 1%) is multiplied by the amount of **parallel detection channels** given in the imaging spin-filter to define an effective 2D figure-of-merit. It is **4 orders of magnitude** larger than the figure-of-merit of single-point detectors.

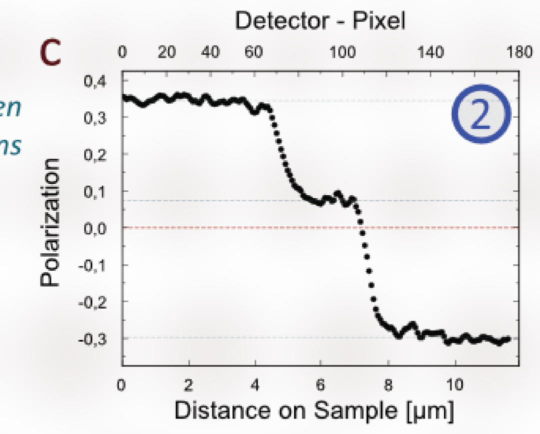
- (a) Field of View = 996 pixel along diameter
- (b) Resolution of domain boundary = 7 pixel
- ↪ 142 resolvable image points (along diameter)
- ↪ π·(142/2)² = **15900 parallel detection channels**



Measured with: NanoESCA, ELI-ALPS, Hg-discharge lamp, 100 meV instrumental energy resolution, Room temperature, 200 s exposure time, 66 µm lateral FoV



Resolution of scattered image

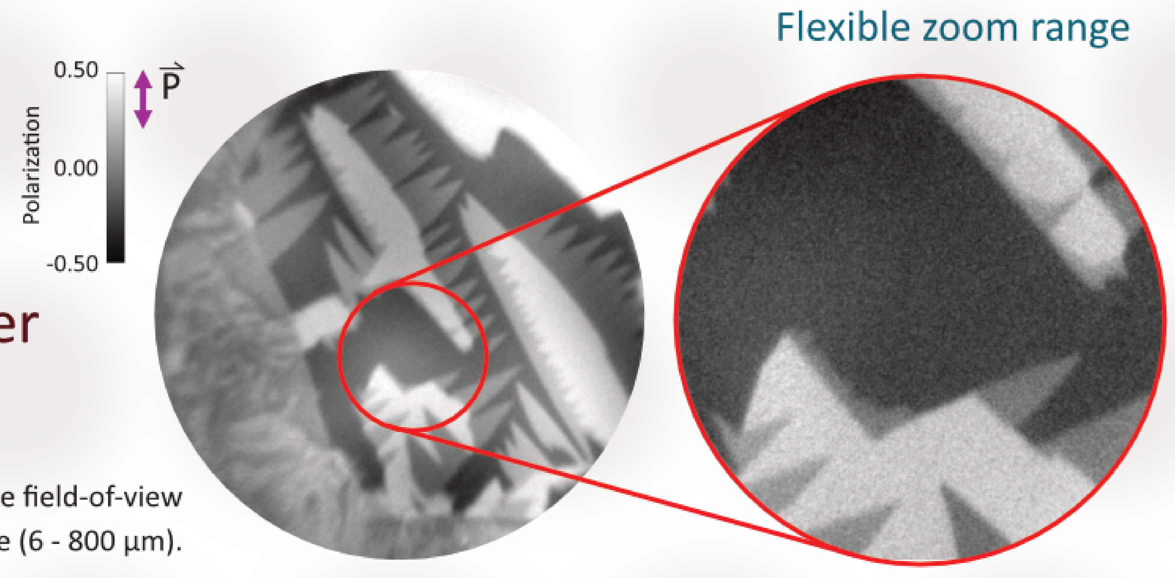


Contrast between different domains

Spin-Filtered branch

The **Imaging Spin-Filter** is integrated into the standard **NanoESCA III** analyzer, directly behind the double-hemispherical Imaging Energy-Filter. The **monochromatic image** behind the Energy-filter is needed to make an optimal use of the Imaging Spin-Filter, which needs a very defined kinetic electron energy for the **spin-sensitive scattering process**.

Flexible zoom range

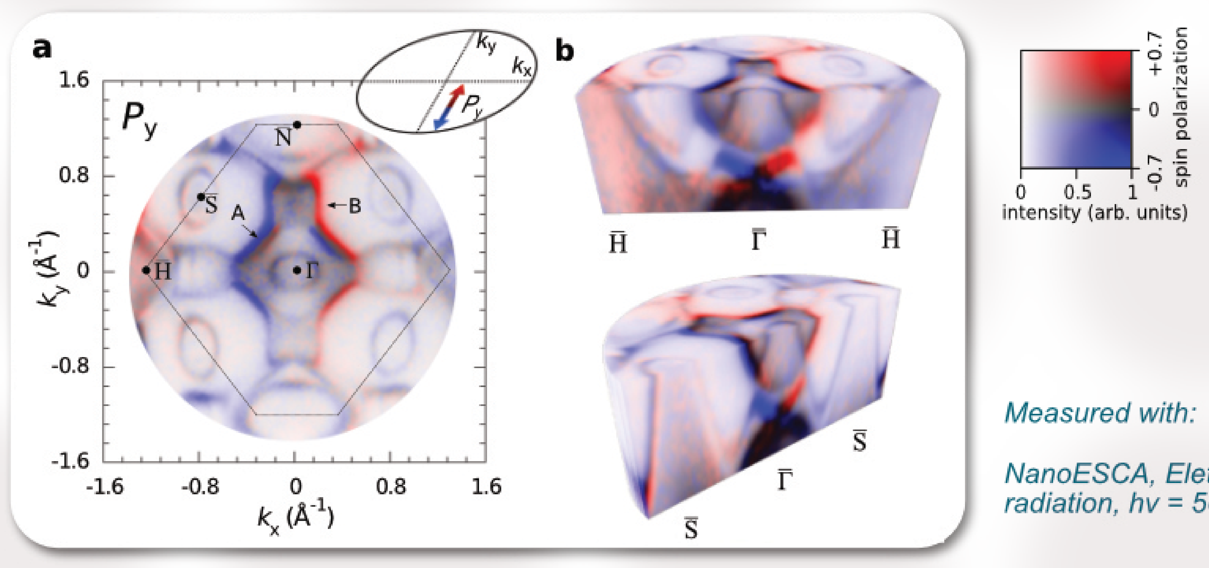


The NanoESCA allows to adjust the field-of-view over a wide range (6 - 800 µm).

Field of view 130 µm — Field of view 36 µm

Spin-Filtered band structure mapping

Adapted from: Ying-Jiun Chen, Christian Tusche et al., Comm. Phys. (2021) 4:179 (CC-by 4.0 License)



The Imaging Spin-Filter works in the momentum microscopy mode in the same way as in the real-space microscopy mode. The graphic shows the spin-resolved Fermi surface of W(110) (a) as well as full 3D spin-resolved momentum maps (momentum vs. binding energy) (b). Note, that a W (100) crystal was used as scattering target in this experiment.

Measured with: NanoESCA, Elettra (Trieste, Italy), Synchrotron radiation, hν = 50 eV, p-polarized, T = 130 K