Data processing: a concrete example from NanoESCA endstation @ ELI-ALPS

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SZÉCHENYI 2020
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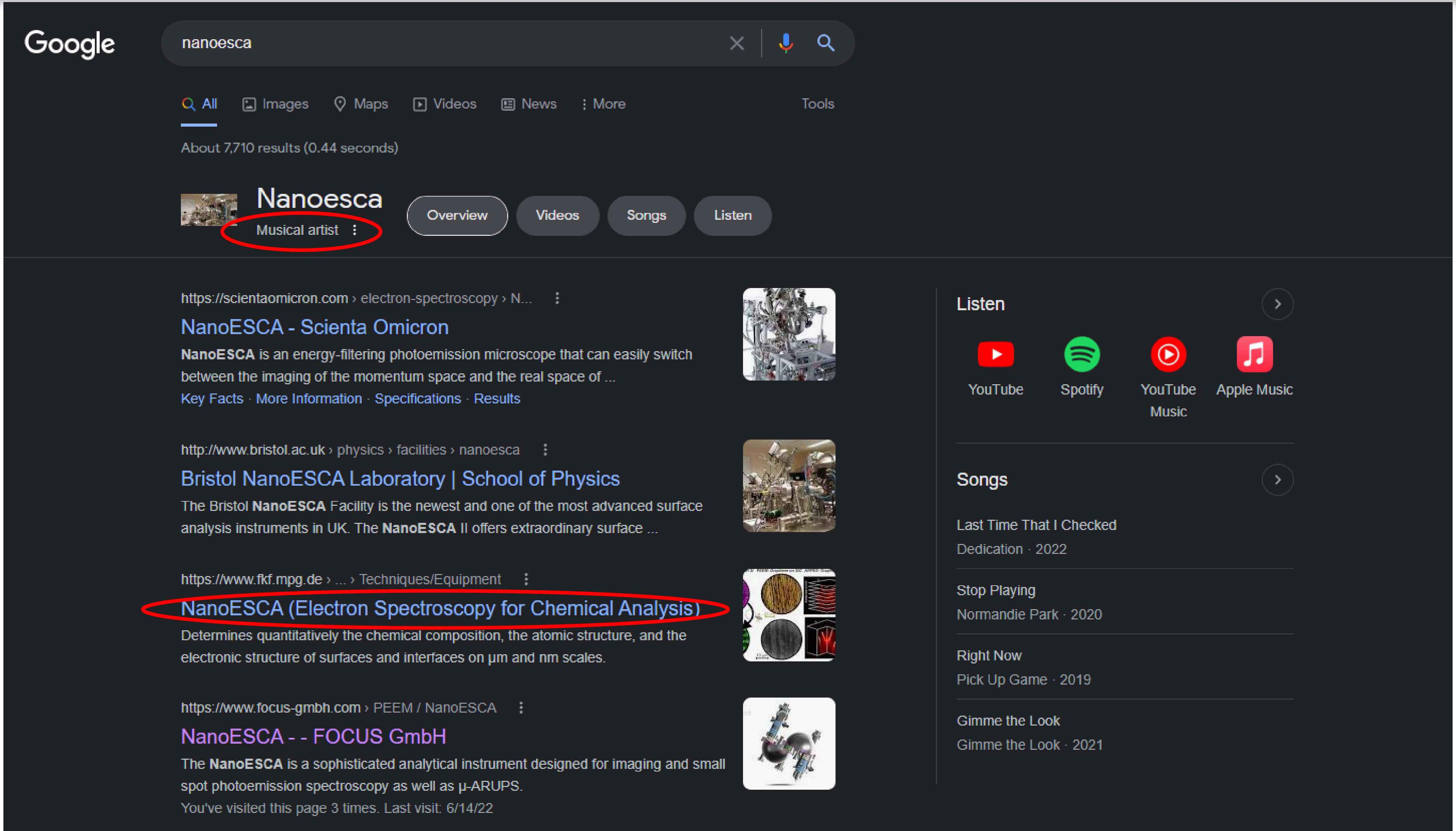
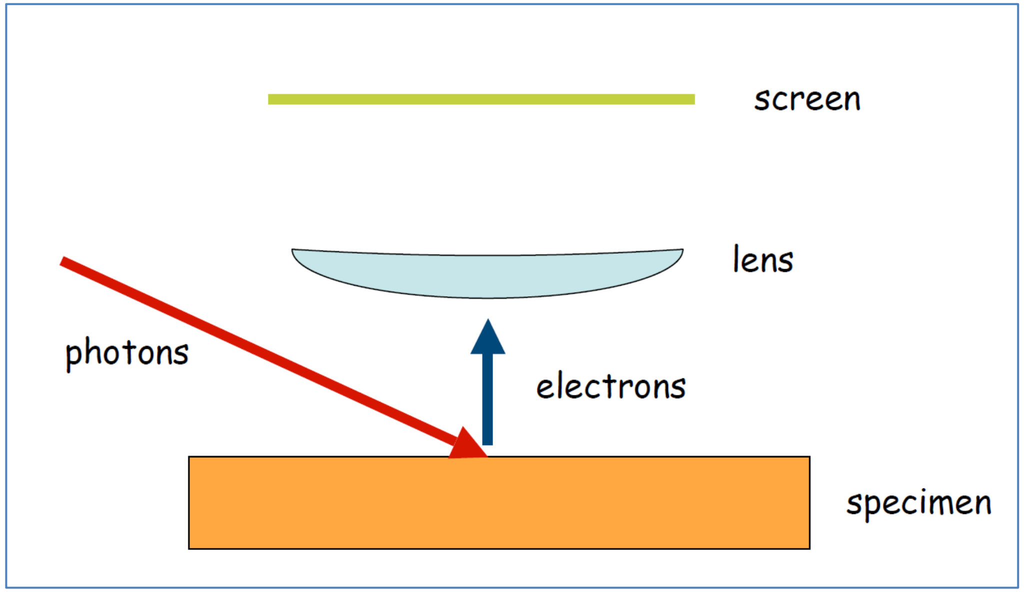
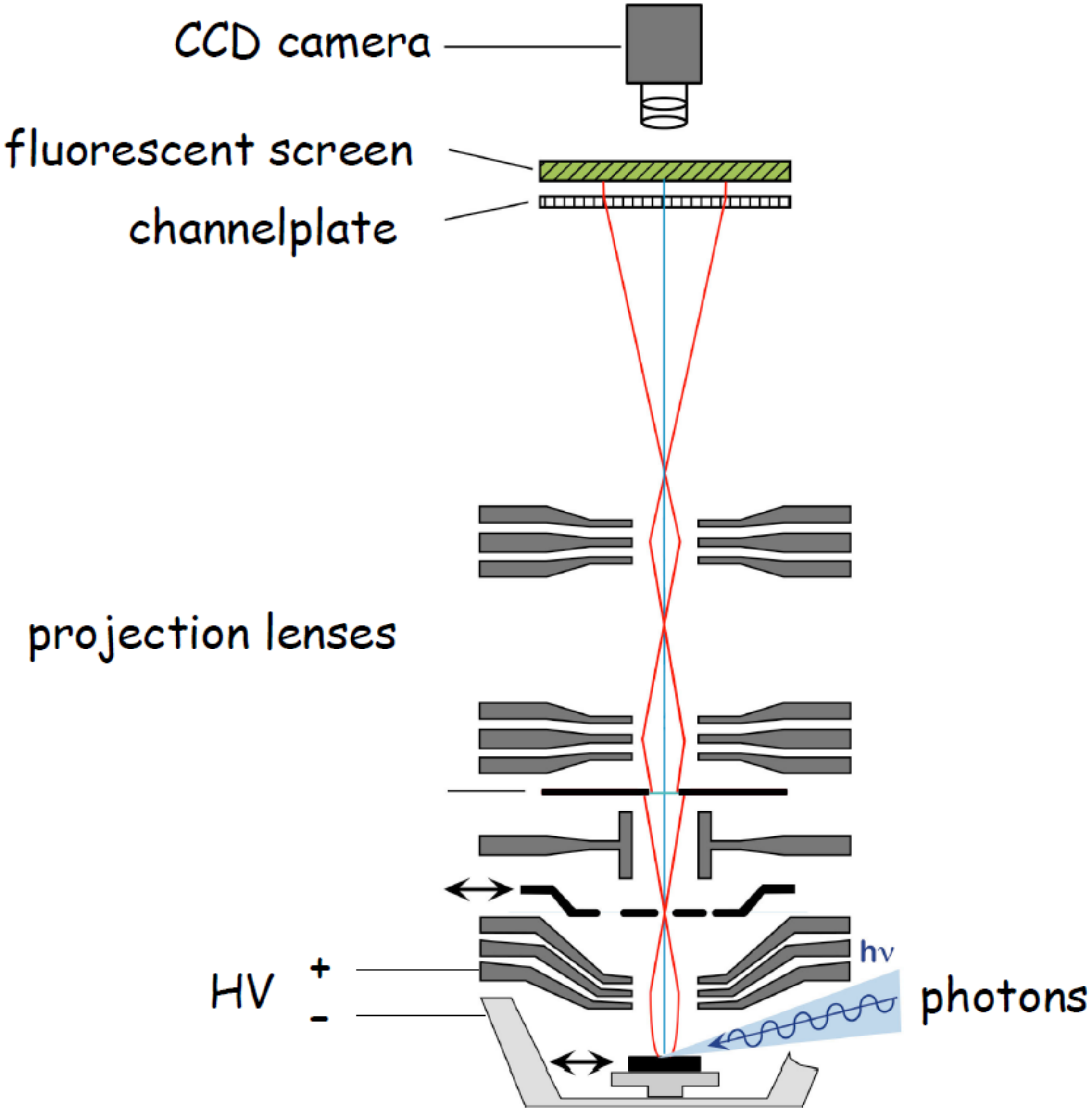
NanoESCA - Google

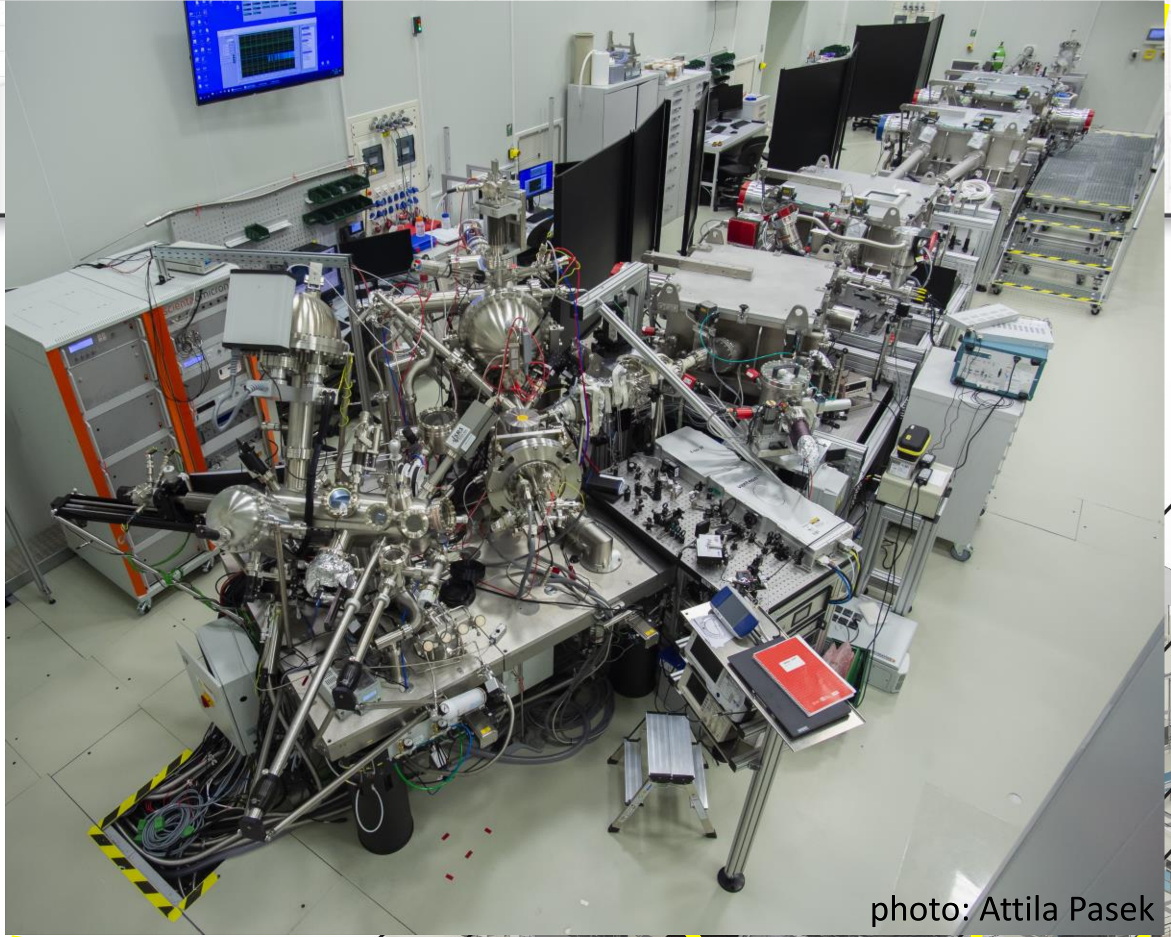


Photoemission electron microscope - PEEM



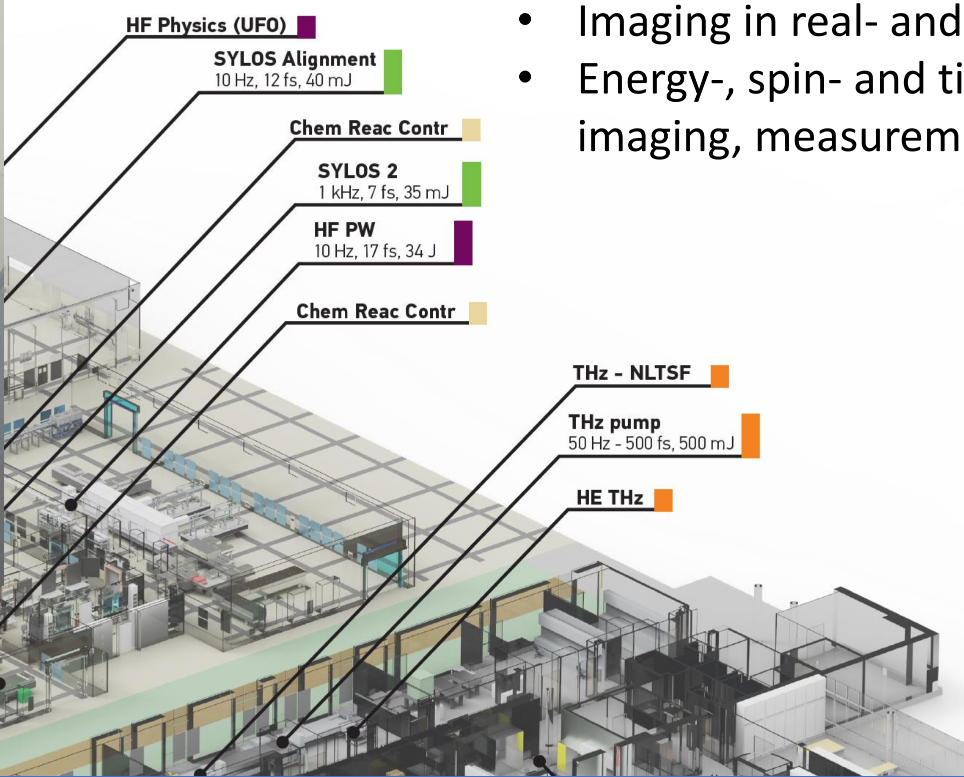


NanoESCA endstation & beamline



NanoESCA endstation: a complex photoelectron spectro-microscope

- Imaging in real- and momentum space
- Energy-, spin- and time resolved imaging, measurements



Photon sources						
IR Pump (HR1 laser)		**XUV source - probe**				**Venteon oscillator**
Wavelength	1030 nm (1.2 eV)	Spectral range of GHHG (with monochromatized option)	17-30 eV (Xe, Kr)	25-55 eV (Ar)	70-90 eV (Ne)	830 nm (1.6 eV)
Repetition rate	100 kHz	Pulse energy at end station for attosecond pulse trains	15-50 pJ	5-25 pJ	3-10 pJ	80 MHz
Average power	100 W	Pulse energy at end station for isolated attosecond pulses	5-15 pJ	3-8 pJ	1-3 pJ	300 mW
Pulse energy	>1 mJ					~2.5 nJ
Pulse duration	6.2 fs					<6 fs (CEP stabilized)

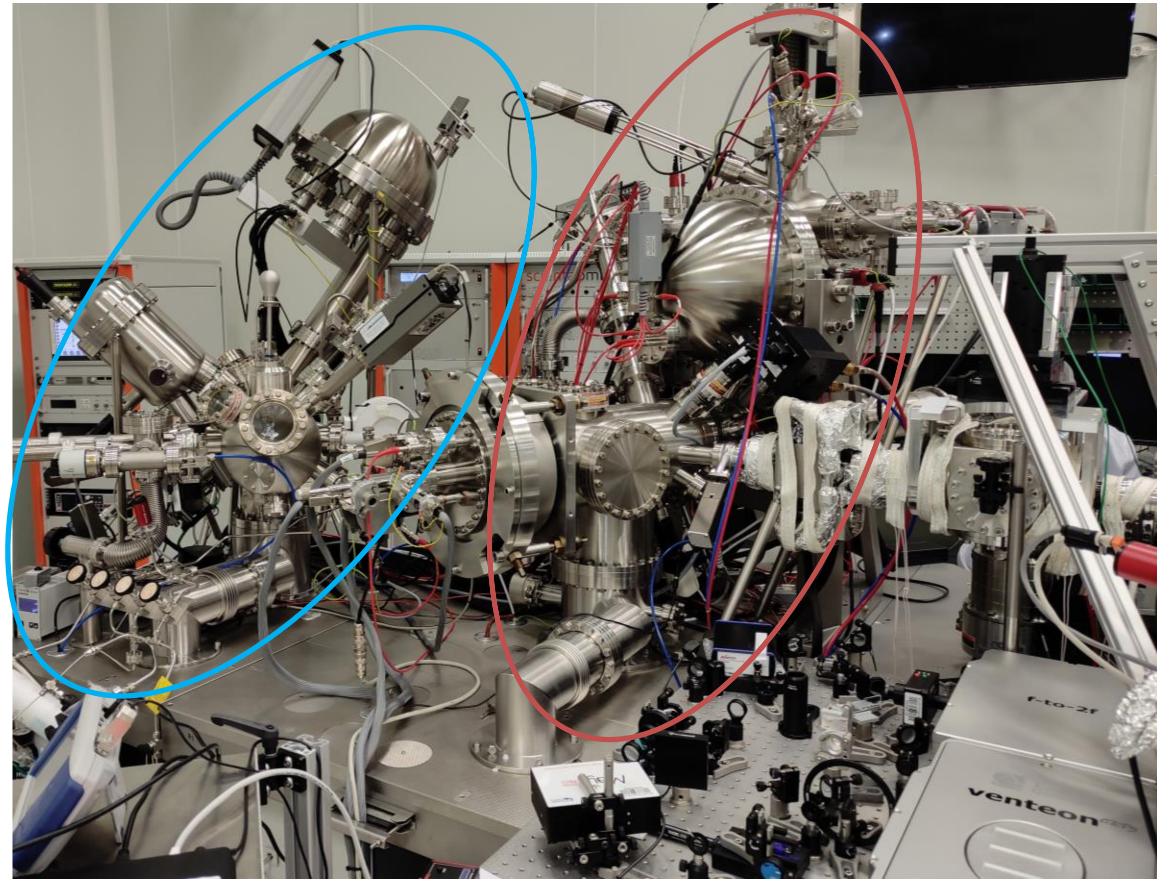
NanoESCA end-station

Preparation chamber
sample cleaning, preparation, and characterization

Cleaning:
- Ar^+ ion sputtering
- Annealing (heat- and coolable manipulator)

Preparation:
- **e-beam evaporator** for metal deposition
- **gas dozer** based on a capillary array
- **magnetizer**
    - Helmholtz coil
    - B field: up to 43 mT

Characterization (laterally averaged):
- **LEED** (Low Energy Electron Diffraction): determination of surface structure
- **AES** (Auger Electron Spectroscopy): determination of surface composition
- **XPS** (X-ray photoelectron spectroscopy):
    - **quantitative chemical analysis of the surface** (top few nm)
    - monochromatic Al K_α X-ray source
    - 128 detection channels
- **RGA** (Residual Gas Analyzer) by quadrupole mass spectrometer



Analysis chamber
NanoESCA – nano- Electron Spectroscopy for Chemical Analysis

Modes (outputs):

PEEM: Photoemission electron microscope

ToF-PEEM: Time of flight + DLD analyzer (delay line detector)

Spectroscopy for selected area: Channeltron detector after first hemisphere

IDEA: Imaging with dispersive energy analyzer

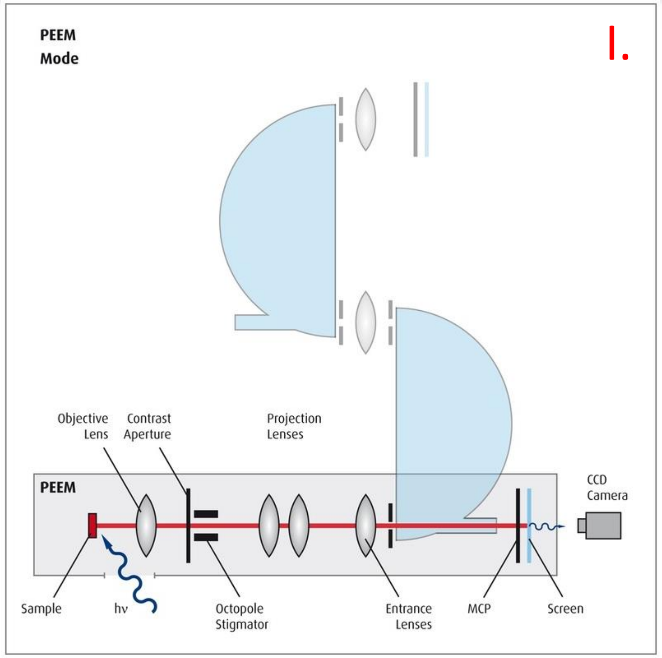
Imaging spin filter: IDEA + spin selective mirror: gold coated Ir(100) crystal

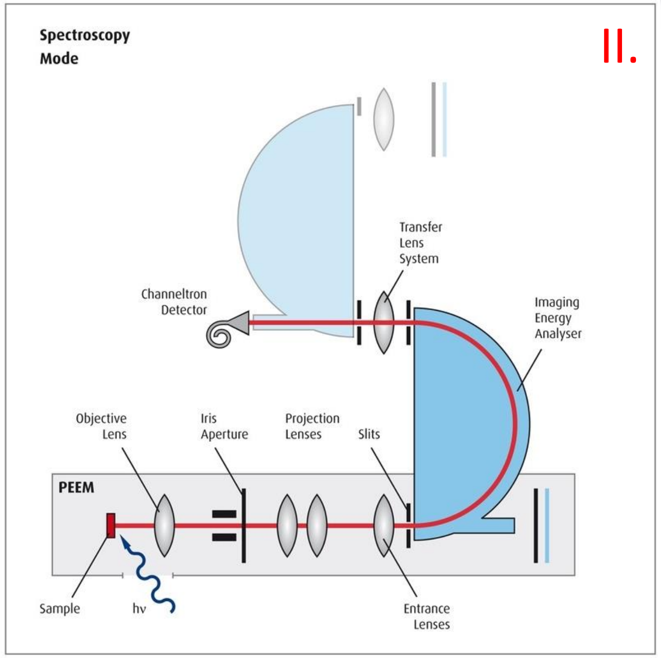
Light sources:

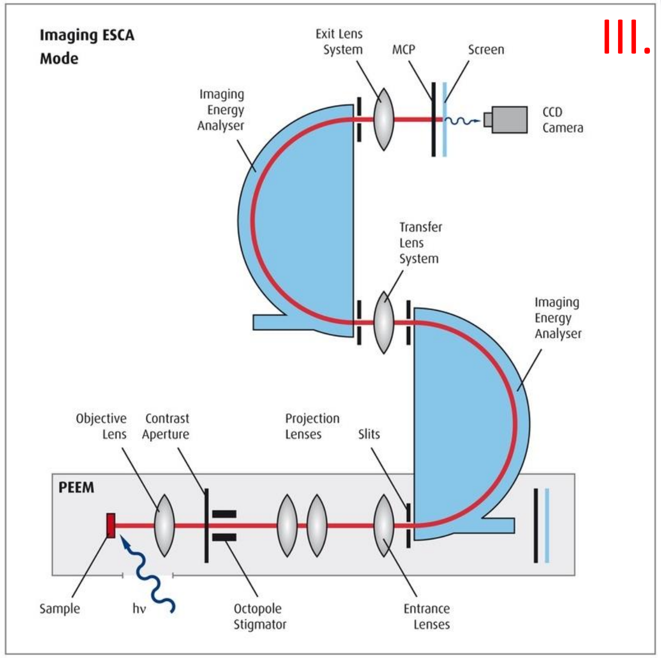
Internal (CW) sources:
- Hg arc lamp (5.2 eV – 238 nm)
- He discharge lamp
    - HeI: 21.22 eV – 58 nm
    - HeII: 40.81 eV – 30 nm

Short pulsed sources:
- pump: HR laser fundamental (1.2 eV – 1030 nm)
- probe: GHH generated XUV (20-90 eV – 62-13.8 nm) (BeamLine condensed)
- Venteon CEP5 oscillator (1.5 eV – 830 nm)

Operating modes I-III. & provided data of NanoESCA



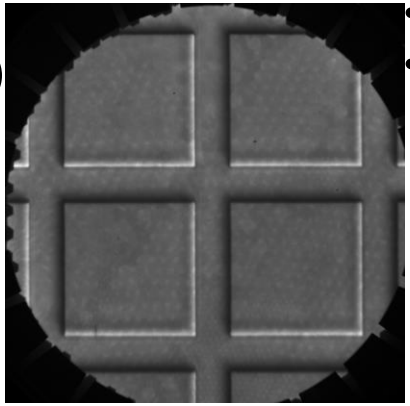




I. PEEM (Photoemission electron microscope) - imaging WITHOUT energy filtering:

Outputs:

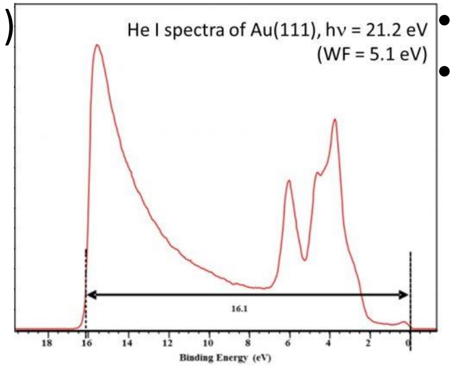
- single images (1MP, 16 bit)
- metadata (ASCII)



II. Spectroscopy mode

Outputs:

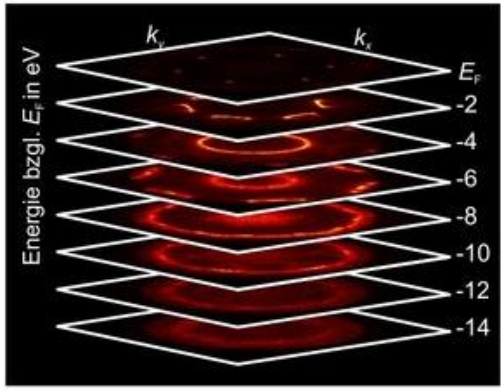
- laterally averaged spectra
- metadata (ASCII)



III. Imaging with dispersive energy filtering mode (IDEA)

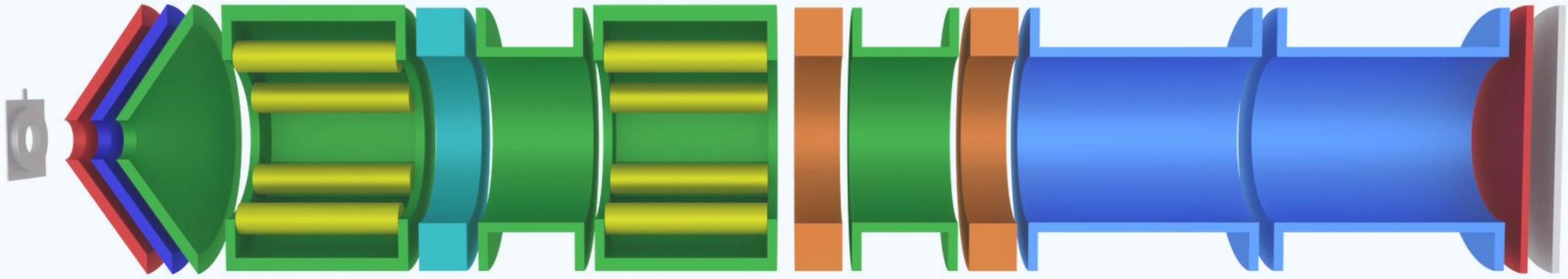
Outputs:

- images stacks (~900)
- metadata (ASCII)



ToF-PEEM & spin-filter

IV.

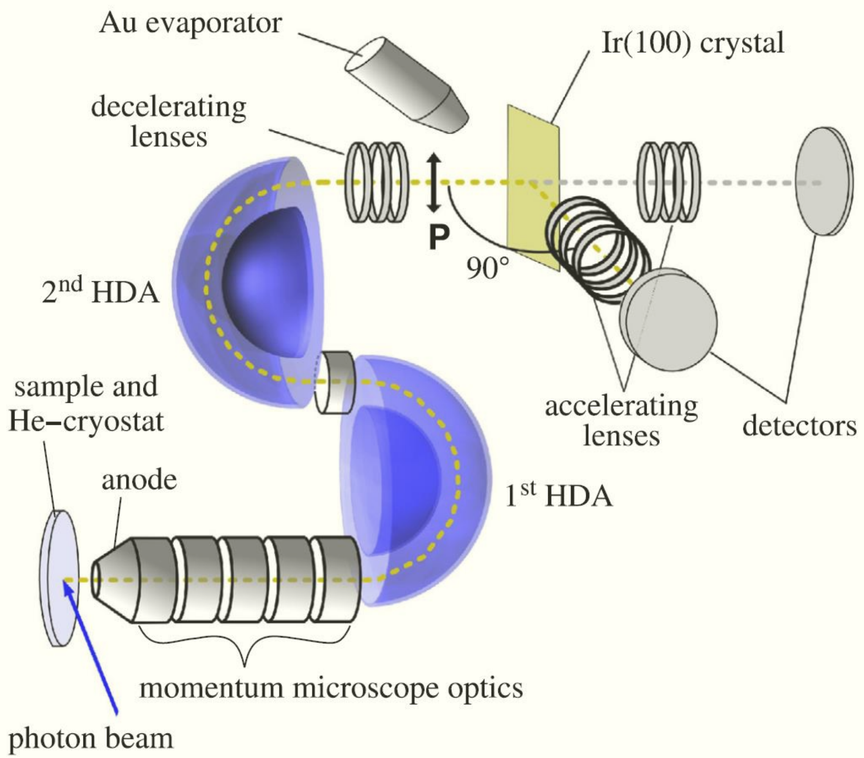


IV. ToF - PEEM (Time of flight analyzer with imaging (delay line detector - DLD))

Outputs:

- image stacks (~900 images)
- metadata (ASCII)

V.



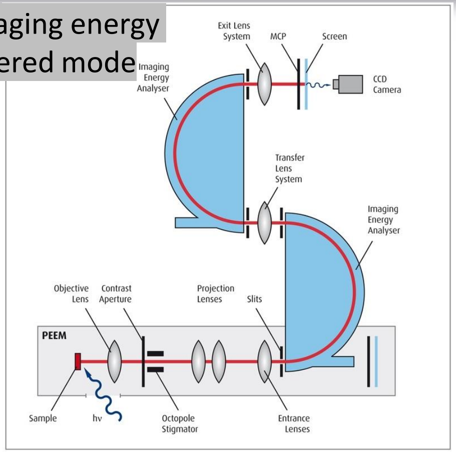
V. Spin filtered mode

Outputs:

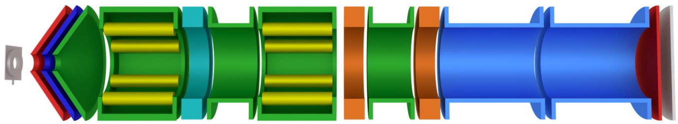
- images stacks (2 spin orientations)
- metadata (ASCII)

Real space vs. momentum space

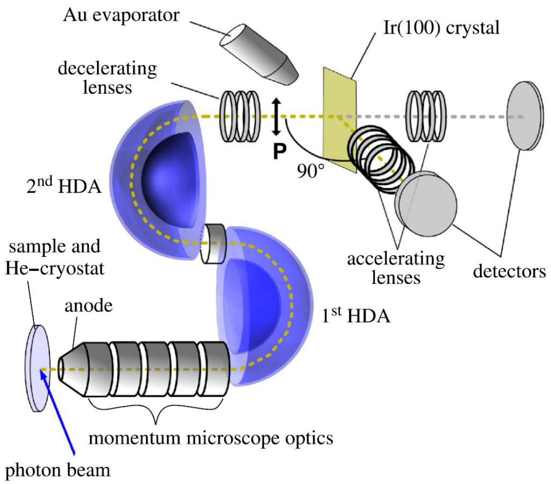
Imaging energy filtered mode

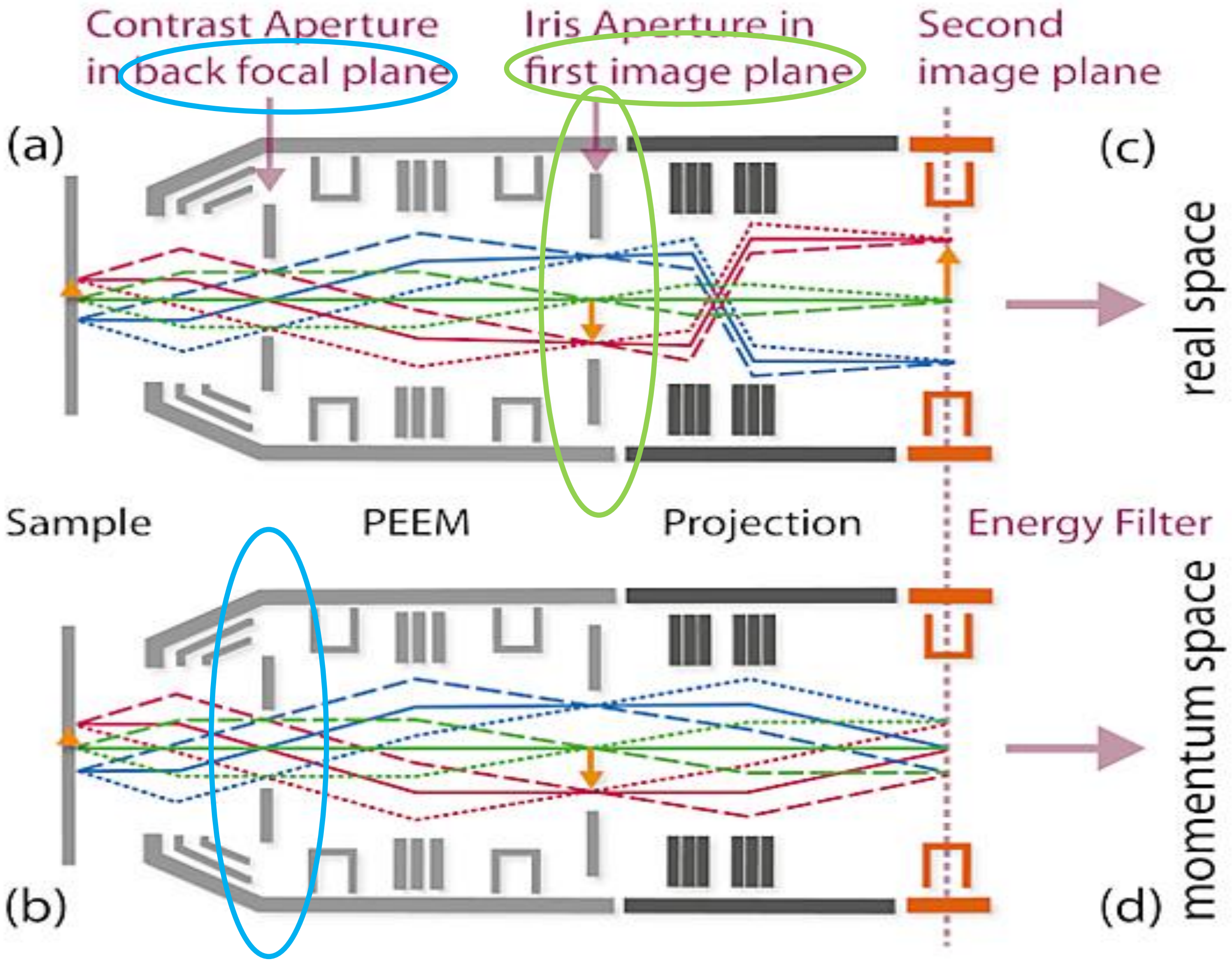


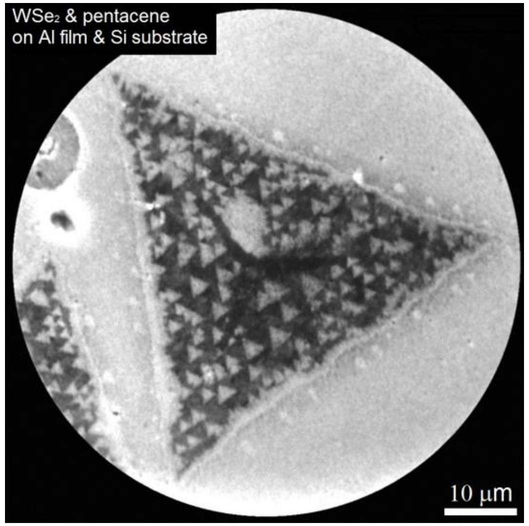
ToF – PEEM mode

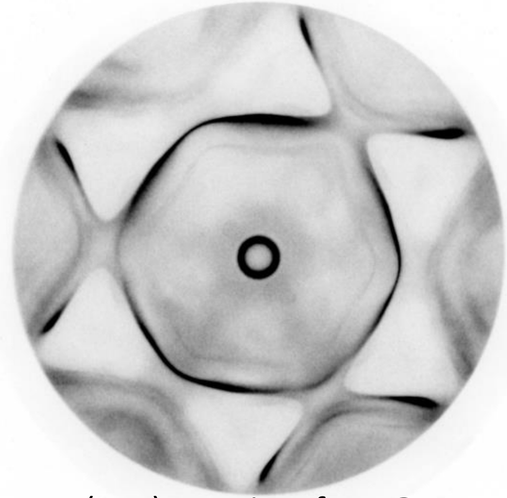


Spin filtered mode



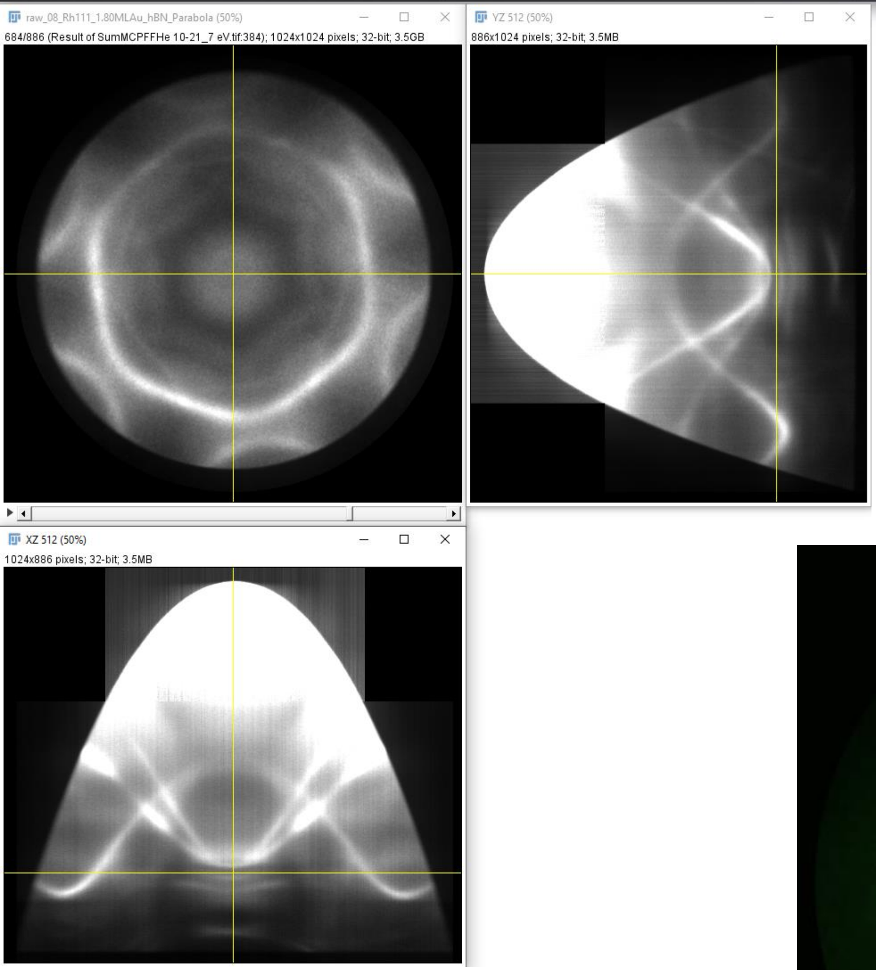


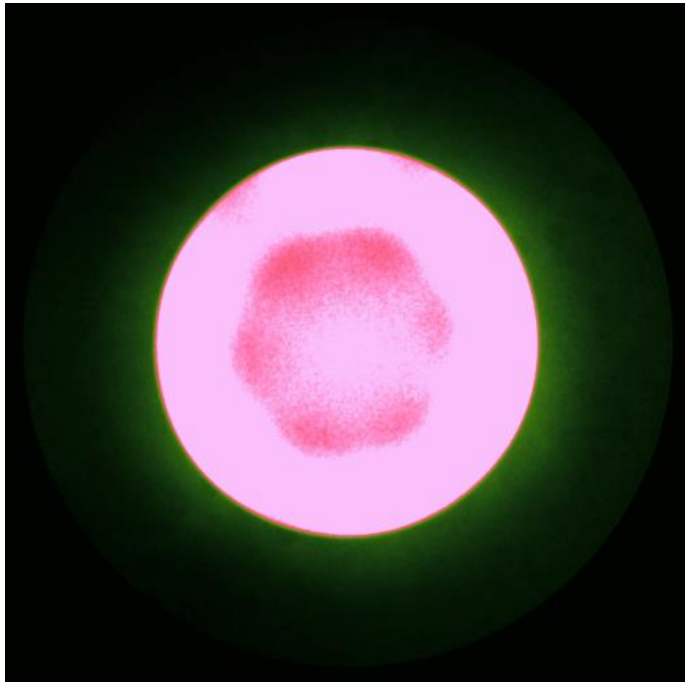


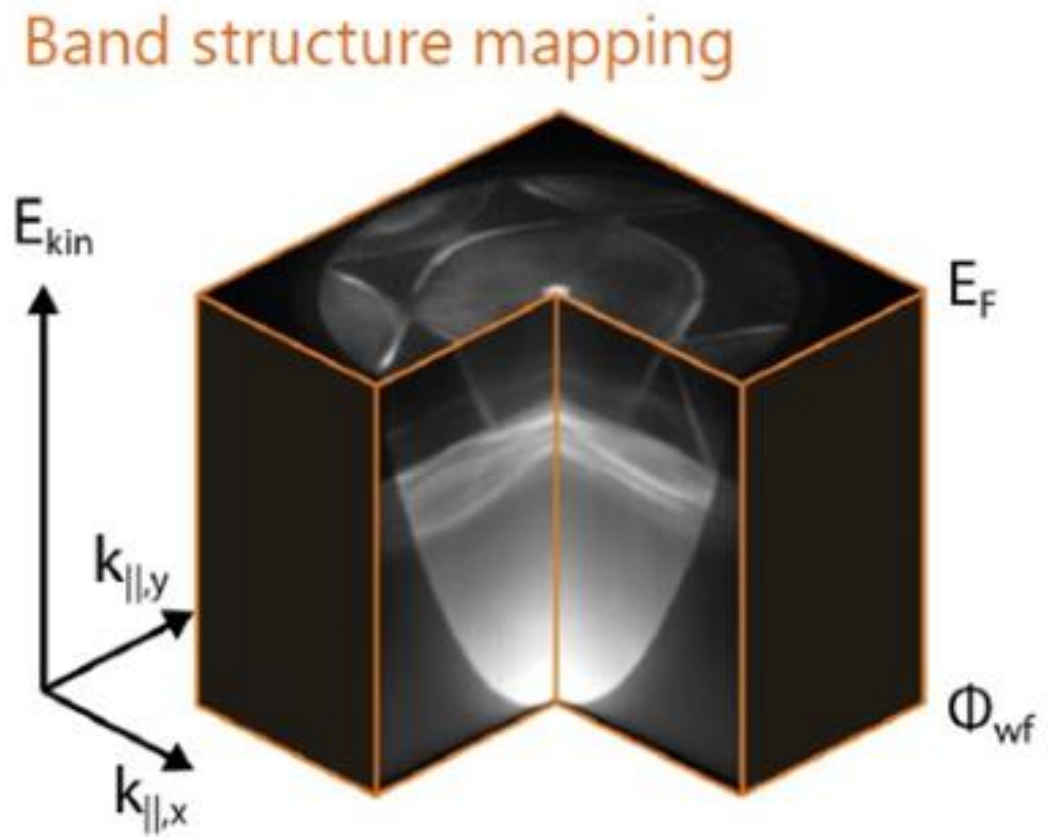


Au(111) Fermi surface @117 K

Band structure







Metadata connected to a NanoESCA in different phase of the project

Initiation and project preparation phase:

- Experimental plan – planned parameter scans, conditions, etc.
- Sample preparation recipes & sample handling @previous studies & users’ knowhow
- Results of preliminary simulations – if relevant

Sample preparation phase:

- Sample preparation metadata & laterally averaged measurement data @LEED PC & XPS PC & handwritten notes – e-LogBook

Experimental phase:

- Automatically stored NanoESCA metadata in an ASCII files @NanoESCA PC
- Automatically stored environmental parameters @Archiving service of ELI-ALPS
- Further relevant but not automatically stored parameters (e.g. positions/status of manually adjusted components) @handwritten notes & e-LogBook
- Metadata of photon sources (internal lamps & laser & secondary sources) @handwritten notes & e-LogBook

Postprocessing & analysis phase:

- Image corrections, calibrations
- Simulations

Publishing phase:

- Final cross sections selection, filtering, etc.

Metadata of initiation

Sample preparation recipes & sample handling @previous studies & users' knowhow

Example I.

Cleaning

Sample cleaning = sputtering 15 min 1.0 kV
1.8×10⁻⁶ mbar Ar, 17 μA

9:00 $P_{pc} = 2.9 \times 10^{-10}$ mbar $P_{mc} = 8.4 \times 10^{-11}$ mbar
Oxidation of sample ✓ @ 5.0×10^{-7} mbar O_2 20 min
~ 550°C
Sputtering ✓
Oxidation 2th ✓
Sputtering 2th ✓
Annealing ✓

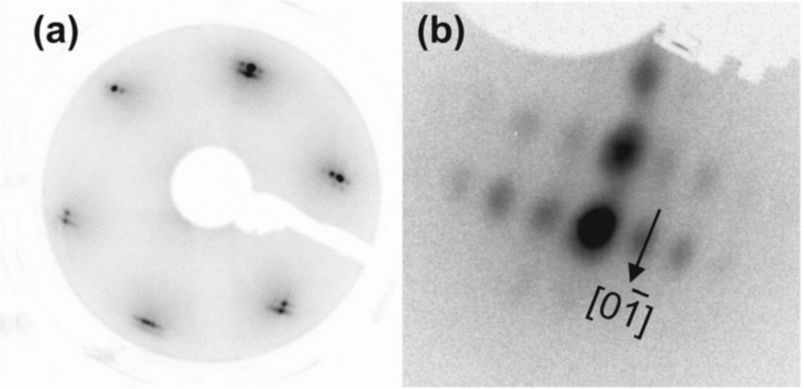
11:00 Sample annealing 1.7A / 400V / 7.1mA for 20 min
sample sputtering 1.0 kV / 25 mA / 17 μA for 20 min
annealing 1.7A / 400V / 4.1mA for 20 min

Preparation

Ce degass: 1.2A / 1kV / 44mA flux 1μA, $P_{pc} = 9.7 \times 10^{-10}$ mbar
4 digit for microbalance:
3'39" 3'55" 3'45" 3'44" 3'35" 3'46"
Ce deposition @ 200°C, 1.0×10^{-6} mbar O_2
Deposition time: 8'38" ~9.2 digit ~0.28 ML
position x = 7 y = 8.75 z = 14.25 θ = 80°

Sample heating 1.65 A for 5 min ↘ 1.25A
After deposition, keep for 2 min, cooling down in O_2 atmosphere for 10 min.

Reference (LEED)



Example II.

- Rh(111) cleaning with Ar^+ sputtering & annealing cycles
- Au deposition @500K & annealing @1000K, afterwards
- Borazine exposure @1000-1050 K
- decomposition of borazine ($B_3N_3H_6$) at ~1050 K

R. Gubó, G. Vári, J. Kiss, A. P. Farkas, K. Palotás, L. Óvári, A. Berkó, Z. Kónya, *Phys.Chem.Chem.Phys.* 2018, **20**, 15473.

The preparation chambers and its subsystems differs in all institute (temperature calibration is the most critical), so the recipes has to be fine tuned to our system to reproduce the sample, which could be time consuming.

Metadata of sample preparation & laterally averaged sample analysis

ELI-ALPS   *Endstation LogBook collection*   Home   Export   LogBook   Templates

Home / LogBook / Preparation of 4ML CeO2 on Au788 (AUCERIA)

Au788 cleaning:
- sputtering 1kV 5mA 1.2E-5mbar 3.8uA 20min [0; 1.5; 24; 270]
- annealing 4.10A 6.3V 10min
- sputtering 0.8kV 5mA 1.3E-5mbar 3.6uA 20min [0; 1.5; 24; 270]
- annealing 4.10A 6.2V 10min

XPS cleaned Au788
- 14kV 14mA Ileak=**545**uA
- [-0.4; **4.42**; 516; 0] sample plate orientation: ear outside
- file: **Au788_cleaned**
- Au live intensity: **313** kcps (87eV CAE100 0.5s)
- spectra (**1503s**):
  - 1x survey 1100-20:0.5eV CAE50eV 0.1s
  - 2x Ce3d 925-875:0.05eV CAE50eV 0.3s
  - 1xO1s 0.05eV CAE50eV 0.3s
  - 2xC1s 0.05eV CAE50eV 0.3s
  - 2x Au4f 94-78:0.05eV CAE50eV 0.3s
  - 2x UPS 12--1:0.05eV CAE50eV 0.3s

CeO_2 deposition: **ML**

Manipulator parameters	[0; 1; 23; 235]
I_{flux} ; I_{fil}	1.0 uA , 1.37 A
U, I_{em}	775 V/ 39.5 mA (38.9)
T sample	2.45A 2.85V 158oC (max.: 165 oC)
p_{base}	1.3×10^{-9} mbar
p O_2 level	5×10^{-7}mbar (IGP off)
Evaporation t	42:27 (mm:ss)
Hold	2 min in O_2 & heating
Cooling down	10 min in O2 (heating off)

XPS Au788 + 8 ML CeO2 => calculated coverage **8** ML (calc.based on Au int.decay)
- 14kV 14mA leak= **545**uA
- [-0.4; 4.35; 516; 0] sample plate orientation: ear outside
- file: Au788_8MLCeO2
- Au live intensity: **129**kcps (87eV CAE100 0.5s)
- spectra:
  - 1x survey 1100-20:0.5eV CAE50eV 0.1s
  - 3x Ce3d 925-875:0.05eV CAE50eV 0.3s
  - 0x Ce4d 135-104:0.05eV CAE50eV 0.3s
  - 4x O1s 542-522:0.05eV CAE50eV 0.3s
  - 4x C1s 298-278:0.05eV CAE50eV 0.3s
  - 2x Au4f 9135-1044-78:0.05eV CAE50eV 0.3s
  - 3x UPS 12--1:0.05eV CAE50eV 0.3s

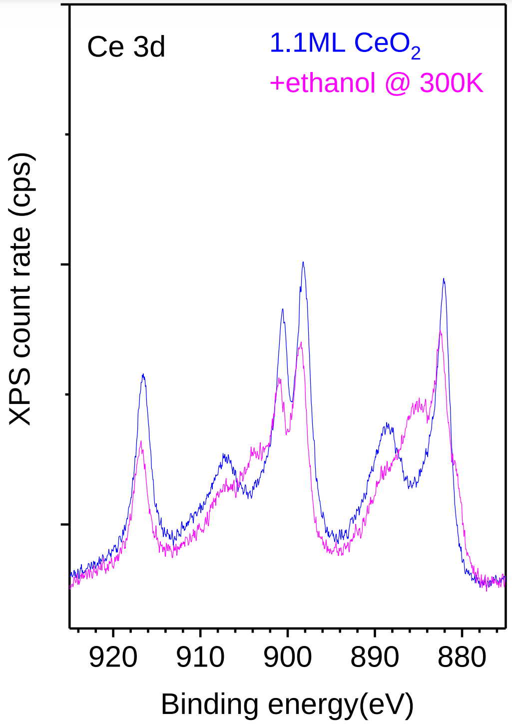
LEED Au788 + 8MLCeO2
- [2.5; 0.25; 257.25; 97]
- 40-200:1 eV
- Ifil=1.45 Uscr=4.5kV

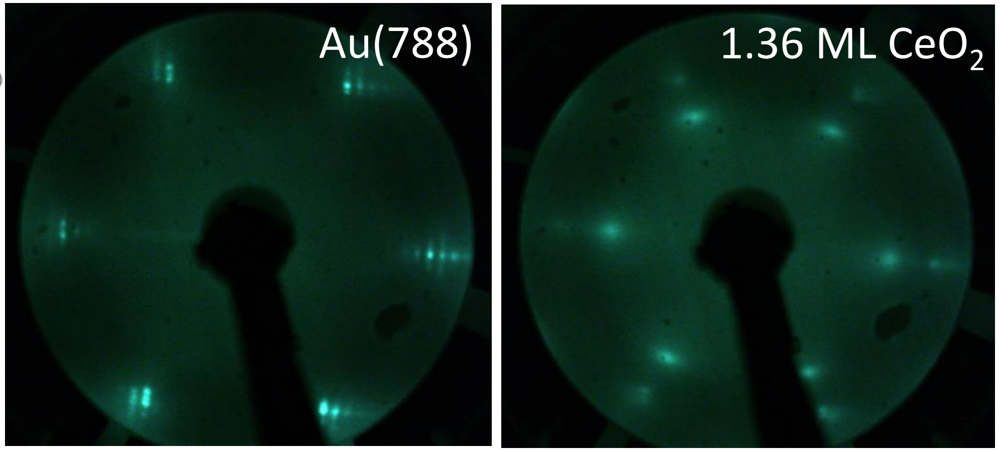
Ethanol adsorption I. on 8ML CeO_2 on Au788
- positions:[-6; 2.5, 256.5, 312, dozer: 30]
- t=15 min
- $p_{ethanol}$=6E^{-8} mbar
- pbase 1.3×10^{-9} mbar
- T_{sample}: 35°C
- IGP OFF

XPS I. Au788 + 8 ML CeO_2 => calculated coverage **8** ML (calc.based on Au int.decay)
- 14kV 14mA, leak= **538**uA , I_{fil}: 4,1A
- [-0.4; 4.35; 516; 0] sample plate orientation: ear outside
- file: Au788_8MLCeO2+ethanol 15min
- p_{op}: $2{,}64 \times 10^{-9}$ mbar
- Au live intensity: cps (87eV CAE100 0.5s)
- spectra:
  - 1x survey 1100-20:0.5eV CAE50eV 0.1s
  - 3x Ce3d 925-875:0.05eV CAE50eV 0.3s
  - 0x Ce4d 135-104:0.05eV CAE50eV 0.3s
  - 2x O1s 542-522:0.05eV CAE50eV 0.3s
  - 10x C1s 301-278:0.05eV CAE50eV 0.3s
  - 2x Au4f 9135-1044-78:0.05eV CAE50eV 0.3s
  - 3x UPS 12--1:0.05eV CAE50eV 0.3s

Ethanol adsorption II. on 8ML CeO_2 on Au788
- positions:[-6; 2.5, 256.5, 312, dozer: 30]
- t=15 min
- $p_{ethanol}$=6E^{-8} mbar
- pbase 1.7×10^{-9} mbar
- T_{sample}: 27,6°C
- IGP OFF

XPS II. Au788 + 8 ML CeO_2 => calculated coverage **8** ML (calc.based on Au int.decay)
- 14kV 14mA, leak= **538**uA , I_{fil}: 4,1A
- [-0.4; 4.35; 516; 0] sample plate orientation: ear outside
- file: Au788_8MLCeO2+ethanol 15 +15 min
- p_{op}:
- Au live intensity: **118** kcps (87eV CAE100 0.5s)
- spectra:
  - 1x survey 1100-20:0.5eV CAE50eV 0.1s
  - 3x Ce3d 925-875:0.05eV CAE50eV 0.3s
  - 0x Ce4d 135-104:0.05eV CAE50eV 0.3s
  - 2x O1s 542-522:0.05eV CAE50eV 0.3s
  - 10x C1s 301-280:0.05eV CAE50eV 0.3s
  - 2x Au4f 9135-1044-78:0.05eV CAE50eV 0.3s
  - 2x UPS 12--1:0.05eV CAE50eV 0.3s





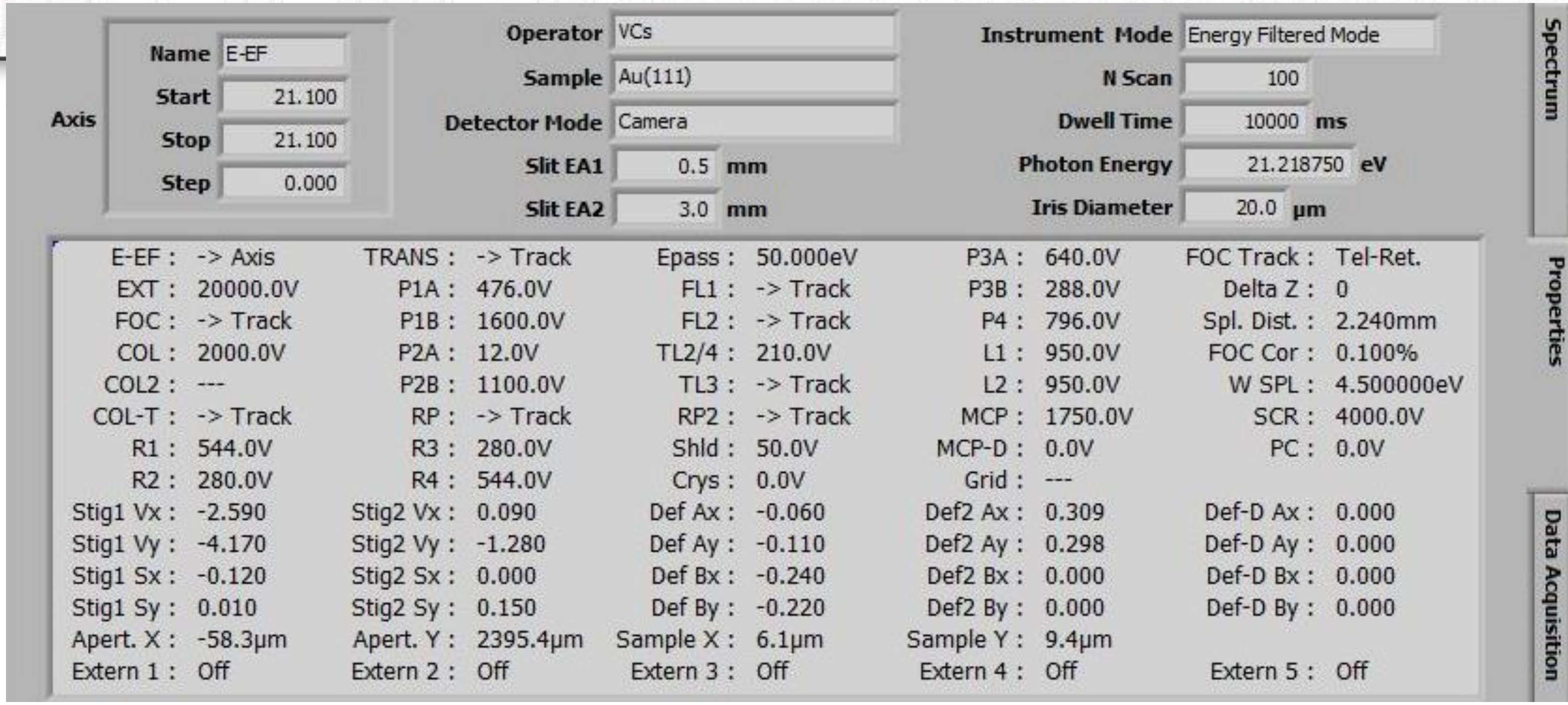
Metadata of NanoESCA measurements

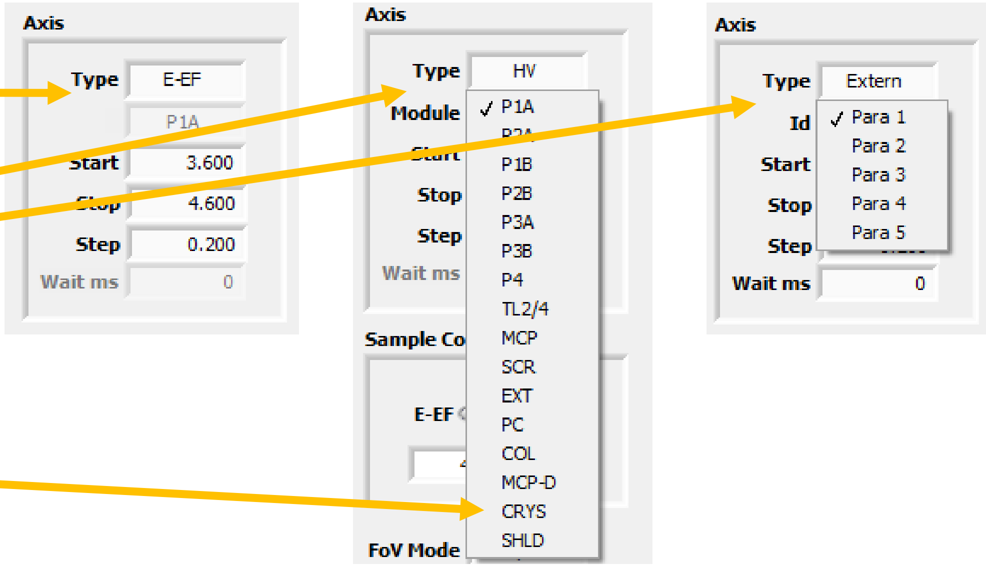
Automatically stored NanoESCA metadata in an ASCII file and display in the history window e.g.:

- Electron–optical parameters (voltage of the lenses & components)
- Exposure-time
- Number of averaged images
- …

- Parameter-scan range (single loop: start – end, step size; nesting loops: under development)
  - Most frequently: kinetic energy scan (of the analyzed electrons)
  - Further parameter (scanning is possible with almost all electron optical parameters)
  - External parameter (e.g.: delay stage positions, CEP (linear stage position), polarization (angle of waveplate))
  - Crystal voltage scan (IV (current-voltage) curve) of the spin filter

History window:





ASCII:

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MOD02_NAME = "P1a"
MOD02_ADDR = "051"
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MOD03_NAME = "P2a"
MOD03_ADDR = "053"
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MOD04_ADDR = "052"
MOD04_PARA1_NAME = "UNOM"
MOD04_PARA1_VALUE = 1500.000000
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Data structure of raw measured data (images) & its metadata

Experiment List

Name	Instr. Mode	Event C.	Axis	Start	Stop	Step	FoV	Dwell [ms]	N Scan	Time
☑ 15-0_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-1_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-2_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-3_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-4_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-5_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-6_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-7_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 15-8_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
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☑ 16-0_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☑ 14-0ref_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-6--4-6eV_ul	Energy Filtered Mode	Off	E-EF	3.600000	4.600000	0.200000	k-Space	10000	8	00:08:00
☐ 15-0ref_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_ul-CEP	Energy Filtered Mode	Off	E-EF	3.000000	6.000000	0.100000	k-Space	10000	8	00:41:20
☐ 21_R5-F1_IDEA_RS_PE100_S1_20kV_FoV83_Hg01_4-85eV_MCP1800_FOC3020_	Energy Filtered Mode	Off	E-EF	4.850000	4.850000	0.000000	Realspace	500	1200	00:10:00
☐ 17_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3-2--5-4eV_FSw15	Energy Filtered Mode	Off	E-EF	3.200000	5.400000	0.100000	k-Space	10000	2	00:07:40
☐ 05_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_4-0eV_FSw0--24	Energy Filtered Mode	Off	Extern	0.000000	24000000.00	2000000.000	k-Space	10000	1	00:02:10

- [2022-08-22_nRhombs_R5_V_RS-KS_2nd]
- [2022-08-23_nRhombs_R5_V_RS-KS_3rd]
  - [01_R5-F1_IDEA_RS_PE100_S1_200V_FoV162_V_4-3eV_spot-size_220823_160815]
  - [02_R5-F1_IDEA_RS_PE100_S1_20kV_FoV83_V_4-3eV_IMG_220823_161308]
  - [03_R5-F1_IDEA_RS_PE100_S1_20kV_FoV83_V_4-3eV_IS40um_220823_161518]
  - [04_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_4-0eV_cent_220823_161930]
  - [05_EXP_4-0eV_FSw0--24_220823_162645]
  - [06_EXP_3--6eV_FSw15_20deg_220823_165922]
  - [07_EXP_3--6eV_FSw15_30deg_220823_171744]
  - [08_EXP_3--6eV_FSw15_40deg_220823_172405]
  - [09_EXP_3--6eV_FSw15_50deg_220823_173127]
  - [10_EXP_3--6eV_FSw15_60deg_220823_174310]
  - [11_EXP_3--6eV_FSw15_70deg_220823_175448]
  - [12_R5-F1_IDEA_KS_PE100_S1_20kV_FoV2-1_V_4-0eV_img_220823_181853]
  - [13_EXP_3--6eV_FSw15_20deg_220823_184603]
  - [14_EXP_3-2--5-4eV_FSw15_20deg_220823_185323]
  - [15_EXP_3-2--5-4eV_FSw15_40deg_220823_185845]
  - [16_EXP_3-2--5-4eV_FSw15_50deg_220823_190352]
  - [17_EXP_3-2--5-4eV_FSw15_60deg_220823_190859]
  - [18_R5-F2_IDEA_RS_PE100_S1_20kV_FoV83_V_4-3eV_IS40um_220823_192319]
  - [19_EXP_R5-F2_3--6eV_FSw14-16_220823_194259]
    - [14-0_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_220823_194259]
      - [Scan]
      - [Sum]
    - [14-0ref_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_220824_103546]
    - [14-1_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_220823_202529]

\14-0_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_220823_194259\Sum*.*

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14-0_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_AV	TIF	2,097,403	2022-08-23 20:25	-a--
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14-0_R5-F2_IDEA_KS_PE100_S1_20kV_FoV2-1_V_3--6-0eV_AV_010	TIF	2,097,403	2022-08-23 20:25	-a--
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Metadata of NanoESCA measurements

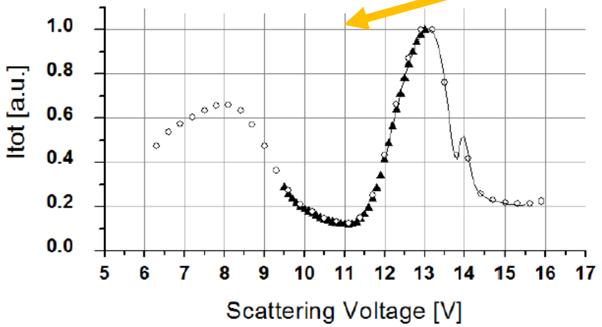
Automatically stored 'environmental' parameters:

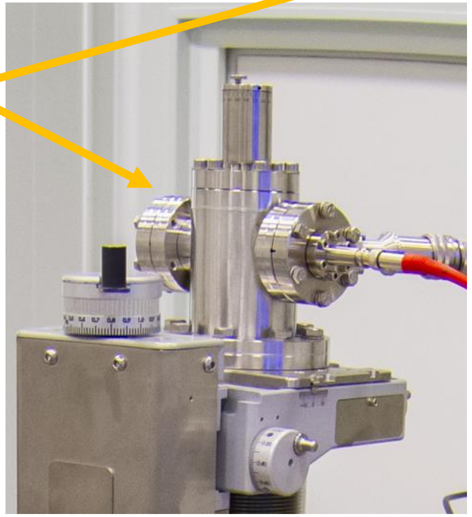
- Chamber pressures (Grafana)
- Sample temperatures (Preparation chamber: Grafana, analysis chamber: local log file, notes)
- Vacuumpump (current & speed) and cooling parameters (pressure, temperature, flow rate)
- Status of the pneumatic gate valves
- Laboratory temperature, air pressure, humidity

Further relevant but not automatically stored parameters

- Sample position
- Spin-filter position
- Spin filter preparation (cleaning, evaporation, annealing) & IV curve

Enable	Axis	Position	Unit	Step Size	Jog Velocity
☑	X	3.437671	mm	0.03	0.1
☑	Y	0.285620	mm	0.01	0.1
☑	Z	2.195930	mm	0.1	0.1
☑	Polar	-0.000234	°	[illegible]	1





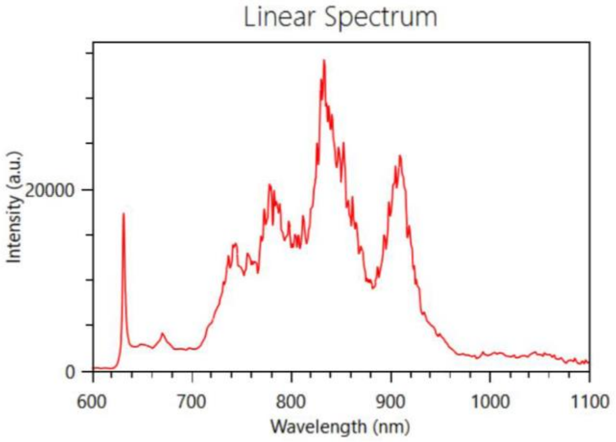
Metadata of NanoESCA photon sources I.
CW & laser sources (e-LogBook & handwritten notes)

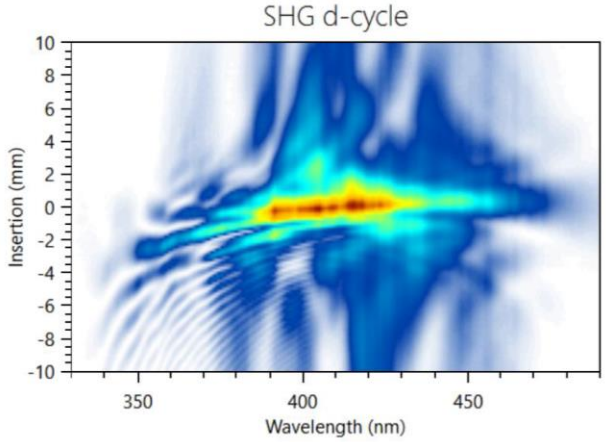
Continuous wave sources for static measurements:

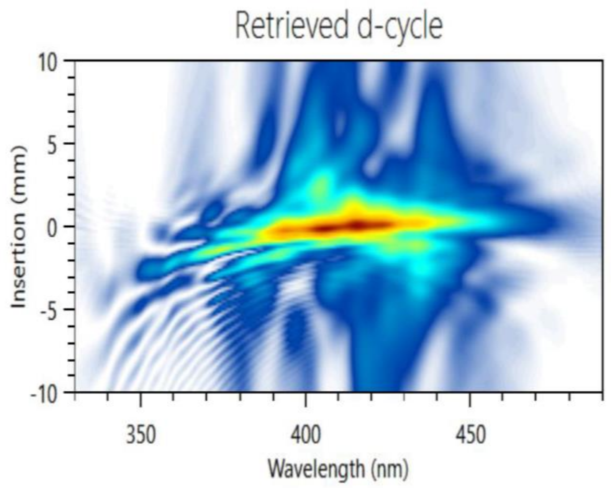
- Hg arc lamp: ON/OFF; intensity determined by the filter (100%, 10%, 1%) – manually stored
- He discharge lamp: current & voltage & pressures - manually stored

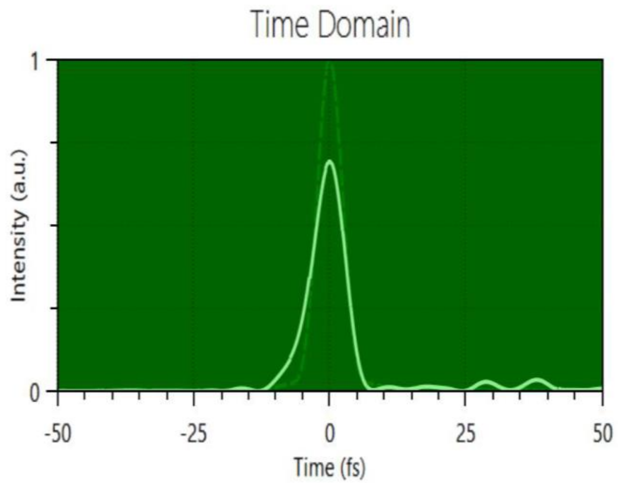
Parameters of laser sources (pump pulse):

- spectrum
- pulse length
- beam profile
- other (mirrors & wedge positions; pressures in the multi-pass cells)









Trace

RMS Error	0.5 %
Max SHG Insertion	-0.16 mm
Trace tilt	11.4 μm/nm

Spectral Domain

Center λ	811.4 nm
Pulse GDD	-8 fs^2
Pulse TOD	154 fs^3
Pulse FOD	833 fs^4

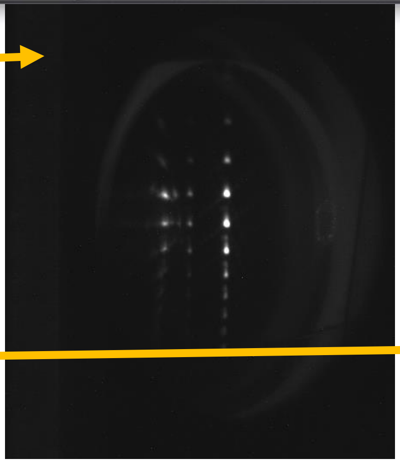
Time Domain

Pulse width	**6.87 fs**
Relative Peak Power	**69.6 %**
λ at Peak	825.0 nm
TL pulse width	5.40 fs

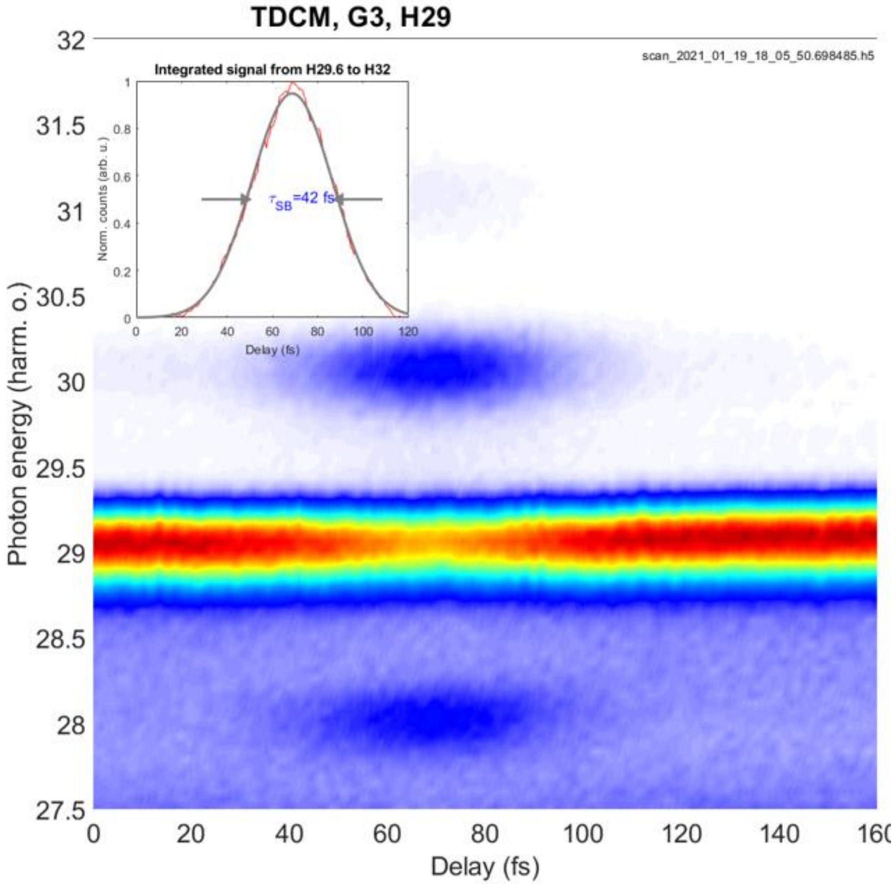
Propagation

Metadata of NanoESCA photon sources II. Characterization of XUV source (e-LogBook)

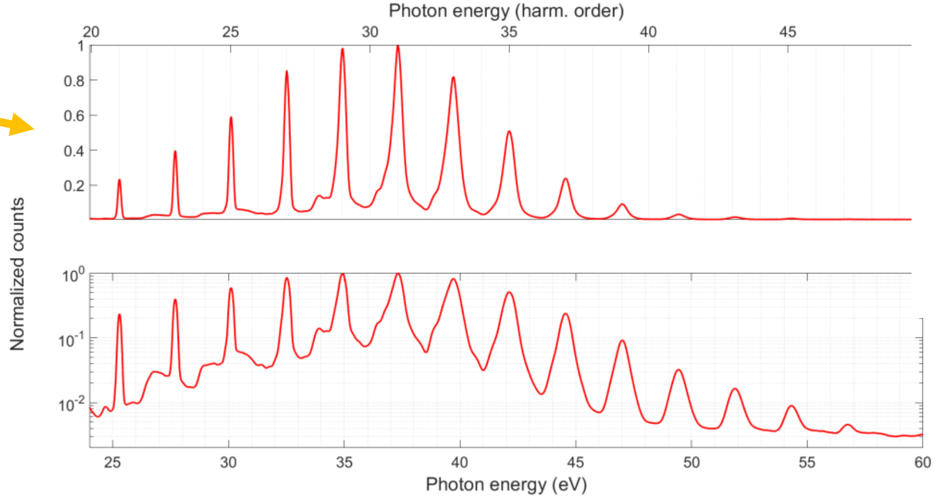
- Beam profile (gas: Xe): fluorescence of diffracted harmonics on Ce:YAG crystal



- Pulse length: IR-XUV cross-correlation spectrogram



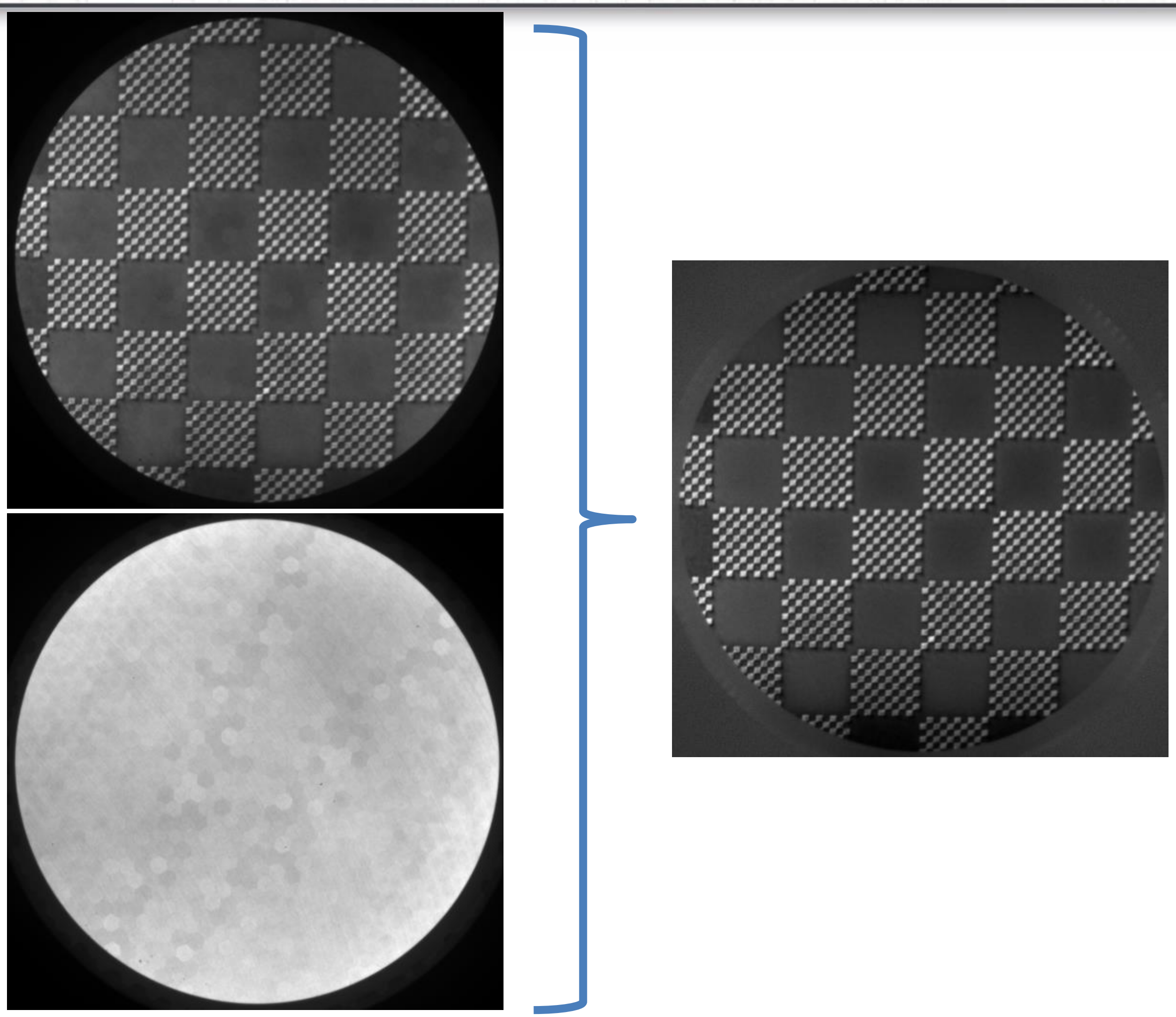
- Spectrum

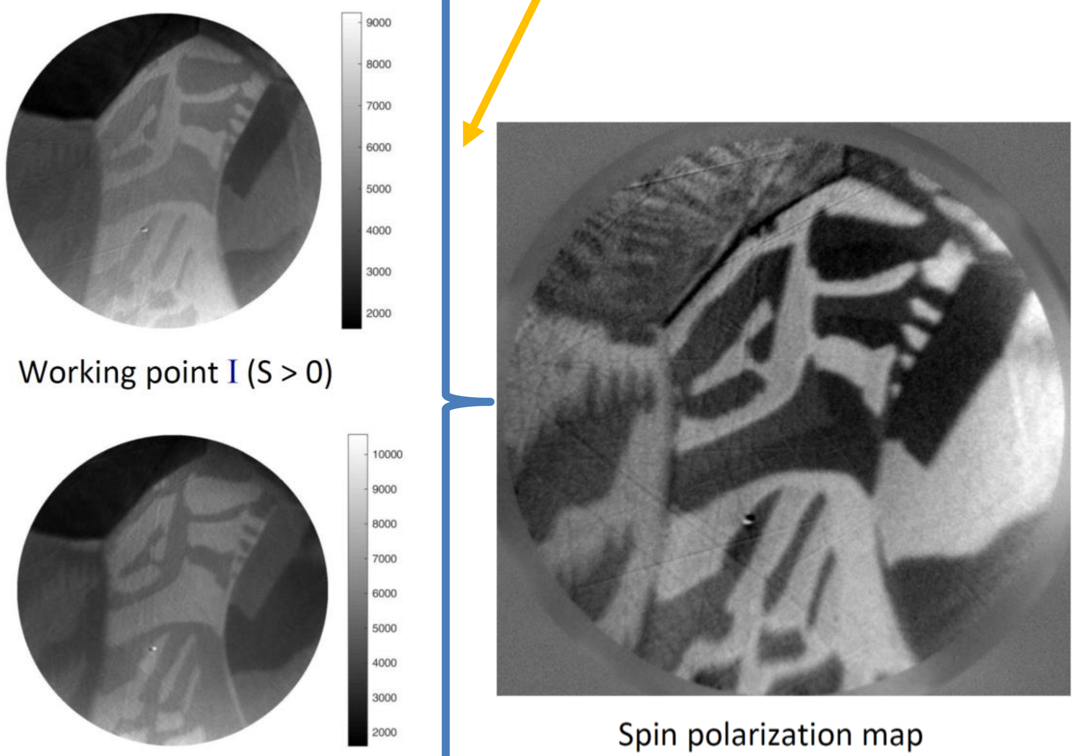


- Operation mode & position of the optical components
- Applied gas
- Position of gas cell
- Intensity of IR & XUV
- Pressure in the target chamber
- Applied filters

Post processing

- Flatfield correction
- Calibration of energy scale and the lateral scales
- Correction of sample tilting & rotation
- Correction of distortions (elliptical distortion of electron optics)
- Calculation of Fermi-edge & work function
- Preparation of spin-contrast images





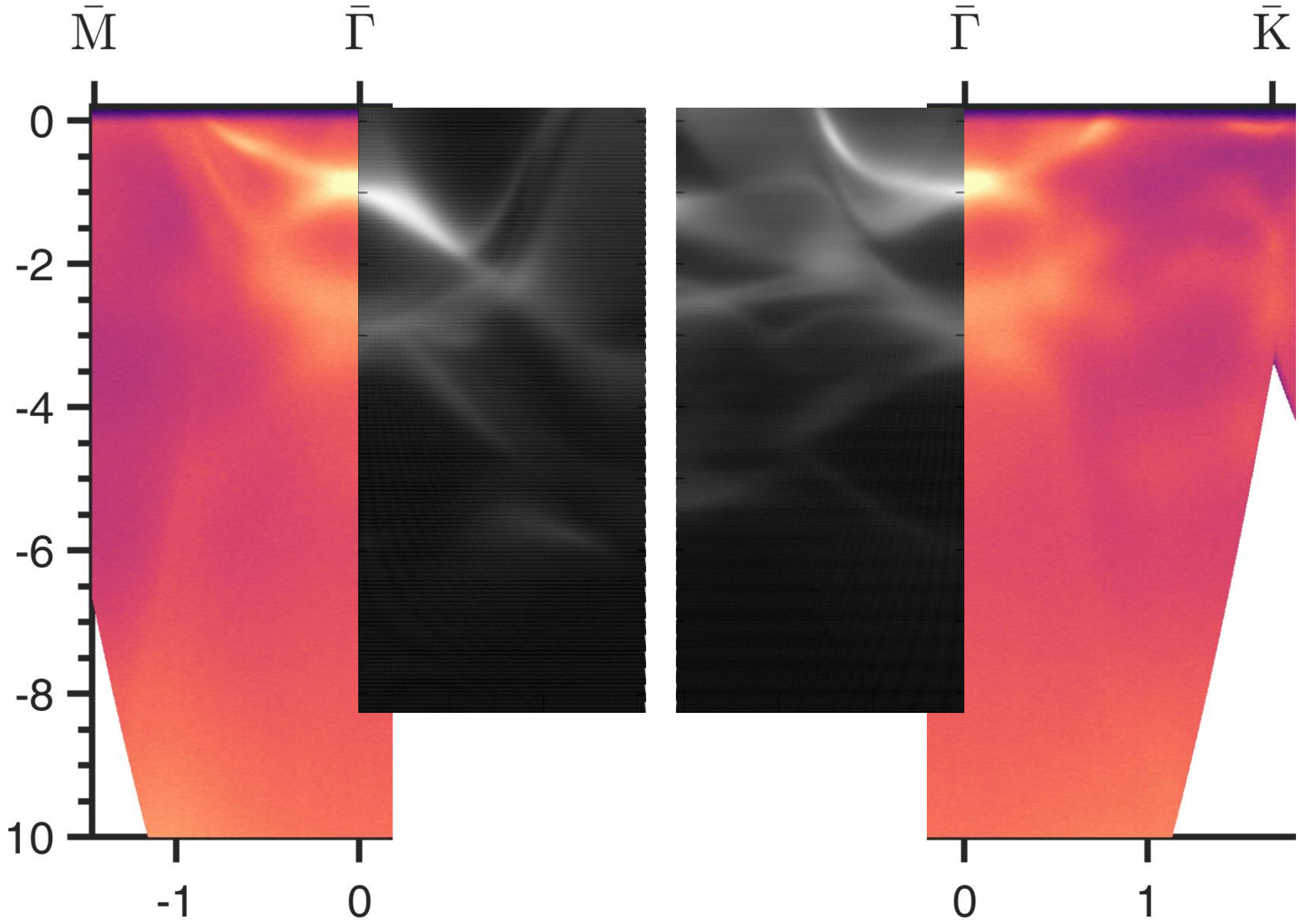
Working point I (S > 0)

Working point II (S < 0)

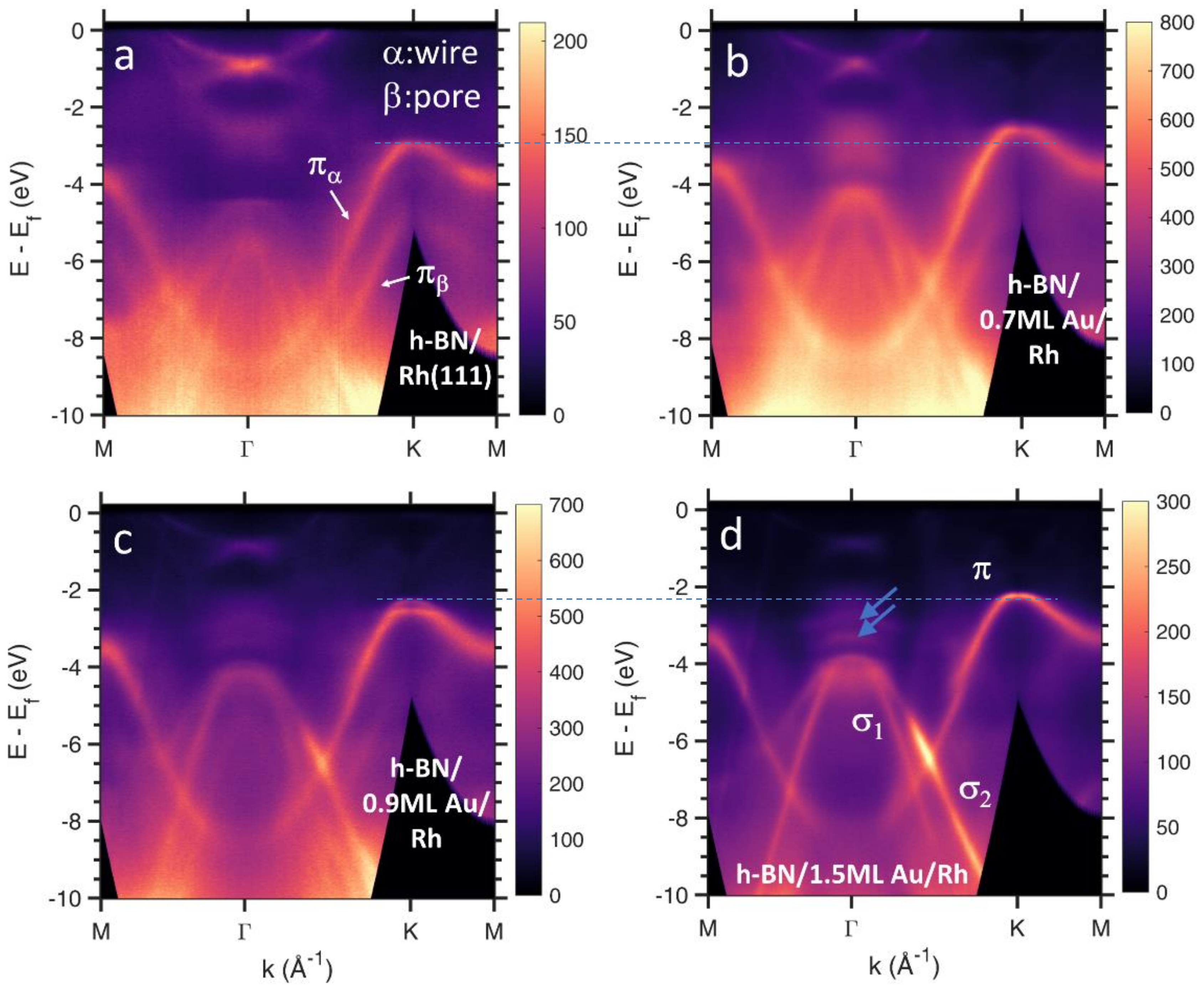
Spin polarization map

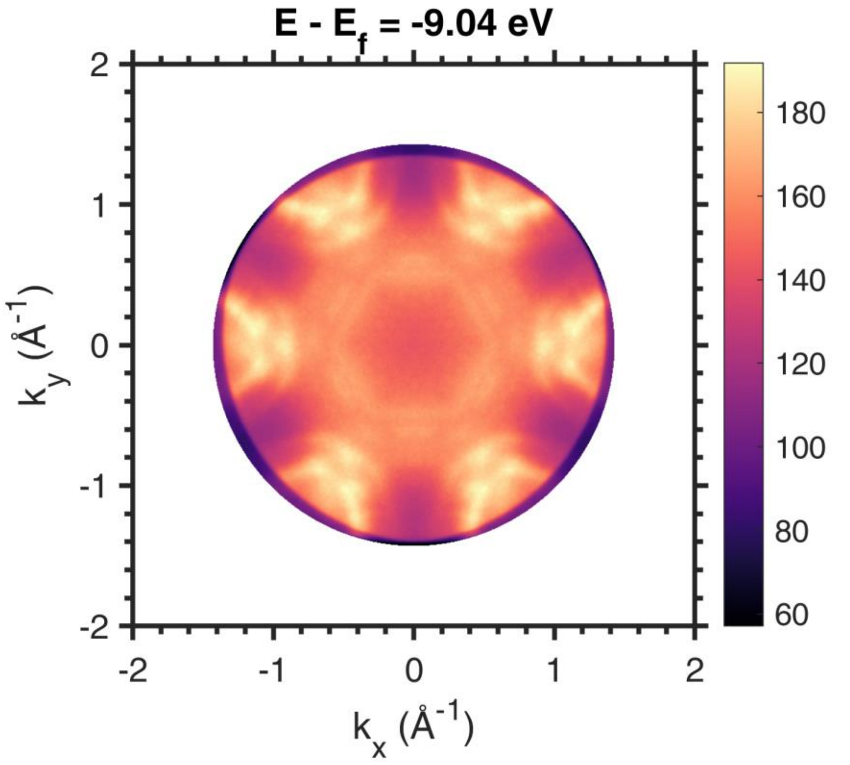
Simulations – cooperation with our simulation group

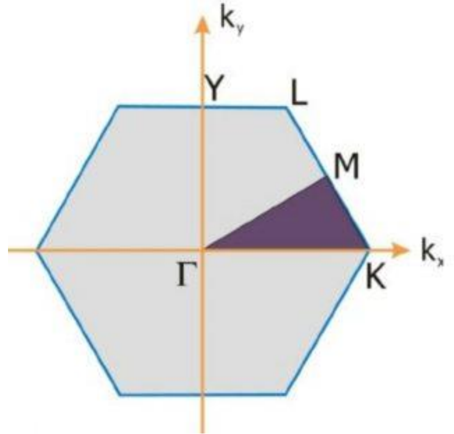
Example: measured (colored) and simulated (grayscale) band structure of Rh(111)



Publishing


a
α:wire
β:pore
π_α
π_β
h-BN/
Rh(111)
b
h-BN/
0.7ML Au/
Rh
c
h-BN/
0.9ML Au/
Rh
d
π
σ_1
σ_2
h-BN/1.5ML Au/Rh
E - E_f (eV)
M
Γ
K
M
k ($Å^{-1}$)


E - E_f = -9.04 eV
k_y ($Å^{-1}$)
k_x ($Å^{-1}$)


k_y
k_x
Y
L
M
Γ
K

Public access to the data

Requirements with the shared NanoESCA data (& metadata):

- Searchable
- Universal/known data structure (ontology)
- Contains all relevant data (and their metadata) for further analysis
  - Sample preparation recipes & result of preliminary analysis (XPS, AES, LEED)
  - Metadata of NanoESCA measurements and photon sources
  - Steps of image correction
- The related data has to link together
- It has to be understood for a specialist in the relevant research field
- Information for the **reproducibility**
- …

Challenges:

Store all the relevant data in universal structure including data from different sources:

- Main data & metadata of NanoESCA - in progress with our software engineers
- Metadata from e-LogBooks – templates with automatic importing possibilities
- Metadata from laser & secondary sources & instruments
- Handwritten notes are not acceptable – has to be eliminate

Ontology:

- New techniques in an existing structures: the structures has to modified (ARPES vs. spectro-microscope)

Thank you for your kind attention!

SZÉCHENYI 2020
HUNGARIAN GOVERNMENT
European Union
European Regional Development Fund
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