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Hamburg, 16. September 2011

Thorsten U. Kampen

# **The Phoibos Analyzer Series**

Electron Spectrometers for Hard x-ray  
Photoemission Spectroscopy

**SPÉCS**<sup>TM</sup>

# PHOIBOS analyzer series

**PHOIBOS 100**



**PHOIBOS 150**



**PHOIBOS 225**



**PHOIBOS 150 WAL**



**PHOIBOS 150 NAP**



# Power Supplies



HSA 3500 plus

- Voltage regions: 10V, 100V, 400V, 1500V, 3500V
- Bipolar
- High stability and resolution
- 24 bit DAC resolution
- 20 bit voltage setting resolution

Voltage Ripple and Noise	< 15 mV <sub>pp</sub> at 15 kV
Temperatur Coefficient	< 1 ppm/K
Long time stability	< 1 ppm over 8 hours



AVC 15 000

# Detectors



Multi Channel



2D CCD



1D/2D Delay Line



2D/3D Spin

Combined Delayline, 9 channel & Micromott – Detector



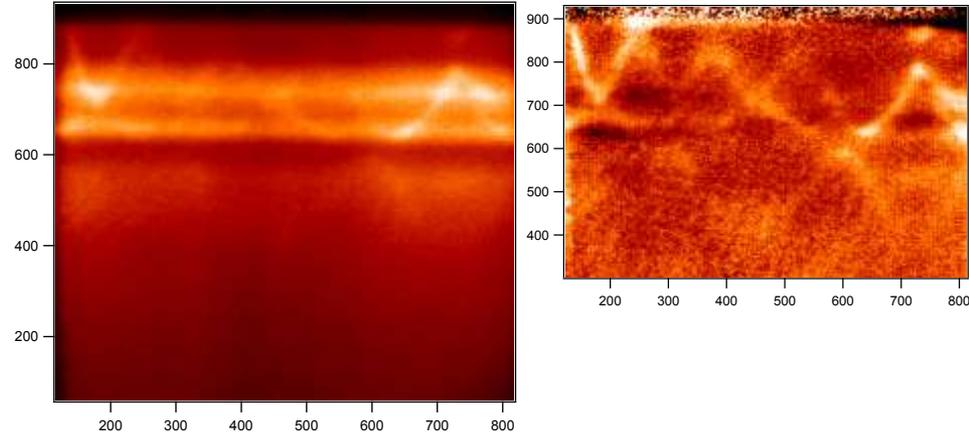
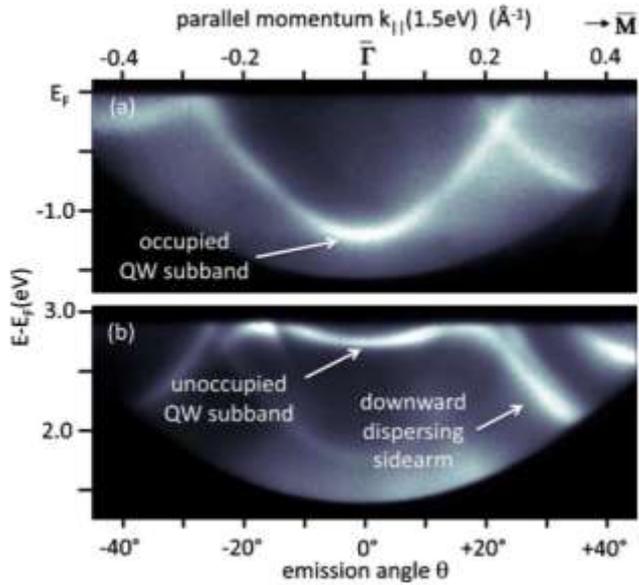
2D-CCD detector



3D-DLD detector

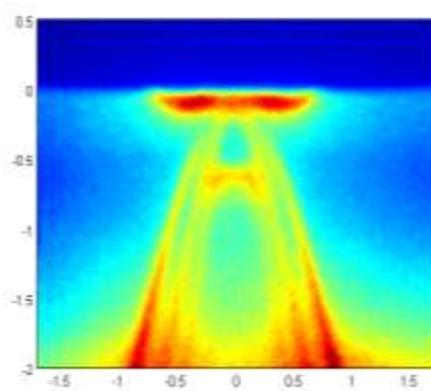
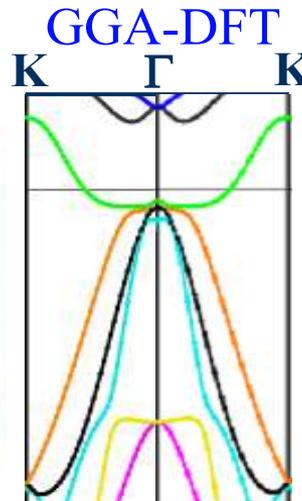


# ARPES



**W(110) @ 5950 eV**  
 Courtesy of C. S. Fadley  
 P09, PETRA III, ADDRESS, SLS

**2PPE on Pb/Cu(111) @ 5.9 eV**  
 S. Mathias et al., PHYSICAL REVIEW B 81, 155429 (2010)

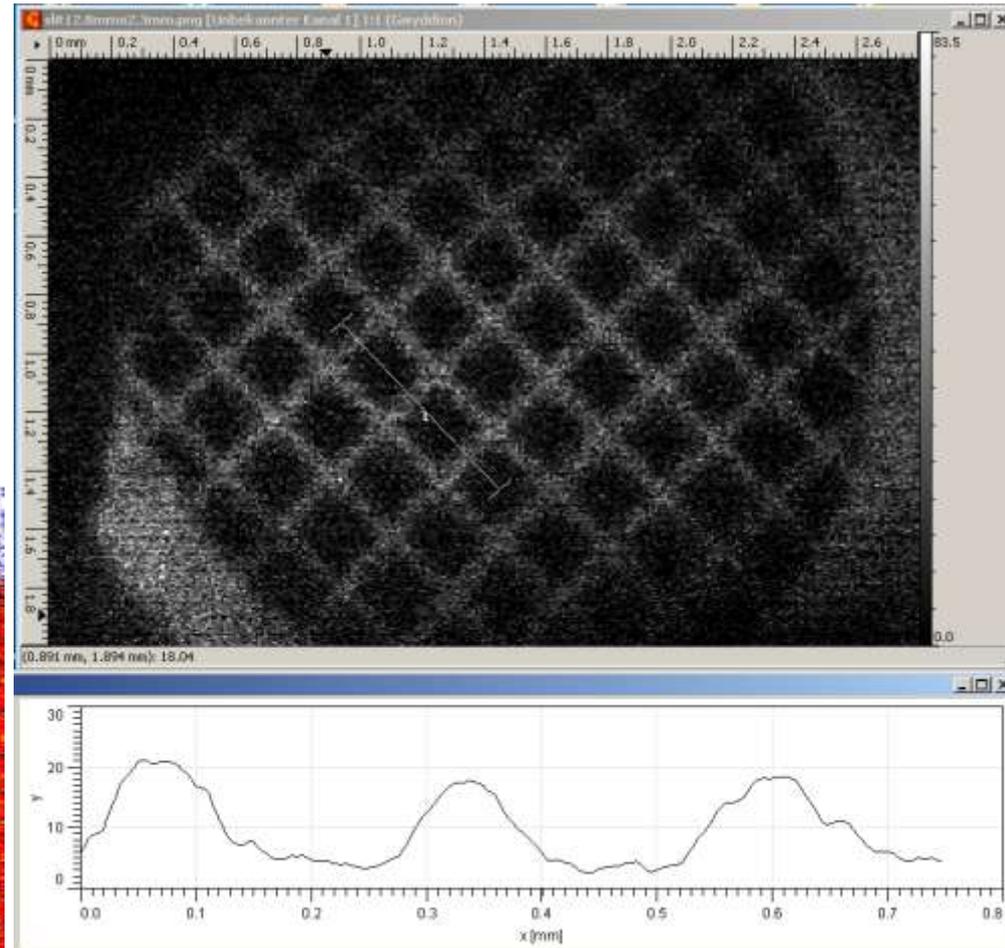


**VSe<sub>2</sub> @ 885 eV**  
 Courtesy of Vladimir Strocov  
 ADDRESS, SLS

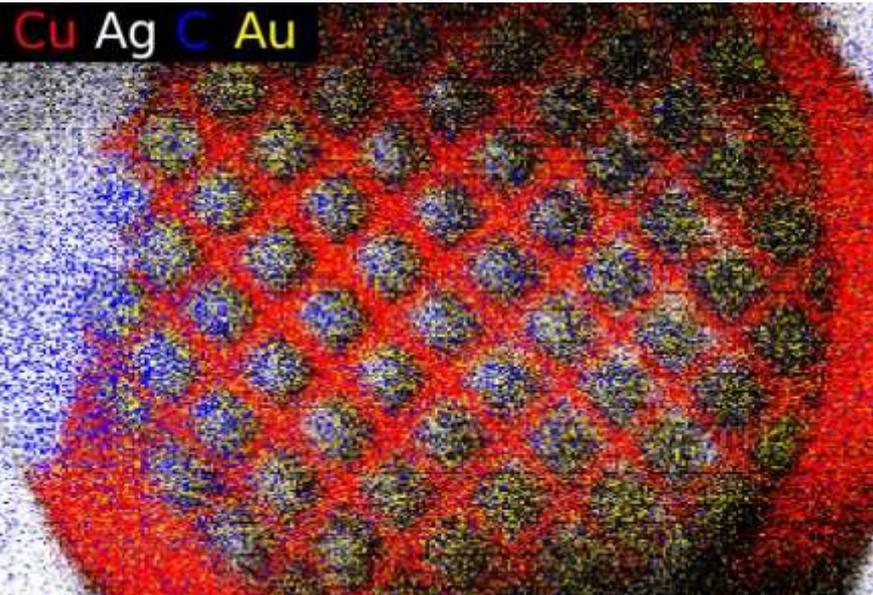
# Imaging

Sample:

- Au fine mesh (25 $\mu$ m width) on Cu mesh (247  $\mu$ m width)
- glued on Ag with Ag containing glue

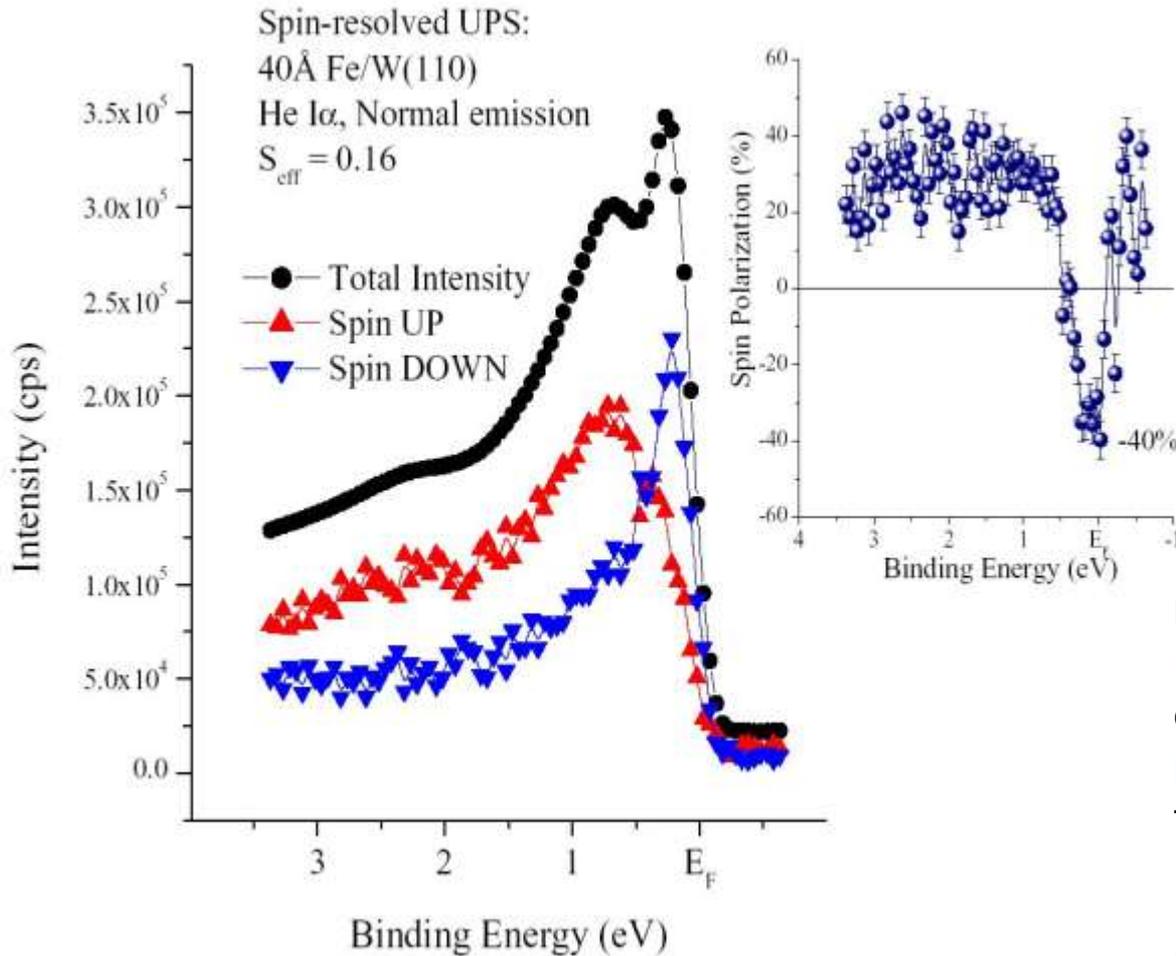


False-color image of the lateral distribution of Cu, Ag, Au, and C



# Transmission

## Valence band

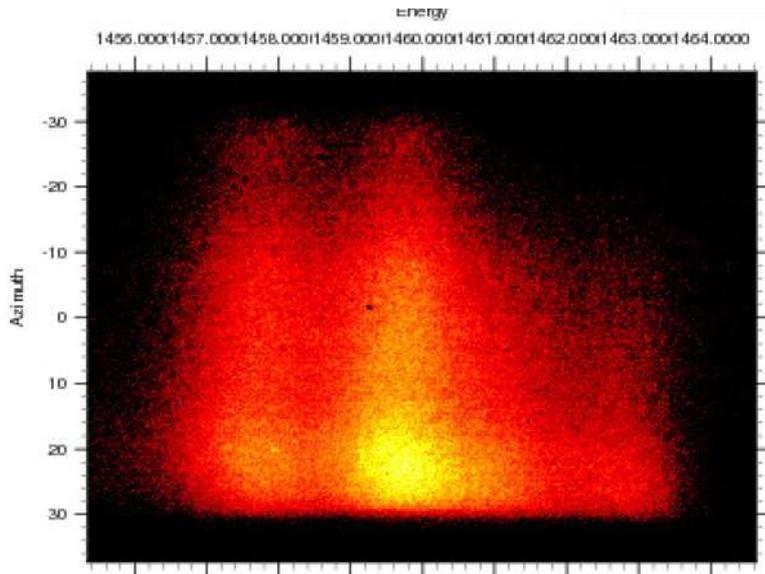
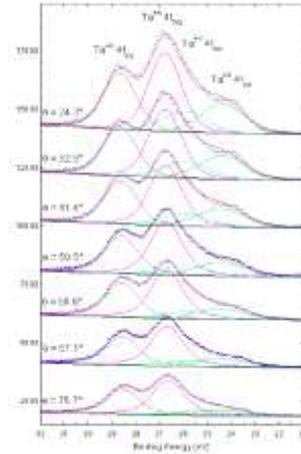
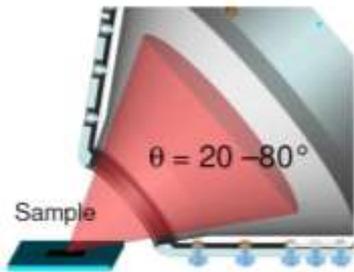


Black: non-spin resolved data  
 Red and blue: spin-up and spin-down component  
 Light blue: polarization derived from the spin detector data.

Data courtesy of Prof. Laubschat, Dr. Dedkov, TU Dresden, Germany.

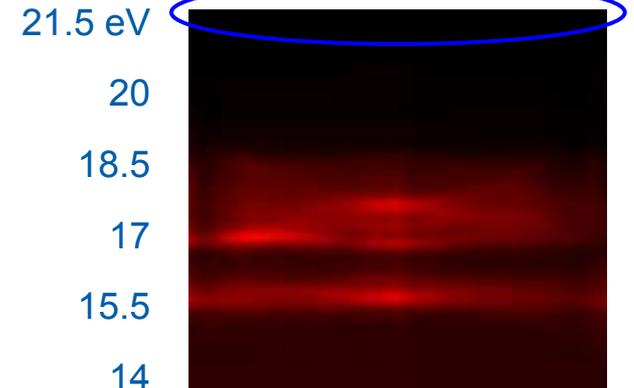
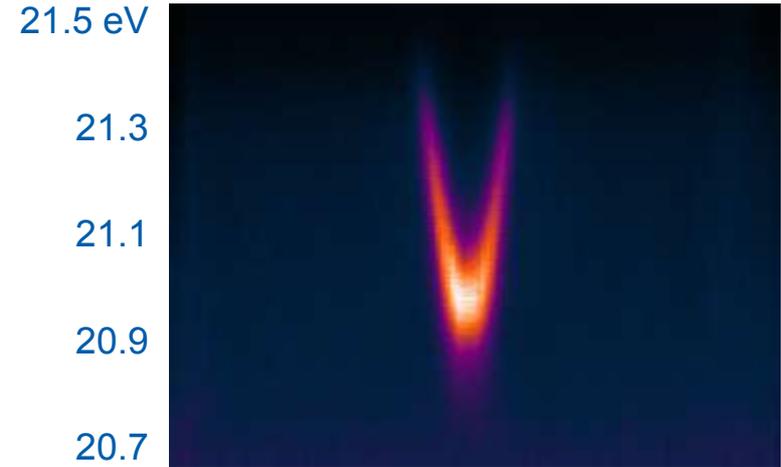
# Wide Acceptance Angle - +/- 30°

TaN/TaON @ 1486 eV



Au(111) @ 21.2 eV

-30°                      0°                      +30°



# Near Ambient Pressure

## Typical operating conditions

Flow rate: 2.2 ml/min

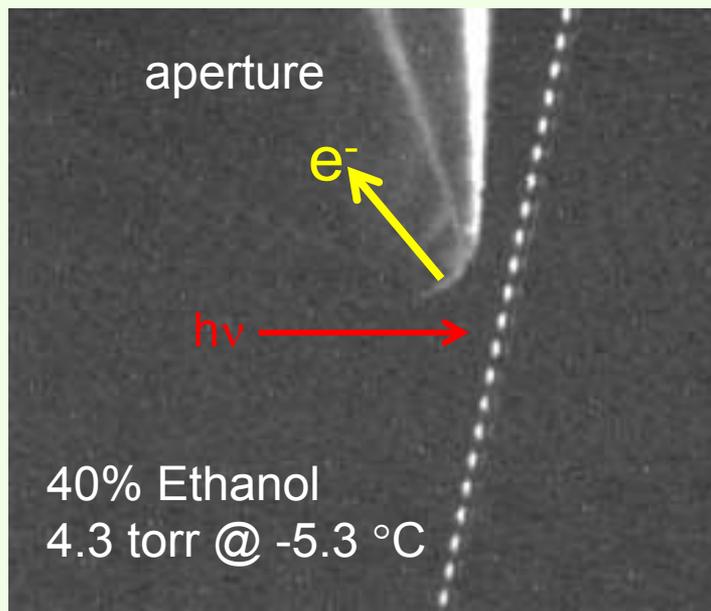
Piezoelectric driving frequency: 54 kHz

Orifice diameter: 50  $\mu\text{m}$

Droplet Velocity: 1870 cm/s

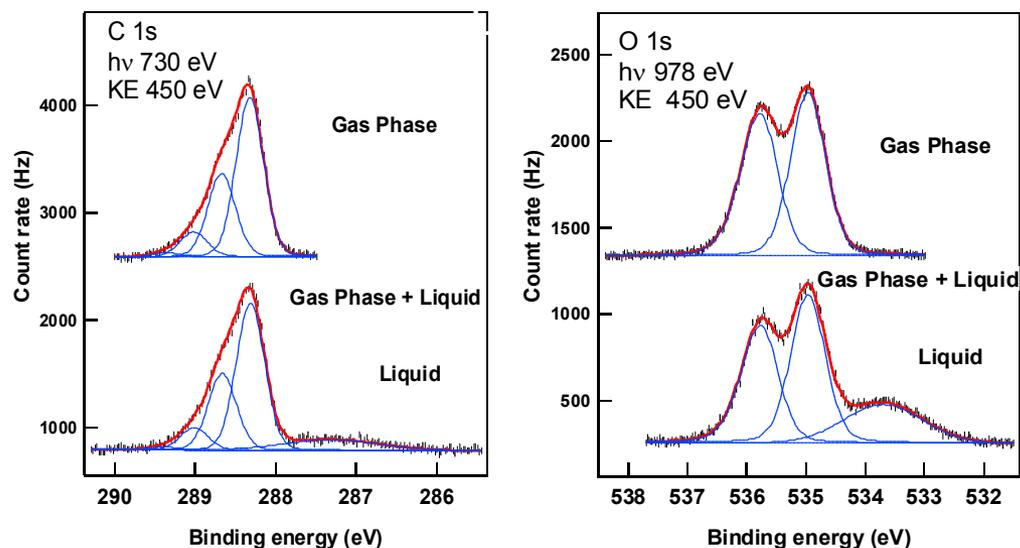
Time of travel from Orifice to Measurement Position ( $\sim 3$  cm): 1.6 ms

Surface Temperature Equilibration Time:  $\sim 0.5$  ms



## Droplet Train/APXPS

### Enhancement of methanol at the surface of an aqueous ( $\chi = 0.21$ ) solution

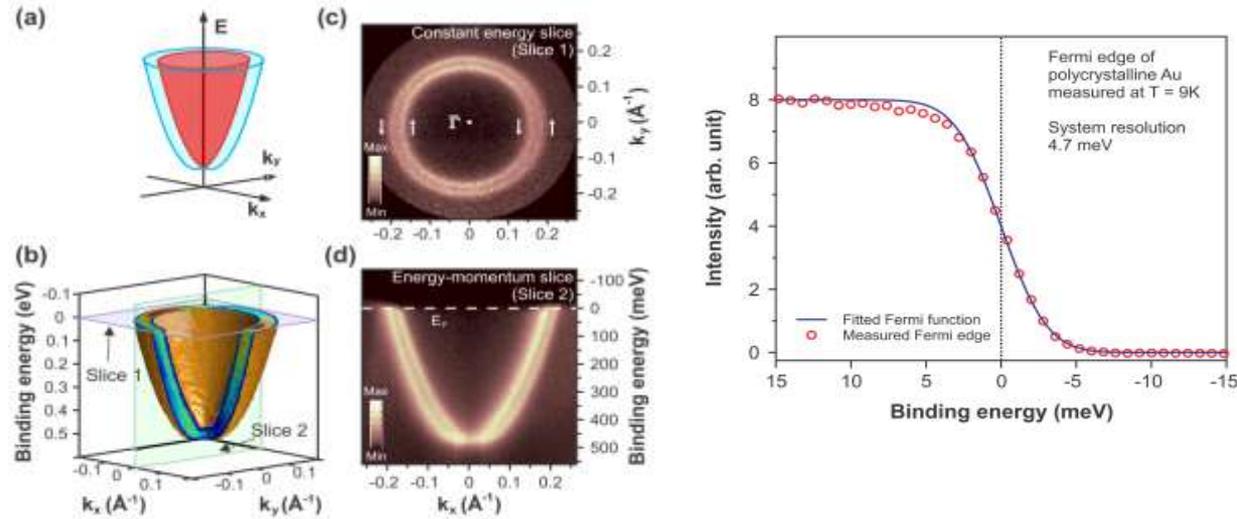


D.E. Starr, E.K. Wong, D.R. Worsnop, K.R. Wilson, H. Bluhm, Phys. Chem. Chem. Phys. (2008).

# THEMIS 600 / 1000

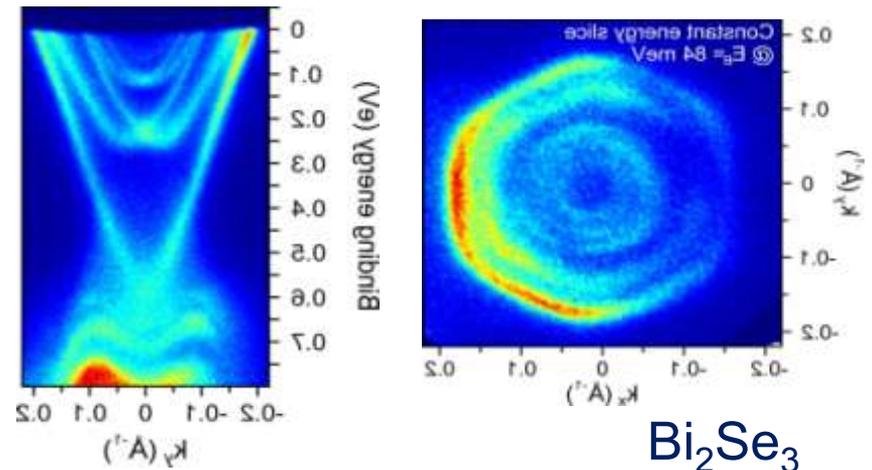


Au(111)



Courtesy of M. Berndsen and O. Tjernberg, KTH, Stockholm

- parallel angle and energy detection with up to  $\pm 13^\circ$  and 70 eV windows
- full spectrum and full emission cone for each photon pulse
- kinetic energy ranges 0 - 40 eV, 0 - 400 eV, 0 - 3500 eV
- high energy option up to 15 kV



$\text{Bi}_2\text{Se}_3$

# PHOIBOS 225 HV

## Features:

- Handles electron energies of up to 15 keV
- High energy resolution in UPS, XPS and HAXPES
- Angular Mapping ( $\Delta\theta < 0.1^\circ$ )
- CCD, DLD and DLD/SPIN detection available
- Low dark-count detector units
- High stability power supplies
- High retarding ratios;  $E_k/E_p$  can be changed continuously
- Different modes of operation (UPS, XPS and HXPS)
- 8 entrance slits ( $< 100 \mu\text{m}$ ) and 3 exit slits

## Applications:

- Investigation of the bulk properties of solids with HAXPES
- UPS with high angular resolution and high energy resolution

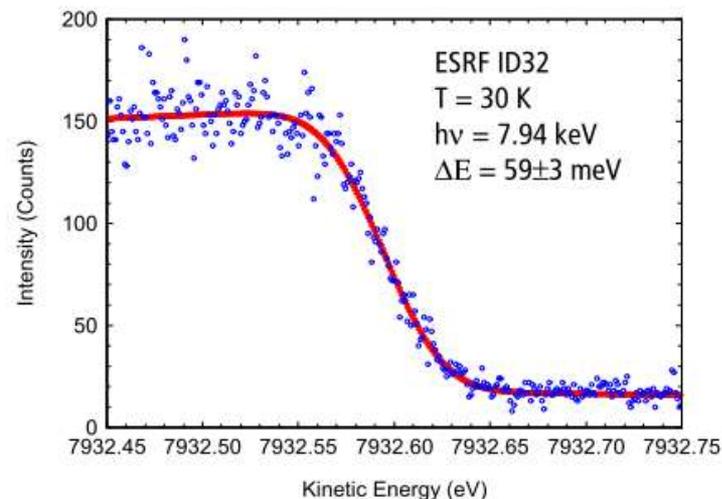
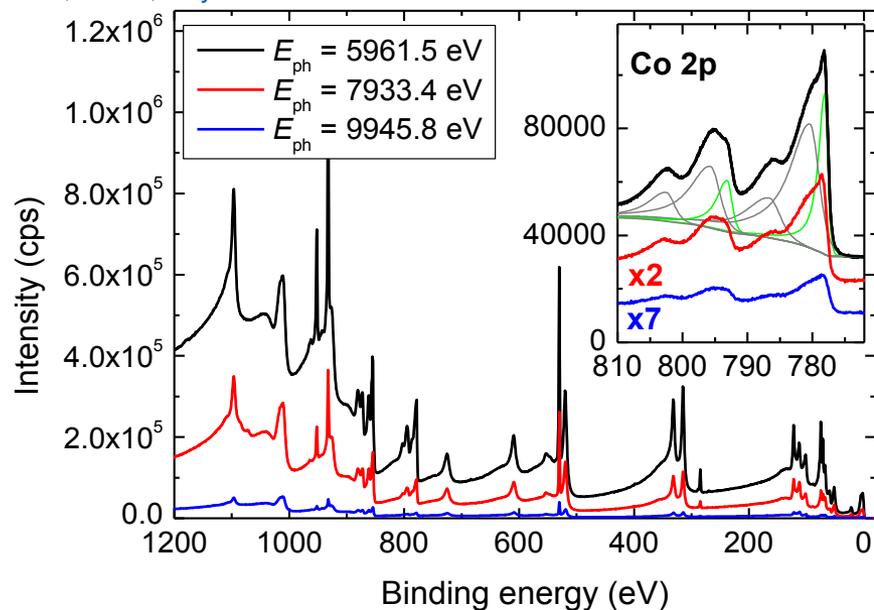
**Latest results:** see Poster 6



# PHOIBOS 225 HV @ ESRF

## Exchange Bias Bilayer System NiO/CoPt

Data courtesy of Blanka Detelefs and Jörg Zegenhagen, ESRF, Grenoble, France and Sara Laureti and Dino Fiorani, C.N.R. - ISM Via Salaria, Roma, Italy



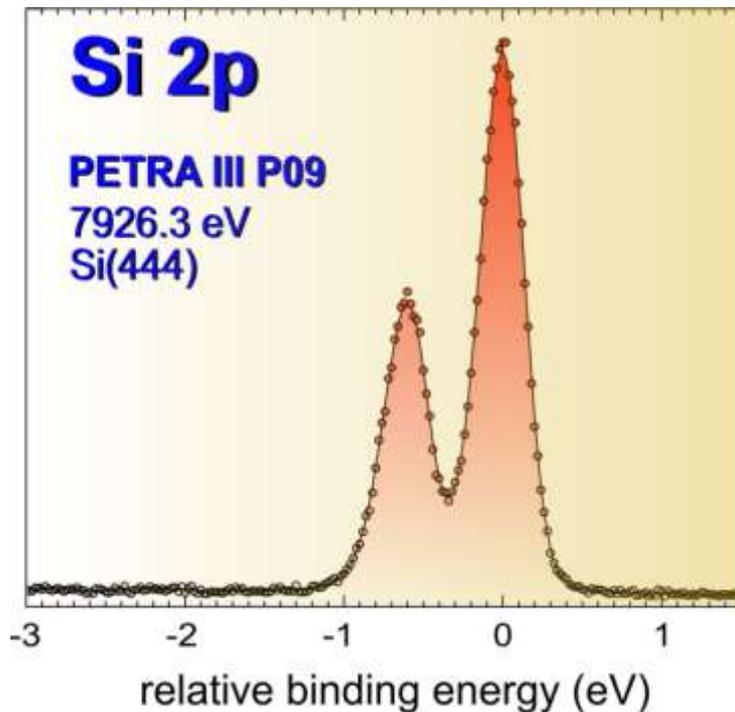
$$\Gamma_A^{HXPS} = \sqrt{\Gamma_M^2 - \Gamma_S^2 - \Gamma_T^2}$$

$$= \sqrt{59^2 - 38^2 - 11^2} \text{ meV} = 44 \text{ meV}$$

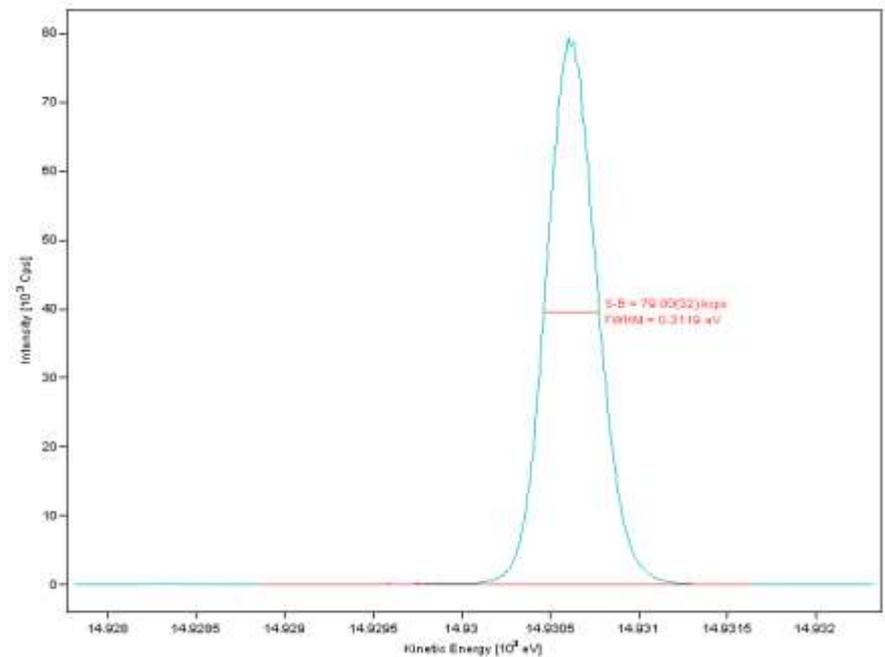
# PHOIBOS 225 HV

## P09 at PETRA III

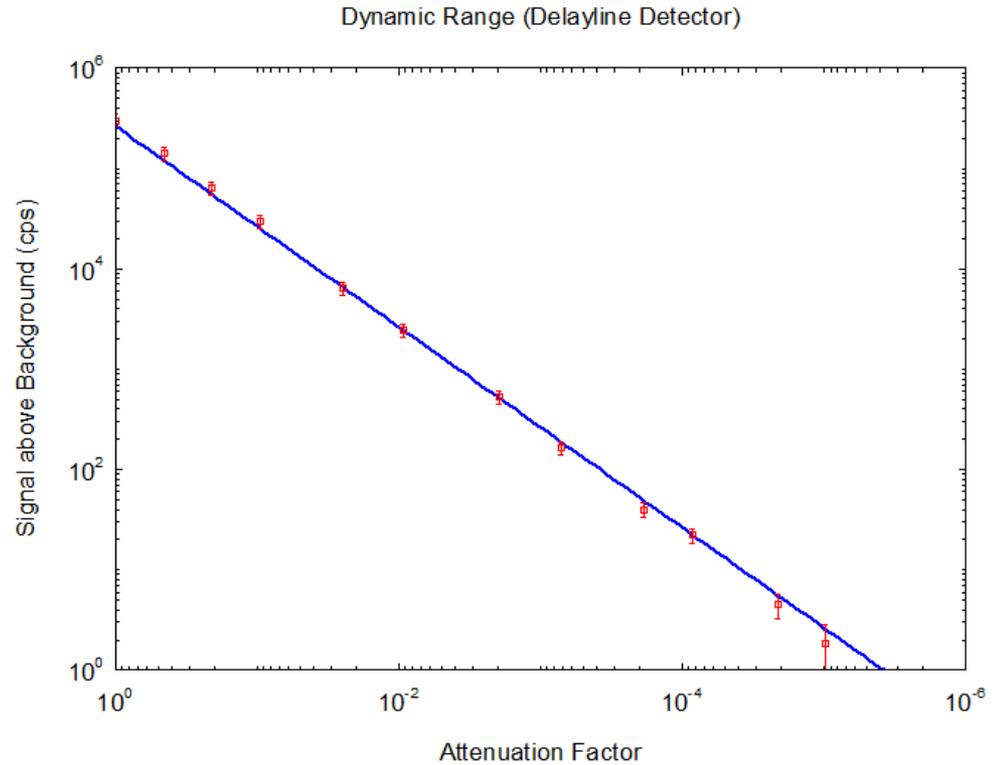
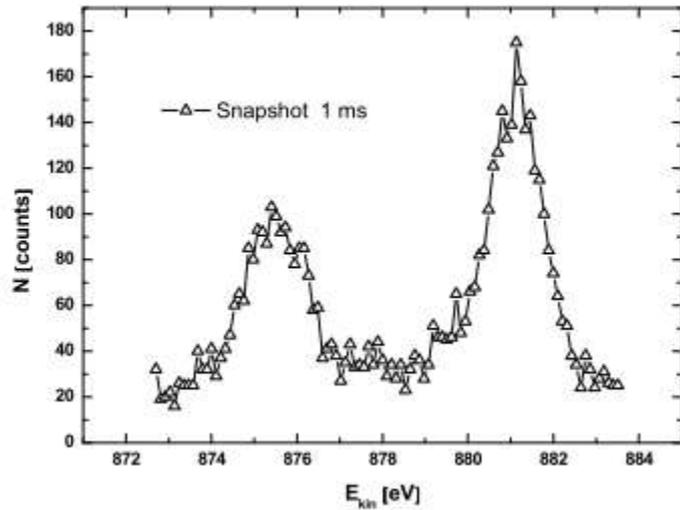
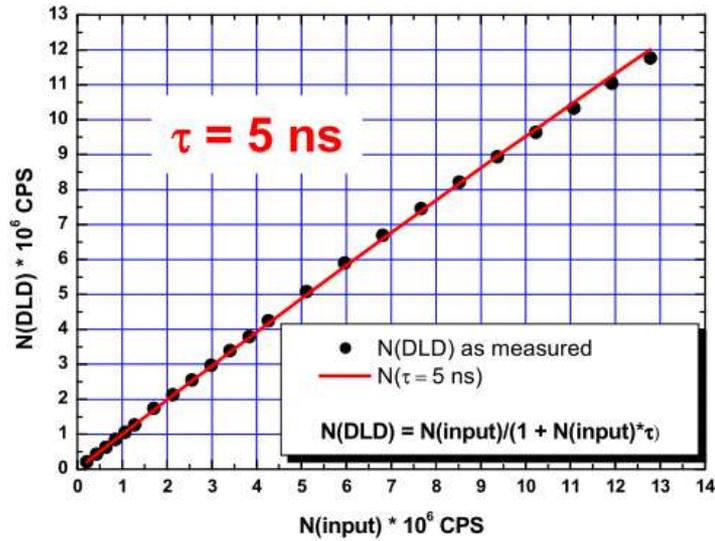
Data courtesy of Andrei Hloskovskyy, Sebastian Thieß and Wolfgang Drube, PETRA III, Hamburg, Germany



## PHOIBOS 225 HV used for Rutherford Electron Backscattering at 15 keV



# 1D-/3D-DLD Detectors



## NEW: PHOIBOS 100/150 & HSA 7000 plus



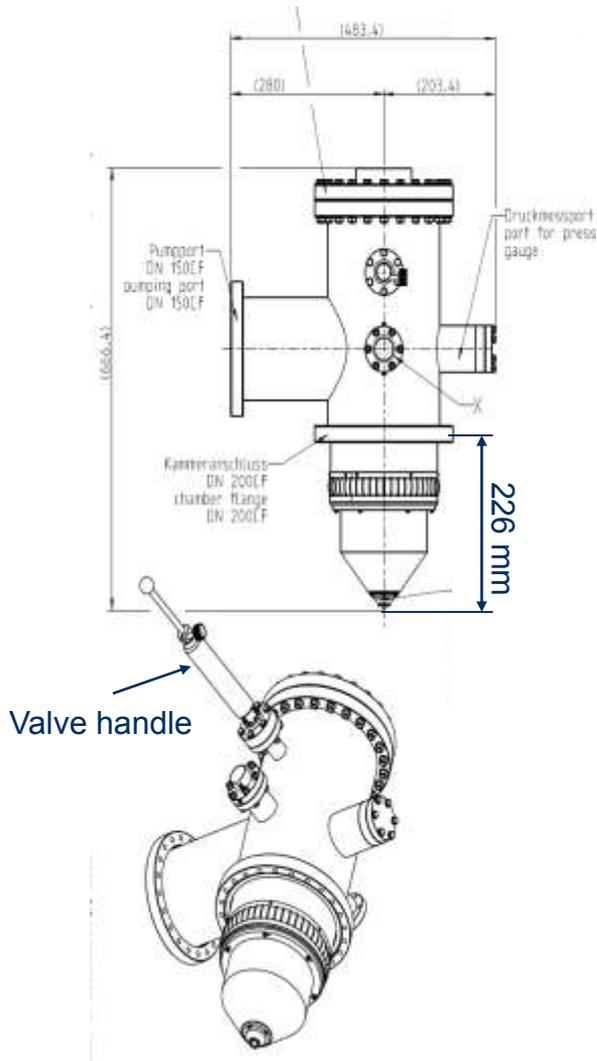
- **For energies up to 7 keV**
- **Fully floating lens and hemisphere**
- **Fast and compact 7 kV power supply**

## NEW: PHOIBOS 150 NAP



- high-pressures up to 25 mbar
- large acceptance angles up to  $\pm 30^\circ$
- **up to 7 keV kinetic energies**

# NEW: HV WAL Pre-Lens



Wide acceptance angle pre-lens for PHoIBOS and THEMIS:

- large acceptance angles up to +/- 30°
- higher transmission
- up to 10 keV kinetic energies
- Modular design

## NEW: X-ray sources for HAXPES

**XR 50**



**FOCUS 500**



- Cr K $\alpha$  (5417 eV) & Cu K $\alpha$  (8055 eV)
- cooled anode head
- complete remote control
- High X-ray flux at the sample

- Cr K $\alpha$  (5417 eV)
- High resolution
- Low background
- No satellites
- Focused X-ray spot 120 – 800  $\mu\text{m}$

# NEW: 2D-DLD HV Detectors

## 3D-DLD6565(HV)



- active area of DLD anode: 65 mm x 65 mm
- typ. image sizes in pixels: 2000 x 2200
- **>1000 Energy Channels**
- **>500 Angle Channels**

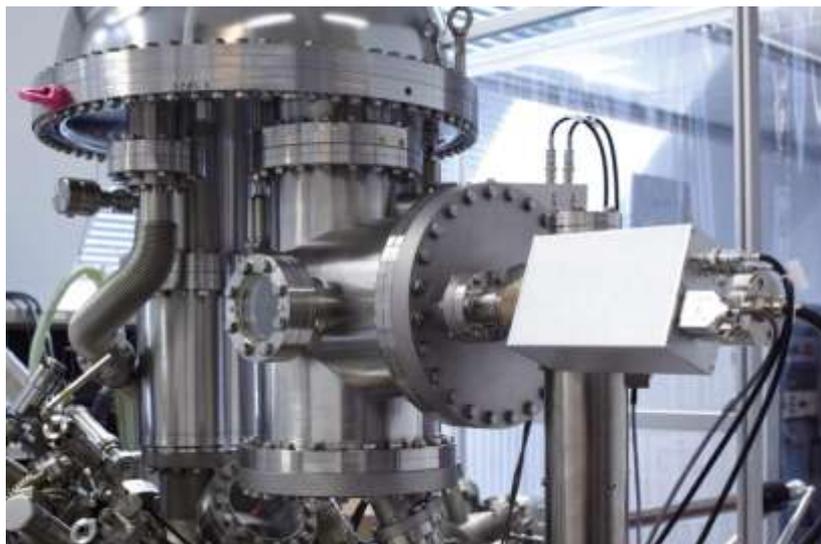
## 3D-DLD6565(HV)



- active area of DLD anode: 80 mm x 30 mm
- typ. image sizes in pixels: 2400 x 1000
- **>1200 Energy Channels**
- **>500 Angle Channels**

- typ. time resolution:  $\leq 240\text{ps}$  absolute,  $\leq 100\text{ps}$  relative
- >4000 Time Slices (from 7 ps to 10 ns)
- spatial resolution  $< 80\mu\text{m}$
- linear response due to single event counting<sup>2</sup>
- extremely low dark count rate: typ.  $< 0.2$  counts per second per  $\text{cm}^2$
- max. random countrate  $> 5$  Mcps in 2D/ 3D mode

## NEW: 2D / 3D Spin Detectors



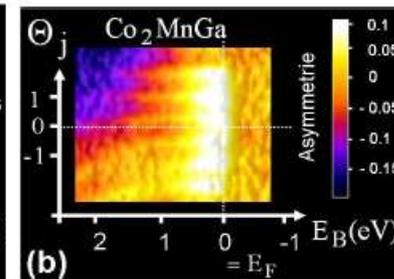
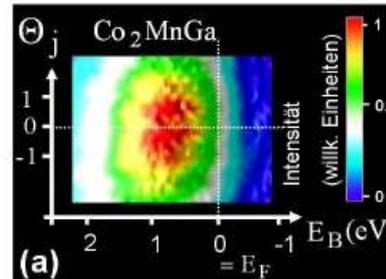
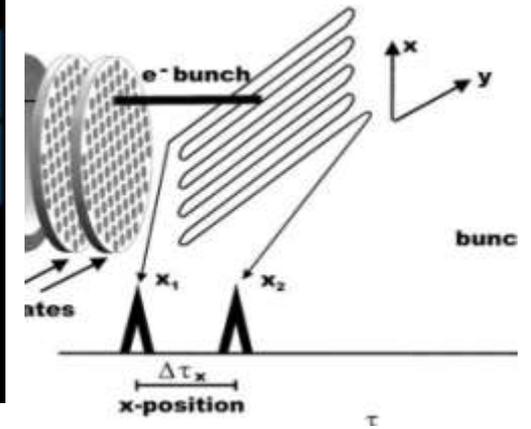
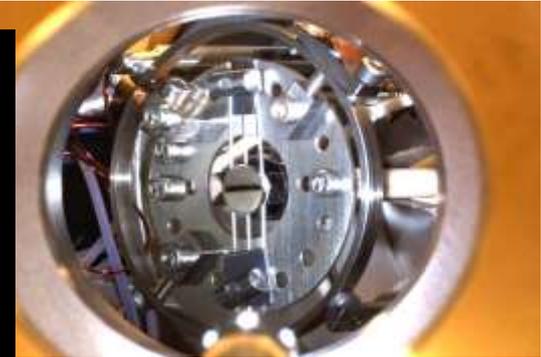
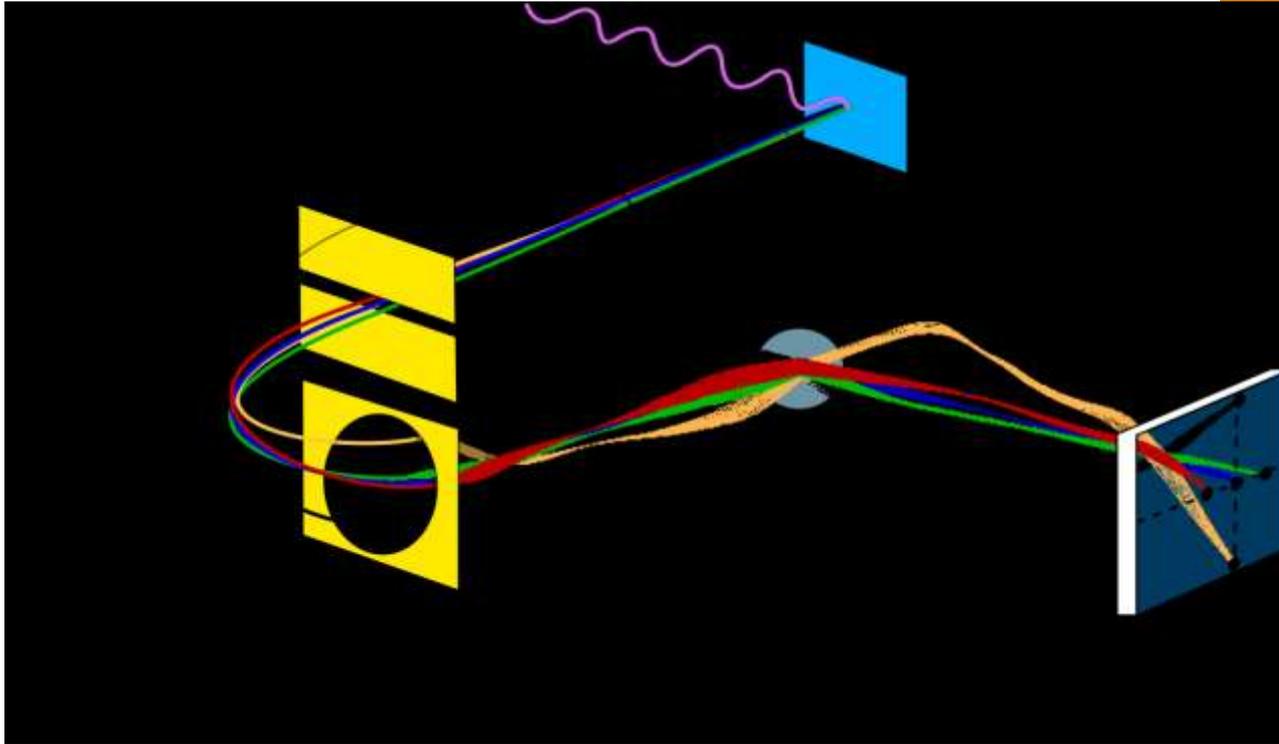
### Combined 2D - Spin Detectors

2D-CCD or 2D-DLD (40 mm)

combined with

2D or 3D Spin Detector

# NEW: Display-type Spin detector



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**Thank you for your attention!**

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## Segmented DLD 4040 – S9HV for HV PHOIBOS 225

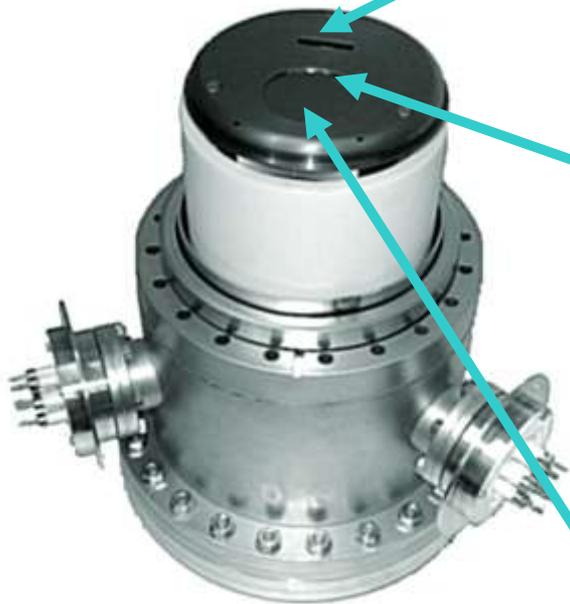


- 2D/3D detector and 9 channel detector in one
- Operation at base potentials ranging from zero up to -15 kV
- 40 x 40 mm<sup>2</sup> active area of DLD body and  $\varnothing$  46 mm active MCP area (active area of 40 x 20 mm<sup>2</sup> in PHOIBOS Analyzers)
- Up to 45  $\mu$ m of pixel size
- Up to 27 ps digital time bin resolution
- < 250 ps over all time resolution
- Linear response due to single event counting
- Extremely low dark count rate: < 5 cps
- Up to 3 MHz count rate in 2D mode
- Up to 20 MHz count rate in 9 channel mode

# Multimode DLD 4030 – S9MMHV :

SPeCS

## Combined Delayline / 9 channel / Micromott – Detector:



### **Micromott detector**

#### **technical parameters:**

- extremely low dark count rate @ -15kV: < 4 CPS per channel
- 4 channel backscattering Mott detector, Au or Th targets
- max. 25 keV scattering energy
- efficiency about  $3 * 10^{-5}$  with a Sherman function of 0.1 (Au target)

### **Delayline detector**

#### **technical parameters:**

- pixel resolution: 45  $\mu\text{m}$  (spatial resolution typ. 150  $\mu\text{m}$ , layout depending)
- max. count rate: 3 MCPS
- detection area: 40 mm x 30 mm
- time resolution: < 250 ps
- true counting, highly linear signal transfer
- extremely low dark count rate @ -15 kV: < 5 CPS at the entire detector

### **9 channel detector**

#### **technical parameters:**

- max. count rate: typ. 20 MCPS
- dark count rate @ -15 kV: < 10 CPS per channel
- true counting, highly linear signal transfer



## pixelfly qe



- quantum efficiency up to 65%
- ultra compact design
- 12bit dynamic range
- high resolution (1392 x 1024pixel)
- temperature compensated
- exposure times from 5 $\mu$ s - 65s



Fast data collection  
(400 spectra in 0.1 sec)

**pco.**  
imaging

## sensicam qe



- quantum efficiency up to 65%
- extremely low noise, down to 4e<sup>-</sup> rms
- 12bit dynamic range
- thermo-electrical cooling (Peltier) down to -12°C
- high resolution (1376 x 1040pixel)
- shutter / exposure times from 500ns - 1000s

### Two operational modes:

- Exposure mode
- Event counting