DFS30

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Stay focused, save time

The DFS30 analyser features ground-breaking Electrostatic 3D Focus Adjustment technology - a major advancement in replacing imprecise mechanical movements with electronic precision and repeatability. This provides significantly improved workflow, speed, and reproducibility when optimizing experimental conditions. High quality ARPES measurements, particularly µARPES and nanoARPES, require optimised alignment of the photon source, sample, and analyser focal point. The DFS30 simplifies this with electronic adjustment of the analyser focal point.

Measuring high quality band structures of realistic samples often requires high spatial resolution to resolve domains, fracture surfaces, gated devices, or twistronics based on flakes. µARPES and nanoARPES provide this capability and have highlighted the importance of optimal alignment for high resolution deflection measurements. Small misalignments between photoemission spot and analyser focal point in the 100 µm range can result in partial to complete blackouts in the measurement intensity.

Innovation for µARPES

The common solution adjusts both sample and photon source to move the emission spot to the analyser focal point. For a specific region of interest, such as a flake, this movement inevitably means losing that position. It is far more favorable to shift the analyser focal point instead, leaving the emission spot mechanically static on the sample, at the region of interest. The DFS30 features this ground breaking capability.

Electrostatic 3D Focus Adjustment

Electrostatic 3D Focus Adjustment technology (patent pending) introduces dynamic lens tables generated in real time for deflection, angular, and transmission modes. The analyser's focal point is conveniently shifted in X, Y, and Z (working distance) to the photoelectron emission spot using software sliders. This replaces imprecise mechanical movements of sample and photon source with electronic precision and repeatability.

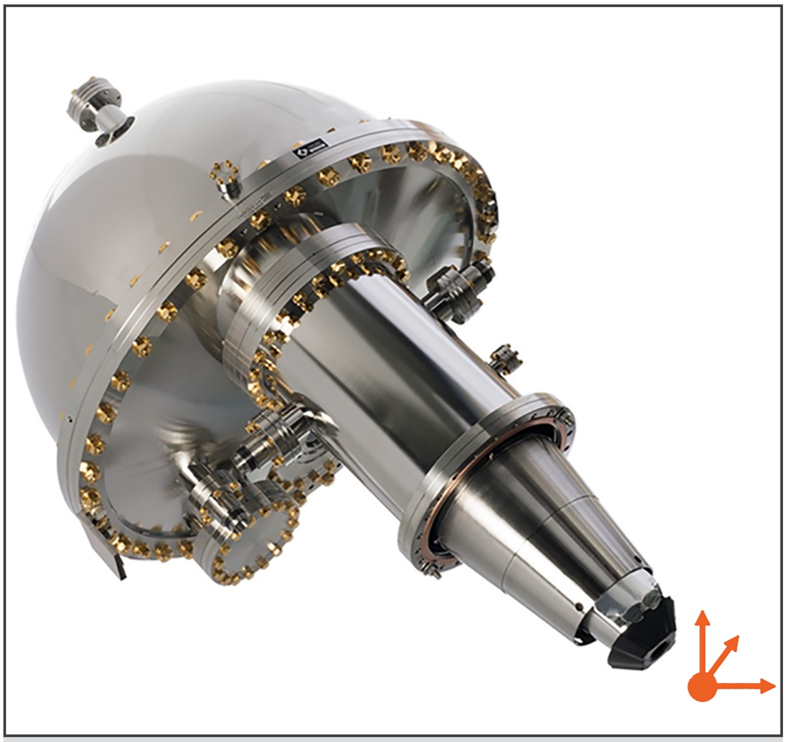


Figure 1: The DFS30, the new standard for angle resolved photoelectron spectroscopy, is equipped with Electrostatic 3D Focus Adjustment. Real time calculated lens tables allow to adjust and shift the analyser focal point to the emission spot on the sample, ideal for small spot µARPES measurements.

- Electronically shift the analyser focal point to the photoemission spot
- Increase effective sample life-time through fast and precise alignment
- Electrostatic 3D Focus Adjustment in X, Y, Z (WD) for best results
- Deflection mode full cone measurements without matrix element effects
- Upgrade from DA30-L available

The emission spot can now remain static on the region of interest, not risking to lose this position, while optimising for best measurement conditions. This significantly improves the workflow, speed, and reproducibility (see Figure 2 on next page) saving hours of alignment time. This leads to preserved sample surface quality and effective sample lifetime for measurements.

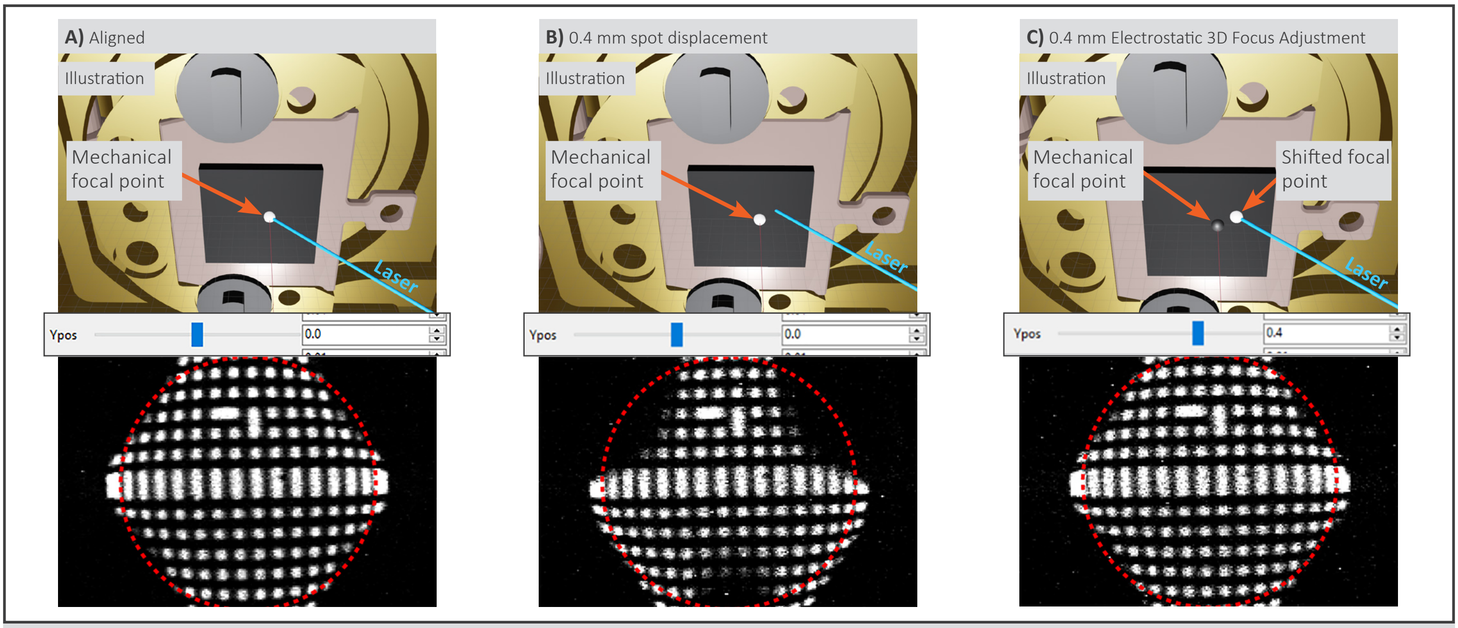


Figure 2: Electronic 3D Focus Adjustment results: A) shows a well-aligned situation with the analyser focal point and emission spot overlapping. The complete analyser acceptance angle, indicated by the red circle, is filled with accurate intensity. B) The 0.1 mm emission spot is misaligned by 0.4 mm. The corresponding measurement shows shadowing and asymmetry between the upper and lower half. C) Using Electrostatic 3D Focus Adjustment, the analyser focal point is easily shifted with a slider to the emission spot without any mechanical movement. The corresponding measurement shows the full accurate data expected for a well aligned situation. The grey point indicates the analyser mechanical focal point, without Electrostatic 3D Focus Adjustment.

High quality ARPES measurements

High quality ARPES measurements require avoiding any uncontrolled modulation of the data. Deflection mode analysers address this by replacing imprecise mechanical motion of the sample with precise electrostatic deflection. This improves angular resolution perpendicular to the slit, previously done mechanically, and keeps the experimental geometry fixed (photon source, sample, and analyser). The latter is crucial to avoid geometry dependent effects such as intensity modulating matrix element effects when measuring the Fermi surface.

High quality ARPES measurements further require small aperture-slit combinations to provide high angular resolution, energy resolution, and reliable energy position determination. Without optimal alignment of analyser focal point and emission spot, some electron trajectories are too steep to pass the aperture-slit combination. This applies particularly to deflection mode measurements with θ_y angles larger than a few degrees. The absence of these trajectories reduces the accessible angular range as shown in the deflection mode measurements in Figure 2.

For small spot sizes typical in µARPES, control of the emission spot and analyser focal point alignment has proven far more critical for deflection mode analysers than for earlier generation instrumentation. To reach the next substantial instrumental improvement, refining the existing parameters is no longer sufficient. Instead, a paradigm shift based on true innovation and deep understanding of limiting factors is required.

Sample region

The analyser lens system is rotationally symmetric and made of homogenous materials and coatings. In contrast, the sample region consist of a variety of critical components: manipulator, cryo shields, focusing optics, sample holder, sample roughness after cleaving, etc. This mix of materials with different work functions leads to fields in the vicinity of the sample.

The fields are geometry dependent and mechanical movements of sample or focusing optics will unpredictably alter the field strength as well as direction. The field acts as a perturbation on the photoelectrons before entering the analyser lens and alters the optimal alignment. Higher photon energies mitigate this effect, however, high energy resolution measurements require low pass energies making the lens more sensitive to the perturbation. To date, this perturbation is often compensated for by shifting the emission spot to a new optimal alignment position, with risk of losing the sample region of interest.

Alignment shift with perturbing fields

Perturbing fields near the sample do not affect photons and do not change the position of the emission spot but they change the optimal alignment of emission spot and analyser focal point.
In Figure 3 this effect is illustrated using simulations for two different transmission modes, with and without the perturbation. The kinetic and pass energies are set to 2 eV.

In Fig. 3(a), an object is placed near the sample region without any bias (black) and biased to 0.2 V to reflect a local work function difference (green). This perturbing field causes a significant deviation of the electron trajectories. This can cause a significant loss of signal intensity if no longer focused on the slit. For higher kinetic energies the same perturbation causes a smaller deviation.

The perturbation can be mechanically compensated by shifting the emission spot on the sample as shown in Fig.3 (b). The emission spot is shifted by –0.65 mm to an offset position (blue) which alters the trajectories enough to bring them back to the slit and the intensity is recovered.

Fig. 3(c) illustrates the effect of the same perturbation for a different transmission mode. The observed trajectory deviation at the slit is now in the opposite direction. The emission spot shift required for compensation remains in the same direction but is now reduced by 100 µm to –0.55 mm.

The perturbation affects angular and deflection modes differently than the transmission mode examples above. The θ_x and θ_y angular positions remain unaffected on the slit position. The perturbation will instead cause a difference in electron incidence path. If this path is too steep the trajectories cannot pass the aperture-slit combination and this is seen as an unsymmetric shadowing of the intensity rather than a deviation in k. This is especially the case for higher deflection angles (see Figure 2). Shifting the emission spot to new optimal alignment conditions mitigates this effect.

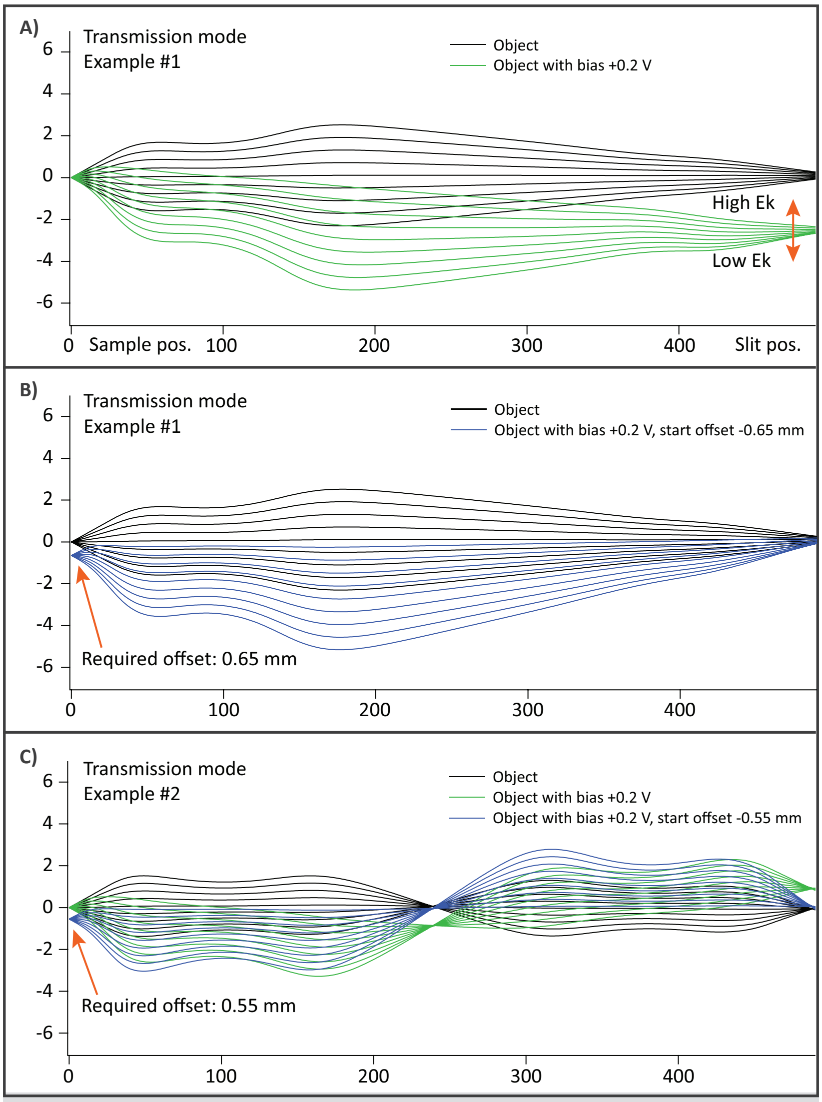
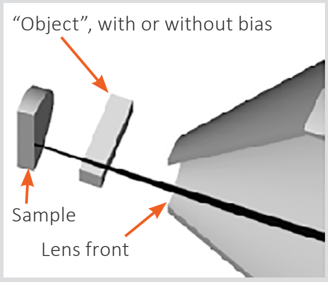


Figure 3: (a) Transmission mode: Local work function differences near the sample result in a perturbing field that cause electron trajectories to deviate (green) from the ideal sample region approximation without perturbation (black). (b) The lost intensity can be recovered by moving the emission spot to a new offset position by –0.65 mm (blue). (c) For a different lens mode, the direction of the offset compensation remains the same, whereas, the value is reduced by 100 µm to –0.55 mm.



The required shift of the emission spot to compensate for a given perturbation clearly depends on energy and lens mode. In addition, the perturbing field itself is geometry dependent. This makes it impossible to find an universal alignment for all lens modes and kinetic energies. Alignment with a test device or a Au(111) sample will for instance not hold true for a small cleaved sample on a pin. Instead of compensating by shifting the emission spot, a far better solution is to adjust the analyser focal point using Electrostatic 3D Focus Adjustment. This avoids any unnecessary mechanical movement of sample or photon source when the alignment conditions change.

Parametric description of sample region

Electronic compensation of the perturbing fields is possible by optimising each kinetic energy point of the lens voltage table purely empirically for each possible experimental condition. While very time intensive, this has been done for transmission and angular modes. For deflection modes, particularly sensitive to alignment, tweaking lens tables manually has not been possible, until now.

Electrostatic 3D Focus Adjustment is ground-breaking as it provides a parametric description of the measurement region near the sample. Parameters with known meaning and function give control of what is changed, by how much, and provide intuitive user-friendly feedback. This removes the ad-hoc corrections and speeds up the empirical optimisation process.

Based on the parametric description, new lens tables and lens element voltages are calculated in real time. These adjust the focal point of the analyser and compensate the perturbing fields near the sample to achieve optimal alignment.

Measuring with an suboptimal alignment leads to poor angular resolution and intensity shadowing effects. With Electrostatic 3D Focus Adjustment easily retrieves the current optimal working distance (Z), X, and Y electronically. This enables to:

- measure with the parametrically found solution for the current conditions, or
- move to the optimal position based on the current reading before proceeding with the measurement.

This replaces the time consuming workflow where multiple acquisitions for varying photon source and manipulator positions are acquired and subsequently compared. Finding optimal alignment conditions faster leads to preserved sample surface quality and effective sample lifetime for measurements.

Technical Data

Property	Specification
Electrostatic 3D Focus Adjustment	Yes
X & Y	± 1 mm
Working distance (Z)	34 mm (± 2.5 mm)
Lens acceptance angle	38°
Angular resolved range	± 15° full cone
Angular resolution	0.1° for 0.1 mm emission spot 0.4° for 1 mm emission spot
Slits	9
Detector type	MCP/digital camera or DLD
Detector interface	Ø 40 mm MCP
Energy channels	> 1 000 simultaneous
Angular channels	> 750 simultaneous
Acquisition modes	Scan, Fixed
Mounting flange	DN200CF, rotatable
Bakeout temperature	150 °C
Pressure	< 2x10^{-10} mbar

Upgrade:

DA30-L analysers can be upgraded with Electrostatic 3D Focus Adjustment. A prerequisite is that the system is upgraded to the PEAK software.

Models	DFS30	DFS30-EXT	DFS30-8000
Energy resolution	1.8 meV	1.8 meV	1.0 meV
Pass energy	2-200 eV	2-200 eV	0.5-10 eV
Kinetic energy range:			
Transmission mode	0.5-1500 eV	0.5-1500 eV	0.5-12 eV*
Angular mode	3-1500 eV	0.5-1500 eV	0.5-12 eV*
Deflection mode	3-200 eV	0.5-200 eV	0.5-12 eV*

The DFS30-EXT has the same resolution specifications as a DFS30 but improves the low kinetic energy performance below 3 eV. The DFS30-8000 is specifically developed for ultra high resolution at the lowest kinetic energies. This is the model of choice for customers who wish to perform ultra high resolution ARPES measurements below 3 eV kinetic energy.

* A UPS upgrade is available offering a mode extending the kinetic energy range to 100 eV.

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For more information on DFS30, please visit: https://scientaomicron.com/en/Components/Electron-Analysers/DFS30