Ultimate energy resolution of the PHOIBOS Energy Analyzer Series

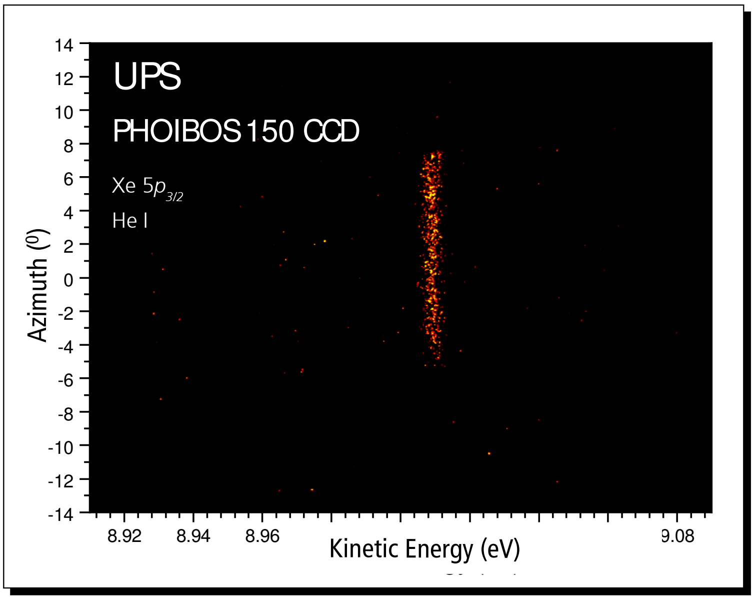
Application Notes

We have measured the line width of the Xe $5p_{3/2}$ gas line using the SPECS gas cell UGC 10 and the SPECS UV-light source UVS 300. The special geometry of the cell includes space charge compensation electrodes to demonstrate the ultimate energy resolution of the PHOIBOS analyzers together with the 2D-CCD Imaging Detector.

The Doppler broadening ΔE_D of the target gas in the cell depends on the mass and the kinetic energy. It is due to the thermal motion of the emitting atoms or ions. For a Maxwellian velocity distribution, the line shape is Gaussian; the full width at half maximum intensity (FWHM) is, in meV,

$$\Delta E_D = 0.7215 \sqrt{\frac{E_{kin} \cdot T}{M}}$$

This expression (ΔE_D in meV) is derived from the Boltzmann distribution, where E_{kin} is the photoelectron energy in eV, T is the absolute temperature, and M is the molecular mass expressed in atomic mass units. The theoretical foundations of line broadening are discussed in *Atomic, Molecular, & Optical Physics Handbook*, Chaps. 19 and 57, ed. G.W.F. Drake (AIP, Woodbury, NY, 1996).



CCD camera image of Xe $5p_{3/2}$ (excited with He) measured with FAT 1.5 . The measurement was performed using a PHOIBOS 150 CCD analyzer.

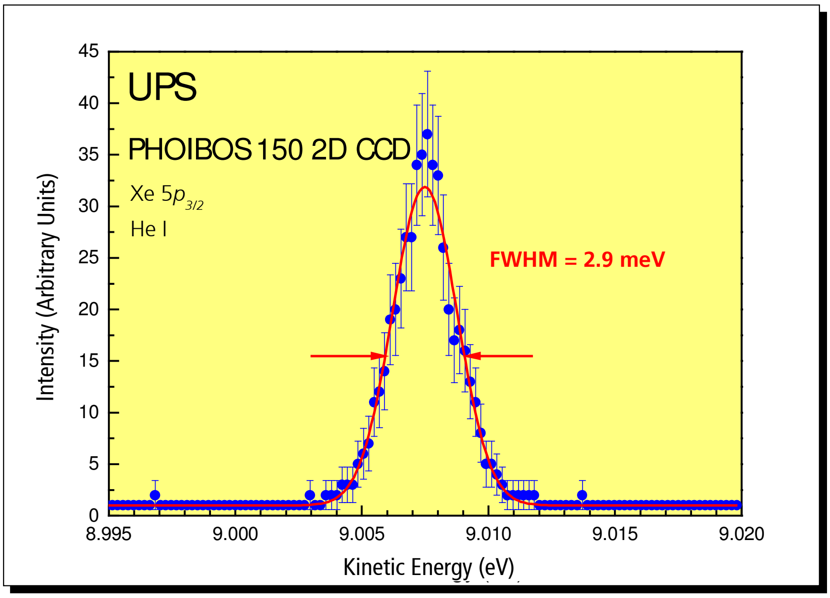
The figure below depicts the Xe $5p_{3/2}$ level excited with He I UV radiation measured with a PHOIBOS 150 2D-CCD analyzer at a pass energy E_p of 1.5 eV and a slit width s_1 of 0.1 mm. The curve fitting is performed using a Gaussian line shape. The FWHM of 2.9 meV includes the line broadening of the excitation source ΔE_S, the Doppler broadening ΔE_D and the analyzer resolution ΔE_A.

The data show that broadening due to the analyzer and UV source can be neglected, at least being much smaller than the calculated 3.3 meV Doppler broadening of the Xe target gas using the formula for a Maxwellian velocity distribution above.

The kinematics of the gas in the cell yields a sub-Doppler resolution and therefore the analyzer resolution can't be calculated. But comparing this data with state of the art measurements achieved by another manufacturer it was confirmed that the analyzer resolution in this measurement is nearly at the theoretical limit. The theoretical limit for ΔE_A is given by the formula below. At $E_p = 1.5$ eV the contribution of the PHOIBOS analyzer to the total line width is nearly:

$$\begin{aligned}\Delta E_A &= \frac{s_1 + s_2}{4R_0} Ep \\ &= \frac{0.1\text{mm} + 0.1\text{mm}}{4 \cdot 150\,\text{mm}} \cdot 1.5\text{eV} \\ &= 0.5\text{ meV}\end{aligned}$$

Xe $5p_{3/2}$ (excited with He I UV radiation) measured with FAT 1.5 . The curve fitting was performed using a Gaussian line shape. It shows the very high resolution capabilities of the PHOIBOS analyzer together with a 2D-CCD detector. The measurement was done with a PHOIBOS 150 2D-CCD analyzer.



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