OPTIMAL OPERATION OF A 4-ELEMENT INJECTION LENS IN A HEMISPHERICAL SPECTROGRAPH: FDM/BEM SIMULATION AND EXPERIMENTAL DEMONSTRATION

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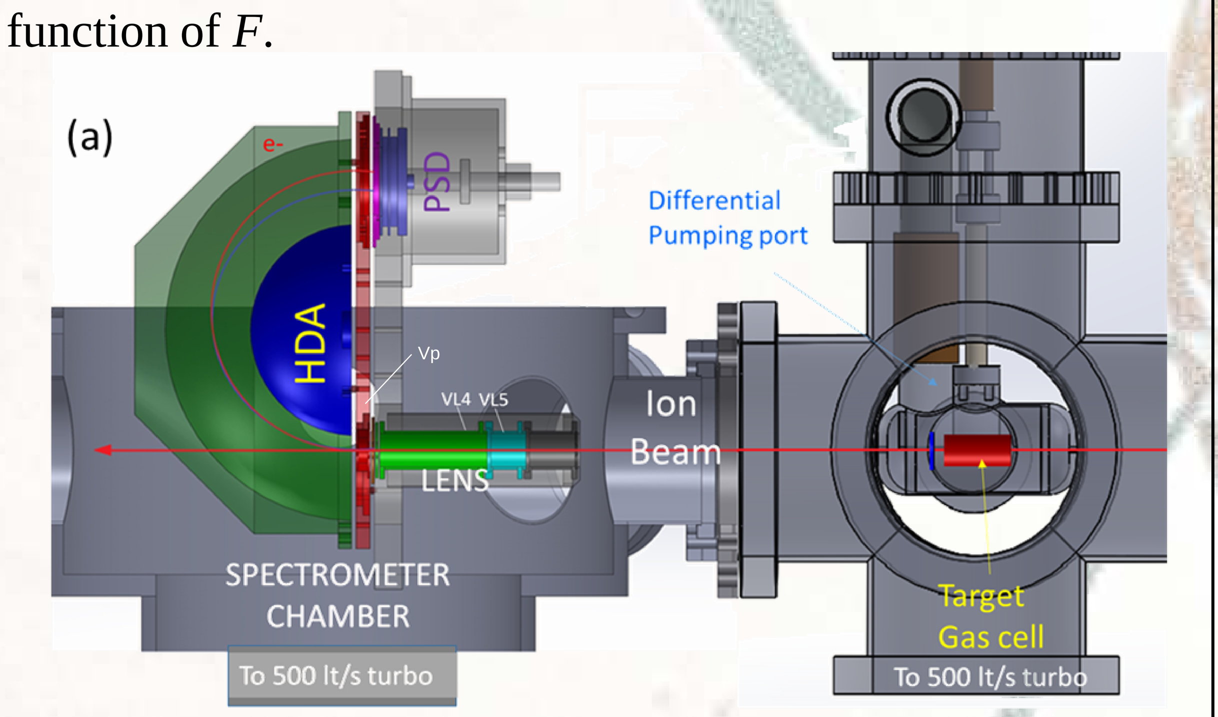
ABSTRACT: Results from a 4-element lens optimization analysis using simulations are presented for a biased paracentric hemispherical deflector analyzer (HDA) with an injection lens. Calculations of electron trajectories in the HDA fringing fields and the lens potentials are based on the boundary-element method (BEM) [1] and the finite-difference method (FDM) [2]. The two adjustable lens electrode voltages were varied as free parameters while beam spots of minimum size Δx_B on the 2-D position sensitive detector were searched for using a beam shaping technique in an effort to obtain improved energy resolution [3]. The resulting lens voltages were then also tested experimentally on the HDA at the Demokritos 5 MV Tandem Accelerator Laboratory [4]. Good overall agreement was found between simulation and measurements, particularly at the best resolution working points.

A 3-D drawing of the complete analyzer system is shown in **Fig. 1(a)**. **Fig. 1(b)** shows a sketch of the full experimental setup modeled in these calculations. Panoramic view of the APAPES beam line is shown in **Fig. 2**. It is well known that the analyzer resolution can be improved by pre-retardation, $F=E_{s0}/E_0$, where E_{s0} and E_0 are the source and pass energy, respectively. In **Fig. 3** we plot the Δx_B contour maps generated for all possible voltage polarity (positive or negative) combinations for V_{L4} and V_{L5}. We observe that in each case the voltages giving rise to the smallest values of lie along elliptical-like curves. Energy spectra are plotted in **Fig. 4**. In the plot of **Fig. 5**, the resolution is plotted as a function of F.



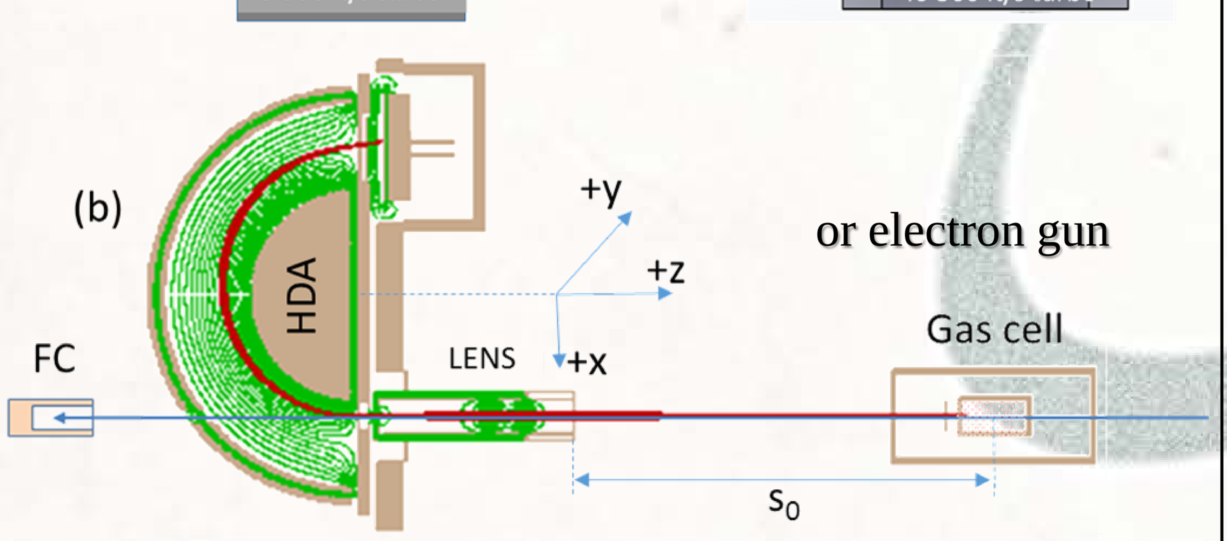


FIG. 1: Schematic representation of the spectrograph consisting of an input lens, the HDA and the PSD. All the important elements are shown. Each colour represents a different voltage. V_{L4} and V_{L5} are the lens voltages varied in the simulations. V_p is responsible for the final electron deceleration.

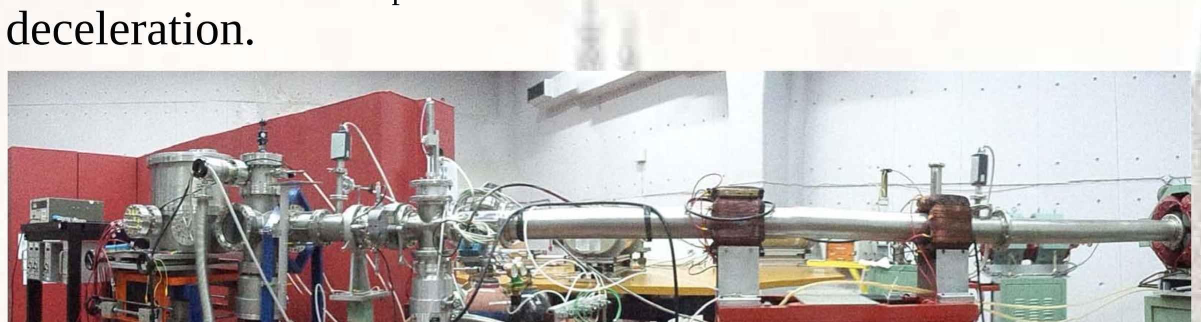


FIG. 2: Panoramic view of the APAPES beam line.

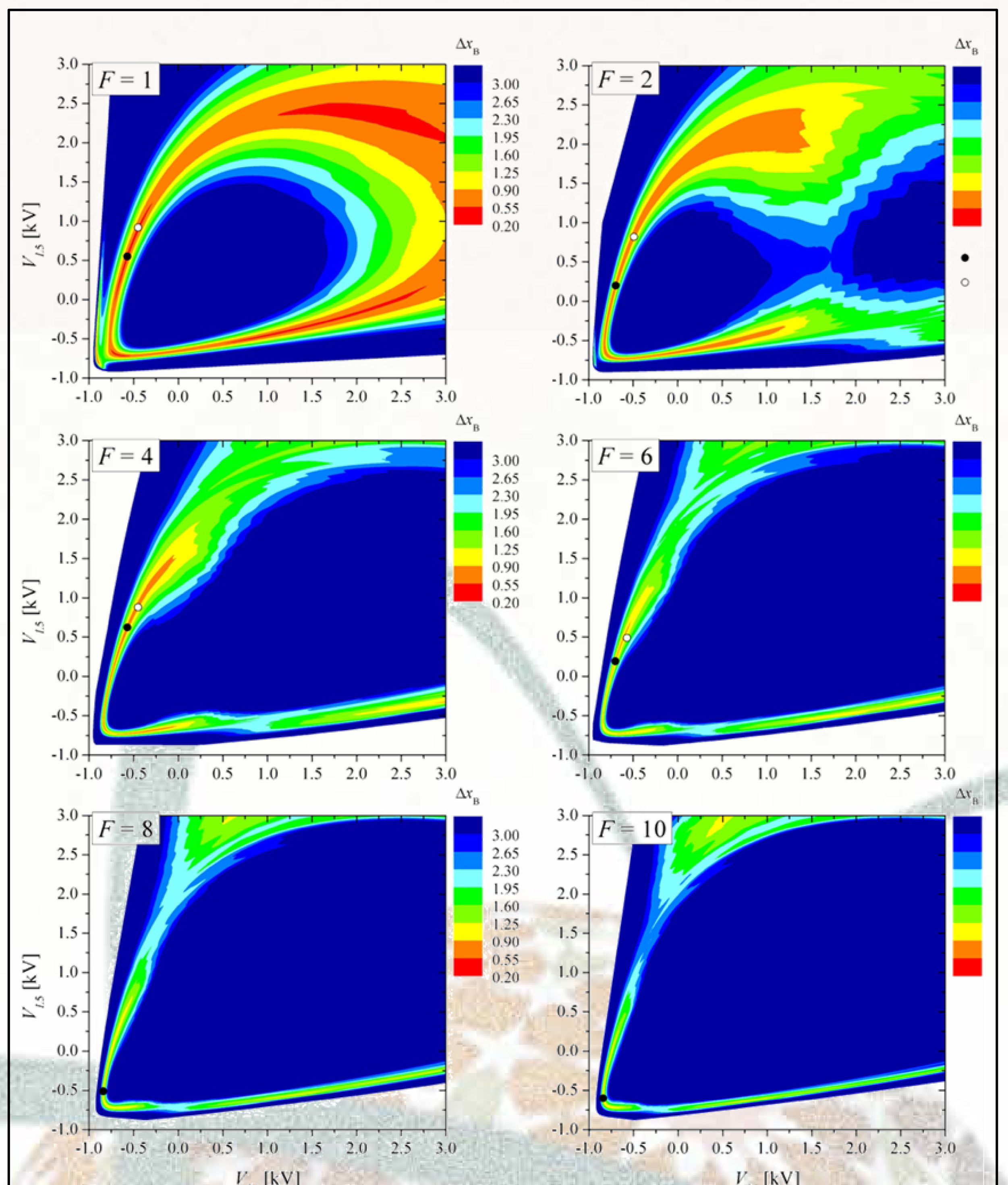


FIG. 3: Contour maps of V_{L4} vs V_{L5} with the z-axis measuring for Δx_B. The black dots represent voltages for the smallest values of Δx_B, while the white dots represent the voltages found empirically.

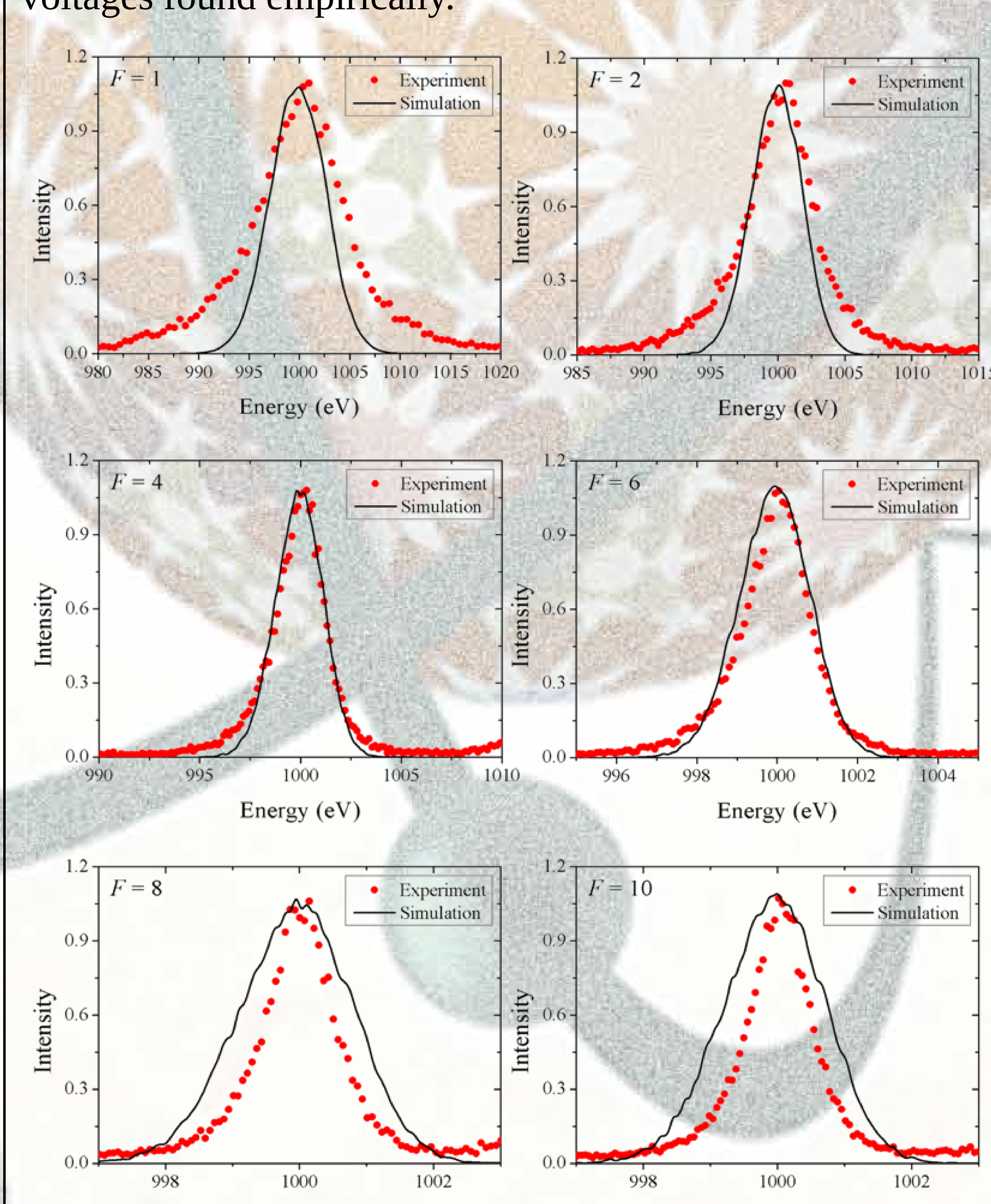


FIG. 4: Experimental (red circles) and computed (black solid lines) energy spectra for different pre-retardation ratios F = 1-10. The optimizing lens voltages have been found using Fig. 3. The instrinsic energy resolution of the electron gun (~1.0 eV FWHM) has been taken into account in the simulation.

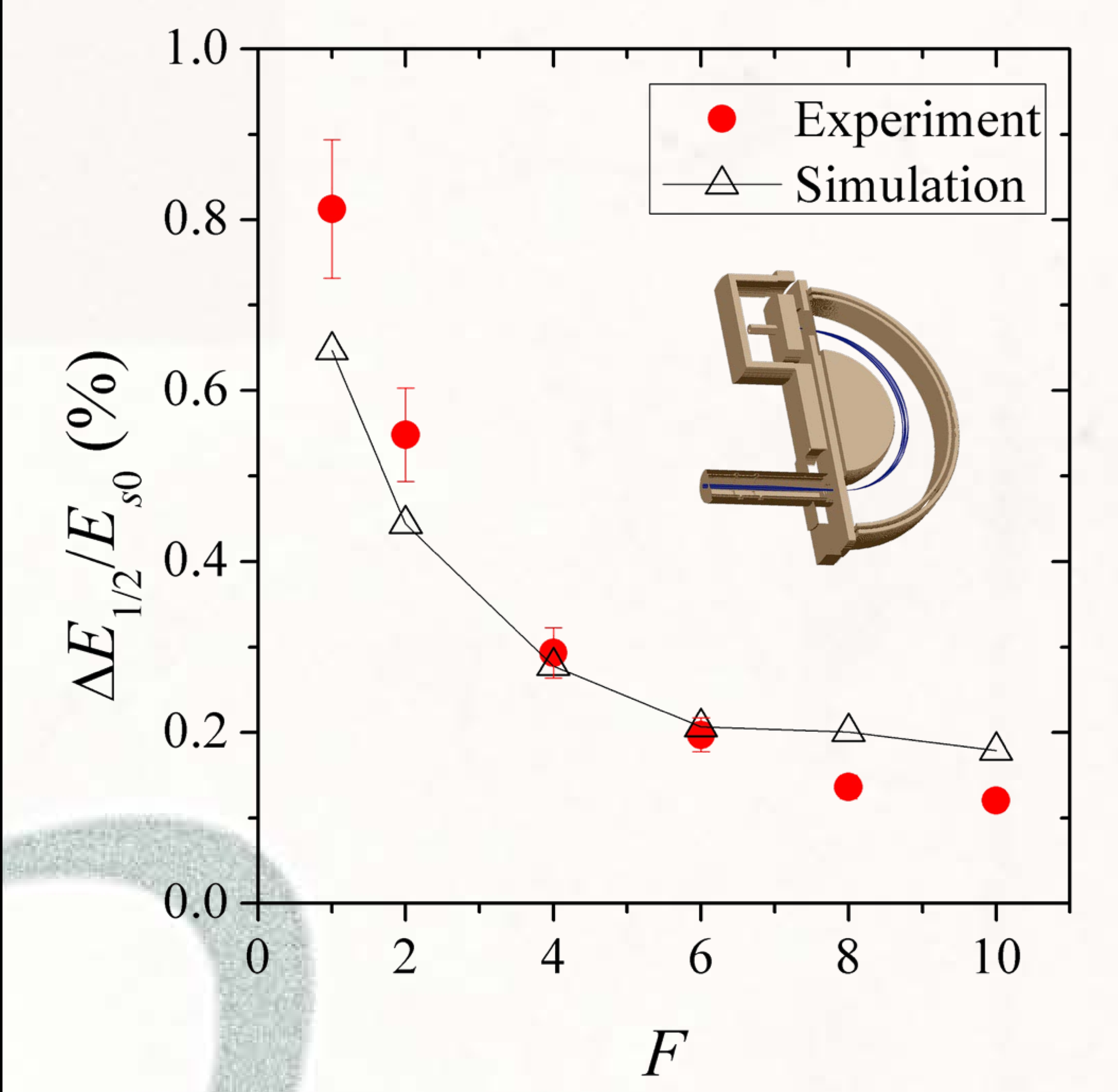


FIG. 5: Relative FWHM Resolution (%) plotted as a function of F: (open triangles) SIMION this work (see Fig. 4); (Red circles) Recent experimental results using the APAPES setup [5] taken with hot wire e-gun using the lens voltages from Fig. 4.

SUMMARY AND CONCLUSIONS

Using the BEM and FDM approaches we have investigated the voltage settings for the 4-element injection lens of an HDA with virtual entry aperture and 2-D PSD that can lead to improved energy resolution. The two well-known approaches in charge particle optics complement one another and are found to be in good agreement. SIMION was primarily used in our brute force search for the two lens voltages that lead to the minimization of the beam trace width on the PSD. The entire voltage space was searched with various step sizes and the best voltage combinations were further checked by BEM simulations.

The optimal two lens voltage combinations were found to lie on families of elliptical-like contours. All 4 possible combinations of positive and negative voltages gave rise to minima and from these only the subset with the smallest voltages were investigated as most practical. We also investigated the 2-D spots (images) on the PSD for these optimal voltage combinations from which we could extract both the FWHM and base widths as well as the line profiles.

As a final test, we also checked our optimal lens voltages on the experimental setup and also measured the FWHM of real electron lines which were in overall good agreement with our simulations.

References

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