Probe Size and Detection Efficiency Optimization in Electrostatic Lens Systems Using Multi-Objective Genetic Algorithms

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Optimization of multi-electrode lens systems has so far been carried out by a combination of manual and automated optimization. This is quite a challenging process, especially for lens systems having many free variables (i.e. geometry and voltages). A fast, fully automated optimization is the solution but it is not yet available, mainly due to the time consuming process of accurate potential calculations, needed to calculate the objective function. In previous work[1], we presented a fast fully automated optimization technique using Genetic Algorithms (GA)[2], and potential calculation based on a combination of COMSOL Multi-physics software and the so-called Second Order Electrode Method (SOEM)[3]. In there, we only considered single-objective function optimization problems. However, in many electron lens design problems, there are more objective functions involved to be optimized simultaneously, and there are constraints to be met (e.g. limited field between electrodes, fixed image plane). Such problems are more complex, especially when the objective functions work against each other. An example is an objective lens design optimization in which the probe size (PS) of the primary beam has to be minimized, while collecting the secondary beam on an in-lens detector with a maximum detection efficiency (DE). This subject is investigated here using our previous technique[1], but now using a Multi-Objective GA (MOGA) applied to a lens system with 5 electrodes (Fig. 1) and the electrode dimensions and voltages as free variables (19 in total). It is shown that MOGA can handle this problem, by using a combination of SOEM+COMSOL for the field calculation. Figure 2 illustrates how the systems improve by MOGA, starting from a system randomly created by GA, not satisfying the constraints (A1 in Fig. 2). Systems A2-4 in Fig. 2 all satisfy the constraints, A2 having low DE and high PS, and A3 a high PS and moderate DE. After thousands of system evaluations (~ 1-2 days) a system, system A4, was found with a low PS and a very high DE.

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[1] N. Hesam Mahmoudi Nezhad et al., Multi-electrode lens optimization using genetic algorithms, Int. J. Modern Physics A , Vol. 34 , p. 1942020, (16 p.) , 2019.
[2] M. Mitchell, An Introduction to Genetic Algorithms, MIT Press, Cambridge, London, 1998.
[3] J.P. Adriaanse, H.W.G. van der Steen, and J.E. Barth, Practical optimization of electrostatic lenses, J. Vac. Sci. Technol. B7, pp. 651- 666, 1989.

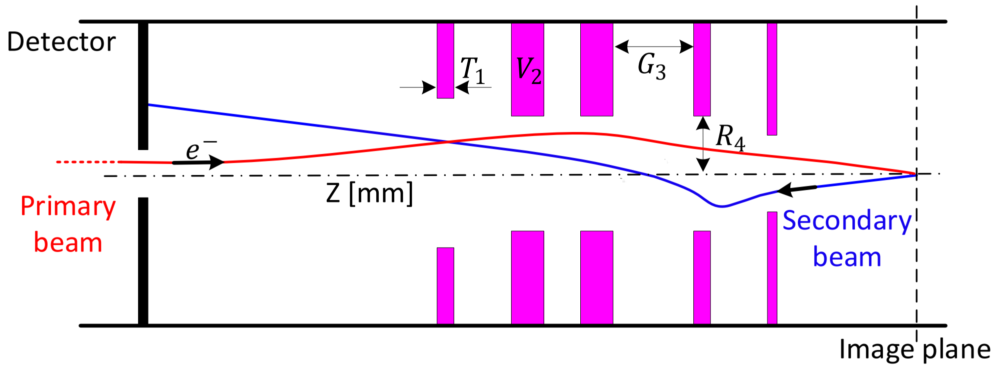

Figure 1: Schematic 2D cross-section of a rotationally symmetric 5-electrode lens system: The primary and secondary beams (shown in red and blue), are passing through the same column. T_i, R_i, and V_i, indicate thicknesses, radii and voltages at each electrode i, the G_i indicates the gaps between two sequential electrodes.

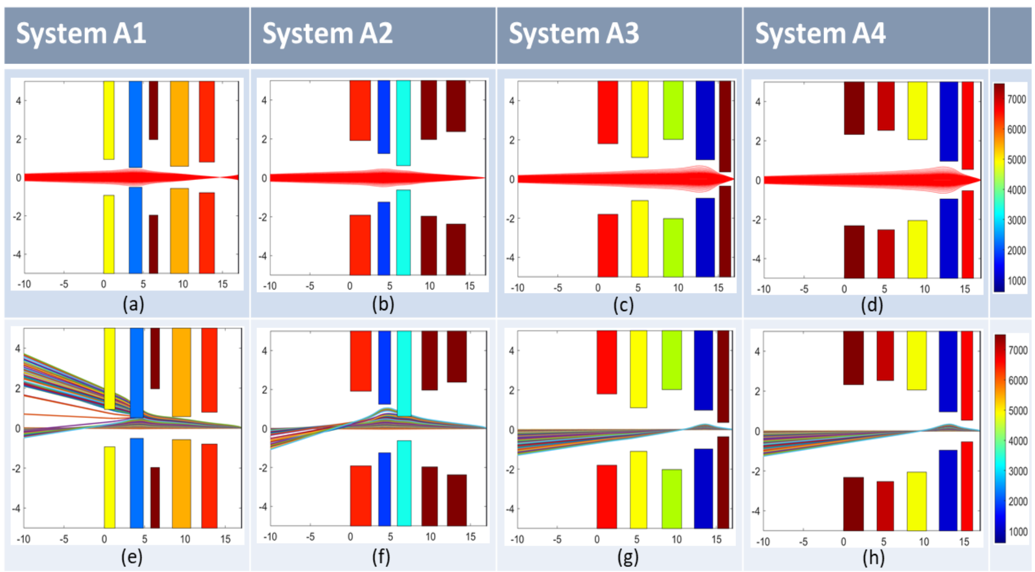

Figure 2: Improvement of lens systems by Multi-Objective Genetic Algorithm (MOGA) optimization in MATLAB. The results are taken from a MOGA run, while trying to find the optimized system which satisfies two constraints (1. focusing the primary electron beam (PE) at the image plane, 2. limitation on fields to prevent discharges) and two objective functions: minimum probe size (PS) at the image plane and maximum detection efficiency (DE) of the secondary electron beam (SE) at the in-lens detector. PEs and SEs passing through the lens systems are shown in the top (a-d) and bottom figures (e-h), respectively. System A1: constraints not satisfied. System A2: constraints satisfied, very low DE and relatively high PS. System A3: constraints satisfied, moderate DE and low PS. System A4: constraints satisfied, very high DE and low PS. The vertical scales are in mm, the horizontal scales in mm, and the colour scale is in Volts. (Note: PEs are coming at different angles, from -23 mm, traced by paraxial ray-tracing. The horizontal axis is sketched from -10, for a better visualization. SE trajectories are produced by real ray-tracing).