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The SPANOCH method: A key to establish aberration correction in miniaturized (multi)column systems?

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Charged particle optics is a continuously developing and expanding technology with a meanwhile broad area of applications.

Unfortunately charged particle optics applications are usually limited by aberrations, especially by the spherical aberration. In the highly sophisticated field of electron microscopy correctors are meanwhile commonly used. Hexapole correctors are state of the art and are continuously advanced by CEOS Company, Germany.

Nowadays charged particle optics finds its way into miniaturized applications. Whereas miniaturized columns including mini lenses exist, the commonly used correctors are too complex for a use in miniaturized single or multicolumn systems. Nevertheless the general principle of multipole based correctors may be transferred to such systems.

The key is the fact that a hole with n-fold shape within an aperture separating two electric fields with different strengths produces a superposition of a round lens field and a 2n-pole field (plus more or less higher order terms depending on the shape). In simple terms all that has to be done in order to use such multipole fields for reduction / correction of aberrations, is to pile up apertures with n-fold shaped holes on adequate voltages in a sophisticated way. The formula how to use which fields may carefully be transferred from working corrector designs.

The method doing so will be denoted by SPANOCH (**S**ophisticated **P**ile of **A**pertures with **no**n **c**ircular **H**oles) in the following, indicating that it uses apertures with non circular holes in order to produce multipole fields (for correction purposes). Using SPANOCH one faces native difficulties:

- The coupling of the round lens- and the multipole fields,
- as well as the coupling of the field strengths with distances and voltages of the apertures and therefore velocity changes.

In 2008 an electrostatic analogue of the commonly used hexapole Cs-corrector was used in order to design a Cs-corrected extraction optics. This was used as a test setting within a ray tracing based computer simulation to demonstrate the SPANOCH concept and its proof of principle. The design did not claim to be of practical interest because of its strong contribution to chromatic aberration and the lack of facilities to adjust it.

Meanwhile the design of a SPANOCH type hexapole corrector is on the run. The design is still in a preliminary state of a generic prototype. It overcomes the disadvantages of the proof of principle design:

- The hexapole strengths and the round lenses can be adjusted independently.
- The entire design shows the well-tried double symmetric structure (see figure (1)) that avoids contributions to second order aberrations.

This is achieved by simultaneously varying five voltages. One controls the strengths of the hexapoles whereas the other four prevent the zeros of the fundamental rays from shifting. The generic design (s. figure (1)) has four parameters: the distances denoted by ‘a’ to ‘d’ in figure (1). Note that the distances denoted by ‘e’ and ‘f’ don’t affect the course of the fundamental rays in the vicinity of the hexapoles and hence don’t influence the correction power of the assembly. Thus we face a four dimensional parameter space for optimization. During the optimization we used two evaluation criteria:

- The continuous and close variability of the correction power under the constraint of reasonable maximum field strength and
- the maximum achievable correction power.

Because of computing time reasons we did the optimization calculations within the SCOFF approximation under the regime of the Gaussian Dioptrics, describing the apertures as thin lenses and the gaps in between as homogeneous fields. Thus the assembly could be described by the transfer matrix method.

As measure of the correction power we used the negative contribution of the assembly to Cs which is related to the Hexapole strengths. Due to the fact that hexapoles can not be described within the used approximations we had to fit analytic functions to simulation results of representative apertures (with 3-fold shaped holes) with the aperture's voltage, the neighboring fields and the aperture's geometry as parameters.

The optimization showed a tremendous optimization potential. For instance decreasing the distance 'a' to one third of its initial value resulted in an increase of the correction power by several orders of magnitude. The results still have to be regarded with some suspicion because the remaining contributions to aberrations of third and higher order have not yet been taken into account.

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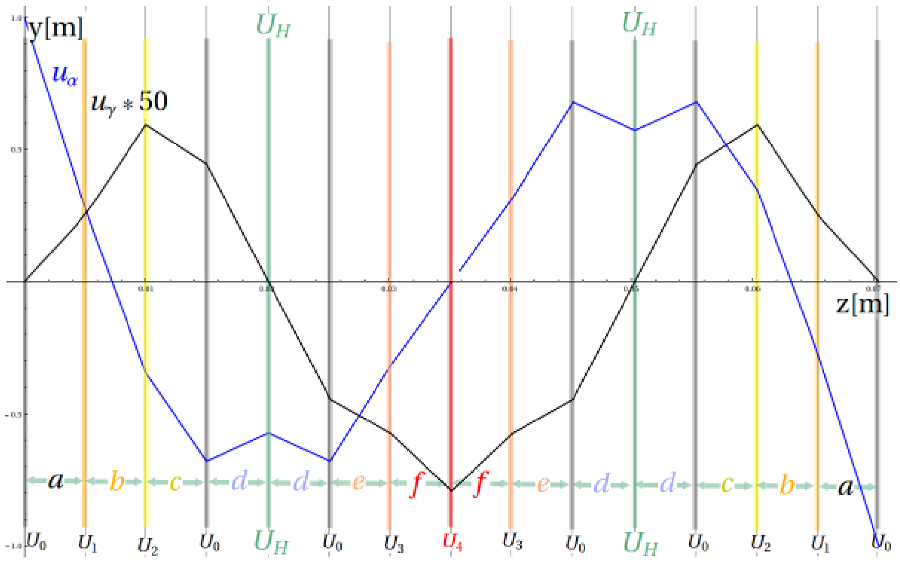

Figure 1. Sketch of the generic design prototype of a SPANOCH-type hexapole corrector together with the course of the fundamental rays. The z-direction is the direction of flight of the electrons. All apertures are represented by colored lines. The two apertures generating the hexapole fields by 3-fold shaped holes are marked in green. All other apertures are conventional ones having round holes. The distances 'a' to 'f' are generic parameters of the design.