Aberration Calculation of Chicane Type Magnetic Sector using Differential Algebraic Method

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For years, Wien filter type deflector (ExB) has been an important electron optical component in scanning electron microscopes (SEMs) to separate the secondary electrons from the primary beam for detection. However, their deflection angles for backscattered electrons (BSE), and often times secondary electrons (SEs), are generally limited to a few degrees and a larger deflection angle is desired to allow for optics dedicated to the BSE. As an alternative to ExB, we have investigated the use of magnetic sectors as beam separators for SEMs. Magnetic sectors have long been used as beam separators with large angle deflection for low energy electron microscope (LEEM) but their use in SEMs has been limited. This is mainly because they deflect the primary beam in the process of deflecting the secondary electrons. In this study, we calculate the optical properties of the primary beam in a chicane-type magnetic sector [1] for use in SEMs using differential algebraic (DA) method [2].

A schematic of a chicane-type magnetic sector is shown in Fig. 1. It consists of two parallel ferromagnetic plates with pole pieces (P1~P7). P1~P5 are excited so the primary beam exiting the magnetic sector lies along the direction in which it entered. Furthermore, the shapes of the pole pieces are designed so that the magnetic sector satisfies a stigmatic focusing condition and, to first order, can be treated as a round lens. Fig. 2 shows the four paraxial rays (Gx and Hx for in-plane and Gy and Hy for out-of-plane paraxial rays, respectively) of the magnetic sector. The four grooves (G1~G4) are adjusted to control the quadrupole lens effect by the fringes [1] to achieve stigmatic condition.

Lastly, the aberration introduced by the magnetic sector is calculated up to third order using the DA method. The DA method is a way of calculating the solution to a differential equation as a polynomial of its initial conditions [2]. Compared to other calculation techniques such as ray tracing, it offers a faster and more accurate calculation of aberrations. The aberrations are calculated for two types of trajectories shown in Fig. 3: symmetric (Sx and Sy for in-plane and out-of-plane of deflection, respectively) and anti-symmetric (ASx and ASy) across the midline of the magnetic sector. The calculation results (not shown) indicate that the aberrations for the symmetric trajectory are dominated by the first order chromatic aberration. This chromatic aberration is suppressed for the anti-symmetric trajectory and the dominant aberrations are second order in nature. Therefore, the anti-symmetric trajectory is desired for SEMs. This result is similar to the result for a magnetic sector that deflects the electron beam 90 degrees [3].

In conclusion, we used the DA method to accurately calculate aberrations of a stigmatic chicane-type magnetic sector and confirmed that the aberrations are minimized when the trajectory is anti-symmetric across the midline.

REFERENCES

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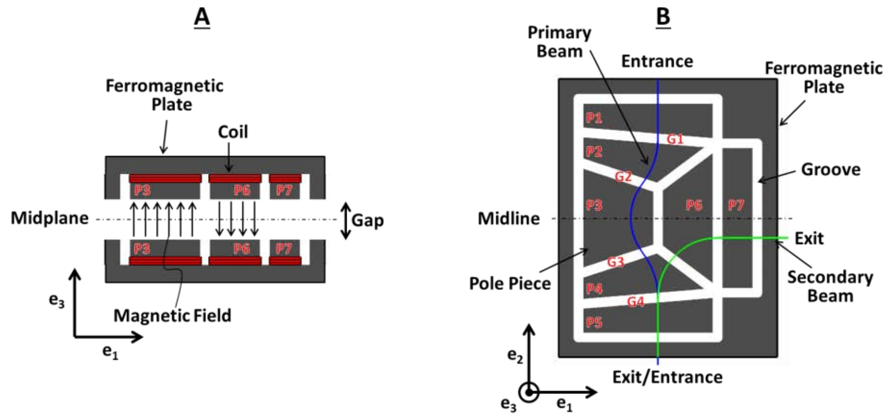

Figure 1: A) side view and B) front view of a chicane-type magnetic sector.

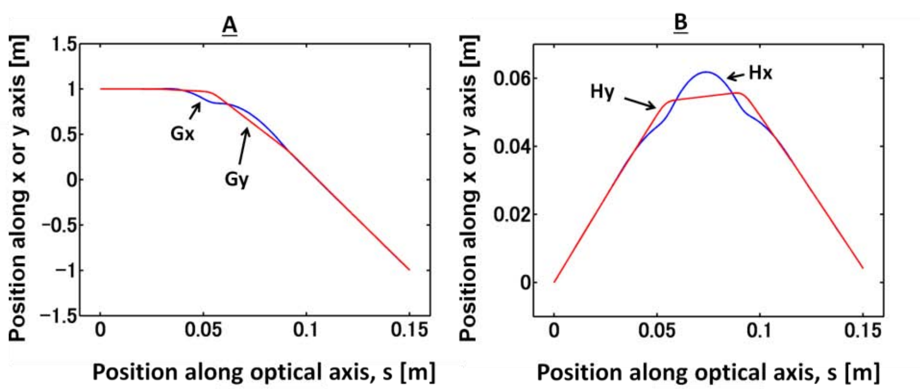

Figure 2: A) G paraxial rays and B) H paraxial rays of the magnetic sector.

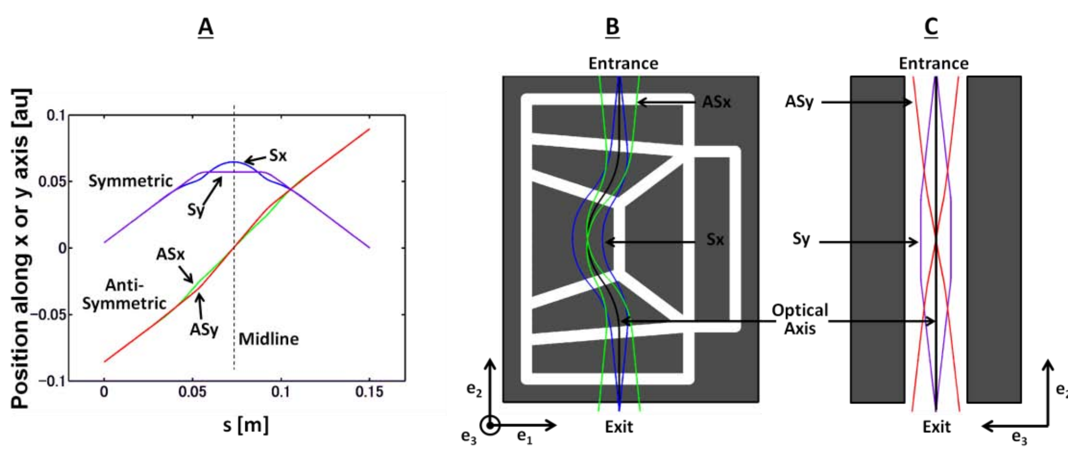

Figure 3: Symmetric and anti-symmetric trajectories respect to the midline of the magnetic sector plotted in A) curvi-linear coordinate, B) Cartesian coordinate (front view), and C) Cartesian coordinate (side view).