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Aberration Corrected Wien Filter as a Monochromator of High Spatial and High Energy Resolution Electron Microscopes

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Monochromator inside a field emission gun (FEG) is an essential tool in high spatial and high energy resolution analytical electron microscopy. Wien filter has a straight optical axis and suitable as a gun monochromator. One of the authors designed a double Wien filter monochromator for Tanaka [1]. Although the size of virtual crossover size of FEG is about a few tenth nanometers, it increases to about a micron after passing through the monochromator. Monochromator reduces the current of the beam about 1/10 by the selection of the energy by the slit. If the beam must be reduced by the condenser lens system, the beam current must be lost further. The origin of the large beam size is the aberrations.

Wien filter consists of a crossed electric and magnetic dipole fields E_1 and B_1. If those fields have a relation of E_1=vB_1 (Wien condition), electrons with the velocity v have a straight optical axis. Rose proposed a multipole Wien filter [2]. FDM simulation for 8-pole filter proved the straight optical axis even at the fringing regions [3]. It has been well known that Wien filter can make a stigmatic focus like a round lens when the quadrupole electric E_2 and magnetic B_2 fields satisfy the relation of $e_2 - b_2 = -1/4$, where $e_2 = E_2R / E_1$ and $b_2 = B_2R / B_1$, R is the cyclotron radius. Rose also proposed a condition of canceling the second order aberrations: $e_2 = -1$, $b_2 = -3 / 4$ and $e_3 - b_3 = 3 / 8$, where $e_3 = E_3R^2 / E_1$, $b_3 = B_3R^2 / B_1$, E_3 and B_3 are the hexapole components. However, no one checked experimentally, because of the difficulty of giving b_2, e_3 and b_3.

We have made an accurate numerical simulation using BEM [4] and found that 12-pole filter can give almost zero hexapole field components including the fringing region. If we have no special field distributions around the fringing region, it is possible to analyze aberrations analytically considering both of objective and image points inside the fields. We have made an analytical theory of Wien filter up to 3rd order. Because the equations of the third order aberration are so long and not possible to write in this short abstract. We will show only the computed results.

FIG. 1 shows electron ray trajectory of a double Wien filter under the stigmatic focus condition for two beams with 1000V (blue and solid beams) and 990V (red and broken beams) for dispersion direction (X; upper figure) and perpendicular direction (Y; lower figure). The beam incidence half angle is 50 mrad, which is extremely large compared to the actual machine, but selected to show the aberration figure of the beam. The beam shows a large aberration at the middle (region with the triangular shape at the middle of the filter), where the slit for selecting the beam energy is inserted. However, at the image plane (right end of the trajectory), aberration vanishes.

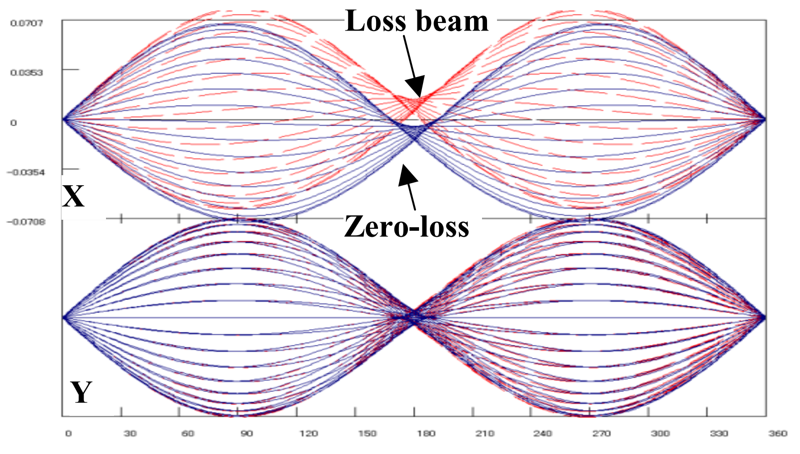

FIG.1. Electron rays of stigmatic focus Wien filter for X- and Y-axes.

FIG. 2 shows aberration figures on the slit plane, where the zero loss (left figures) and loss beams (middle figures) are separated, and on the image plane (right figures), where the both beams are concentrated to form an achromatic image. Conditions of the fields are: $e_2 = -(m+2)/8$, $b_2 = m/8$ and $(e_3-b_3) = m/16$ for m=0~6. The condition m=0 is the stigmatic focus condition it with FIG. 1 and m=6 is Rose's condition [2]. Rose's condition gives a small beam on the slit plane, and gives a large energy resolution. Here, we propose a new condition, m=2, where the geometrical aberration on the image plane is completely vanish up to the third order. Negative chromatic aberration is left on the image plane. At this plane, all the conditions m=0 to 6 give zero geometrical aberrations (that means aberration figure is a point) up to the 2^{nd} order. However, if we consider aberrations up to the 3^{rd} order, all the geometrical aberrations disappear only when m=2.

References

[1]. M. Tanaka et al., Microsc. Microanal. **8** (Suppl. 2) 68.
[2]. H. Rose, Optik **34** (1987) 26.
[3]. K. Tsuno and J. Rouse, J. Electron Microsc. **45** (1996) 417.
[4]. G. Martinez and K. Tsuno, Ultramicroscopy **93** (2002) 253.

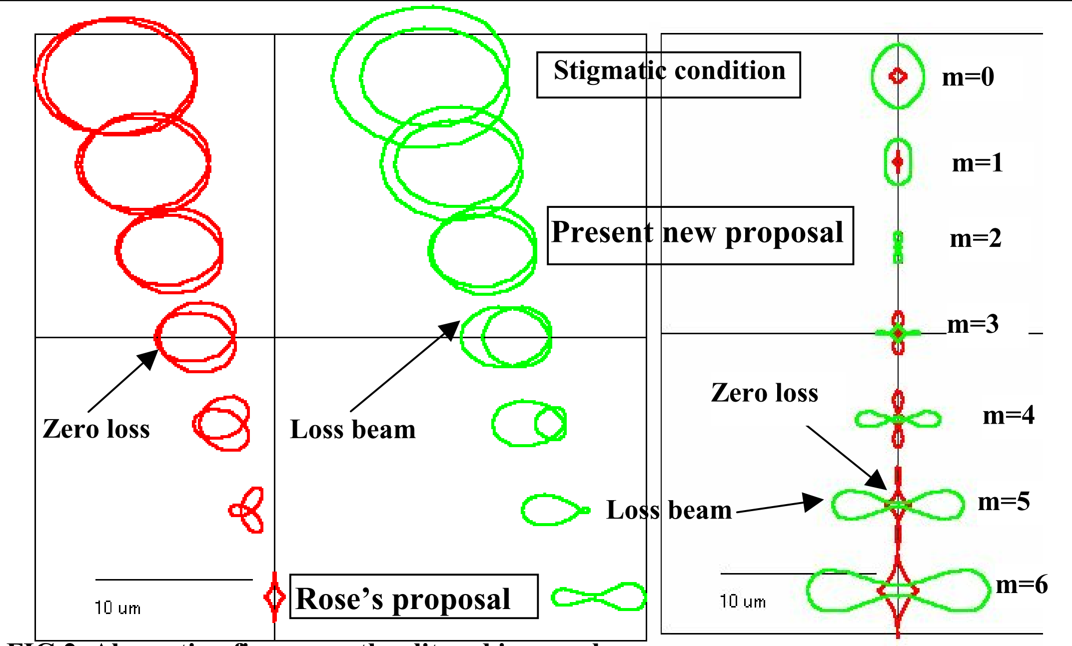

FIG.2. Aberration figures on the slit and image planes.

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