The 4-Wienfilter-Monochromator integrated in a conventional SEM

W. Kaiser, F. Engeser, and E. Plies

Institute of Applied Physics, University of Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen, Germany

waldemar.kaiser@uni-tuebingen.de
Keywords: monochromator, Wien filter, low voltage SEM, chromatic aberration

We present the assembling of the 4-Wienfilter-Monochromator proposed in [1] and its integration in a conventional SEM (DSM 950, Zeiss). This SEM has a thermionic source and three magnetic lenses (no booster voltage). For an accelerating voltage of 3 kV the kinetic energy of the electrons is therefore 3 keV from the anode down to the sample. In this low energy regime the axial chromatic aberration dominates the spot size and hence the use of a monochromator will increase the resolution of the system. The design of the four Wien filters has been chosen to be simple in fabrication as well as in excitation. To shape the field in the fringing regions and to avoid field overlap, field clamps made of Mu-metal are used. The four Wien filters are aligned by eight rods going through the whole monochromator. For technical reasons the monochromator is positioned below the 2nd condenser lens of the SEM (Fig. 1).

The paraxial rays and all aberrations of second rank in the case of the 4-Wienfilter-Monochromator have been calculated with aberw2 [2]. The dispersion in the energy selection plane is found to be 10 µm/eV. Though there are aperture aberrations of second order in this plane, it should be possible to reduce the energy width from $\Delta E = 1.5$ eV to $\Delta E = 0.2$ eV (FWHM) using a 1µm wide selection slit. To measure the energy width a retarding field analyser has already been built. Aperture aberrations of second order and the dispersion vanish in the image plane of the monochromator as a result of the highly symmetric design. Limited only by the chromatic aberrations of second rank a spot size of approximately 17 nm has been predicted in its image plane, and the resolution of the overall system should be improved from ca. 65 nm to 19 nm.

In figure 2 one of the four Wien filters of the monochromator is shown. It consists of four equal segments which form a four-pole near the optical axis with an angle of 45° between two poles as well as an outer circuit for magnetic flux return. Nevertheless, they offer enough space for the coils. The bore in the middle has a diameter of 10 mm. To avoid voltage breakdowns between individual poles and to keep the magnetic resistance small on the outer circuit the segments are separated by a gap of 1 mm. The individual segments are made from Permenorm with a measured coercive force of 0.04 A/m. The coils are suitable for use under high vacuum conditions and are able to generate a magnetic excitation of ±228 Ampere-turns with a current as low as 100 mA to avoid warming-up. This results in a magnetic field of 44 mT on the optical axis. The magnetic field necessary to operate the first and the last Wien filter of the monochromator is about 6 mT. The two Wien filters in the centre of the monochromator require an even lower excitation. In figure 3 the magnetic field lines in one of the four Wien filters are shown, which have been calculated with Poisson Superfish [3] including the hysteresis of Permenorm. Since the calculations predict a maximum magnetic field in the material of 160 mT, no saturation occurs.

The individual segments of the four Wien filters have been fabricated on a CNC-machine. To get accurate dimensions the Wien filters have been stress-relieved after a first milling with an oversize of 0.2 mm. Afterwards the segments have been faced to the final

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology, DOI: 10.3217/978-3-85125-062-6-027, © Verlag der TU Graz 2009

dimensions and the bore in the middle has been cut to the final size. To achieve the specified magnetic properties of Permenorm, a final stage annealing has been accomplished.

1. E. Plies, J. Bärtle, Microscopy and Microanalysis **9**, Suppl. 3 (2003) p28.
2. aberw2 by Munro's Electron Beam Software Ltd. (MEBS) London.
3. Poisson Superfish by Los Alamos National Laboratory LAACG.
4. Constant support of Carl Zeiss NTS GmbH, Oberkochen is gratefully acknowledged.

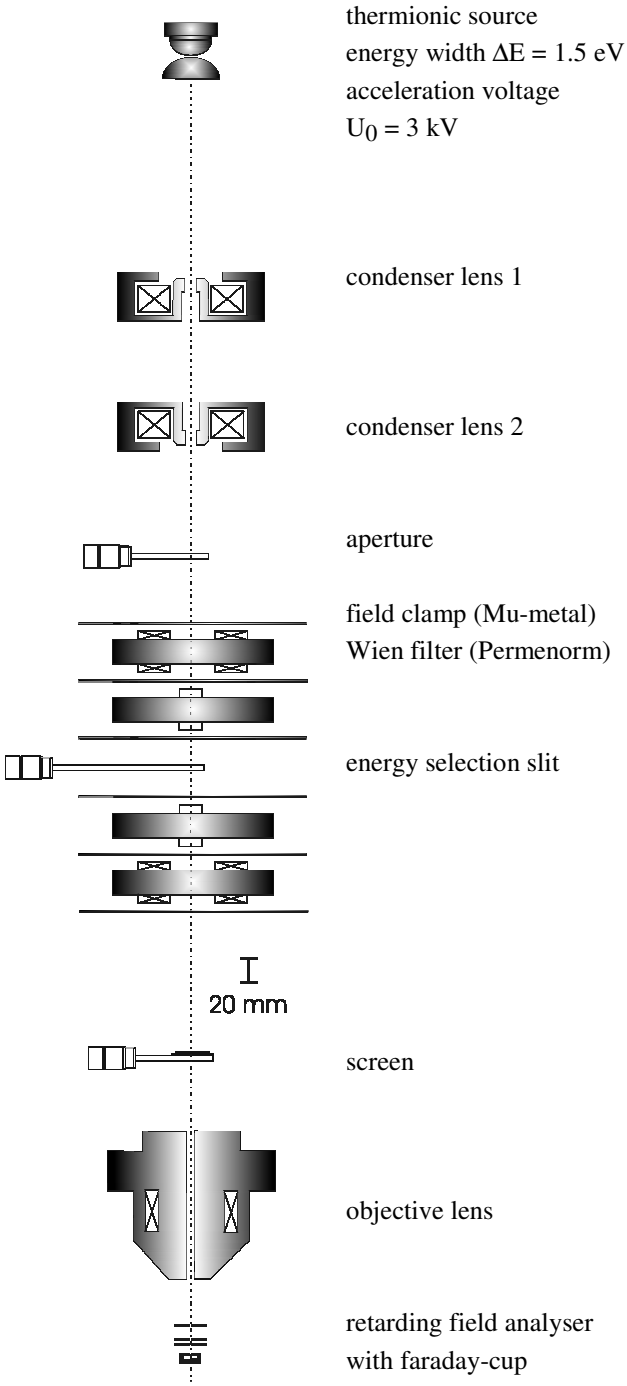

Figure 1. Schematic arrangement of the monochromator integrated in the DSM 950.

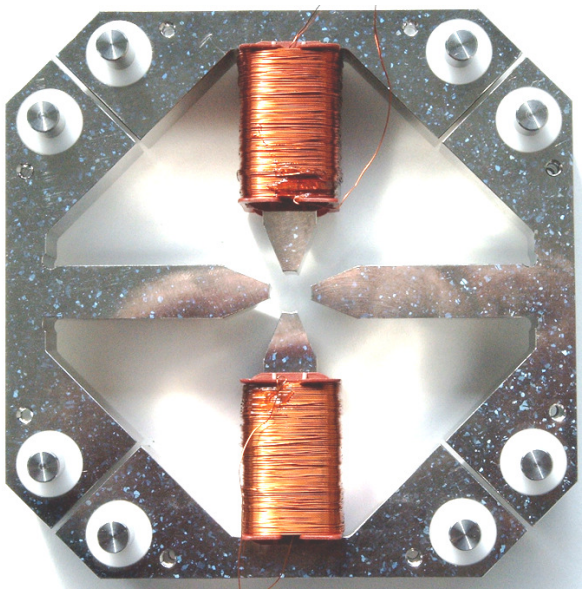

Figure 2. Photo of one of the four Wien filters, pole distance = 10 mm.

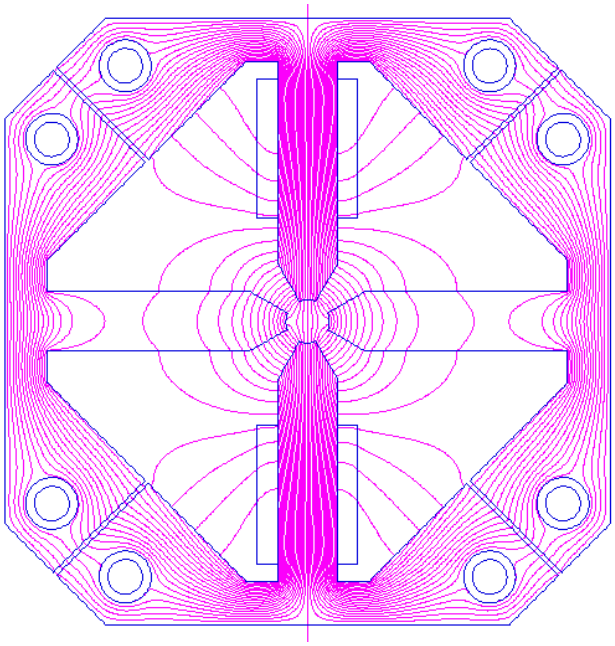

Figure 3. Magnetic field lines in one Wien filter, pole distance = 10 mm.

G. Kothleitner, M. Leisch (Eds.): MC2009, Vol. 1: Instrumentation and Methodology,
DOI: 10.3217/978-3-85125-062-6-027, © Verlag der TU Graz 2009