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Experimental Setup and Verification of the MANDOLINE Energy Filter

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We present setup and experimental results of the new Mandoline high performance imaging energy filter as proposed by Uhlemann and Rose [1] that has been developed within the SESAMe (Sub-eV-Sub-Ångstrom Microscope) project [2].

Fine structure investigations demand very high energy resolution and a high filter acceptance, which is also necessary for applications using large scattering angles such as CBED or RDF measurements. The Mandoline energy filter enables and simplifies such high end energy filtering TEM applications by the high dispersion of 6.2 µm/eV at 200kV, a filter current stability of 2×10^{-7} and an unrivalled acceptance, described by the transmissivity T_{real} [3]. The transmissivity of T_{real} = 3300 nm²/eV for a 1 eV energy window width allows for energy filtered observation of large fields of view and large scattering angles with excellent isochromaticity.

The Mandoline energy filter (Fig. 1) consists of a homogeneous magnet M1, two symmetrically arranged inhomogeneous magnets M2 and M3 focussing the ray continuously in both principal sections and nine symmetrically arranged correction elements C1 - C9 performing up to third order correction. The path of the optical axis intersects itself twice within the homogeneous magnet, resulting in the very short total length of this "in column" energy filter and a high mechanical stability of the TEM column. Inhomogeneous magnets are well known from accelerator physics, but their usage in a corrected imaging energy filter is new and more demanding. Higher precision is necessary because of the smaller dimensions and the distortion free imaging in a TEM. Strong quadrupole fields on the correction elements C1 and C9 pose additional practical demands on the filter correction procedure compared to other imaging energy filters.

We have experimentally evaluated the imaging properties of the Mandoline energy filter on two TEM setups. The test bed shown in Fig.2 serves for the basic investigations and verification of the alignment strategy. We present the experimental verification of alignment algorithms and demonstrate experimental verifications of the imaging properties of the Mandoline energy filter at 200 kV, for example distortion free imaging of a 5 µm specimen area. The experimentally determined dispersion is in excellent agreement with the theoretical value of 6.2 µm/eV.

In the final setup in the SESAMe microscope [4] an overall energy resolution of 200 meV is enabled by the filter current stability of 2×10^{-7} (peak to peak), the high tension stability of 5×10^{-7} and the monochromator [5], which allows for a primary beam energy width of 100 meV.

References
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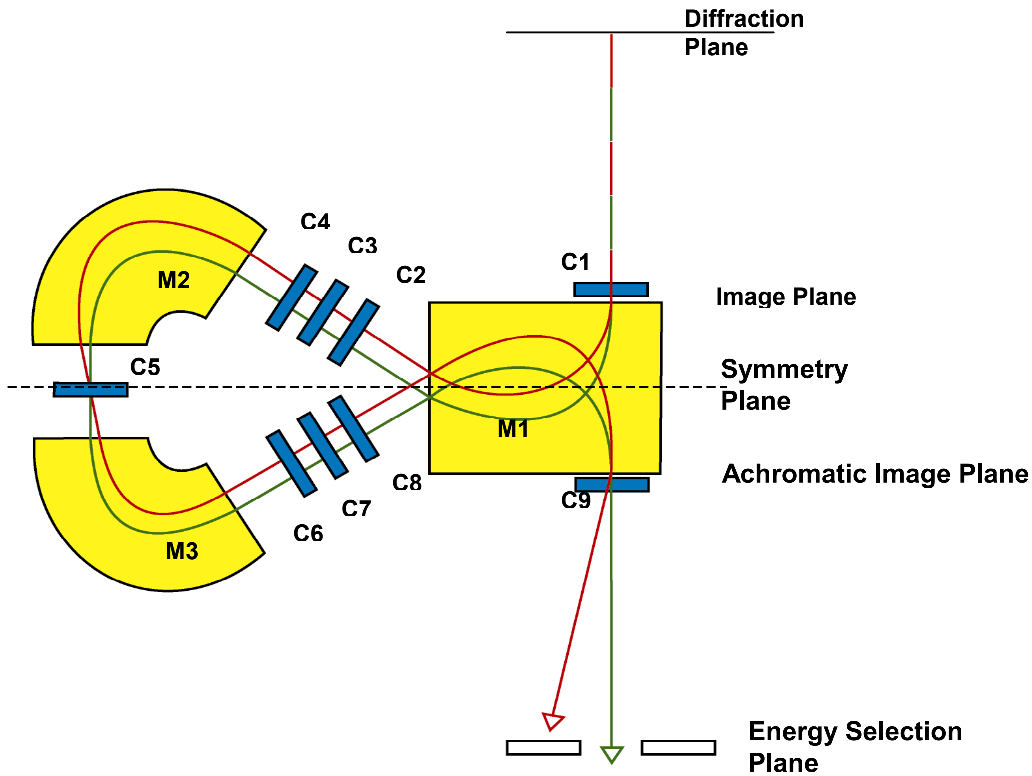

Fig. 1. Main components of the Mandoline energy filter (schematic diagram).

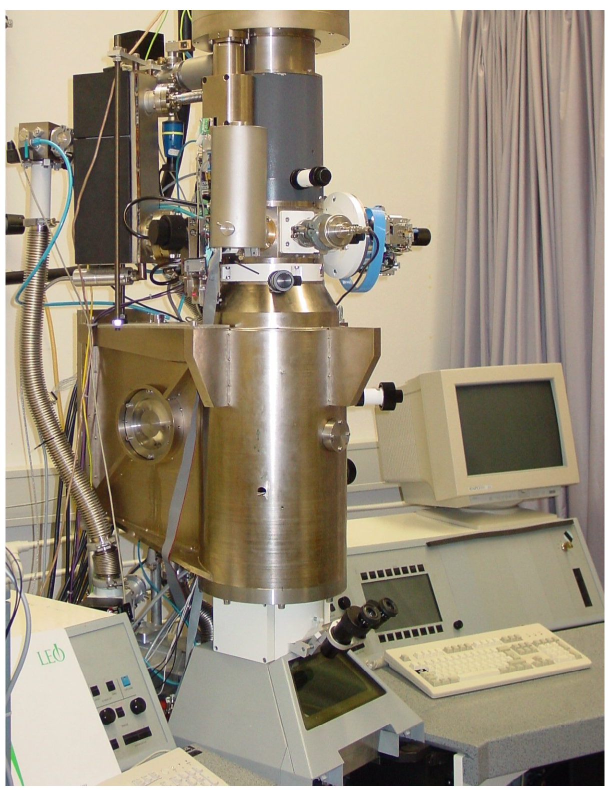

Fig. 2. Experimental setup of the Mandoline energy filter in the test bed microscope.

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