Miniaturized electrostatic column for electrons with a variable permanent magnetic snorkel lens

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A miniaturized electron optical column optimized for final beam energies below 1 keV is presented. The system consists of an electrostatic condenser lens, two electrostatic eight-pole deflection units and a combined electrostatic magnetic objective lens. The condenser lens and the electrostatic part of the objective lens are manufactured from conventional components used in electron-microscopy such as platinum apertures, whereas the magnetic part of the objective lens is realized by a snorkel lens driven by a permanent magnet. The detection of the secondary electrons is carried out by a conventional combination of scintillator, light guide and photomultiplier.

The final system (Fig. 1) is about 93 mm in height and is currently being tested. Both electrostatic lenses are manufactured from conventional platinum apertures as described in [1]. Just below the condenser lens the detection system has been placed, which also holds the aperture diaphragm in place. The scintillator can be exchanged without disassembling the whole column. Beam alignment, astigmatism correction and scanning are realized using two electrostatic eight-pole deflection units. These have been placed just above the objective lens. In the intermediate region between condenser and objective lens the primary electron beam can be varied between converging and diverging mode. The linertube is set to a potential of 10 kV relative to the emitter thus increasing the immersion ratio of both electrostatic lenses and reducing aberrations. The sample holder is placed below the objective lens resulting in a working distance of 1 mm. Below the sample a magnetic snorkel lens (Fig. 2) similar to the add-on lens described in [2] has been placed. This arrangement further decreases the chromatic aberration most important for low energy systems. The on-axis magnetic field strength of the snorkel lens at the position of the sample (Fig. 3) can be varied between nearly 0 mT and more than 40 mT. Simulations show, that a field strength of about 18.4 mT is necessary for optimal performance of the column.

Assuming a virtual source size of 20 nm, an energy width of 0.8 eV (FWHM) and an angular current density of 500 µA/srad, calculations (Fig. 4) show that a probe size of less than 30 nm is achievable at an emitter side aperture angle of 10 mrad and a probe current of 67 nA. At the cost of restricting possible applications a further reduction of the probe size is attainable by applying an additional electric field at the sample. Of course, operating both lenses in internal acceleration mode would result in an even smaller probe size. This mode of operation has been simulated but not realized in the current design because the necessary electric field strength would be far beyond the vacuum breakdown field strength.

The possibility of in-column detection of the secondary electrons has been confirmed by simulating their trajectories and calculating the collection efficiency. The secondary electrons are accelerated through the objective lens towards the detection system. The relatively strong magnetic field at the sample position even increases the collection efficiency of the system. Placing the scintillator with a 2 mm bore 50 mm above the sample simulations show for starting energies up to 10 eV a collection efficiency of about 30% up to 55%

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depending on the additional electric field strength at the sample. In these calculations a cosine distribution of the starting angles as well as a Maxwellian energy distribution with a maximum at 2 eV have been assumed. First experiments show promising results.

1. C.-D. Bubeck et al., Nucl. Instrum. Meth. Phys. Res. **A 427** (1999) p104.
2. A. Khursheed, N. Karuppiah, and S.H. Koh, Scanning **23** (2001) p204.
3. Simulations of fields and trajectories were carried out with the program EOS of E. Kasper.

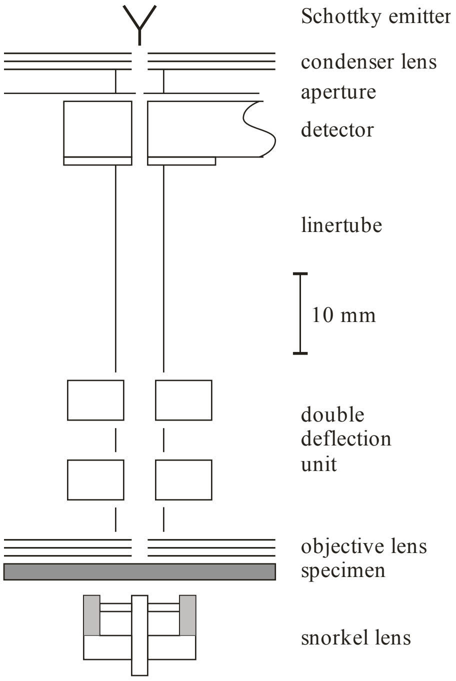

Figure 1. Schematic system overview.

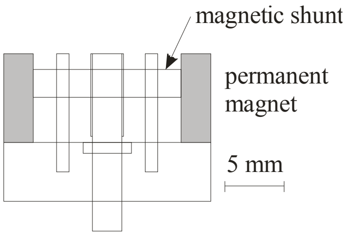

Figure 2. Schematic of the snorkel lens.

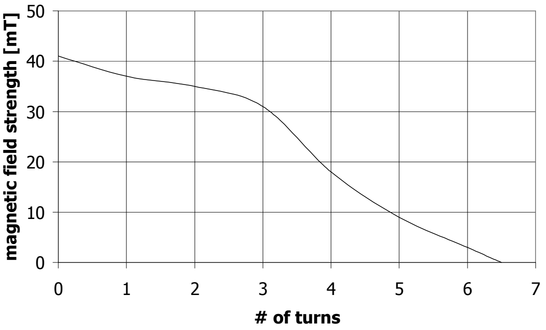

Figure 3. On-axis magnetic field strength.

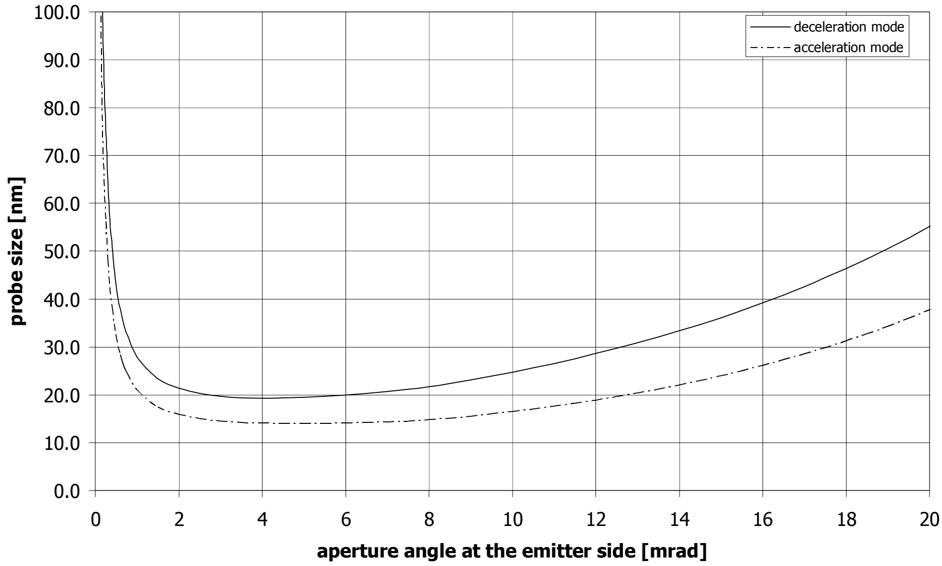

Figure 4. Achievable probe size for a final beam energy of 1 keV.