Software for Particle Optics Computations

SPOC

Dr. Bohumila Lencová
Fleischnerova 15, 63500 Brno
Czech Republic

http://www.lencova.cz, Email lencova@cmail.cz

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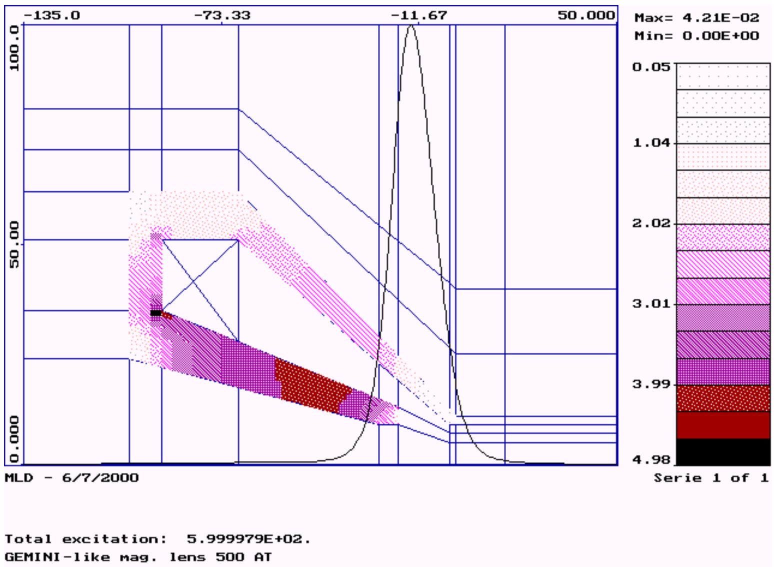
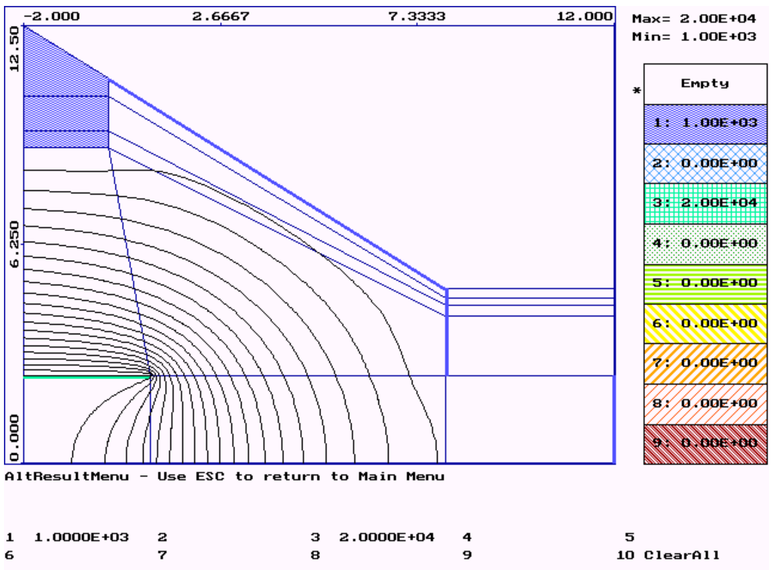
We provide license of a comprehensive set of programs for the design of electron lenses and deflectors for electron microscopy. The original programs were developed by B. Lencová and G. Wisselink in the ISI AS CR in Brno and in the Particle Optics Group of TU Delft. The 2D electrostatic and magnetic fields for focusing and deflection of charged particle beams are computed by the finite element method. For the computations of optical properties we can either evaluate paraxial trajectories and aberration integrals or evaluate the properties by direct ray tracing in numerically computed fields.

The FEM programs are equipped with interface programs that allow the generation of data by graphical editing and the display and export of results. By generating the input data (the coarse and fine meshes and the specification of regions) on screen, most errors in the computation data are avoided. The coarse mesh specifying the geometry of the problem can have up to 100 mesh lines in *r* or *z* directions. In order to reach the best accuracy of the computation, the fine mesh for the computation of potential is using smoothly graded mesh step and contains up to 200000 mesh points. The fine mesh is automatically generated in the interface programs. Up to 9 different types of material regions can be specified with magnetic materials and coils for magnetic problems or electrodes for electrostatic problems. Saturated magnetic lenses can be computed with default or user specified magnetization curves. The interface programs are written in Borland Pascal®. The computation programs are in Fortran for 32-bit Windows operating systems. They run on IBM® PC compatible systems with 32 MB RAM.



The programs are organized in packages MLD (Magnetic Lens Design), ELD (Electrostatic Lens Design), MMD (Magnetic Multipole Design), EMD (Electrostatic Multipole Design) and TRC (Trajectory Ray Computations). User manuals of all programs are available in electronic or printed form. The principles of the programs were described in a number of publications. Original algorithms are used for the accurate computation of both rotationally symmetric and multipole potentials. Demo version of MLD and ELD programs is available for the computation of potential in smaller meshes.

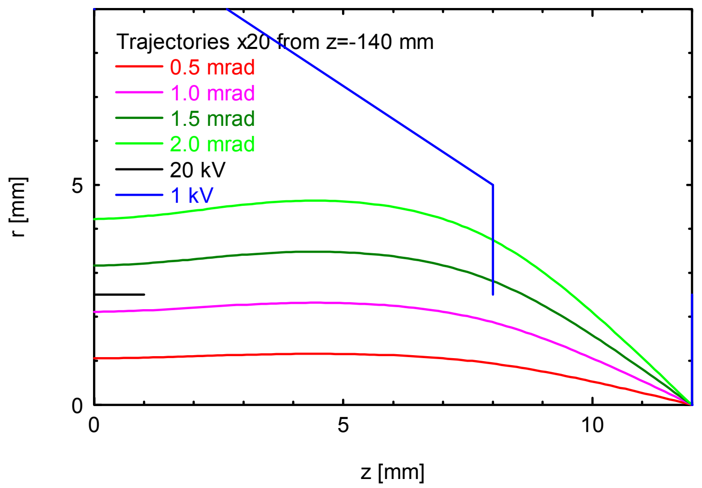


Examples of the use of programs

An example that shows well the function of our programs is a combined magnetic-electrostatic SEM lens .

The first figure shows the magnetic lens with "saturation", i.e. distribution of flux density in iron materials (maximum value close to 0.5 T) and axial flux density (0.04 T for 600 At). In the bore of the magnetic lens an electrostatic lens is placed that slows down the electrons, here we suppose from 20 keV to 1 keV energy

The trajectories of electrons in the meridional plane are shown for particles starting at z=-140 mm with angles 0.5 to 2.0 mrad with respect to the axis before they reach the sample. The last figure shows also the electrodes, the trajectories are thus expanded in *r*. These trajectories were computed with TRASYS in the potentials obtained from MLD and ELD programs. They are accurate enough to evaluate the aberration coefficients of such a combined lens.



Example of Wien filter according to K. Tsuno and J. Rouse, J. Electron Micr. **45** (1996) 417.

The electrons with energy E=60 eV enter crossed electrostatic and magnetic dipole fields E_x and D_y and electrostatic quadrupole field Q. The dipole field is generated by 40 mm long 8-pole electrodes. The dipole fields fulfill the Wien condition $E_x=v*D_y$, where v is the velocity of the electron, and the quadrupole field is $Q=e/8*E_x^2/E$, where e is the electron charge (D_y≈0.19 mT).

The Wien filter then acts as a rotationally symmetric lens with energy dispersion in *x* plane. The figure below shows the shape of dipole and quadrupole fields. The two figures to the right show the electron trajectories in *x* and *y* planes for angles up to 2 degrees with the axis. The bottom line of figures shows the beam section in three planes with z=31, 32 and 33 mm.