NEW FEATURES IN THE SIMULATION OF ION EXTRACTION WITH IGUN

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Abstract

Since its first presentaion in 1991, the program IGUN(C) [1] for the simulation of ion extraction from plasmas has found wide-spread application in the optimisation of electrode design, which has resulted in well acknowledged feedback for improvements by the users. By the improvement of compilers 32-bit versions became available with interactive coloured graphics, even under plain DOS operating systems. For the same reason, memory restrictions virtually disappeared, supported by the requirement of higher operating systems for more and more memory.

1 INTRODUCTION

An important step of improvement consisted in the definition of all geometrical input parameters in mesh independent user defined units. This has been easing the setup of input files from drawings with arbitrary offset and scaling, the setup of concatenation runs, using different mesh sizes for enhancing the resolution and transfer of the trajectory end data from one run to the next. Recently, features have been added for the simulation of ions with different charge and/or mass, also providing profiles, emittance diagrams, emittance growths diagrams and electrode loss tables for the different ion species. For multi-aperture systems, the stopping of trajectories by arbitrary thin grids has been implemented as well as the provision of a radially non-uniform plasma density. The simulation of thermal starting conditions has been improved by the possibility to start ions on an equipotential line, which is also useful for the simulation of plasma-immersion devices. In order to provide a mesh independent input for magnetic fields, two options have been added: Up to 10 real solenoids can be defined by specifying the center of their windings, their thickness, their length and their ampere-turns. The most favourable new option, however, is to read the output file of INTMAG[2], a magnetostatic boundary element program. This allows to calculate off-axis fields with high accuracy and also permits to generate a common plot of electrostatic and magnetic elements, which allows to detect easily mistakes in the transfer of magnetic data to IGUN (compare fig. 1).

2 MESH INDEPENDET INPUT

In order to set up an input file for IGUN from a drawing with arbitrary offset of the drawing coordinates and arbitrary different scaling as needed for the input file, a mesh independent input with appropriate offset and scaling options has been mandatory. In consequence, also the output of equipotential and field lines for making concatination runs, had to use these coordinates. As a result, concatination runs now are defined with the same coordinates and without any offset to the previous run. They begin, where the former run ends, including trajectory end and starting data. An important spinoff of this procedure is the definition of the mesh resolution by just specifying the number of maximum meshes to be used in one coordinate direction. This is easing the study of the influence of refining the mesh on the wanted result and permits to establish something like "error bars" for simulation results.

Unfortunately, however, the inclusion of magnetic fields has been strictly tightened to the computational grid, because off-axis fields are calculated by radial expansion from axial derivatives, determined numerically from the values on the grid nodes. Introducing radial and axial maps of Br and Bz is only useful for improving the accuracy of the off-axis fields, however, does not free from their mesh dependent definition: for any change in the electrostatic mesh resolution, new magnetic input data were required.

To improve this unpleasant situation, firstly a new input option for real (thick) coils has been introduced, which is superior to the old EGUN[3] definition of MAGSEG polynomial segments by using real (iron free) solutions of the field equations. In order to extend this to magnetic circuits formed also by iron parts, very recently a new option has been added to read the output file of INTMAG(C), a high accuracy boundary element program. In contrast to IGUN, where the solution consists of potentials and space charge values on the nodes of a grid, the result of a boundary element program consists in surface currents in elements along the iron boundary as well as of the driving currents in the real windings. The information available in the INTMAG output file allows to reconstruct the magnetic field everywhere off-axis to highest accuracy, without any radial expansion, however this may still be used closer to

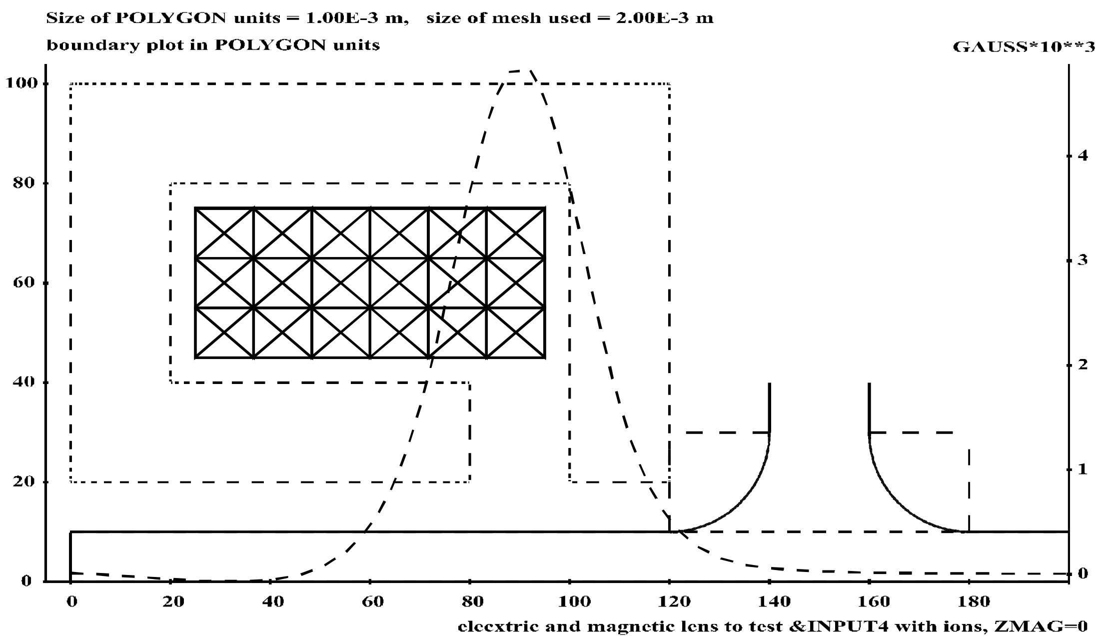

Figure 1: Display of the magnetic elements (left upper part) on top of the electrostatic lens (right lower part)

the axis for gaining speed at moderate accuray. Since the INTMAG output file contains all the geometrical information about the boundary elements used, a combined plot of electrostatic and magnetic elements can be generated, which is extremely useful for easy inspection of the relative position of electric and magnetic components.

3 GROUPS OF IONS WITH DIFFERENT MASS AND CHARGE

The extraction of ions from sources of multicharged ions, like PIGs nd ECRs, has resulted in the demand for the simultaneous treatment of species with different charge and mass. While this will have no effect without a magnetic field, in sources with high magnetic field different losses and emittances may be expected for different charge to mass ratios. Accordingly the trajectories of these different ion species are plotted with different colours, which are also used for the display of profiles and emittances in scanned positions along the beam path. For each group of ions, a different fraction of the total current, current density, or plasma density may be specified, opening very sophisticated studies on ion beam mixing.

4 SIMULATION OF MULTI-APERTURE EXTRACTION SYSTEMS

For a more correct simulation of multi-aperture systems it has been necessary to improve the stopping algorithm of ions on electrodes: now, even arbitrary thin electrodes will stop the ray tracing, and book keeping will add up the lost currents for each ion species and each electrode. By this, a detailed insight is provided, where ions of different charge-to-mass ratio were lost and ions may pass an electrode to less than half a mesh, as has been the limiting resolution before.

In addition to correct stopping on thin electrodes, the radial variation of the plasma (and ion current) density can be defined as a Taylor series up to 4th order:

$$j(r) = j_0 + j_2 \left\{ \frac{r}{r_p} \right\}^2 + j_4 \left\{ \frac{r}{r_p} \right\}^4 \qquad (1)$$

where r_p defines the limiting aperture at the plasma meniscus. For 2D rectangular simulations, also odd powers and coefficients can be used with eq. 1.

5 EQUIPOTENTIAL STARTING

Many applications needed to start ions on equipotential surfaces. For the simulation of thermal beam expansion this is the only way to provide realistic initial angular and radial beam starting positions. In order to initiate this feature, the potential USTART must be defined as well as the length STARTL along this equipotential. Trajectories will then be started according to their initial energy perpendicular to the equipotential line at U=USTART. Especially for thermal starting, e.g.for ions with a defined transverse energy, this feature helps to prevents artefacts, like space charge contribution fom outer trajectories with much higher current, coming close

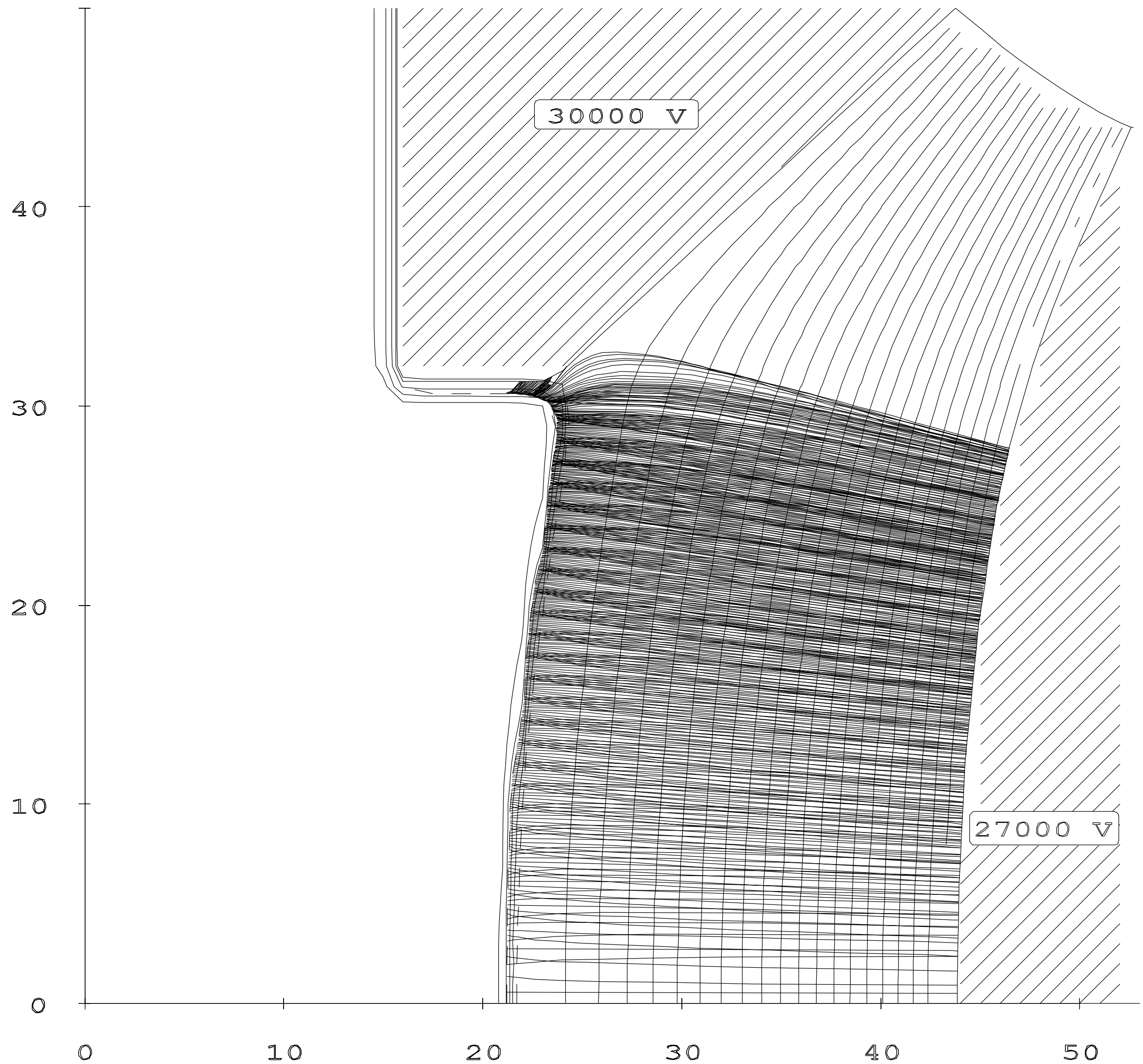

Figure 2: Using equipotential starting for thermal simulation in the magnified plasma region of CHORDIS

to the axis at low energy, resulting in a hollow beam. Another application of this feature is plasma immersion technique, where ions from a sheath along the whole plasma volume are accelerated towards an immersion substrate, which is put in a short puls to relative high negative potential.

5 ORGANISATIONAL MODIFICATIONS

In order to make housekeeping with input and output files easier, all output files are using the same file header as the input file, however, with endings, showing their specific character:

*.CPL ==> plot file
*.BND ==> boundary data
*.EGN ==> EGUN style input file
*.OUT ==> output file of IGUN
*.FLD ==> field line coordinates
*.EQU ==> equipotential line coordinates
*.TRJ ==> trajectory end data

For plotted output, the LASER=.TRUE. option no longer exists. Instead, all plot panels are writen in sequence on the *.CPL file. XHPLOT and DXFPLOT will make individual files out of this, while converting to HPGL and DXF, the latter by keeping the colour information electrodes, trajectories, field lines , equipotential lines, profiels and emittances alive.

REFERENCES

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[2] R. Becker, Nucl. Instr. And Meth. B42(1993)303
[3] W.B.Herrmannsfeldt, SLAC-331 (1998)