An Interactive Version of the PBGUNS Program for the Simulation of Axisymmetric and 2-D, Electron and Ion Beams and Guns.

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Abstract

PBGUNS, a program for the simulation of ion and electron beam extraction systems has been modified to permit their interactive design on an IBM-PC. The program can be interrupted after any relaxation cycle and its electrode configuration, and most other parameters, modified. A graphical interface is used in the modification of the electrodes on the screen without exiting the program or having to save (or restore) binary data. The program uses previous results to speed convergence of the new configuration and is quite tolerant of significant changes in electrodes and/or potentials. It is written in FORTRAN 77 (with DOS extenders) and can be run on any high end PC with at least 16 MBytes of memory.

I. INTRODUCTION

PBGUNS, a relaxation program including space charge and some thermal effects, was originally described at the 1993 ICOPS (Vancouver). It simulates virtually any type of axisymmetric or 2-D, relativistic or non-relativistic electron or, positive or negative, plasma, thermal, or sputter source ion extraction system. The program has been considerably refined and improved over the past two years to solve these types of problems faster and more accurately. The program has always had the capability of saving binary data and then restarting on the next run. As the program has improved it was found that it became more tolerant of changes in parameters and electrode shapes on restarts.

The electrodes are defined with quadratic line segments. The segments are connected head to tail around the electrode and may extend from boundary to boundary or may close around the electrode. The input data describe the line segments using their endpoints (and center and radius for circles) for each electrode.

While running designs of various beam systems it became evident that the process could be significantly speeded if the program could be interrupted, modified and restarted without exiting and restarting. Initial work permitted the interactive modification of the electrode shapes and parameters by changing the values on the input file and then resuming execution with the new values. This led to errors that were not obvious when they were introduced and would occasionally terminate the run catastrophically.

The greatest problem came with changing the electrode configuration where modest changes in an electrode could bomb the program if not carried out properly. It was necessary to develop a graphical interface to the interactive routines so that errors in the configuration would be evident on the screen (and could still be corrected before resuming execution) while making changes in the electrodes.

The 25,000 line FORTRAN program currently runs on an 80386 or better, IBM-PC or clone, with at least 16 MBytes of memory, using DOS extenders. NDP-FORTRAN and NDP-PLOT (from Microway) are used for the compiler and the plotting capability. It will run small problems (100x50 arrays) in as little as 10 minutes, but may require several hours for very large problems (450x200) arrays, (about the limit for 16 MBytes of memory) on a MHz 486 PC. Obviously larger memories would permit larger simulations and faster processors would require less time. All calculations are done in double precision (8 byte) arithmetic.

The potentials are solved on a two dimensional array using Poisson's equation in rectangular or axisymmetric configurations. The beam is simulated by computing representative trajectories (up to 7000) through the device. Space charge is computed from the trajectories and stored on a matrix identical to the voltage array. The cathode or plasma region for extraction problems is simulated on a second (and usually finer) matrix so that greater accuracy and resolution can be obtained, most importantly at the cathode or plasma surface. Thermal effects, which can be very important for either electron or ion extraction, can be simulated including skew (azimuthal) angular distributions.

II. INTERACTIVITY

At the end of each voltage relaxation-trajectory computation cycle it is possible to switch to the interactive routines. Here it is possible to change either the electrodes or many of the parameters, such as voltages, electron or ion temperatures or densities, or both. After the initial relaxation of 10 to 15 cycles the program will generally require only 3 or 4 cycles to approach a new convergence. This can require from 1 to 15 minutes depending on the speed of the processor and the size of the matrix. It is usually not necessary or desirable to wait for a complete convergence before starting the modifications again.

The graphical routines permit the easy changing of the voltage, shape, deletion, addition, moving, or the replication of an electrode. The arrow keys are used to move a curser on the screen and to define end points of the lines to 4 decimal places, and the center of circles to 5 decimal places. Circles are defined by their endpoints and the location of their center using the curser to determine both. Curser motion is followed from point to point by a rubber-band line

so that the changes are immediately seen, and exact numerical location of the curser location also appears on the screen. The next version of the code may permit the use of the mouse, but it must also enable the same accuracy as the above routine.

Electrodes can be modified by moving, deleting, or adding line segments. One or both ends of a line segment can be moved with the curser. If a segment is deleted the new connection for the preceding and succeeding line segments can be made with the cursor. Adding a new line segment is accomplished by specifying the segment after which it is to be inserted. Preceding and succeeding segment endpoints are then automatically adjusted to make a continuous surface.

It is also possible to generate an entirely new electrode using this same cursor technique. For more elaborate electrode shapes the circle drawing routines are especially useful for creating smooth contours. If an electrode is to be extensively modified it may be desirable to delete it and then generate a new electrode.

Fairly extensive changes can be made in the anodes without unduly destableizing the program but one needs to be careful in the emission region where high space-charge density beams are being extracted. The space-charge densities from preceding cycles, which can be very large near an emission surface, can cause large transients in the calculations. Indeed, extensive changes in the cathode will require restarting the program. If one plans ahead it is possible to make relatively large adjustments in the plasma region of an ion beam.

One of the most useful features is the ability to generate a large number of electrodes by replicating a given electrode so that the potentials can be varied along the axis of the beam. One can adjust the voltages on the electrodes over a small section of the beam line until the desired beam is obtained. Usually the multiple electrodes can then be combined into larger electrodes and the process continued up the column. The interactive routines also permit the extension (or contraction) of the matrix (axially or radially) as one progresses down the line. The ability to change the voltages and immediately see the effect can sometimes lead to surprising results, especially when you try things you do not expect to work.

Electrodes may be moved axially and/or radially by specifying the distance to be moved or arbitrarily using the cursor. The most frequent use of this is to adjust the axial position of the electrodes to modify focussing or extraction effects.

If the matrix is expanded radially all lines that reach the top of the mesh are extended in a straight line to the new radial limit. Some care must be taken if these lines should cross in the extended region.

Parameters used in the simulation can be viewed and modified on the screen.

III. RESULTS

Results obtained with the interactive routines have been very encouraging. Problems that would have taken days saving and restoring data, have is some cases been reduced to a few hours (and sometimes minutes) by using the interactive routines. Complex electrode shapes are easier to develop on the screen, using the interactive routines, than they are trying to do them by hand. With a few simple configurations to start only a basic knowledge of how the program works should be necessary to use it.

Making detailed improvements in an already good design are made easy by making small changes in the configuration and observing the changes in a very short time. The effects of raising or lowering a voltage or moving an electrode back and forth are rapidly observed.

The program has become very tolerant of large changes in the electrodes and seldom fails. Results are saved as the program executes so that recovery is frequently possible

IV. FUTURE DEVELOPMENT

The next version of the program will require the faster processors, such as the Pentium, Alpha or Power PC, and probably a better resolution screen so that actual results can be shown in separate windows on the screen while the program runs. All input will be from the screen so that mistakes will become nearly impossible. All modifications will be handled from the screen and virtually no knowledge of the programs inner workings will be required.

V. REFERENCES

[1] Boers, J.E.,"PBGUNS: a Digital Computer Program for the Simulation of Electron and Ion Beams on a PC", *Conference record, 1993 ICOPS, Vancouver, BC, 7-9 June 1993.*