LEBT Modeling with ARGUS

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Abstract

ARGUS is a 3D particle-in-cell (PIC) simulation code that, in addition to full time-dependent PIC capability, supports steady-state calculations using an iterative PIC procedure similar to that used in a conventional gun design code[1]. Examples of ARGUS simulations in LEBT design are presented, including a simulation of a test model for the helical electrostatic quadrupole LEBT being designed at the SSC Laboratory.

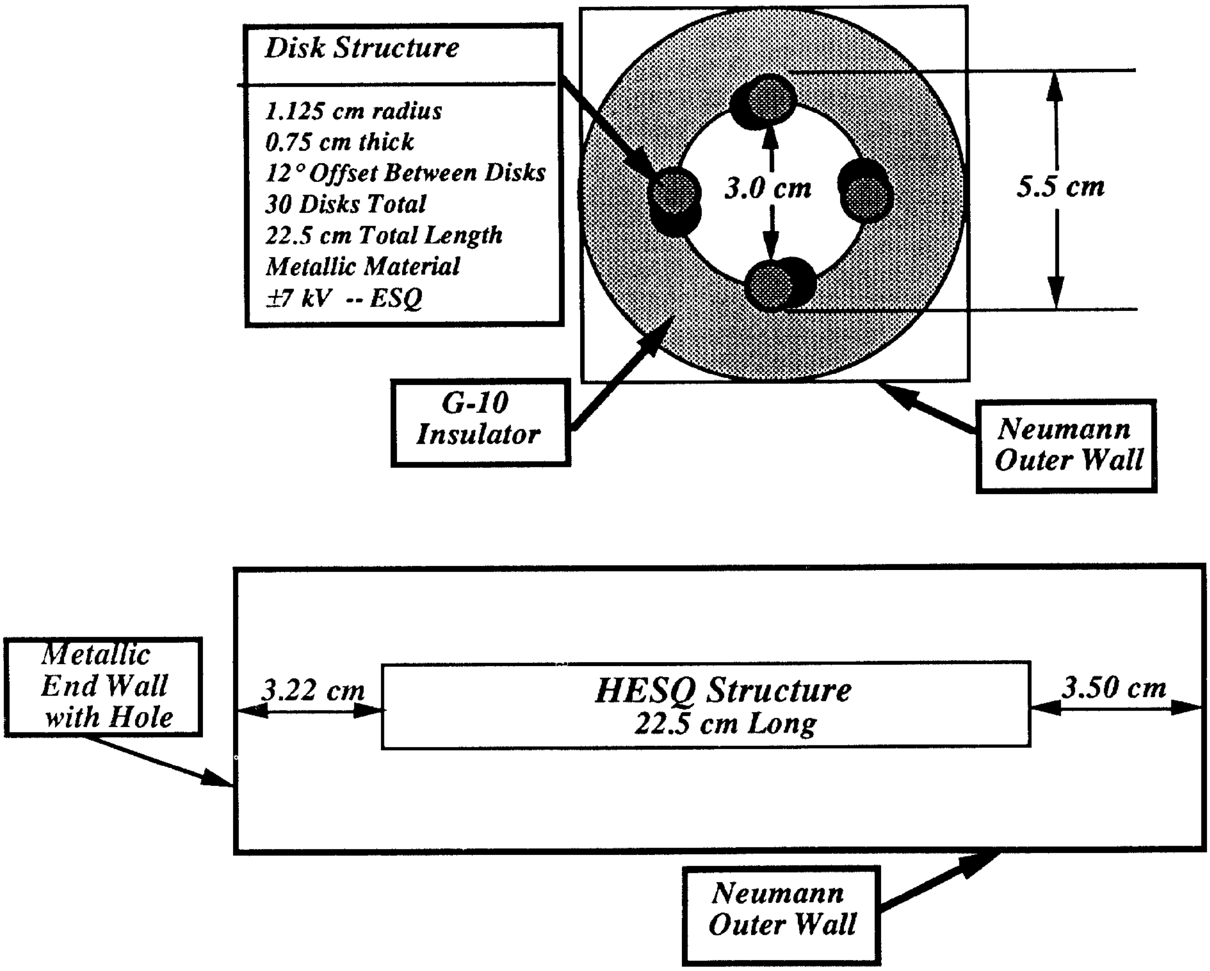

Figure 1. Model of HESQ

THE MODELING OF ELECTROSTATIC QUADRUPOLE DEVICES WITH PIC CODES

Electrostatic quadrupole (ESQ) accelerators and LEBT's are in fact very stressing problems for conventional PIC simulation codes. PIC codes, such as ARGUS, typically employ discretized spatial operators that are constructed from centered derivatives and therefore are accurate to second-order in the spatial cell size for a uniform mesh. If the mesh is made nonuniform, these operators lose second-order accuracy and approach first-order accuracy in the limit of extremely nonuniform gridding.

The electric field near the axis of an ESQ (i.e. near the beam) must, in fact, be computed to at least second order for the code to produce physically meaningful results. The need for second order accuracy (or better) arises from the presence of an external transverse potential gradient across the beam that is large compared with that of the beam space charge. The solution for

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the potential must have the accuracy to include sufficient significant digits to resolve the space charge fields. In the HESQ runs, we used an error estimate of 1.0×10^{-7}. Typical gun problems do not have external transverse field gradients which dominate in this way.

Utilizing a uniform grid makes the Poisson solver accurate to second order. We have discovered that electrostatic quadrupole focusing systems require extremely high accuracy in PIC simulations. These problems can take as many as 15-25 iterations where typical Pierce gun PIC simulations take only 7-15 iterations. In addition to assuring second order accuracy by choosing a the uniform grid, the simulation must also be made with a tight error tolerance on the electrostatic solver. This also increases the number of iterations necessary for convergence.

Resolving the small beam size that occurs at the focal points in an ESQ system and the relatively small ESQ structures require the use of nonuniform gridding in the simulation if the number of cells is to be kept manageable. In simulations of the helical ESQ structure[2] at the Texas Accelerator Center we have observed that iterative, steady-state PIC simulations using a nonuniform grid near the beam will not converge if the tolerance set for the Poisson solver is made small. With a uniform grid over the region containing the beam, the algrorithm does converge, but requires more cycles than usual for the particle flow to converge to the point where the Poisson solver remains converged (without further iterations) from one cycle to the next.

ARGUS RESULTS FOR THE HESQ AT TAC

The helical electrostatic quadrupole (HESQ) is a primary candidate as the LEBT for the SSC accelerator[3]. An experiment at the Texas Accelerator Center (TAC) provides a test bed for the design of the HESQ at the SSC. Figure 1 shows a schematic drawing of the TAC device and the parameters used in the ARGUS simulation. The device is constructed from 30 discrete quadrupoles, made from disks, each 0.75 cm thick, held in G10 insulator. Each plane of disks is offset 12° from its neighbors, so that the resulting structure forms a helical quadrupole.

Figure 2 shows the representation of this structure in the ARGUS code. ARGUS required 25 cycles to converge to a steady-state PIC solution for this structure with a 93x93x80 Cartesian grid, and using a tolerance figure of 10^{-7} for the Poisson solver. The transverse grid has been forced uniform over the HESQ aperture of 1.5 cm, and is stretched through the HESQ disks out to the edge of the grid at 5 cm. The axial grid is close to uniform everywhere. The holes in the end plates are larger than those in the actual device at TAC, but they appear to have only a small effect on the result. The HESQ disks are held to ±7 kV.

A cold H^- beam is launched 3.0 cm upstream from the entrance to the HESQ, with an energy of 35 keV, a current of 30 mA, and with Courant-Snyder parameters, $\alpha_x=\alpha_y=0$, $\beta_x=\beta_y=2.5$ cm.

Figure 3 shows projections of the particle trajectories in the x-z and y-z planes for the converged solution. The beam was launched cold. The emittance reached a maximum value of 9×10^{-6} rad-m during the simulation.

There is significant (>50%) beam loss within the HESQ in this simulation. The loss is at odds with observations at TAC and with Raparia's simulations with PARMELA. These differences are still under study.

ACKNOWLEDGEMENT

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REFERENCES

1 C.L. Chang, D. Chernin, A. Drobot, K. Ko, M. Kress, A. Mankofsky, A. Mondelli, and J. Petillo, *Three-Dimensional Modeling of Accelerators*, Proc. Conf. on Computer Codes and the Linear Accelerator Community (Los Alamos National Laboratory, January 22-25, 1990, LA-11857-C), pp. 27-56.

2 C.R. Meitzler, P. Datte, F.R. Huson, P.Tompkins, and D. Raparia, *Progress on the TAC Ion Source and LEBT*, Proc. 1990 Linear Accel. Conf. (Albuquerque, NM, 1990), p. 710.

3 D. Raparia, *HESQ, A Low-Energy Beam Transport for the SSC Linac*, Proc. 1990 Linear Accel. Conf. (Albuquerque, NM, 1990), p. 405.

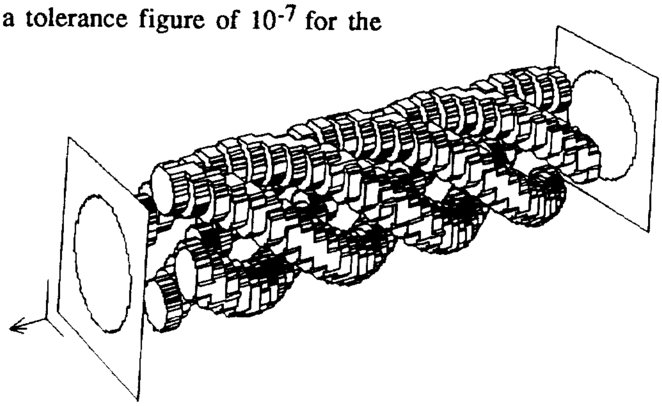

Figure 2. ARGUS Structure Plot for the TAC HESQ

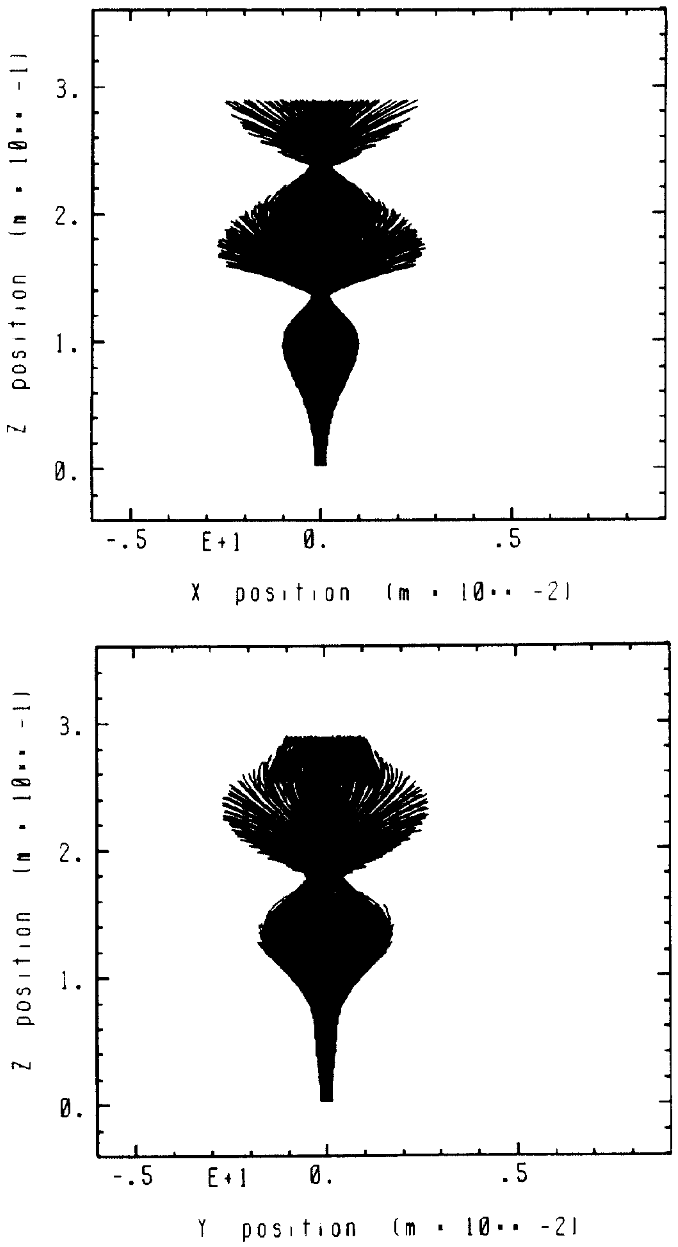

Figure 3. X-Z and Y-Z projections of Particle Trajectories in the HESQ