THE LOS ALAMOS ACCELERATOR CODE GROUP *

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Abstract

The Los Alamos Accelerator Code Group (LAACG) is a national resource for members of the accelerator community who use and/or develop software for the design and analysis of particle accelerators, beam transport systems, light sources, storage rings, and components of these systems. Below we describe the LAACG's activities in high performance computing, maintenance and enhancement of POISSON/SUPERFISH and related codes and the dissemination of information on the INTERNET.

I. POISSON/SUPERFISH

The LAACG supports the PC version of POISSON, SUPERFISH and PANDIRA, currently used by several hundred people. POISSON/SUPERFISH is a collection of programs for calculating static magnetic and electric fields and radio-frequency electromagnetic fields in either 2-D Cartesian coordinates or axially symmetric cylindrical coordinates. The programs generate a triangular mesh fitted to the boundaries of different materials in the problem geometry. The original version of POISSON/SUPERFISH was written in the early 1970s by R. F. Holsinger from theory developed by Klaus Halbach[2]. An older UNIX version of these codes is also still available, but this version has not had any significant development in the past few years. At PAC93 [1] we described a new SUPERFISH root finder and some other improvements that we had implemented in the PC version.

During the past two years, we have made about 120 changes in the codes which include new features, bug fixes, and other improvements. The most significant of these changes include

- Run-time memory allocation of all mesh-point arrays and temporary data,
- A more robust meshing algorithm in AUTOMESH,
- A new field-interpolation algorithm that satisfies boundary conditions for rf, magnetostatic, and electrostatic problems,
- Automation and mouse support in the plotting program VGAPLOT,
- HPGL and PostScript graphics support in all plotting codes,
- Configuration options in file SF.INI,
- Up to 10-line problem descriptions for better record keeping,
- A utility program for examining contents of the solution file,
- For program developers, a linkable field-interpolation module for use in user-developed post processors and source code for reading the solution files.

Run-time memory allocation means that the computer's available memory is the only limit on the maximum problem size. The codes require 3 MB or more of memory. The more memory available, the larger the number of mesh points the codes can use to solve problems. We recommend at least 8 MB of installed RAM plus at least 100 MB of disk space for temporary data storage. If there is insufficient RAM, SUPERFISH and PANDIRA write temporary data to disk. The size of the temporary file depends upon the number of mesh points and the shape of the problem geometry.

The code distribution now includes the programs PANDIRA, a direct solver version of POISSON that also can handle permanent-magnet materials, and FORCE for calculating the force on coils and iron elements in magnetostatic problems. We hope to add the optimizing code MIRT to the package later this year. The complete PC SUPERFISH distribution contains 26 executable codes, 25,000 lines of on-line documentation, plus input files for about 50 sample problems. These examples include all of the sample problems from the Reference Manual and User's Guide [3]. Documentation specific to the PC version resides on disk. Programs are provided to display the documentation or produce indexed, paginated files suitable for printing. The installation requires about 13 MB of disk space. The codes are compiled from approximately 590,000 lines of FORTRAN source code.

We distribute the PC package, which includes an installation program, by internet FTP or, upon request, on either 3.5-inch or 5.25-inch floppy diskettes. Postage for mailing diskettes and printed manuals is paid by Los Alamos National Laboratory. Customs charges, if any, are paid by the recipient. Registered users receive notification of updates and bug fixes by Email. New users can register and request access to our FTP server by sending their postal address, phone and fax numbers to SUPERFISH@LANL.GOV.

II. HIGH PERFORMANCE COMPUTING

Accelerator-driven technologies are now being proposed to solve problems of national and international importance. These technologies have both economic and environmental implications. They include Accelerator Production of Tritium (APT), Accelerator Transmutation of Waste (ATW), Accelerator Based Conversion of plutonium (ABC), accelerator-driven production of spallation neutrons for materials science and biological-science research, accelerator driven production of neutrons for fusion-materials testing, and accelerator-driven fission-energy systems. All of these projects require next-generation linear accelerators that operate with extremely low beam loss. A maximum beam loss in the accelerator of roughly 10 parts per million is required to assure hands-on maintenance capability. Beam loss at this low level is due to the presence of a very low density beam halo at large transverse distances from the core. In order to predict beam halo with confidence, one must perform numerical simulations of unprecedented resolution. For example, to have a

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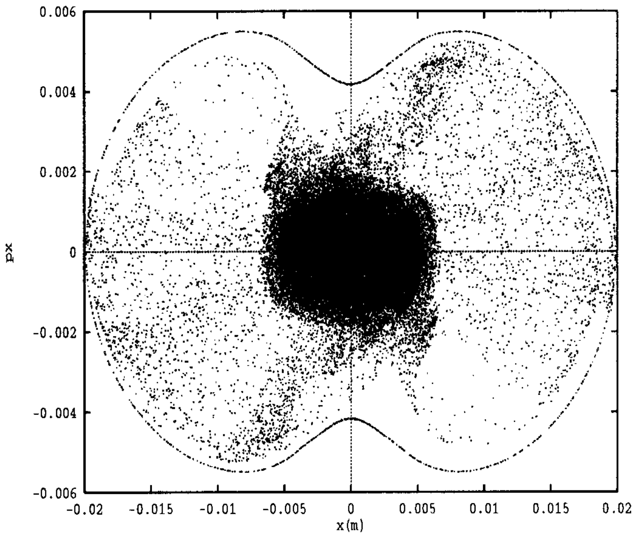

Figure 1. Beam phase space from a 2 million particle simulation on the CM-5 (65536 points are plotted). The outer peanut-shaped set of points were obtained from the particle-core model.

10% confidence in the number of halo particles, one would need to perform a simulation that resulted in roughly 100 particles in the halo; but if the halo accounted for 10 parts per million, this would mean that the simulation would require a total of 10 million particles. This is a major step beyond the linac simulations of the 1980s that typically used only 10,000 particles.

The LAACG has had much success in developing such a high-resolution accelerator-modeling capability[4]. Starting in 1994, we began using the massively parallel CM-5 at the Advanced Computing Laboratory at LANL to perform beam-halo simulations. The tools we are developing to model next-generation accelerators provide us with a means to test new designs, test theoretical models, and optimize our designs.

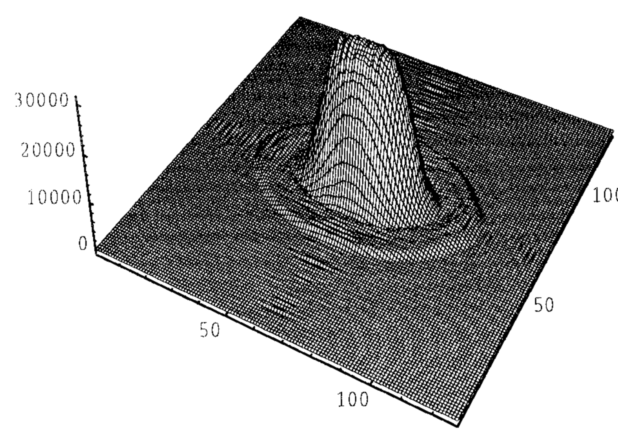

Figure 2. Output from a direct Vlasov/Poisson simulation. The 4-dimensional distribution function was integrated over p_x and p_y to obtain the beam density on a 128x128 grid.

We have developed and used a two-dimensional Particle-In-Cell code to model long beams in a variety of focusing systems. Using our code, we routinely perform simulations with several to ten million particles. One of our early applications was to model a mismatched KV beam in a constant focusing channel. We found that when the beam was unstable the charge redistributed itself in such a way that, though a halo was formed, it was bounded, and furthermore the extent of the halo was in excellent agreement with a theoretical model called the particle-core model of halo evolution in mismatched beams. This is shown in Figure 1. We have also performed simulations that dealt with the controversial issue of whether of not quadrupole focusing can cause significant halo formation for matched beams. Our results indicate that breathing due to quadrupole focusing will not be a problem in the physics regime of the projects described above, where the tune depression is at worst approximately 50%. Besides developing particle simulation codes we are also studying other approaches to modeling and predicting beam halo. For example, we have developed a two-dimensional (four-dimensional phase space) direct Vlasov-Poisson simulation code. We have performed very high resolution simulations on a 128x128x128x128 grid, for a total of 268 million grid points. A typical simulation of a beam in a quadrupole channel is shown in Figure 2.

At present multi-million particle simulations are the best means we have to quantitatively predict extremely low beam loss, so they are crucial to lending support to the validity of proposed designs.

Since all of our codes are written in the CM FORTRAN program language (a FORTRAN90-like language), it will be easy to port them to other platforms that support the data parallel paradigm. So far our activities have emphasized two-dimensional modeling. Our future goals are aimed at modeling three-dimensional (i.e. bunched) beams including acceleration.

III. INFORMATION RESOURCES FOR THE ACCELERATOR COMMUNITY ON THE INTERNET

In October 1994 the LAACG began making information available via the World Wide Web (WWW). The documents can be accessed at the address:
<http://www.atdiv.lanl.gov/doc/laacg/codehome.html>. The published documents provide a variety of information of interest to the accelerator as well as other scientific communities. The documents include:

- information about the LAACG and its services,
- general information of interest for the accelerator community,
- extensive list of links to accelerator laboratories and institutes worldwide (approximately 100),
- information related to the field of electromagnetic field calculations and information on other computational tools for accelerator physics,
- online versions of the previously published Accelerator Code Compendium from 1990 and a new up-to-date Code Compendium,
- excerpts from the user-documentation of the codes distributed by the LAACG,

- an online information service for the 1995 Particle Accler-ator Conference in Dallas, Texas.

This new service is well accepted by the scientific community. This is documented by an average number of 235 accesses per month with an approximate monthly use of 1800 documents. 64 % of the accesses are from within the USA and Canada. The rest is predominantly from Europe and Japan (based on activities before April 19, 1995).

Table 1: Most Frequently Used Services

	Service	accesses
1.	PAC-Conference	1242
2.	Code Group Services	419
3.	Electromagnetics	297
4.	List of Accelerators	224
5.	General information	209
6.	POISSON/SUPERFISH	163
7.	Old Code Compendium	156
8.	P/S Userguide	119
9.	New Code Compendium	109

We encourage the community's interaction to help us improve the services provided on the WWW. Our major interest lies in the extension of a new online Code Compendium. The last printed version is from May 1990. With the rapid development of codes and computers this compendium is outdated. For this new compendium, the LAACG needs the community's input. At the conference questionnaires are available to enter new codes and update information on entries in the old compendium.

We also set up a FTP-server that allows the community to get the codes distributed by the LAACG over the network without extensive interaction with us. We still recommend subscribing to the POISSON/SUPERFISH mailing list. This is the only way to become aware of bugs, code corrections or code upgrades. The FTP-address can be obtained from the new WWW online Code Compendium.

Another activity of the code group on the INTERNET in mid 1993 led to the creation of a USENET discussion group on accelerator physics. The group *sci.physics.accelerators* is a discussion forum on accelerator physics, beam physics and general contacts between researchers.

Lastly, at the request of the LAACG an electronic preprint service centered on accelerator physics has been created. Such forums allow access to preprints of publications before they are available in paperbound journals. This service is availabe on the WWW at the URL: <http://xxx.lanl.gov/> as well as by electronic mail and FTP.

References

[1] J. H. Billen and L. M. Young, "POISSON/SUPERFISH on PC Compatibles," Proceedings of the 1993 Particle Accelerator Conference, Vol. 2, p. 790.

[2] K. Halbach, R.F. Honsinger, "SUPERFISH – A Computer Program for Evaluation of RF Cavities with Cylindrical Symmetry", Particle Acelerator 7(4), 213-222 (1976)

[3] Reference Manual for the POISSON/SUPERFISH Group of Codes, Los Alamos National Laboratory Report LA-UR-87-126 (1987); and User's Guide for the for the POISSON/SUPERFISH Group of Codes, Los Alamos National Laboratory Report LA-UR-87-115 (1987).

[4] R. Ryne and T. Wangler, "Recent Results in Analysis and Simulation of Beam Halo," International Conference on Accelerator Driven Transmutation Technologies and Applications, Las Vegas, NV (July 1994)