

THE USER FRIENDLY INTERFACE FOR BEAMDULAC-RFQ CODE

P.O. Larin, S.M. Polozov, National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia

Abstract

The BEAMDULAC [1] beam dynamics simulation code is under development at MEPhI Department of Electrophysical Facilities since 1999. Such code includes versions for beam dynamics study in a number of accelerating structures as RFQ, DTL, APF, transport channels, etc. The motion equation for each particle is solved self-consistently in the external fields and the inter-particle Coulomb field simultaneously. The BEAMDULAC code utilizes the cloud-in-cell (CIC) method for accurate treatment of the space charge effects. The external field can be represented analytically, as a series or on the grid. The absence of user-friendly interface was the main disadvantage of the code. Last year such interface was developed and will present in the report.

INTRODUCTION

A number of codes for beam dynamics study as DYNAMION, TRACE, PARMELA, COBRA and etcetera are well known. Any one of codes has own field of use, own abilities and disabilities, a different methods for motion equation and Poisson equation solving are used.

The BEAMDULAC code is developing at Department of Electrophysical Facilities of MEPhI by E.S. Masunov, N.E. Vinogradov and S.M. Polozov through 1999. This code was early designed for self-consistent beam dynamics study in RF focusing linacs as axisymmetric radio frequency focusing (ARF, [2]), ribbon radio frequency focusing (RRF, [3]) accelerators and undulator linear accelerators (UNDULAC, [4-8]). 2D and 3D versions were developed for axisymmetric structures and for ribbon beams respectively.

Later new code versions were developed to simulate the beam dynamics in RFQ or DTL linacs, transport channels [1]. Especially versions for electron linacs were designed. The beam dynamics taking into account beam loading and Coulomb field can be studied with the help of these codes [9].

But all code versions have one serious disadvantage. They are compiled as dos operation system application and have not user friendly interface. Now we start to solve such problem and the interface for BEAMDULAC-RFQ version was modified first.

BEAMDULAC CODE AND USED ALGORITHMS AND METHODS

The BEAMDULAC code utilizes the cloud-in-cell (CIC) method for accurate treatment of the own beam space charge effects that are especially important for high-intensity beams. The motion equation of each particle is

solved in the external fields and the inter-particle Coulomb field simultaneously. The charge density is deposited on the grid points using the CIC technique. To determine the potential of the Coulomb field the Poisson equation is solved on the grid with periodic boundary conditions at both ends of the domain in the longitudinal direction. The aperture of the channel is represented as an ideally conducting surface of rectangular or circular cross-section. Therefore the Dirichlet boundary conditions are applied in transverse boundaries of the simulation domain. In such approach the interaction of the bunch space charge with the accelerating channel boundaries is taken into account. This allows considering of the shielding effect which is sufficiently important for transverse focusing in the narrow channel. The fast Fourier transform (FFT) algorithm is used to solve the Poisson equation on a 3D grid. The Fourier series for the space charge potential obtained can be analytically differentiated and thus each component of the Coulomb electrical field can be found as a series with known coefficients. The Coulomb defocusing force is the main factor limiting the beam current in high-intensity linacs. In our code the space charge field can be calculated with the same precision as the Coulomb potential without numerical differentiation. Time is used as an independent variable and standard fourth-order Runge-Kutta method is applied for integration of the motion equation. The external fields in BEAMDULAC code can be represented by three different methods: analytically, as a series of space harmonics (the field amplitude is representing as a polynomial coefficient series) and in a "real field" which can be defined on 2D or 3D grid by electrodynamic simulation codes or experimental measurement [10].

Especially versions of code were developed to study the ion beam dynamics with different charge to mass ratio in low energy transport systems, RF bunchers and linacs, as an example for simultaneous acceleration of positive and negative ions and beam space charge neutralization study [1, 8].

The RF field induced by the beam in the accelerating structure depends on the beam velocity as well as the current pulse shape and duration. The influence of the beam loading can reduce the external field amplitude and induce the irradiation in the wide eigen frequency modes. Therefore we should to solve the motion equations simultaneously with Maxwell's equations for accurate simulation of beam dynamics. The method of beam loading effect treatment was developed by E.S. Masunov [11]. It provides to define eigen modes amplitude variation equations in stationary and transient cases for standing and traveling wave periodical structures. Such technique was used for BEAMDULAC-BL code version development [9].

The BEAMDULAC-RFQ code versions were developed for beam dynamics study in RFQ linacs. The linac channel parameters can be defined by two ways. The preliminary simulations could be done using synchronous phase, electrodes modulation, aperture size and ets. defined as slow functions of longitudinal coordinate into accelerator channel. The second way is to define the structure parameters period-to-period. An example of beam dynamics simulation results for 2 MeV RFQ is presented in [12].

INTERFACE AND NEW ABILITIES OF BEAMDULAC-RFQ

The developed code with graphical user interface is an improvement for BEAMDULAC-RFQ code. It is a convenient tool for handling simulation process, data visualization and constructing a simulating structure. It uses BEAMDULAC-RFQ code as a simulator engine and some own algorithms for complex structure simulation.

The main window is shown in Figure 1. The top part (it is marked as “A”) contains a ribbon panel with separated tabs for adjusting initial beam parameters, simulation settings and selected structure item properties. The simulation conditions sets by “INJECTION” and “SIMULATION” tabs. The “INJECTION” tab sets initial beam parameters: ions charge, energy, separatrix size, average velocity, Twiss-parameters and particles distribution functions. The “SIMULATION” tab sets beam parameters and cloud-in-cell mesh. In addition, top panel contains an “ELEMENTS” tab arranges the content of extendable accelerator elements library for under simulation structure constructing.

One of the program abilities is a constructing of arbitrary simulating structure. Each structure item is a special library entity and can be designed independently of main program code. Each item is an accelerator element model and defines the equations of particle

moving in its electromagnetic field. At the moment, there are RFQ and PMQ elements in library. The structure layout is carried out using the area marked as “B”. This is an RFQ section example in the picture. The panel marked as “C” shows the computed data during simulation runtime. This panel arranges the beam envelopes, phase portraits and channel configuration parameters. An example of beam dynamics in RFQ section simulation results is shown in Figure 1. Such section is designed as first 2 MeV section of high-power CW linac [12]. The first tab named “Envelopes” shows longitudinal dependencies of beam parameters such as emittance, transverse sizes and particles number. The second data tab named “Phase portraits” shown in Figure 2 arranges a beam phase portraits in different longitudinal direction coordinates. The channel configuration characteristics arranged by third tab named “Channel configuration”. These characteristics are presented as longitudinal dependencies of synchronous velocity and aperture (Fig. 3).

CONCLUSION

The results of modern interface development for BEAMDULAC-RFQ code were presented. The new program was designed using conventional BEAMDULAC Fortran codes for simulation and visual possibilities of .NET Framework 4.5. An example of test simulation illustrates the new code abilities.

REFERENCES

- [1] S.M. Polozov. Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations, 3 (79), 2012, pp. 131-136.
- [2] E.S. Masunov, N.E. Vinogradov. Phys. Rev. ST Accel. Beams, 2001, No 7, 070101.

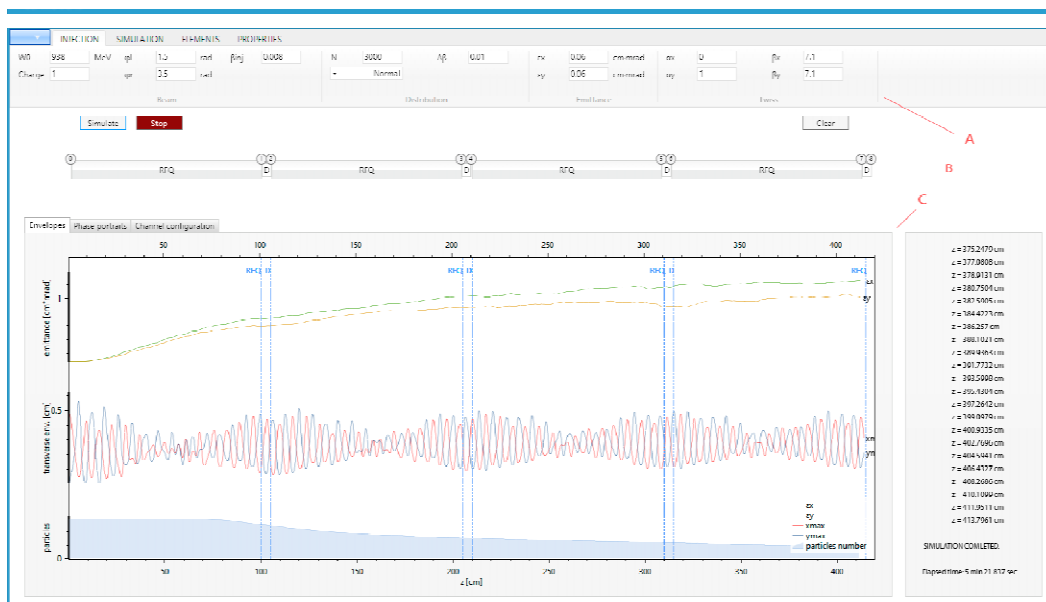


Figure 1: Main window of the new BEAMDULAC-RFQ code interface.

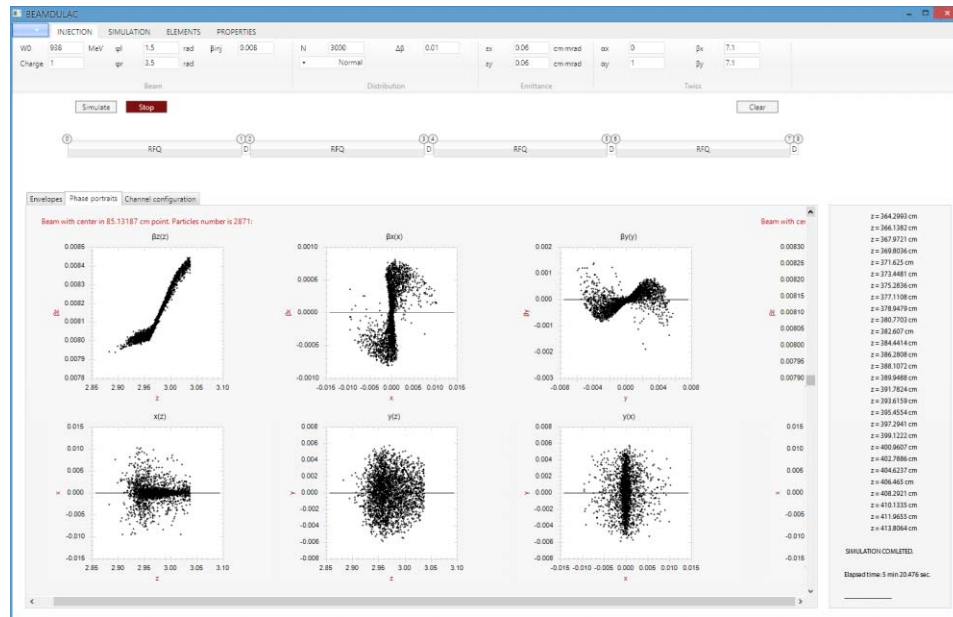


Figure 2: Main window: phase portraits.

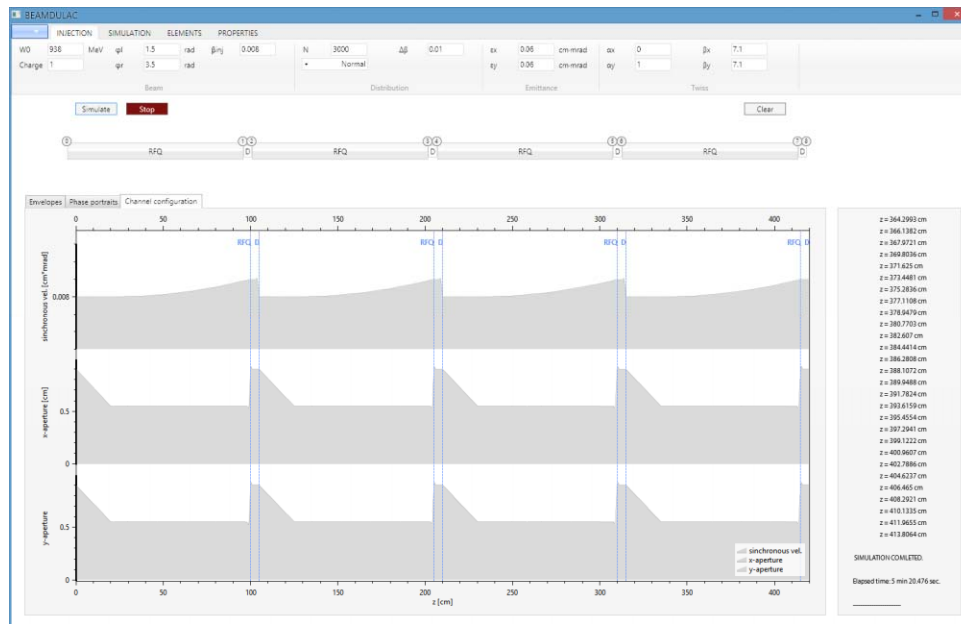


Figure 3: Main window: structure configuration.

- [3] E.S. Masunov, S.M. Polozov, N.E. Vinogradov. Problems of atomic science and technology. Series “Nuclear Physics Investigations”, 5 (39), 2001, pp. 71 – 73.
- [4] E.S. Masunov, S. M. Polozov, A.S. Roshal. Radiation Physics and Chemistry, 2001, v. 61, pp. 491-493.
- [5] E.S. Masunov, S. M. Polozov. Problems of atomic science and technology. Series “Nuclear Physics Investigations”, 2 (43), 2004, pp. 141-143.
- [6] E.S. Masunov, S.M. Polozov. NIM A, 558. 2006, p. 184–187.
- [7] E.S. Masunov, S.M. Polozov. Phys. Rev. ST AB (11), 2008, 074201.
- [8] E.S. Masunov, S.M. Polozov. Problems of atomic science and technology. Series “Nuclear Physics Investigations”, 5 (50), 2008, pp.136-139.
- [9] T.V. Bondarenko, E.S. Masunov, S.M. Polozov. Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations, 6 (88), 2013, pp. 114-118.
- [10] E.S. Masunov, S.M. Polozov. Problems of Atomic Science and Technology. Series Nuclear Physics Investigations, 3 (47). 2006, pp. 119-121.
- [11] E.S. Masunov, V.I. Rashchikov. Accelerators, Atomizdat, Issue 17, 1977, p. 96 (in Russian).
- [12] A.Y. Aksentyev, S.M. Polozov, T.V. Kulevoy. Proc. of IPAC’14, 2014, pp. 3286-3288.