Status of the 3D Time-Dependent FEL Simulation Code GENESIS 1.3

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Since its release in 1999 the 3D time-dependent simulation code GENESIS 1.3 has become a helpful tool for the design-studies and analysis of a single-pass Free-Electron Lasers experiments. with the latest version new features have been added such as support for wake-fields and incoherent spontaneous radiation. In addition the more modular structure of the open-source code and the improved support of external input files allow a better understanding of the code, supporting users who want to add new features to the code.

1. Introduction

Numerical simulations have become an essential part of any FEL project. They are used to either conduct design-studies for proposed experiments or to compare experimental results with the underlying theory embedded in the codes. Numerous codes have been written focusing on the specific FEL interaction between electron beam and radiation field within an undulator. Most of them use simplifications such as the steady-state regime or axi-symmetric beams.

Since its first release the FEL simulation code GENESIS 1.3 [1] is used at various FEL labs around the world and extends the set of time-dependent FEL codes [2,3] by treating the FEL interaction self-consistently in all dimensions. It has been successfully benchmarked with FEL experiments [4] and other codes [5].

2. The Physical Model

The core of the physical model in GENESIS 1.3 is a finite-difference based solver for the eikonal FEL field equations [6] using the alternating direction implicit (ADI) method on a Cartesian 2D mesh. A 4th order Runge-Kutta solver integrates the equation of motion for the electron energy and phase while a symplectic solver tracks the transverse variables through the magnetic lattice of the undulator.

Two new features are incorporated with the propagation of the electron beam. The effect of energy loss due to spontaneous radiation and the growth of the energy spread due to the quantum fluctuation of the spontaneous radiation follow an analytical model [7] and is applied to the particle distribution without introducing unphysical bunching effects in the longitudinal phase space.

The second feature is the effect of wake fields on the electron beam which is mainly modeled by a mean energy loss per integration step. The wakefield potential has to be calculated prior to the run of GENESIS 1.3 and supplied by an external file. Neither the choice of the wake field model nor the explicit calculation of the wake field potential is part of the GENESIS 1.3 distribution and has to be done by 3rd party programs.

3. Interface

The list of input parameter has been extended to roughly 100 parameters, mostly replacing less intuitive parameters. Still the single input is only capable to describe an FEL under certain approximations or assumptions such as predefined bunch profiles or fixed undulator and focusing lattice. To allow more flexibility for the user the GENESIS 1.3 input has been extended to multiple input files, each describing a specific part of the simulation. In particular it allows an easy interface to other simulation tools for e.g. start-end or two stage FEL simulations.

The magnetic field can be describe up to the level of each individual undulator pole and includes the main undulator field, arbitrary quadrupole and solenoid fields as well as field errors, quadrupole misplacements and corrector magnets. The structure of this ASCII input file can be simplified by formating commands and comments for easy reading and editing by the user.

Similar, beam parameters as a function of the longitudinal position within the bunch as well as entire sample distributions of the complete 6D phase space can be imported into GENESIS 1.3 to model the electron beam with a high level of detail and flexibility.

Several external programs have been written to support the use of GENESIS 1.3. They simplify the set up of input decks, calculate analytical results or supply correct magnet strength compensating field errors.

4. Outlook

GENESIS 1.3 is written in FORTRAN, which implies two major drawbacks. First, the size of the memory demand is determined during compilation time. Thus the efficiency of the memory usage is low. In particular the array containing the slippage field is the dominant part of the high memory demand of GENESIS 1.3, although not used for steady-state simulations. The other drawback is the poor support of FORTRAN for string processing. As a consequence the functionality of the external input files are limited.

Those problems are solved if the code is converted to C or C++, using dynamical allocation of memory and a wide library support for input and string parsing. It is a prerequired step for extending the input and output to other file formats. Two promising formats are SDDS [8] and XML [9]. The first allows a better interface to other codes such as ELEGANT [10] as well as the support by an extensive library to process and display the GENESIS 1.3 output. XML is currently the most promising standard for any kind of ASCII documents. It automatically guarantees validity of any input or output file due to its strict format and syntax requirement. GENESIS 1.3 files can rely on compability to any other program supporting the XML standard.

The main algorithm of GENESIS 1.3 in time-dependent mode requires only to pass a limited amount of information to adjacent slices. Thus GENESIS 1.3 can be ported to a parallel architecture without any major modification in the code. Using the message-passing interface (MPI) [11] for synchronizing the nodes of the parallel computer and passing the required data to the next nodes will significantly reduce the computational time for CPU intensive time-dependent simulations.

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