

THE FERMI@Elettra ON-LINE MODELING TOOLKIT

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Abstract

FERMI@Elettra is a new 4th generation synchrotron radiation source currently under construction at the Elettra laboratory, and it is based on a single-pass free electron laser. The toolkit is a rapid application development environment based on Matlab and on the *elegant* simulation code. Its purpose is to provide machine physicists and operators with tools for estimating and plotting the main beam parameters of the running accelerator, calculating new settings and corrections, and finally setting or updating the machine parameters with new calculated values. The on-line modeling toolkit consists of a set of programs and libraries which provide a bridge between the accelerator control system, based on Tango, and the simulation codes. The toolkit also provides the means to perform all the conversions from machine parameters and variables (such as a current circulating in a magnet) to beam dynamics variables (the magnetic field strength, in the example) and vice-versa. The conversion is performed by a set of virtual Tango devices that implement an on-line magnet model; these devices contain all the needed calibration tables and the logic to read and set the appropriate power supply.

INTRODUCTION

FERMI@Elettra is the 4th generation light source under construction at the Elettra laboratory. It is a user facility based on a seeded harmonic Free Electron Laser (FEL) driven by a 1.5 GeV electron linac. Four lasers are used for driving the photocathode gun, laser heating, FEL seeding and pump-and-probe experiments in the beamlines.

The control system, described in [1], is completely based on Tango [2]. The new accelerator, whose first sections are presently under commissioning, requires powerful and flexible control programs for performing tests and measurements of beam and accelerator parameters from the control room. The control room programs are based on a set of tools (software libraries, tango device servers, etc.) which must be easy to learn and use also for non-professional programmers. The set of tools is known as the on-line modeling toolkit.

Toolkit Requirements and Constraints

The purpose of the toolkit is to provide machine physicists and operators with tools for estimating and plotting the main beam parameters of the running accelerator, calculating new settings and corrections, and possibly setting or updating the machine parameters with the newly calculated values.

Operational Tools

An important requirement is the possibility to exploit the *elegant* machine physics code [3] for performing all the beam optics calculations, since this code has been extensively used during the design of the accelerator and is well known by the machine physicists.

Ease of programming, together with the possibility to rapidly test, correct and modify programs is a fundamental requirement of the toolkit. In order to fulfill this requirement we have selected Matlab as the programming language for the machine physics group. This was also made possible by the availability of a specific Matlab library for interfacing with the Tango control system (Matlab bindings).

The constraints of modularity, design of componets for re-use and strict adherence to the Tango object model have directed all the phases of the design and implementation of the toolkit components.

INTEGRATION OF ELEGANT WITH MATLAB AND THE CONTROL SYSTEM

In order to use *elegant* as on-line machine model we had to solve a couple of problems: how to run a simulation with actual accelerator parameters (e.g. magnet strengths) acquired from the “live” machine, then how to import the simulation results (e.g. transport matrices, Twiss parameters or new strengths after correction) into the Matlab workspace. We exploit the `load_parameter_elegant` command, which reads the desired accelerator parameters from a file in SDDS [4] format. The parameter file is filled-in by calling the specially developed `readfield2sdds()` function. This function extracts the requested *element/parameter* couples and maps them to control system *device/attribute* couples; the predefined mappings are stored in a MySQL database and are automatically retrieved. Then the parameters are acquired from the machine by calling the appropriate Tango functions and written to the desired SDDS parameter file. When the machine parameters have been acquired, *elegant* is run from Matlab as an external program. The results of the simulations, written into SDDS files, can then be analyzed and plotted in Matlab. By means of the `writesdds2file()` function new settings for the machine can also be directly set to the accelerator. This Matlab function is analogous to `readfield2sdds()`, but sets values instead of reading them. The possibility of settings value will be exploited for doing model based beam optimizations and corrections. A schematic view of the information and actions flow is presented in Fig.1.

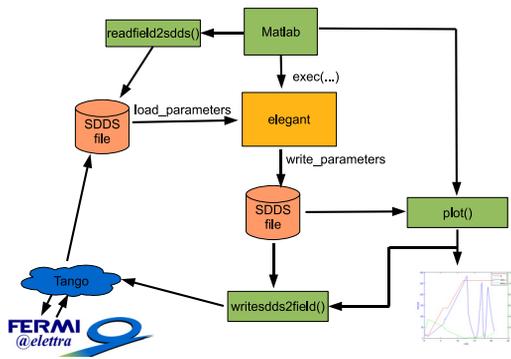


Figure 1: Matlab-elegant data flow.

An example of the of the *elegant* calculated parameters plotted from Matlab is presented in Fig. 2.

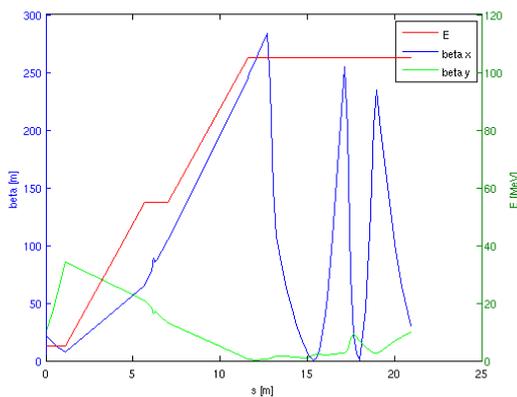


Figure 2: Matlab plot of *elegant* calculated optics functions.

MODELING OF ACCELERATOR ELEMENTS

Elegant works with accelerator parameters expressed as normalized machine physics quantities (e.g. strength for quadrupoles, kick in radians for correctors) while most of the control system devices work with engineering quantities, such as current or voltage. We had to implement the means to convert these quantities into each other.

Magnet Calibrations and Database

The conversion between these quantities is based on calibration tables. The calibration tables of the FERMI magnets are stored in a MySQL database. The calibrations are supplied by magnet experts in the form of normalized spreadsheet files. A set of python utilities have been used to automatically extract the calibrations and load them into the database. The calibrations can be accessed from the database using many programming languages, including Matlab for which an appropriate macro has been provided.

Operational Tools

The database is also readable via a web browser by means of an interface written in php (see Fig. 3).

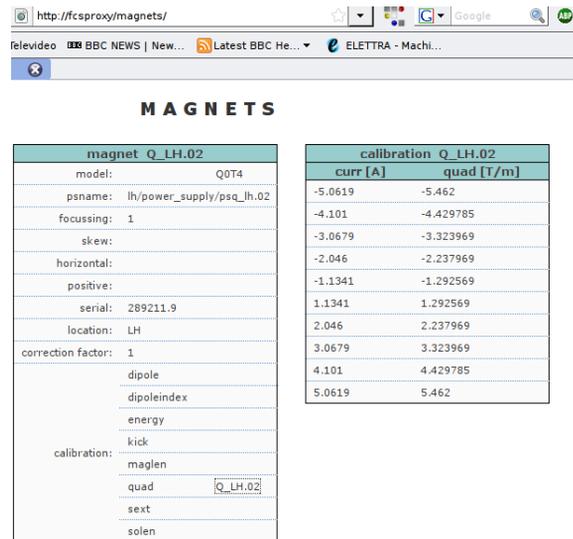


Figure 3: Web page with magnet calibrations.

Element Models as Tango Devices

The actual task of conversion is carried out by specially developed Tango devices which act as live or on-line models of the most important accelerator elements.

The magnet models are based on our HLF toolkit already developed for the control of the Elettra booster [5]. These Tango devices perform all the required steps for converting an engineering quantity into the magnetic field and vice-versa: load the appropriate calibration tables at startup, read the actual power supply setting, check its status, then call the conversion routine that interpolates the calibration table values.

The radio-frequency accelerating sections models are new and are still under development and testing. They will make available as a control system attribute the effective total accelerating voltage and phase of each accelerating section. This device model is a little more complex than that of the magnet since, depending on the particular plant, it must acquire the setting of several devices: klystron high voltage, phase shifters, RF drive amplitudes and phases, etc. Several other RF plant characteristics, such as waveguide losses, cavity impedances, klystron output curves, etc, must be known to estimate the effective energy gain of an accelerating section. Some of these parameters are known by design while others will be measured as part of the accelerator commissioning.

The accelerator element models, mainly developed for the *elegant* on-line modeling of the FERMI accelerator are immediately available to any programming language supported by Tango, giving us a very high degree of component reuse and standardization.

DIRECT MANIPULATION OF MACHINE PHYSICS QUANTITIES

The development and deployment in the form of Tango devices of some of the accelerator element models has opened up the possibility for control room operators to view and manipulate the accelerator directly in terms of machine physics quantities. Control panels for the main accelerator magnets have already been developed and are available in the FERMI control room (see Fig. 4). The operational impact of this novel capability has yet to be fully assessed and exploited by the FERMI commissioning team. In our view it will give us the possibility to “see” and “manipulate” the accelerator in terms directly related to the electron beam dynamics. Due to the modular and layered design of the control system, this new view will not preclude to look at the accelerator in terms of traditional devices: currents, voltages, etc. Depending on the specific task to be carried out, the most convenient view will be selected.

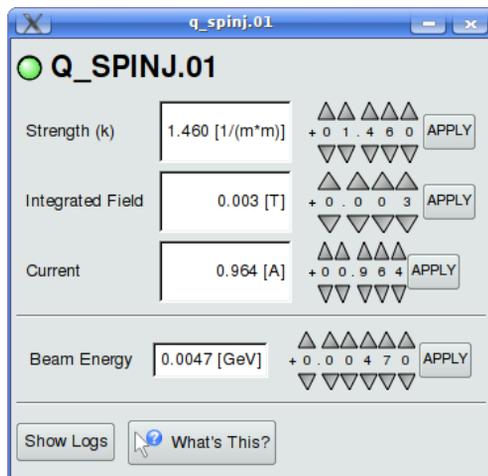


Figure 4: Control panel of quadrupole magnet.

STATUS AND PERSPECTIVES

The on-line modeling toolkit is being tested with the real machine during the first phase of the commissioning and will almost surely undergo several debug and development cycles as bugs and new requirements will emerge with usage. A new tool for browsing the nominal layout of the accelerator has already been requested. Its main usage will be for retrieving static information about the accelerator elements, layout and geometry: list of elements, global coordinates of an element, nominal electron path length between two elements, etc. The deployment and testing of the prototype is scheduled for the end of October 2009. This layout tool will be available in the form of a standard control system Tango device.

The modular and fine-grained design of the on-line modeling toolkit will allow us to easily adapt to the scenarios that will arise during the commissioning of our new and Operational Tools

challenging light source. The availability of ready made high level componets allow our commissioning team to concentrate their efforts in solving real problems, since most of the low level technicalities are handled by the toolkit components.

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