

## **EXTERNAL DATA INTERFACE TOOLS FOR THE PARTICLE BEAM OPTICS LABORATORY**

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### *Abstract*

An external data interface tool has been developed for the Particle Beam Optics Laboratory (PBO Lab™). The PBO Lab application provides an environment for the graphical set up of beam line models and execution of multiple optics programs that are implemented as Application Modules in a single user-friendly graphic interface shell. The external data interface (EDI) tools that have been implemented in PBO Lab version 2.0 support the import and export of beam line model parameters, as well as exporting diagnostic data generated from the different PBO Lab Application Modules. A variety of data exchange capabilities are provided through the EDI tools, including a basic implementation using ASCII text files in several different formats. However, one new EDI tool is described here that supports dynamic data exchange with MATLAB™. In addition to the exchange of beam line model parameters and computational diagnostics, this tool also implements an integrated simulation loop. This allows the user to modify beam line model parameters and specify the execution of PBO Lab Application Modules in a loop that is externally controlled from MATLAB using C or Fortran MEX files, or MATLAB M files.

### **1 INTRODUCTION**

The Particle Beam Optics Laboratory [1] is a multi-platform software package that combines the capabilities of several different particle optics programs under a single graphic user interface (GUI) shell. The focus of the PBO Lab package is on improving the ease-of-use and accessibility for legacy optics codes trusted in the accelerator community, as well as supporting recently developed object oriented codes, all within a consistent user interface shell. A multi-platform open architecture framework called the Shell for Particle Accelerator Related Codes (S.P.A.R.C.-MP) [2] has been developed for the implementation of optics codes as Application Modules in the PBO Lab environment. The framework implements a sophisticated beam line object model [3] and an extensive library of GUI components that support a variety of optics codes and add-on tools. This provides an environment for the graphical set up of beam line models and the execution of multiple optics programs from a single user-friendly interface, without requiring any knowledge of the various formats and specific syntax of the input required by the different optics programs. PBO Lab is capable of generating all the necessary input for each Application Module supported by the framework.

The S.P.A.R.C.-MP framework also provides external data interface tools that extend the users ability to configure PBO Lab for specific tasks in a variety of ways. One such tool is described here, for integrating PBO Lab with the MATLAB™ environment. MATLAB by The MathWorks, Inc. [4], provides users with a mathematical workspace environment, development tools for creating user interface windows and plotting data, as well as supporting both compiled and interpreted programming languages. The PBO Lab version 2.0 GUI enables point-and-click selection of import/export variables and application-specific diagnostic output data to be used with the EDI tools. The PBO Lab EDI tool for MATLAB allows the user to exchange their selected beam line model parameters and diagnostics with the MATLAB environment. This data is made accessible directly in the MATLAB workspace. The MATLAB EDI tool supports the execution of compiled C functions or Fortran subroutines, in addition to routines written in MATLAB's interpreted programming language. A basic simulation loop is provided for the automation of user defined operations.

### **2 PARTICLE BEAM OPTICS LABORATORY**

The Particle Beam Optics Laboratory provides a unique graphic user interface shell (described in References [5,6,7]) for multiple particle accelerator related codes. Selected windows from a new version of the PBO Lab currently under development are shown in Figure 1. The PBO Lab environment presents a consistent and intuitive graphic user interface for related functionality in different optics codes. For example, a wide variety of fitting capabilities are supported by the different Application Modules in PBO Lab and the native specification of fitting variables and constraints for each of these codes is considerably different. The consistent treatment in PBO Lab, of similar capabilities in different optics programs, greatly reduces complexity for the user. The S.P.A.R.C.-MP framework provides PBO Lab with a variety of data visualization tools that are used to generate ellipse plots, scatter plots, line plots and bar graphs from the diagnostic data generated by the different Application Modules. The framework architecture also supports plug-in tools such as an interactive particle trajectory module, a hypertext help system, interactive tutorials, and external data interface tools.

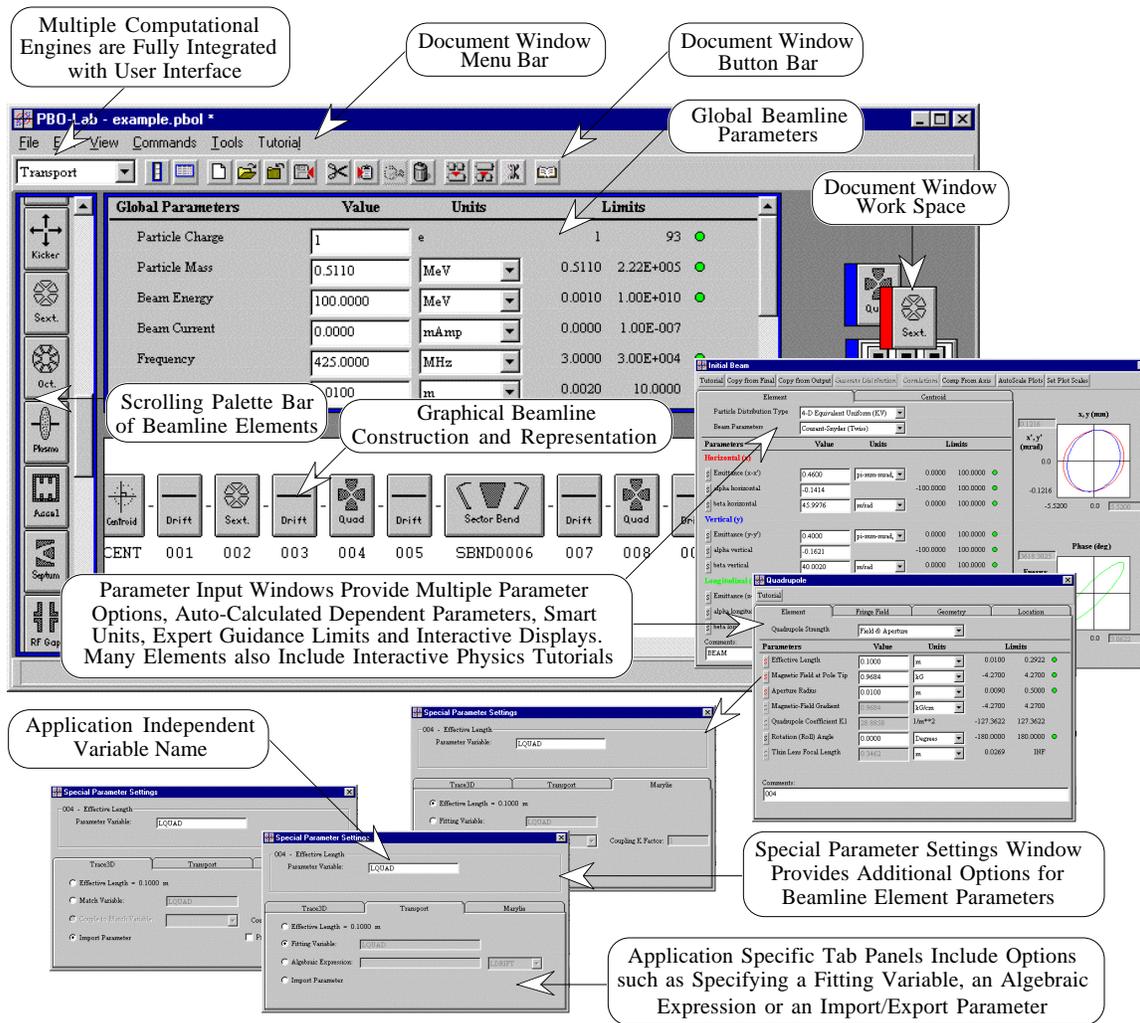


Figure 1. Screen Screenshot from the new Particle Beam Optics Laboratory on Windows™.

### 3 PBO LAB EXTERNAL DATA INTERFACE TOOLS

The PBO Lab external data interface bar tools are implemented in the S.P.A.R.C. MP framework as independent modules that import and/or export specific data formats through a generic EDI tools interface. The EDI tools can be described as a system of modules (Data Repositories) that fill an intermediate data structure (Data Interchange) which represents the generic interface for the development of plug-in tools for specific import/export targets. The Data Interchange is application independent and supports import/export targets that range from simple ASCII files in a variety of specific formats, to more dynamic data interfaces with external environments, such as the MATLAB EDI tool described here. Although not currently under development, an application-programming interface for the end user to create EDI plug-ins could be supported with the S.P.A.R.C. MP framework.

A new external data interface tool has been developed for PBO Lab that supports dynamic data exchange with

the MATLAB environment. MATLAB is an interactive technical computing environment for numerical computation, visualization and simulation [4]. The PBO Lab EDI tool for MATLAB supports the exchange of beam line model parameters (Control Parameters) and Application output (Computational Diagnostics) with the MATLAB environment. The EDI tool also implements an integrated simulation loop with MATLAB that allows the user to modify PBO Lab model parameters, control the execution of Application Modules and access diagnostic data in the MATLAB environment. The simulation loop can be controlled from MATLAB using C or Fortran MEX files, or MATLAB M files [8,9].

The user directly controls the basic import/export tool for MATLAB, i.e. the user executes the import and export commands from PBO Lab to exchange selected Control Parameters and Computational Diagnostics with MATLAB. If MATLAB is not running then it will be launched and the data will be placed in the MATLAB workspace. MATLAB can then be used for a variety of tasks such as post-processing diagnostic data for custom graphics or additional analysis with MATLAB toolboxes and/or user defined operations. Model Control Parameters

are modifiable directly from MATLAB and are extracted from the MATLAB workspace at the users' request in PBO Lab.

The PBO Lab EDI Tool also implements an automated dynamic data interface with MATLAB, passing Model Control Parameters, Simulation Control Parameters and Computational Diagnostics in a simulation loop that is illustrated in Figure 2. The simulation loop automates the external control of PBO Lab Application Modules by using compiled MEX files or MATLAB interpreted M files to perform a user-defined function. Figure 2 illustrates the Simulation Loop execution and data flow.

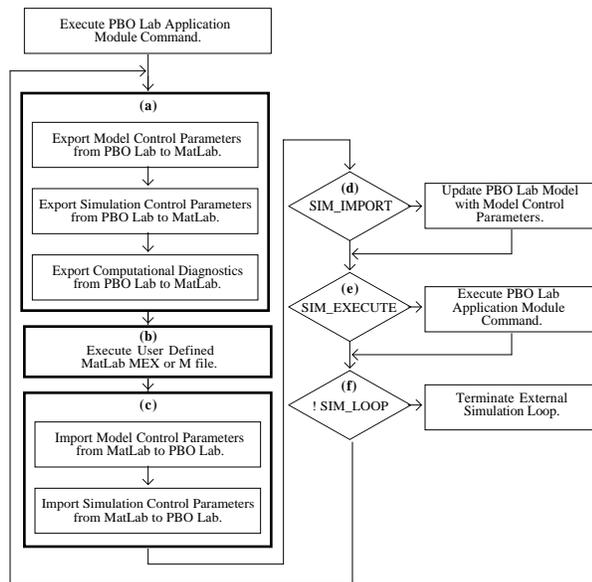


Figure 2. Simulation Loop Flow Chart.

Control Parameters passed to MATLAB (Figure 2(a)) are modifiable in the MEX or M files executed in the simulation loop (b). Simulation Control Parameters passed to MATLAB (a) and returned to PBO Lab (c) are used to control: (d) updating the PBO Lab beam line model with modified Control Parameters, (e) executing an Application command, and (f) terminating the simulation loop. After execution of MEX or M files (b), PBO Lab will import the Model Control and Simulation Control Parameters from MATLAB (c). Model Control Parameters are held in the Data Interchange while the Simulation Control Parameters are used by PBO Lab to execute (d), (e) and (f) of the Simulation Loop. The SIM\_IMPORT parameter indicates whether the PBO Lab beam line model will be updated with the imported Model Control Parameters. The SIM\_EXECUTE parameter is used to execute an Application command, and SIM\_LOOP is used to terminate the simulation loop. The loop is simple, yet provides the control that is necessary to perform a variety of automated tasks. The PBO Lab EDI tool for MATLAB enables access to a large collection of MATLAB and third party tools, including Power Systems, Communications, Control Systems, Signal Processing, Fuzzy Logic and Neural Network toolboxes.

## 4 SUMMARY

An external data interface tool has been developed for the Particle Beam Optics Laboratory that leverages the popular mathematical environment, MATLAB. The PBO Lab EDI tool for MATLAB supports the import and export of beam line model parameters, as well as diagnostic data generated from the different PBO Lab physics Application Modules, although Data Repository modules have not been completed for all PBO Lab Applications. The MATLAB EDI tool supports an integrated simulation loop that automates the exchange of data and execution of user defined operations with MATLAB MEX or M files.

## 5 ACKNOWLEDGEMENTS

The assistance of James S. Gillespie in the design of the S.P.A.R.C.-MP framework is gratefully acknowledged.

## 6 REFERENCES

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