

# THE PARTICLE BEAM OPTICS LABORATORY (PBO LAB™): A NEW EDUCATION AND TRAINING AID

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## *Abstract*

The Particle Beam Optics Laboratory (PBO Lab™) represents a new approach to providing software for particle beam optics modeling. The PBO Lab includes four key elements: (1) a graphic user interface shell, (2) a graphic beamline construction kit, (3) a set of physics and technology tutorials, and (4) various charged particle optics computation engines. The graphic user interface shell and beamline construction kit software utilize a new multi-platform (MP) version of the Shell for Particle Accelerator Related Codes (S.P.A.R.C.). S.P.A.R.C. MP provides the software framework for the PBO Lab, allowing it to run on all popular computer platforms including those running the UNIX/X-Windows, Windows95/NT and Macintosh operating and windowing systems. The PBO Lab tutorial system incorporates a knowledge database on particle optics and technology, and is implemented with a combination of S.P.A.R.C. MP graphic components and a hypertext system. Several computation engines are available. A first-order matrix code, including a space charge model, can be used to produce scaled images of beamlines, with overlays of individual trajectories and beam envelopes. The results of graphically moving beamline components, or adjusting bend and edge angles, can be explored interactively. Quantitative computation engines currently include the third-order TRANSPORT code and the ray tracing program TURTLE. The PBO Lab is described and illustrations from the Windows95/NT implementation are presented.

## 1 INTRODUCTION

Both accelerator operators and designers are placing increased emphasis upon the use of simulation programs to improve their productivity. Improved software tools are now becoming available which offer to the accelerator community the same types of benefits that have become standard in many other fields. This paper summarizes selected features for one of these new tools: The Particle Beam Optics Laboratory (PBO Lab).

An overview of the four primary components of the PBO Lab software has been presented previously [1]. Underlying the graphic user interface shell and the beamline construction kit [2] is a powerful beamline object model [3]. The model provides an efficient representation of both flat and hierarchical beamline descriptions, which makes the PBO Lab equally suitable for modeling both small accelerators [4] and large

machines that have many identical components and repetitive lattice structures [2].

An important objective of the PBO Lab is to assist new users in learning about accelerators and accelerator optics, as well as how simulation codes model beams and accelerator components. Several training and education features are built into the core PBO Lab application module. These features include a dynamic interactive tutorial system on charged particle optics and accelerator technology, a set of trajectories and envelope modules that allow users to graphically and interactively explore the impact of parameter changes, and an expert system type of rule relationship to assist users in inputting and editing parameters. This paper describes these features that make the PBO Lab a unique training and education aid.

## 2 PBO LAB TUTORIAL SYSTEM

An information and knowledge database, on charged particle optics and the technologies and hardware used in charged particle beamlines, is integrated into the PBO Lab. Parts of the knowledge database are incorporated into the expert system features of the Data Tables and Piece Windows [2] used to edit individual beamline parameters. However, the majority of the information is presented to the user through PBO Lab tutorial system. Interactive, self-directed tutorials include content on particle optics, beam physics, and accelerator technology. Much of the material developed for the PBO Lab tutorials was utilized as part of a U. S. Particle Accelerator School (USPAS) optics course aimed at graduate and upper division undergraduate students.

The presentation format consists of two components: (1) an interactive slide show and (2) a hypertext component. The hypertext component includes narratives, graphics, equations, glossaries and similar content with many hypertext links. The slide show component presents conceptual graphics and useful formulae with numerical results for individual optics components that are based upon the user's input parameters for that component.

### 2.1 Slide Show Component

Figure 1 illustrates several of the "slides" from the PBO Lab tutorial for a magnetic bend. This series of slides is activated by selecting the Tutorial button that appears in the Piece Window [1,2] for any PBO Lab bend element (e.g. Bend, Sector Bend or Rectangular Bend). The first

slide image displayed is composed of several photographs of magnets from different laboratories. It is intended to be visually interesting as well as informative. Subsequent slides are accessed using the NEXT button appearing in the lower left of the Slide Show tutorial window. These slides summarize key features of how the optics in a

bending magnet is described, and provide specific information that is derived from the user's parameters for the bend Piece from which the tutorial was launched. The content of a given slide changes dynamically as the user modifies relevant data in the component's Piece Window.

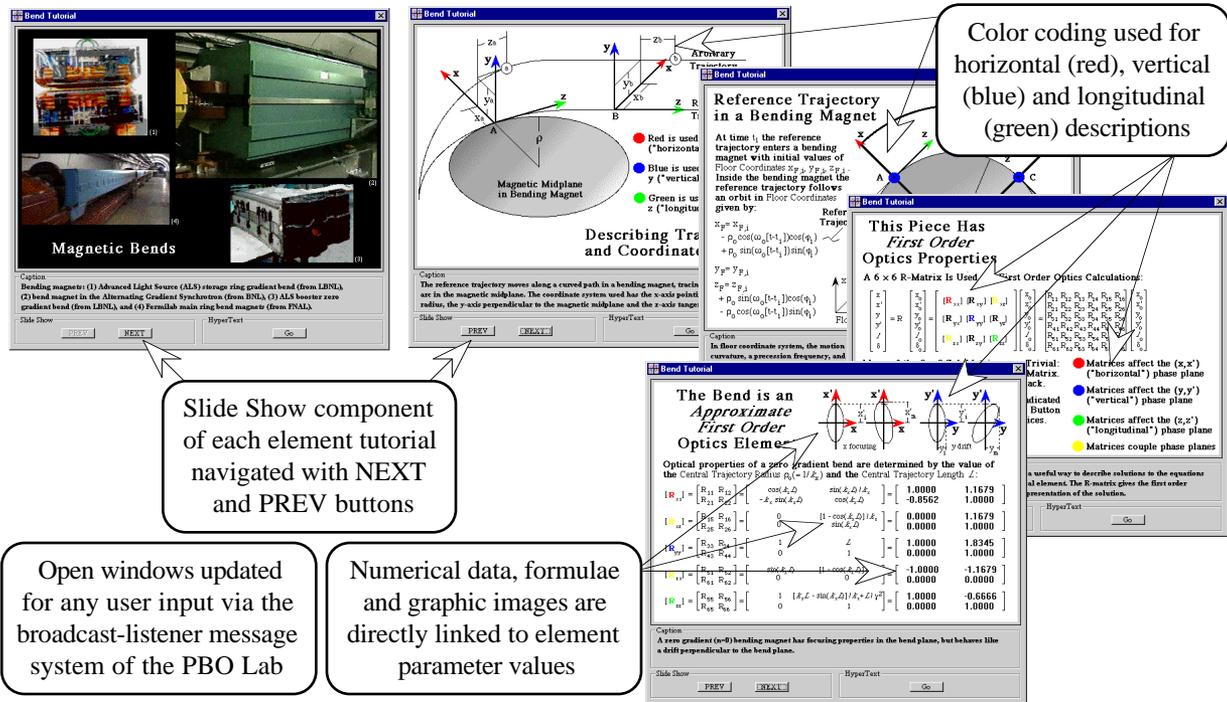


Figure 1. Windows from the Slide Show component of the PBO Lab tutorial system for a magnetic bend element.

The Slide Show component of the PBO Lab tutorial system is written in C++ and the objects form part of the class hierarchy of the overall S.P.A.R.C. MP framework. The full power of the S.P.A.R.C. MP architecture is available. The dynamic broadcast-listener message system for object communication allows displays to be updated interactively as the user modifies beamline parameters. New tutorial objects are instantiated whenever a Tutorial is launched from a Piece Window. Consequently, a new Slide Show sequence is displayed each time this component of the tutorial is activated, with data that is unique to the parameters of the corresponding beamline component. As many distinct Slide Show tutorials as desired may be launched and all can be displayed on the screen simultaneously.

Each beamline element in the PBO Lab has a Slide Show tutorial that provides the same basic features as those described for the bend elements. The general content for the series of slides provides basic information that is characteristic of that type of beamline element, but the specific images, including text, formulae, graphics and numerical data, are specific to that particular element.

## 2.2 Hypertext Component

The Hypertext component of the PBO Lab tutorial system provides more detailed information on the theory of charged particle optics and on the technology of magnets and other particle optics devices. This component of the PBO Lab tutorial follows a book-like format. The material is divided into chapters, and each chapter has a detailed outline of its content. Figure 2 illustrates a couple of the "pages" from the PBO Lab tutorial for a magnetic bend.

There are number of navigation aids to assist users in negotiating the tutorial material. The Hypertext component can be launched either from a Tutorial selection on the Menu Bar of a PBO Lab Document Window [1,4] or from the GO button of a Slide Show window (see Fig. 1). The first option starts the Hypertext tutorial at the first chapter, while the second option links to the chapter associated with the corresponding optical component. Other tools include (1) a page history of the current session, allowing users to retrace their trek through the material, (2) keyword and topic searches, (3) browse buttons for paging through selected material, and (4) user definable bookmarks.

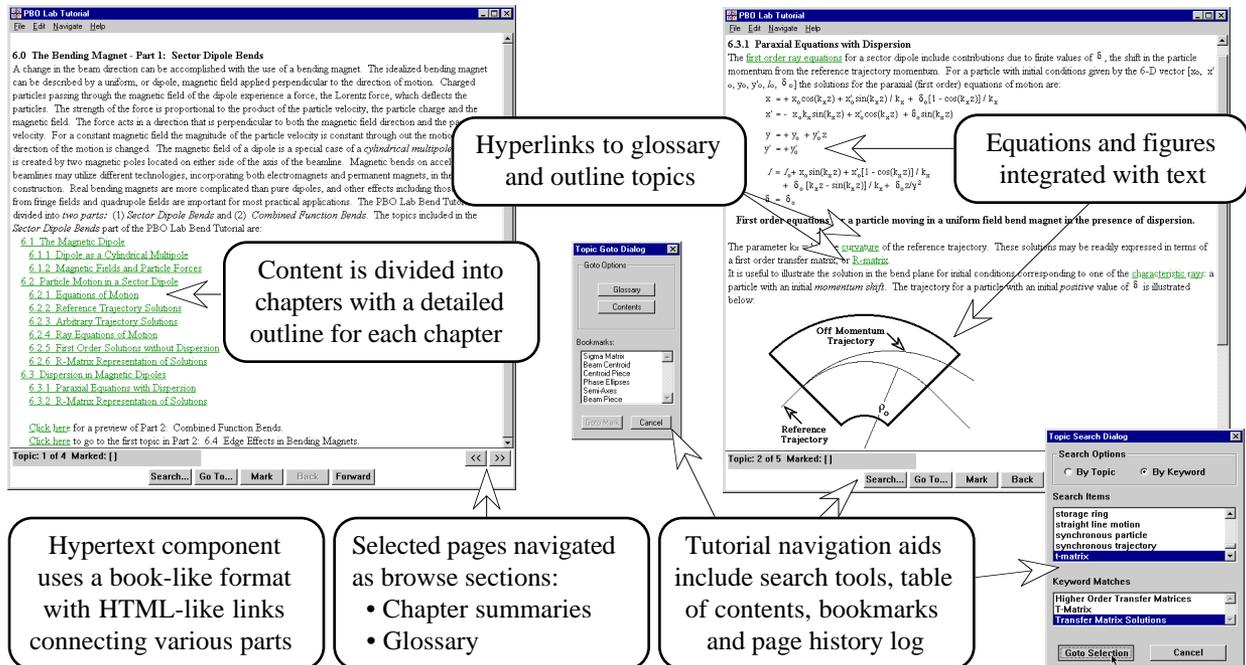


Figure 2. Windows from the Hypertext component of the PBO Lab tutorial system

### 2.3 Tutorial Expandability

An important feature of the design of the PBO Lab tutorial system is the ease with which it can be modified and expanded. Training and education needs are frequently changing and evolving. The requirements for one group of accelerator professionals (e.g. operators) may be different from that of another group (e.g. graduate students). The ability to easily update, modify and add to the content is one of the keys to the success of the PBO Lab tutorial system.

Individual slides in the Slide Show component can be modified and replaced simply by exchanging a bit mapped picture (BMP) file. New slides, with additional dynamic links to the PBO Lab beamline object model, are readily incorporated without affecting other parts of the software, due to the object oriented design of the S.P.A.R.C. MP framework itself.

## 3 SUMMARY

The PBO Lab is an innovative software package that was designed from the ground up to provide an engaging and flexible environment for learning about accelerator science. The extensive tutorial and help system integrated with the PBO Lab makes it ideally suited as a training and education aid for a variety of the communities involved in the operation, design, and study of particle accelerators. When coupled with particle optics and simulation codes such as TRANSPORT and TURTLE [1,4], the PBO Lab also becomes a powerful design tool, making the design codes readily accessible to both new and experienced users.

## ACKNOWLEDGMENTS

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