USING TRACE 3-D IN THE PARTICLE BEAM OPTICS LABORATORY (PBO LAB™)

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Abstract

A TRACE 3-D module has been developed for the Particle Beam Optics Laboratory (PBO Lab™). TRACE 3-D is a FORTRAN program that calculates envelopes, centroids, and phase space ellipses of a bunched beam, including linear space charge forces. TRACE 3-D can now be executed from PBO Lab on a PC running Windows or Windows NT, along with other computational programs, including TRANSPORT, TURTLE, DECAY-TURTLE and MARYLIE. The PBO Lab environment provides a single graphic user interface for multiple optics codes. Beamline models are constructed graphically using a palette bar of accelerator element icons. Models can be organized using any hierarchy of sublines and alias components, which are easily created with drag and drop editing of the graphical beamline representation. Several electrostatic and traveling wave elements have also been developed for use with the TRACE 3-D module in PBO Lab.

1 INTRODUCTION

The TRACE 3-D [1] program has been integrated with the graphical environment of the Particle Beam Optics Laboratory (PBO Lab™). The PBO Lab environment provides an intuitive and consistent graphic user interface for a variety of optics codes in addition to TRACE 3-D, including TRANSPORT [2], TURTLE [3], DECAY TURTLE [3], and MARYLIE [4]. The PBO Lab environment [5] supports the interactive graphical setup of beamline models and execution of multiple optics codes using a single beamline model representation. Beamline models are constructed graphically using a palette bar of accelerator element icons. Models can be organized hierarchically using sublines and aliases, which are easily created with drag and drop editing of the graphical beamline representation. An example is presented here to illustrate using the TRACE 3-D module in PBO Lab.

2 MATCHING EXAMPLE A

Example A, from the TRACE 3-D Documentation, Second Edition [6], involves matching a beam from the exit of an RFQ into the entrance of a drift-tube linac (DTL). First the matched-beam at the exit of the RFQ is determined. Then the input beam for the DTL is determined. The final step fits selected parameters in the matching section between the RFQ and DTL sections.

The graphic beamline representation in the PBO Lab Document Window is shown in Figure 1. The beamline model consists of the final two cells of a 400-MHz RFQ and the first two cells of a 400-MHz DTL, separated by a 100-mm drift space. The drift space will be replaced with a matching section composed of drifts, quadrupoles, and an RF Gap. In Figure 1, the matching section is temporarily stored on the Work Space of the Document Window. The RFQ cells are grouped together in a Subline and the first two cells of the DTL are grouped into a separate Subline. The individual elements in these two Subline are also show in Figure 1.

2.1 Matched Beam for RFQ Exit

The first step is to determine the matched beam parameters at the exit of the RFQ. TRACE 3-D is used to find a matched beam in x, y and z phase planes. The locations of the PBO Lab Beam and Final Pieces [7] are used to define the beginning and end of dynamic calculations for TRACE 3-D. The PBO Lab Match Specification Window [7] is used to quickly select among the different beam matching and parameter fitting capabilities of TRACE 3-D. Selection of the Perform Matching option from the Commands menu results in a Beam Piece with the desired matched beam. This Beam Piece containing the matched beam for the RFQ section is saved on the Work Space

2.2 Matched Beam for DTL Entrance

The second step is to find the Beam Parameters that are matched to the input of the DTL. The first two cells of the DTL are represented in the PBO Lab model with a subline that includes a series of PMQs, Drifts and RF Gap Elements (Figure 1). The Beam and Final Pieces are moved graphically (drag and drop) in the beamline model to define the DTL section for matching. This is illustrated in Figure 2. The Match Specification Window is then used to set the match type for a matched beam in the x, y, and z planes with upright ellipses. The Perform Matching Command results in a Beam Piece with the matched beam. The Final Piece is opened and the Copy from Initial button [7] button is used to store these beam parameters on a Final Piece. This Final Piece is then also saved on the Work Space.

2.3 Parameter Fitting in the Matching Section

The final step is to set up the matching section between the RFQ and DTL. The matching section is grouped in a

Subline Piece that has been stored on the Work Space of the Document Window (Figure 1). The Drift Piece, following the RFQ Subline in the beamline, is replaced with the matching section Subline.
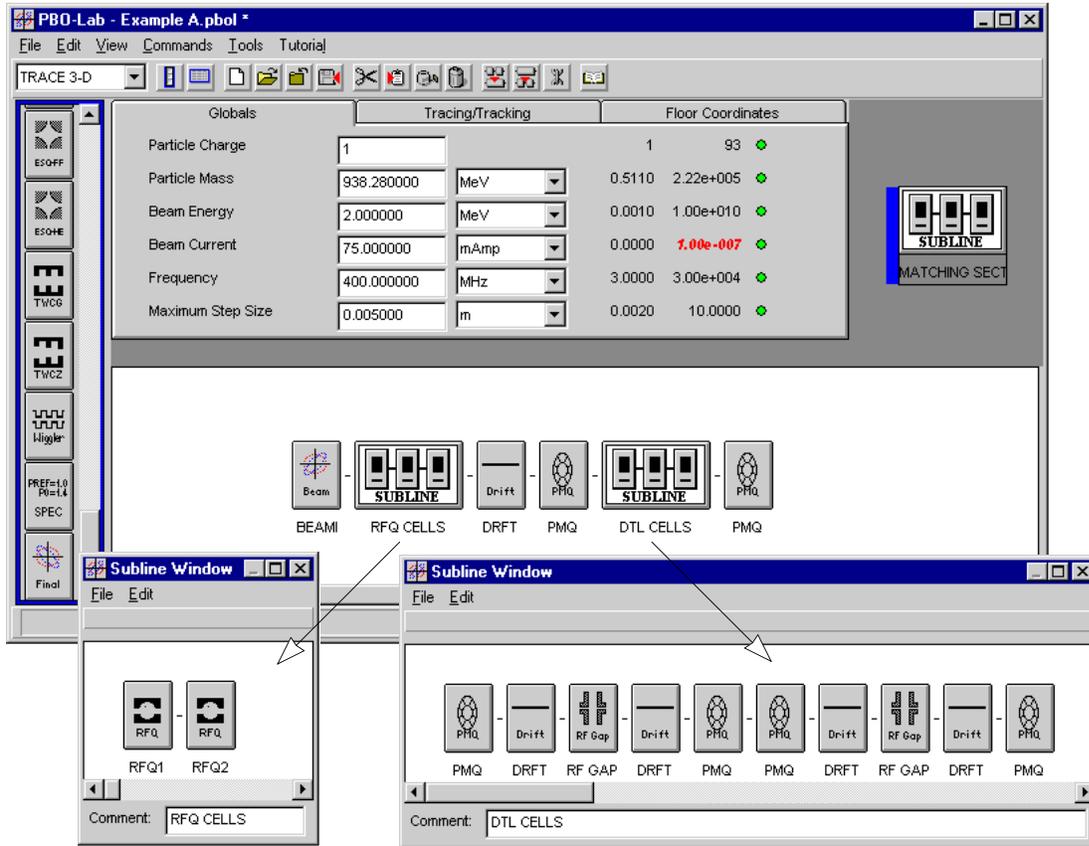

Figure 1. PBO Lab Document Window and the RFQ and DTL Subline Windows for TRACE 3-D Example A.
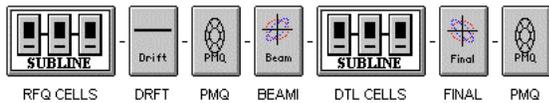

Figure 2. Locations of the Beam and Final Piece icons are use to define the beginning and end of dynamic calculations for TRACE 3-D.

The Beam Piece containing the matched beam for the RFQ section, which was saved on the Work Space in the first step, is added to the beginning model by dragging it from the Work Space and dropping it at the beginning of the beamline. The Final Piece saved on the Work Space in the second step is then inserted between the PMQ following the matching section Subline and the DTL Subline. The PBO Lab beamline configuration is shown in Figure 3.
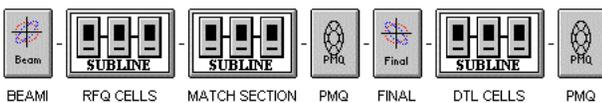

Figure 3. PBO Lab beamline layout for fitting the matching section quadrupole and RF gap parameters.

The match type is set to Vary Selected Element Parameters to Fit a Desired Final (Output) Beam in the PBO Lab TRACE 3-D Match Specification Window [7]. The initial beam is the matched beam for the RFQ found in step 1 and the desired final beam at the exit of the matching section is the DTL matched beam from step 2.

Four parameters (one drift length, two PMQ strengths, and the RF gap voltage) in the matching section Subline are selected as Match Variables in the individual Piece Windows [7]. The parameters are listed in the Match Variables List Window, illustrated in Figure 4.

Figure 4. PBO Lab Match Variables List Window.

The Perform Matching Command is used to find the fitted values for the four match parameters. The Graph Beam Line command can be executed from the TRACE 3-D Command Menu in order to display the beam passing through the matching section. The resulting Graph Output Window is shown in Figure 5.
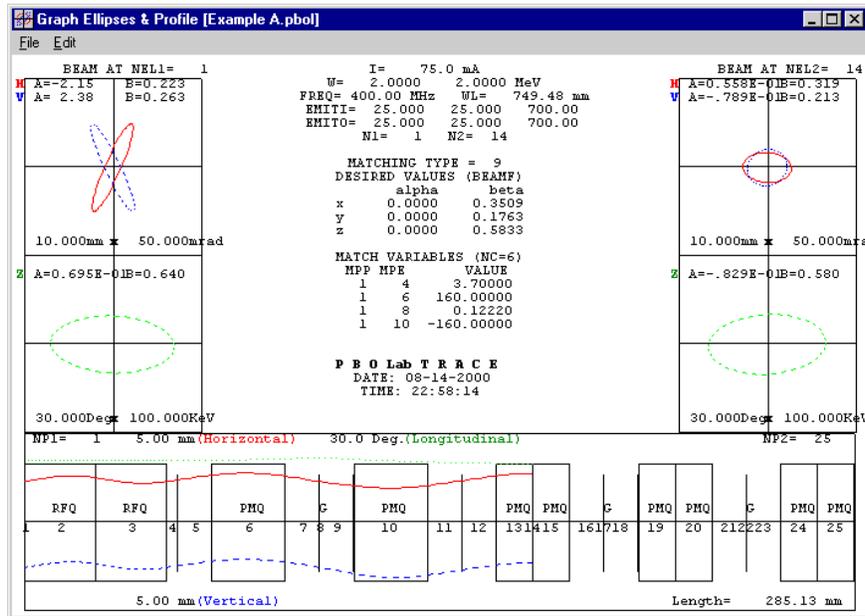
Figure 5: Matched beam transported from the RFQ to the DTL, shown in the PBO Lab TRACE 3-D Graph Window.

3 ELECTROSTATIC ELEMENTS

Several ElectroStatic (ES) elements have been implemented for use with the PBO Lab TRACE 3-D Module. The new models include a number of options for: (1) einzel lenses,
(2) accelerator columns and gaps,
(3) electrostatic prisms, and
(4) electrostatic quadrupoles.

The ES elements are fully integrated with all the standard TRACE 3-D Magnet and RF elements. The ES elements support 4-D continuous or 3-D bunched beam calculations, calculation of equivalent continuous beam current, as well as matching and fitting capabilities.

4 TRAVELING WAVE ELEMENTS

In addition to the ElectroStatic elements, there are also two Traveling Wave (TW) Cavities that are supported by the TRACE 3-D module in PBO Lab. The TWCG element is a Constant Gradient Traveling Wave model and TWCZ is a Constant Impedance model. Self consistent beam loading is included in fields. The Traveling Wave elements are fully integrated with the standard elements of TRACE 3-D and also support matching and fitting.

SUMMARY

A new TRACE 3-D module has been developed for the PBO Lab family of software applications [8]. The full functionality of TRACE 3-D is available through a common graphic interface that supports several optics codes, where users need have no knowledge of the I/O format of the individual codes. Two add-on palettes of additional elements for modeling electrostatic systems and beam-loaded traveling wave accelerators are also available for use with the new TRACE 3-D module for PBO Lab.

REFERENCES

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[4] A. J. Dragt, et al, "MARYLIE 3.0 User's Manual, A Program for Charged Particle Beam Transport Based on Lie Algebraic Methods (draft)," 721 pp (1999).

[5] AccelSoft, Inc., "Particle Beam Optics Laboratory User Manual 2.0", 99 pp (2000).

[6] K. Crandall and D. Rusthoi, "TRACE 3-D Documentation," Second Edition, LA-UR-90-4146, 92 pp (1990).

[7] AccelSoft, Inc., "TRACE 3-D Supplement to the Particle Beam Optics Laboratory User Manual", draft, 51 (2000).

[8] The PBO Lab software is available from AccelSoft Inc., www.ghga.com/accelsoft.