Bz CALCULATION OF TPS LINAC FOCUSING COILS AND A TOOLKIT FOR Bz OPTIMIZATION

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Abstract

A set of focusing coils is installed along TPS (Taiwan Photon Source) linac beam centerline at low energy region (< 10 MeV) in order to confine the beam radius within 5 mm. The longitudinal magnetic field calculation along the beam centerline has been carried out in this study. The estimated Bz is obtained based on Biot-Savart law calculation. Then, it is verified by field measurement using Gauss meter at specific centerline locations. Calibration process is performed by comparing the calculated and measured Bz fields at selected operation settings. The comparison result is presented in this report. The linac operation experience indicates that tuning of the coil settings is critical concerning beam property optimization. Consequently, a Bz calculation toolkit is developed to cope with the multi-knobs optimization process while tuning of numerous focusing coils installed in the system at various locations. The applications of the Bz calculation toolkit is briefly described.

INTRODUCTION

Electrons emitted from the electron gun, guided by the designed magnetic field Bz along beam centerline, are arranged to go through various rf-processing steps in the low energy region (LER, < 3 MeV) before entering the first acceleration section. A set of 30 coils, which can be individually current driven, provides the required Bz in LER. There are three sequential acceleration sections in TPS linac. Each section provides capability of powering 50 MeV kinetic energy to the electron beam. The linac operation experience indicates that tuning on the coil settings is critical concerning beam property optimization. Therefore, we choose to focus on the investigation of some of the critical operation parameters which dominate the behavior of the electron beam in LER. In order to do so, a Bz platform in LER has been established in this study. This Bz platform will be used for further investigation of beam property optimization.

First, the parameters of the focusing coils and its locations at the beam centerline are identified for practical needs. Then, the Bz produced by the individual coil along centerline is calculated using Biot-Savart law. The final Bz is the linear sum up of all the above calculated Bz. A check up procedure is designed to examine whether the calculated Bz agrees with the measurement result. In this particular case, setting of 50 A is applied to all focusing coils in the linac LER and a Gauss meter [1] is used to carry out the Bz measurement at some selected centerline locations. The comparison result is presented in this report.

The Bz calculation is also applied on the case of linac routine operation and its comparison with the measurement result is given as well. Since the Bz calculation is a trial and proceed process if any of the coil current is adjusted in practical need, therefore it is worth of developing an interactive toolkit for further application purpose, especially for beam property optimization purpose. This Bz calculation toolkit is briefly described in this report.

Bz CALCULATION

The Linac Beam Centerline at Low Energy Region (< 10 MeV)

The electron beam acceleration process of the TPS linac is similar to the designed protocol of previous products of the manufacturer with improvements implemented at various progressing phases [2]. They are:

- Electrons emitted from the cathode is accelerated by the static electric field to 90 keV.
- The 90 keV electrons pass through prebuncher and final buncher gaining energy up to 300 keV and 3 MeV, respectively.
- The 3 MeV electrons pass through three similar acceleration tubes each with exit beam energy at 50 MeV, 100 MeV, and 150 MeV, respectively.

The layout of the linac beam centerline at low energy region, together with the hardware photo, is depicted in figure 1 for illustration purpose.

The Focusing Coils Solenoid

The major purpose of installing the focusing coils solenoids, as shown in figure 1, is to keep the accelerated beam envelope within 5 mm [3]. For high energy electron beam (≧ 50 MeV), focusing quadrupole is more efficient. Yet it breaks the radial symmetry. In this study, only the solenoids Bz at low energy region (< 10 MeV) is considered. The physical arrangement of the focusing coils constitutes a solenoid with Bz relatively insensitive to the radial position variation along beam centerline.

Bz Calculation Based on the Solenoids Coils Arrangement

The Bz at any specific location of centerline is a sum up field strength of all powered coils. Consequently, it is practically applicable to calculate the Bz, at the location of interest, by adding the contribution of all coils based on the Biot-Savart law. One of the benefits of using set of coils in the case of TPS linac is that each coils can be independently powered which provides system tuning capability for beam property manipulation in the subsequence study phases. With this approach for numerical

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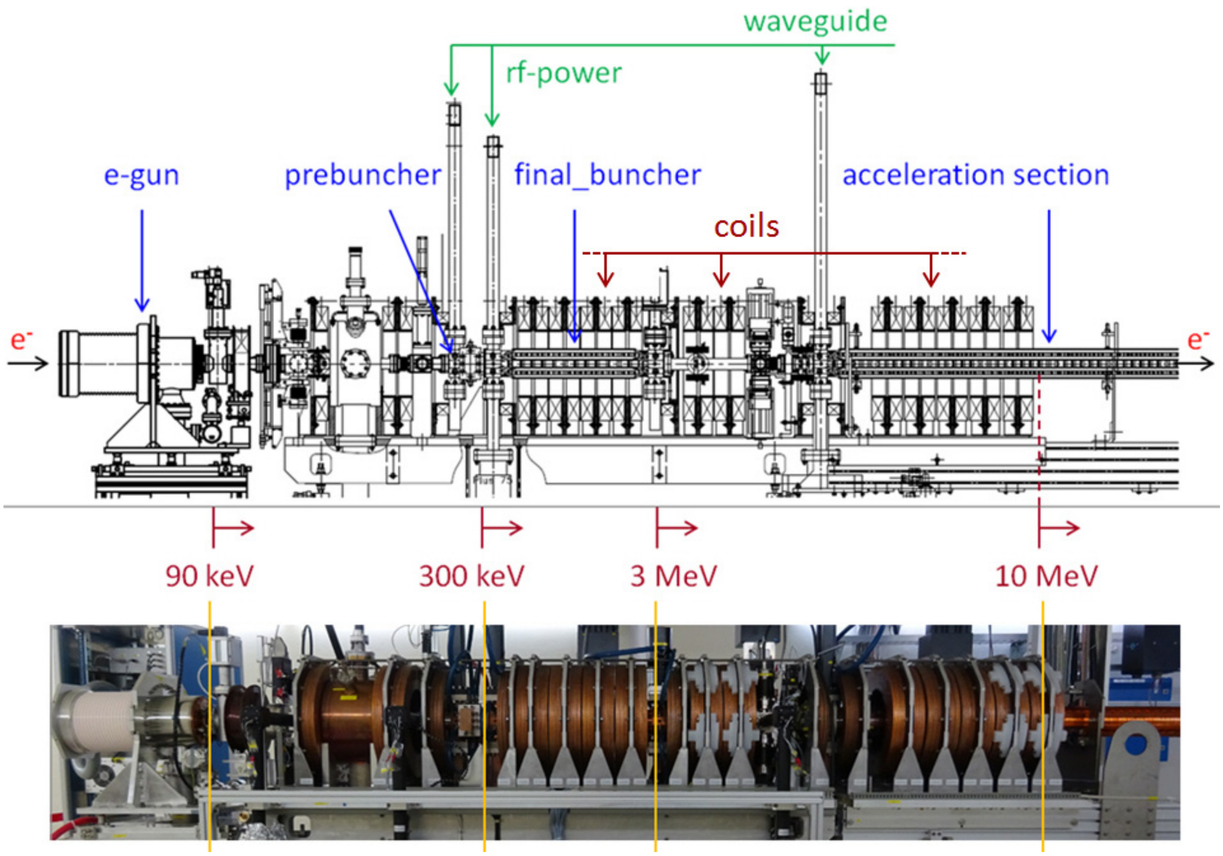

Figure 1: Layout of linac low energy region (< 10 MeV).

estimation of the Bz along beam centerline, a linear combination of all powered coils has to be calculated. In case of an adjustment need, the calculation is redone according to the tuning knobs used in the consideration. It is a tedious process if trial-and-proceed is exercised for beam property study. Consequently, developing an interactive toolkit would be practically advantageous for this study needs.

Bz MEASUREMENT

The Bz measurement along beam centerline at low energy region is described in following sections.

Calibration Checkpoint

The measurement of Bz along beam centerline has been performed by using Gauss meter at selected locations. Since the coils are tightly arranged together with the acceleration tube, as shown in figure 1, only limited space is available where the B-field probing next to centerline is accessible. The set of measurement points, as shown in figure 2, is taken for the use of cross-checking purpose. Also shown in figure 2 is the calculated Bz while setting the same driving current to all focusing coils (50 A is adopted in this particular practice). The measured and calculated Bz values agree well with each other [4].

Nominal Set Values for Routine Operation

The comparison of the calculated and measured Bz along beam centerline under typical routine operation is shown in figure 3. The results agree well with each other. It implies that the centerline Bz can be properly described by the calculation adopted in this study.

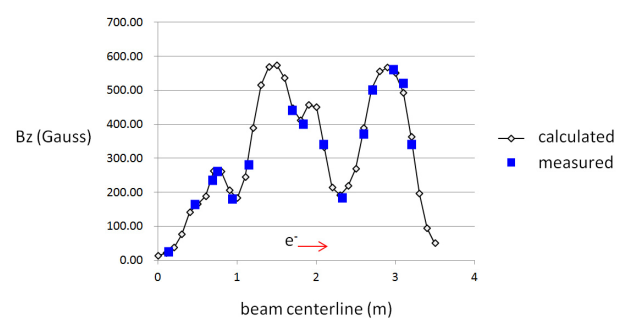

Figure 2: Comparison of the calculated and measured Bz along beam centerline.

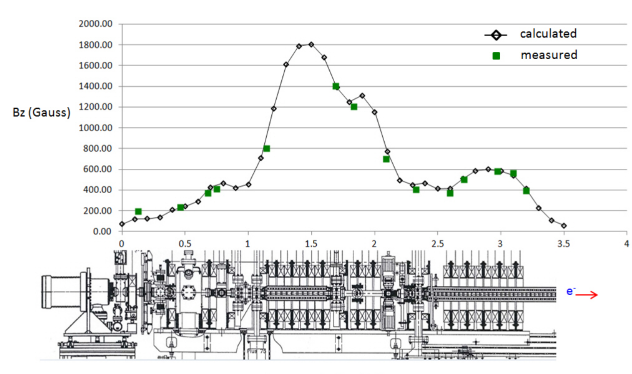

Figure 3: Comparison of the calculated and measured Bz along beam centerline.

TOOLKIT DEVELOPMENT

A toolkit is developed to cope with this trial-and-proceed process in calculating the Bz along beam centerline [4]. Since the Bz at every locations of interest are recalculated whenever the driving current in any of the coils is varied. Developing an interactive toolkit to deal with the tedious recalculation steps will benefit the efficient beam property optimization processing. Moreover, this toolkit provides tuning knobs of each coil current setting that the Bz is allowed to be interactively modified and plotting on-screen while adjusting the knobs. The selected beam parameters of Bz associating with are designed to be interactively modified as well. It will be described in the forthcoming study reports.

Input File for Using Toolkit – Linac_Bz

A typical example of the text input file for the beam centerline Bz calculation specifying the focusing coil locations and relevant parameters is listed in table 1 for illustration purpose. Loading the text input file to the toolkit: linac_Bz, the corresponding calculated Bz along centerline will be displayed accordingly, as shown in figure 4.

Table 1: Typical Example of a Text Input File for Bz Calculation Using the Toolkit: Linac_Bz.

EndX 4.0 ← centerline range	
Step 0.1 ← calculation step	
Total 30 ← number of coil	
Graph 1 Center 0.442 Rad 3.30	Graph 16 Center 1.95 Rad 3.30
Graph 2 Center 0.703 Rad 3.30	Graph 17 Center 2.003 Rad 3.30
Graph 3 Center 0.772 Rad 3.30	Graph 18 Center 2.073 Rad 3.30
Graph 4 Center 0.916 Rad 1.50	Graph 19 Center 2.347 Rad 1.50
Graph 5 Center 1.163 Rad 1.50	Graph 20 Center 2.446 Rad 1.50
Graph 6 Center 1.234 Rad 3.30	Graph 21 Center 2.619 Rad 3.30
Graph 7 Center 1.304 Rad 3.30	Graph 22 Center 2.689 Rad 3.30
Graph 8 Center 1.357 Rad 3.30	Graph 23 Center 2.747 Rad 3.30
Graph 9 Center 1.427 Rad 3.30	Graph 24 Center 2.817 Rad 3.30
Graph 10 Center 1.48 Rad 3.30	Graph 25 Center 2.875 Rad 3.30
Graph 11 Center 1.55 Rad 3.30	Graph 26 Center 2.945 Rad 3.30
Graph 12 Center 1.603 Rad 3.30	Graph 27 Center 3.003 Rad 3.30
Graph 13 Center 1.673 Rad 3.30	Graph 28 Center 3.073 Rad 3.30
Graph 14 Center 1.795 Rad 1.50	Graph 29 Center 3.131 Rad 3.30
Graph 15 Center 1.88 Rad 3.30	Graph 30 Center 3.201 Rad 3.30
↑ coil number ↑ coil location ↑ coil parameter	

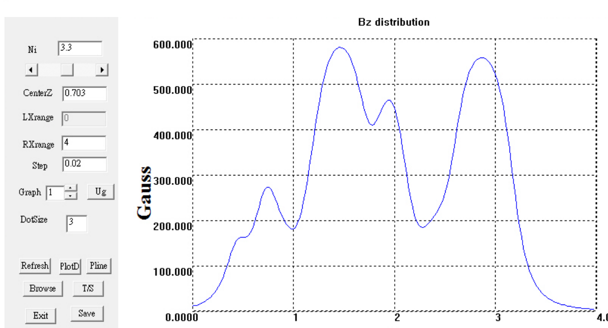

Figure 4: Typical example of the calculated Bz using the toolkit: linac_Bz.

Input Column of Interactive Tuning Knobs

As shown in figure 4, the related parameters for Bz calculation involving in this toolkit are listed on the left column in a sequential manner. Detailed information concerning these parameters tuning and the limitations set in the toolkit are described elsewhere. The Bz distribution given in figure 4 is a reproduction of the same coil current setting utilized in figure 2. The same Bz distribution shown in both figure 2 and figure 4 confirm a numerical cross checking of the calculation given in the toolkit: linac_Bz. A demonstrating example is given in figure 5. A couple of the coil current settings are adjusted in left column using parameter {Ni} and the Bz distribution is replotting on the right interactively. It is obvious that the toolkit provides superior flexibility in dealing with various knobs tuning practice. Ni can be adjusted by settings knob within 10% range.

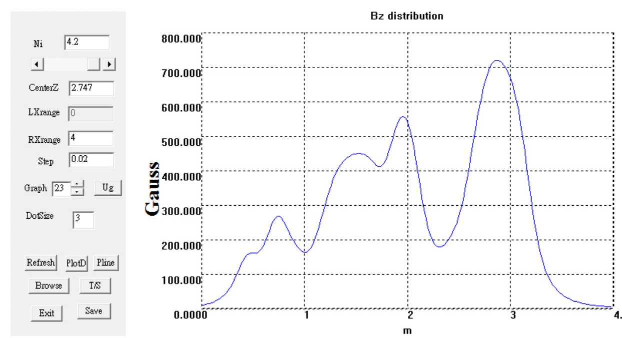

Figure 5: The Bz distribution is interactively repotting on the right while adjusting some of the coil current settings knobs on the left column.

SUMMARY

Calculation of the beam centerline Bz distribution established by the focusing coil in the low energy region of the TPS linac has been carried out in this study. The calculation is based on the Biot-Savart law and the results agree well with the measurement. Since the operation experience indicates that tuning of the coil settings is critical concerning beam property optimization, a Bz calculation toolkit is developed to provide a visual interactive capability while tuning the drive current in the focusing coils. This toolkit will be utilized as a platform to study beam property optimization for linac operation.

REFERENCES

[1] Gauss meter measurement: F.W. BELL, 5180 Hall Effect Gauss / Tesla meters. (resolution: 0.1 G @ 300 Gauss; 1 G @ 3 kGauss)

[2] Research Instrument GmbH has manufactured five Linacs for synchrotron light sources: SLS (2000), Diamond (2004), ASP (2006), NSRRC (2011), NSLS-II (2013).

[3] K. Dunkel, "150 MeV electron linear accelerator for the TPS project at NSRRC", ACCEL design report: 2008-BP-8067-0, February 16, 2009.

[4] Y. K. Lin, "User manual for Toolkit: Linac_Bz", in preparation.