

HIGH LEVEL CONTROL COMMAND FOR THOMX TRANSFER LINE*

C. Bruni[†], I. Chaikovska, S. Chance[‡], N. Delerue, A. Gamelin, H. Guler, H. Monard, C. Vallerand
LAL, Univ. Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France
A. Loulergue, Synchrotron SOLEIL, Gif-sur-Yvette, France

Abstract

ThomX Compact X ray source is a 50 MeV storage ring, and a linear accelerator based on a photo-injector. As the electron beam in the ring will not be damped by synchrotron radiation, the transfer line should rely on a precise injection in the ring. In order to fulfill this requirement, especially in terms of optics function and orbit correction, different tools have been prepared and tested on the accelerator toolbox of Matlab Middle Layer. We will present the different tools and the underlying physics for the ThomX transfer line.

THE TRANSFER LINE (TL)

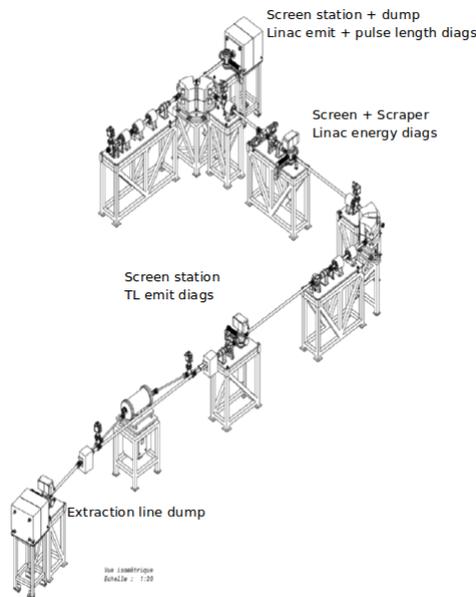


Figure 1: Drawing of the transfer line and extraction line.

The ThomX machine is a Compton scattering based x-ray source. It will produce x-rays with a flux up to 10^{13} photons / seconds. The ThomX machine has four parts : the LINAC based on a photo-injector followed by a TL injecting into the ring and the extraction line. As the damping is negligible during the storage time in the ring, the electron beam will keep the characteristics given by the linac and the TL. In addition, to transport the beam from the linac to the ring and to match both devices, the TL has been designed in order to minimize the beta function error at injection or orbit error

which can induce emittance growth. Also efforts have been made to minimize the impact of the collective effects as coherent synchrotron radiation on the emittance growth.

The magnetic elements in the TL are the same as in the ring. The ThomX Transfer Line is made of 7 quadrupoles, 4 dipoles, a short dipole for the injection into the ring, 4 horizontal and 4 vertical BPMs and 5 correctors horizontal and vertical. The schematic layout of the TL is shown in Fig. 1.

From the linac, the electron beam is kept symmetric as only solenoids are used from the transport. As a consequence the optics functions are the same in horizontal x and vertical y planes. The optics at the linac output are : $\beta_x = \beta_y = 34m$, $\alpha_x = \alpha_y = -4.34$, and the dispersion function is zero $\eta = 0m$. The optics parameters along the TL are shown in Fig. 3. A short dipole is inserted at 11.2m in order to give a small angle for the injection into the ring.

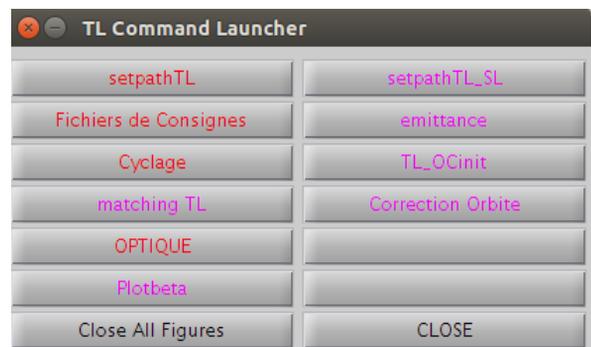


Figure 2: TL setup interface.

In addition to beam transport, the TL has several diagnostics to quantify the properties of the electron beam coming from linac and to ensure a good adaptation. In the straight line, there is a screen station and a dump with a faraday cup. The screen allows the transverse dimension measurements. A triplet of quadrupoles has been placed just after the linac in order to measure the emittance thanks to the three gradient method (Linac emit in Fig. 1). This method is robust at this energy and allows the reconstruction of the twiss parameter at the linac exit. This reconstruction will serve as a starting point to match the optics from the linac to the ring with the quadrupoles of the TL. A second screen station (TL emit diags in Fig. 1) could be used to cross check the matching with a second reconstruction of the twiss parameters. Concerning the orbit, 4 horizontal and vertical BPM have been put along the line. 5 horizontal and vertical correctors are used for the orbit correction. Energy, energy spread and dispersion function can be measured thanks to an other screen station placed after the first dipoles (see Linac energy diags

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[†] bruni@lal.in2p3.fr

[‡] chance@lal.in2p3.fr

in Fig. 1). A scraper is also placed at this location for the measurements or for the beam tail cleaning.

For the real machine operation, the ThomX machine hardware will be directly controlled by TANGO [1]. As a consequence, the high level applications will be written with MatLab scripts connected to TANGO with MatLab Middle Layer (MML) [2]. A description of the commissioning ring is given in [3]. Main applications are available in a general Panel called TLSetup (see Fig. 2). In this article, we will present some applications already written and tested with the Accelerator Toolbox (AT) [4] directly linked to MML.

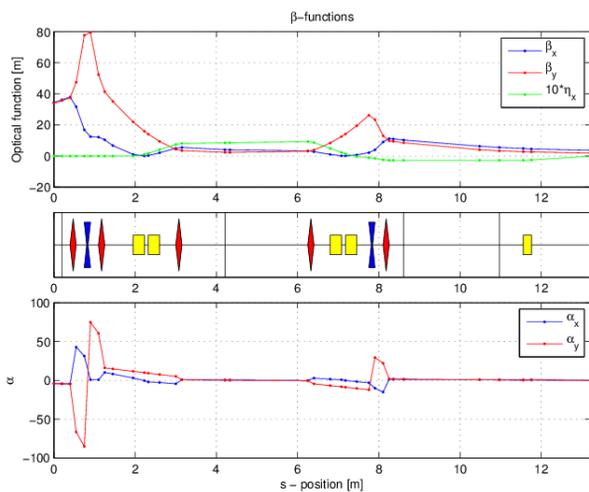


Figure 3: TL optics functions.

Efforts have been made in order to adapt MML scripts to the transport mode. The panel have been written to be versatile with the variety of structures needed for the different diagnostics of the TL. Details are given here for the orbit correction, the matching to the ring and the emittance measurement.

ORBIT CORRECTION

A minimal application to correct the orbit in the TL has been implemented in order to be used for the commissioning. The three steps for the orbit correction are well known:

- A small error (about 1.5 mrad) is put on the third horizontal and vertical corrector.
- The ΔA is calculated by the BPMs response matrix and the SVD method.
- The correction value found is put in the correctors.

The panel for the orbit correction is shown in Fig. 6 The correction has been made on the model via the Accelerator Toolbox tool and works correctly.

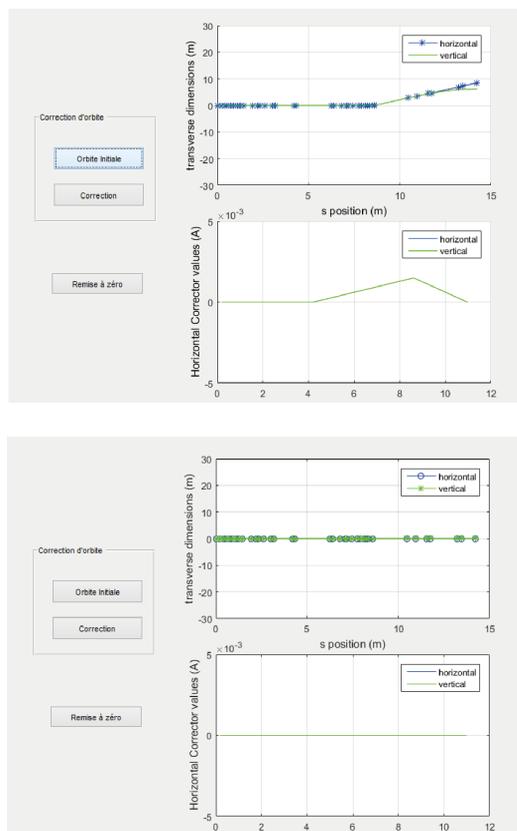


Figure 4: Orbit correction panel

TWISS AND EMITTANCE MEASUREMENT

A dedicated panel for the twiss parameter reconstruction thanks to the three gradient method has been realized (see fig 6). This panel works for the two stations. For each quadrupole step we have to measure a transverse dimension σ_x which is linked to the initial twiss parameters via the following equation :

$$\sigma_x^2 = T_{11}^2 \sigma_{11_0} + 2T_{12}T_{21} \sigma_{12_0} + T_{22}^2 \sigma_{22_0} \quad (1)$$

σ_{ij_0} being the matrix terms of the beam envelop at the end of the linac, T_{ij} the transport matrix terms. For each quadrupole strength step, several images will be acquired. A program, which analyses the images to give the transverse sizes is already included. It is based on the experience developed at the PHIL test line [5]. This part will be tested as soon as Tango will be available.

The panel runs also on AT. The transport matrix terms are then calculated with the twissline MML function. Transverse dimensions are deduced in AT according to the input emittance value and the beam matrix terms at the screen station. The quadrupole scan beam dimension results are plotted in the bottom right of the panel. Then, several method are available to retrieve the matrix terms of the beam envelop : the ordinary or the weighted least squares. Emittance is simply given by : $\sqrt{\sigma_{11_0} \sigma_{22_0} - \sigma_{12_0}^2}$ and the twiss parameter can then be deduced. Statistical errors on the data of

beam dimensions would be used to evaluate the error made on the emittance and Twiss measurements with variance or Monte Carlo error propagation.

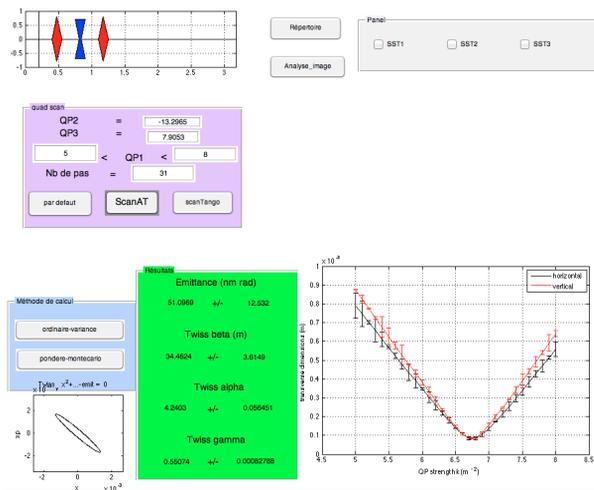


Figure 5: Emittance interface

OPTICS MATCHING

The electron beam properties from the linac are sensitive to various parameters. Since, the nominal charge of ThomX being large (1nC), the properties will be dominated by space charge effect. As we also deal with a photo-injector with a gradient of 80 MV/m, the Schottky effect will also induce charge variation coupled with a Magnesium photocathode. Also solenoids will be adjusted for emittance compensation according to the charge and beam size at the cathode. As a consequence, during the commissioning phase, the twiss parameters of the beam at the linac exit will change and evolve with respect to the nominal beam foreseen. In operation, we need a rapid tool to match the optics from the linac to the ring thanks to the seven quadrupoles available.

Then, a dedicated panel has been developed and tested with AT. The Twiss parameters at the linac exit obtained with the emittance measurement or in the astra simulations are defined in the lattice file of the TL. The input constraints are the optical function values needed at the TL exit noted as $TWISS_TL_CONSTRAINTS$ as seen in the blue box of Fig. 6. By default, the 7 quadrupole strength variables are taken into account. The transport is calculated via the twissline function, which can give the twiss parameters at the TL exit noted $TWISS_TL$. The minimization is done on the difference : $TWISS_TL^2 - TWISS_TL_CONSTRAINTS^2$. Iterations are done until the tolerance value is reached. We use the optimset function to create an optimization structure. The algorithm is based

on a non linear least square. The best result is obtained for a Levenberg-Marquardt algorithm, which allows to find a solution even if the starting point is far from the solution.

It is possible to select the desired constraints and to change its value. The minimization can be also done with a weight. It is foreseen to be able to apply the quadrupole field values given by the minimization algorithm on AT or on Tango machine directly. It is also possible to go back to the previous step if the matching is not convenient with the beam.

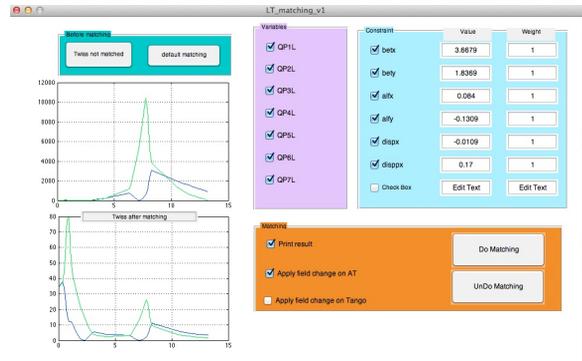


Figure 6: Matching interface

CONCLUSION

Applications dedicated to the TL have been written. They have been tested with the accelerator toolbox and validated with some change in the MML functions. Further tests will be done when the Tango base will be available. The equipment have been bought for most of the part. The magnets are under processing. The building is under construction. The commissioning of the TL is expected during 2017.

REFERENCES

- [1] www.tango-controls.org.
- [2] J. Corbett, G. Portmann and A. Terebilo, "Accelerator Control Middle Layer" in *Proc. PAC'03*, Portland, Oregon, USA, May 2003, paper WEPE020, p. 2369.
- [3] I. Chaikovska, C. Bruni, S. Chance, A. Gamelin, H. Monard, A. Loulergue, "Status of the preparation to the commissioning of the thomx storage ring", presented at IPAC'16, Busan, Korea, May 2016, paper MOPOW052.
- [4] A. Terebilo, "Accelerator modeling with MATLAB Accelerator Toolbox", in *Proc. PAC'01*, Chicago, Illinois, USA, June 2003, paper RPAH314, p. 3203.
- [5] M. Alves, C. Arnault, D. Auguste, J.L. Babigeon, F. Blot, J. Brossard, C. Bruni, S. Cavalier, et al., "PHIL photoinjector test line", *Journal of Instrumentation*, vol. 8, p. T01001, 2013.