

AN INTERACTIVE PROCEDURE OF A TRANSVERSE BEAM MATCHING AND CORRECTION IN INR LINAC

S.E. Bragin, A.V. Feschenko, O.V. Grekhov, N.F. Lebedeva, V.N. Mikhailov, A.N. Mirzozan, V.A. Moiseev, O.M. Volodkevich

*Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
E-mail: bragin@inr.ru*

An application package is developed to carry out an interactive procedure for a transverse beam matching and correction in INR Linac. The results of multiple beam profile measurements in several accelerator areas are used. The currents in steering coils are found to suppress the beam displacement. The gradients in quadrupole lenses are calculated to match the beam. This procedure is successfully used in accelerator tuning.

PACS: 29.27.Eg

1. INTRODUCTION

The Linac of Institute for Nuclear Research of the Russian Academy of Sciences (INR) is a high intensity accelerator [1]. Therefore, it is important to achieve optimal beam transportation throughout the accelerator with minimum beam losses.

There are five areas in the high energy accelerator part (above 100 MeV) where the measurements are done to observe and to adjust beam characteristics.

2. INSTRUMENTATION

Transverse behavior of the beam is monitored by wire scanners. From three to five wire scanners are installed in each measuring area of the accelerator. The scanner consists of two perpendicular wires, which are parallel to horizontal and vertical axes. The two-wire assembly is moved across the beam by a step motor. Scanning is made through the whole accelerator channel aperture in the range of ± 20 mm. A scan step is set by an operator and can be equal to 0.5, 1 or 2 mm. The duration of measuring cycle depends on a number of scanners used and is about 10...15 minutes. Processing of experimental profiles (Fig.1) gives rms size of the beam and position of the beam centre for both transverse planes. These data along with information on focusing structure of the measuring area are further used for data treatment.

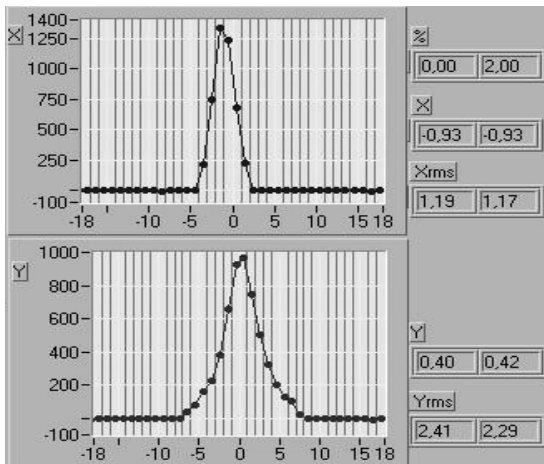


Fig.1. Example of beam profile measurement

3. TREATMENT OF PROFILE MEASUREMENTS

The results of rms beam size and the beam centre measurements in the point of wire scanner longitudinal location for each phase plane represent vertical lines. The disposition of these lines can be transferred to an arbitrary point of measuring area by a matrix transformation.

The results of measurements with several scanners transferred to a selected position represent a set of lines. The phase ellipse is inscribed with the iteration algorithm in central part of the phase space separated by the lines, the sum of distances for all the lines to the ellipse being minimized (Fig.2).

The parameters of phase ellipses $\alpha_x, \beta_x, \gamma, \alpha_y, \beta_y, \gamma$ and the emittances ϵ_x and ϵ_y are calculated in rms meaning for any point of interest. Below the results of treatment of measurements are presented for a 100 MeV INR Linac measuring area.

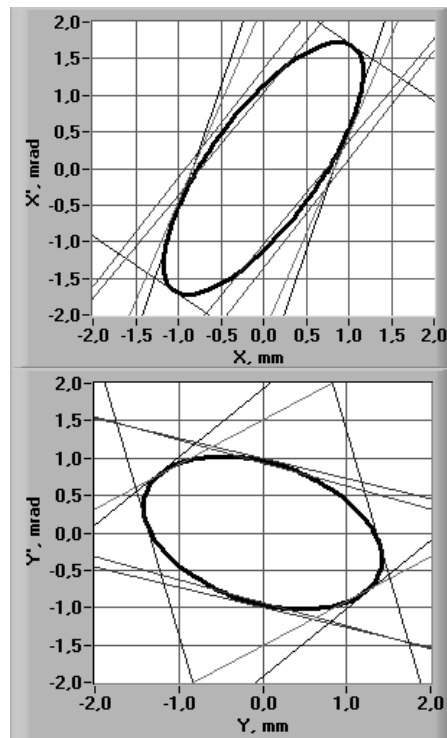


Fig.2. The inscribed beam phase ellipses related to the entrance of the measuring area at 100 MeV region

The method mentioned above has computational errors in determination of the ellipse parameters which depend on mutual disposition of the lines. To decrease these errors, a procedure is carried out for several points along the measuring area. Then the parameters of all the ellipses are transformed to the point of interest by the matrix transformation and the mean values of the parameters are calculated. For example, the parameters at the entrance of the 100 MeV measuring area are the following:

$$\beta_x = 1.01 \pm 0.03 \text{ mm/mrad}; \quad \beta_y = 1.48 \pm 0.04 \text{ mm/mrad};$$

$$\alpha_x = -1.22 \pm 0.04; \quad \alpha_y = 0.24 \pm 0.04;$$

$$\varepsilon_x = 0.63 \pm 0.01 \text{ mm-mrad}; \quad \varepsilon_y = 0.66 \pm 0.01 \text{ mm-mrad}$$

The errors shown represent procedural errors of the method and are only the part of the total errors.

Similarly one can get a series of transformed straight lines for a beam centre. Ideally, an intersection point of these lines is a beam centre in a phase space. Normally, due to errors, all the lines do not intersect in one point, so the point of beam centre is found by minimizing the sum of distances to all the lines (Fig.3). Similarly to the procedural errors for ellipse parameters there are procedural errors for centre determination and the values related to Fig.3 are:

procedural errors for centre determination and the values related to Fig.3 are:

$$X_{centre} = -0.13 \pm 0.17 \text{ mm}; \quad Y_{centre} = 0.50 \pm 0.14 \text{ mm};$$

$$X'_{centre} = -0.16 \pm 0.31 \text{ mrad}; \quad Y'_{centre} = -0.80 \pm 0.18 \text{ mrad}$$

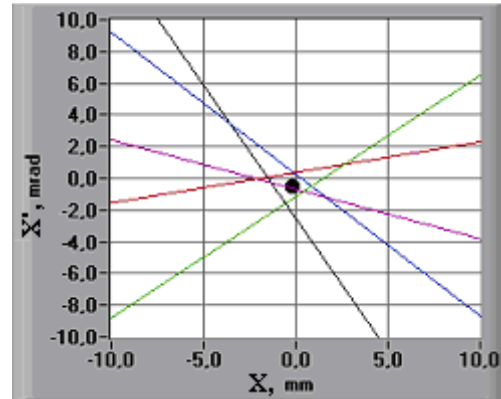


Fig.3. Determination of the beam centre for the entrance of the measuring area at 100 MeV region

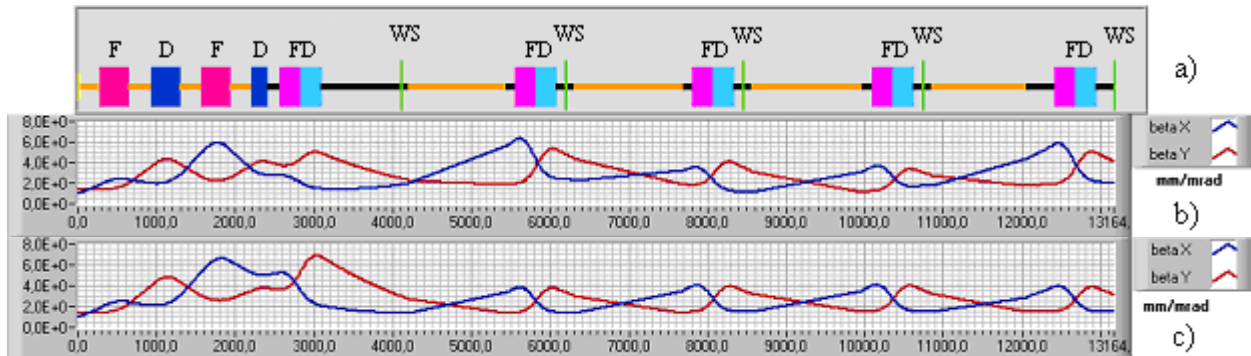


Fig.4. Lattice (a) and tracing of the β -function before (b) and after (c) matching procedure

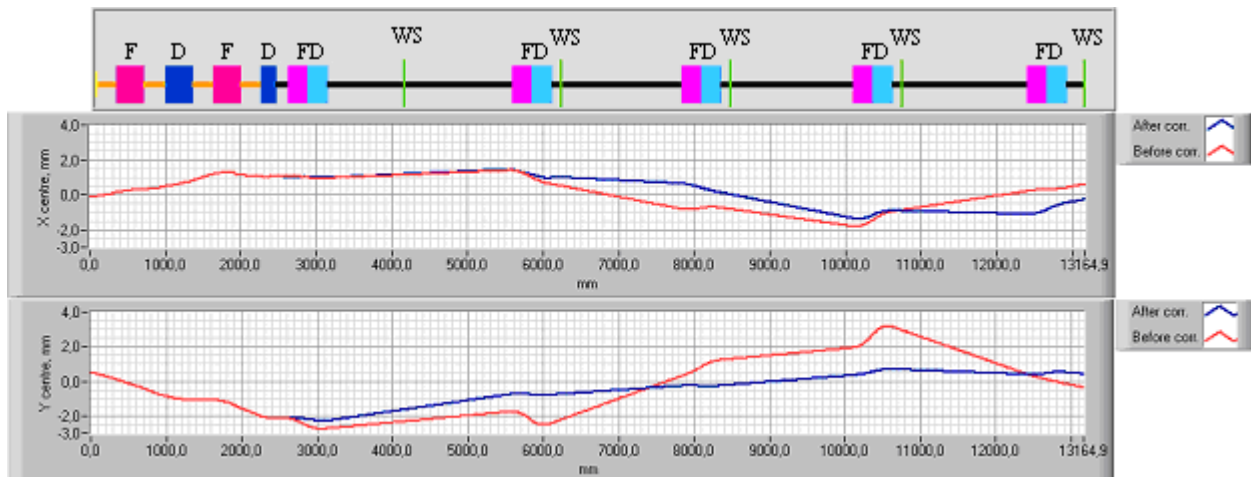


Fig.5. Tracing of the beam centre before and after correction (first step of procedure)

4. MATCHING PROCEDURE

Reconstruction of transverse beam phase ellipses and determination of the beam centers in an arbitrary longitudinal point is necessary for the subsequent procedure of beam matching and correction. The elements of focusing structure and wire scanners for 100 MeV measuring area are shown in Fig.4.a. The tracing of the

found phase space ellipse parameters along the measuring area is presented in Fig.4.b. To minimize the beam size, a specially developed matching algorithm is used. The gradients in the first four quadrupoles (for 100 MeV area) or quadrupole doublet assemblies (for other measuring areas) are varied to match the entrance beam parameters found by the method mentioned above with the downstream accelerator structure. After

selection and setting the values of gradients the profile measurements are repeated. Fig.4,c shows a behavior of the beam after proper matching. Sometimes the matching procedure must be iterated several times for better results.

5. BEAM CENTRE CORRECTION

There are additional windings in the quadrupoles to produce an additional dipole field for beam steering. Two steering elements for each plane are used in each measuring area. A standard correction procedure [2] enables to suppress displacement and angle of the beam at the exit of the second steering element in both horizontal and vertical planes.

The correction procedure is carried out after completion of the procedure of beam matching.

The steering currents are calculated with a separate code. Fig.5 demonstrates a behavior of beam centre throughout the measuring area before and after correction.

To estimate the correction efficiency a special parameter was introduced. It is determined as an rms deviation of the beam centre from the ideal axis averaged over the measuring area. Fig.5 demonstrates an im-

provement of beam behavior after the first step of correction. The parameters defined above are $X_{cen_{rms}}=0.95$ mm, $Y_{cen_{rms}}=1.81$ mm before correction and $X_{cen_{rms}}=0.87$ mm, $Y_{cen_{rms}}=0.70$ mm after correction. To improve the accuracy several iterations are required though further studies are necessary.

6. CONCLUSION

All the algorithms mentioned above are included to the application package. The method has been tested at a 100 MeV region and is planned to use in all the measuring areas of INR Linac. This application package is developed for interactive analysis and control of transverse beam parameters. Effective beam matching and correction are achieved in the first experiment.

REFERENCES

1. B.P. Murin et al. *Ion Linear Accelerators*. М.: «Atomizdat», 1978.
2. I.N. Biryukov, A.N.Mirzozjan et al. *Investigation of Transverse Beam Dynamics at the INR Linac*. INR Report, 1991.

ИНТЕРАКТИВНАЯ ПРОЦЕДУРА ПОПЕРЕЧНОГО СОГЛАСОВАНИЯ И КОРРЕКЦИИ ПУЧКА НА ЛИНЕЙНОМ УСКОРИТЕЛЕ ИЯИ РАН

С.Е. Брагин, А.В. Феценко, О.В. Грехов, Н.Ф. Лебедева, В.Н. Михайлов, А.Н. Мирзоян, В.А. Моисеев, О.М. Володкевич

Разработан пакет программ для проведения интерактивной процедуры поперечного согласования и коррекции пучка по результатам измерения профилей пучка на различных участках линейного ускорителя ИЯИ РАН. Определяются режимы включения корректирующих элементов для выведения пучка на ось ускорителя и градиенты полей квадрупольных линз для согласования пучка с фокусирующим каналом ускорителя. Разработанная процедура успешно используется при настройке режимов работы ускорителя.

ІНТЕРАКТИВНА ПРОЦЕДУРА ПОПЕРЕЧНОГО УЗГОДЖЕННЯ І КОРЕКЦІЇ ПУЧКА НА ЛІНІЙНОМУ ПРИСКОРЮВАЧІ ІЯД РАН

С.Є. Брагін, А.В. Феценко, О.В. Грехов, Н.Ф. Лебедева, В.Н. Михайлов, А.Н. Мирзоян, В.А. Моисеев, О.М. Володкевич

Розроблено пакет програм для проведення інтерактивної процедури поперечного узгодження і корекції пучка за результатами виміру профілів пучка на різних ділянках лінійного прискорювача ІЯД РАН. Визначаються режими включення коригувальних елементів для виведення пучка на вісь прискорювача і градієнти полів квадрупольних лінз для узгодження пучка з фокусуєчим каналом прискорювача. Розроблена процедура успішно використовується при налаштуванні режимів роботи прискорювача.