TRANSVERSE PHASE PORTRAIT TOMOGRAPHY OF PROTON BEAMS AT INR RAS LINAC

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Abstract

Measuring of the parameters of the transverse phase portraits is crucial for beam dynamics. A method of tomographic reconstruction is implemented at INR RAS linac as an alternative to already existing quadrupole variation method. In this work new feature of disturbing online measurements of phase portrait parameters and important experimental results are discussed. Comparison of tomographic method with quadrupole variation method is presented.

Introduction

Tomographic reconstruction is a method of measuring transverse phase portrait parameters of a beam. It can be attributed to quadrupole variation method and differs only in processing of obtained information. An automatic procedure of emittance measurements was implemented at the exit of INR RAS linac on the base of ionization Beam Cross Section Monitor (BCSM). Also a program for offline measurements was implemented.

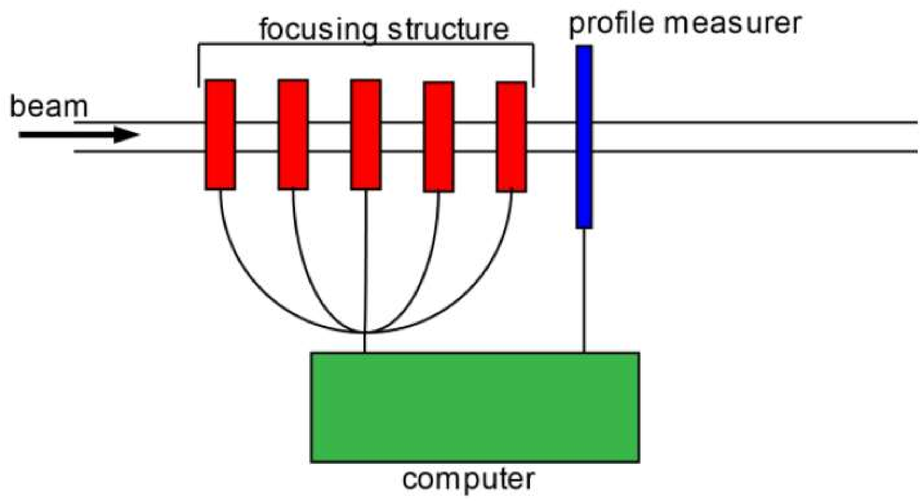

Fig. 1. Layout of components required for quadrupole variation method measurements.

Experimental results

For now tomography at INR linac is going through various tests. Figure 4(a) shows results of tomography based on previously collected data from BCSM. It is seen that various "tail" artefacts exist. Method of splitting phased portrait to sub portraits allows choosing sub portrait without artefacts. A minimum of a specially constructed weight function was chosen as a selection criterion. Figure 4(b) shows phase portrait without artefacts. Figure 5 shows value of weight function depending on intensity of chosen phase portrait.

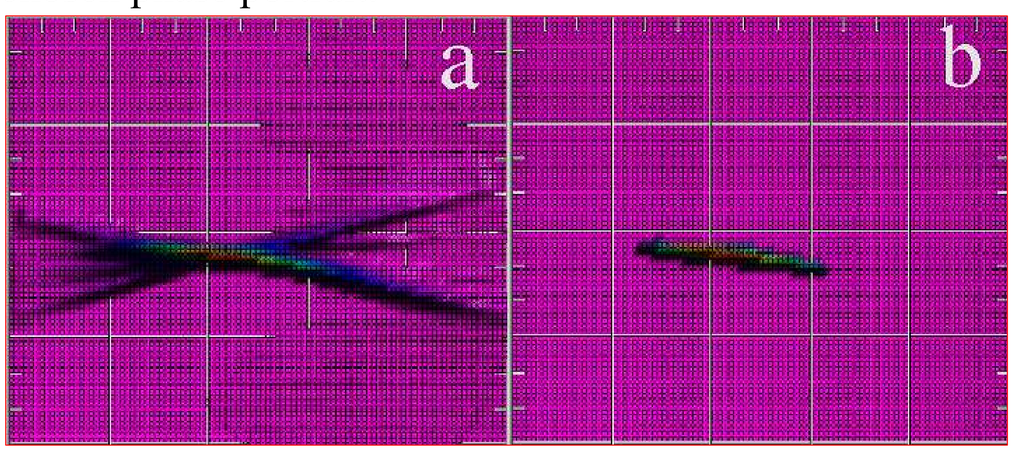

Fig. 4. (a) is a raw result of reconstruction; (b) is a result without artefacts.

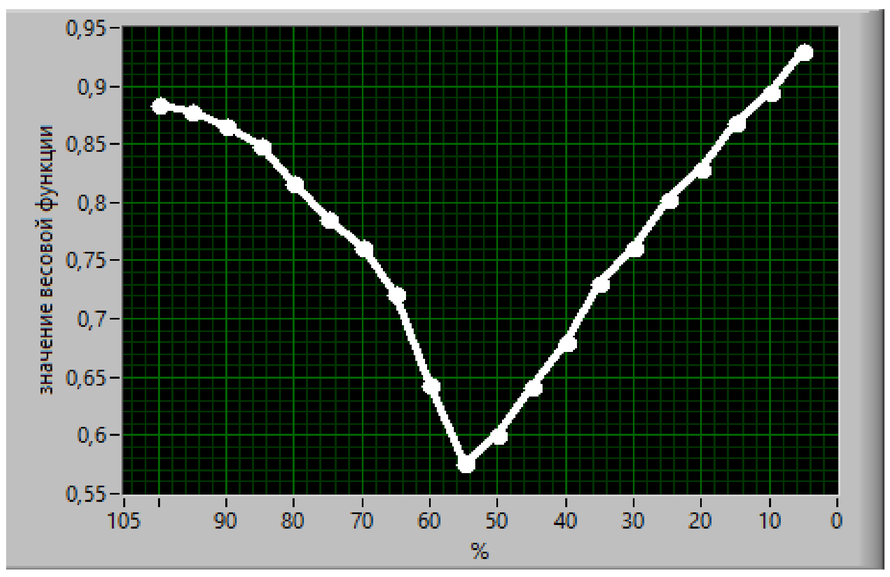

Fig. 5. Value of weight function depending on intensity of chosen phase portrait.

Design and software features

Image from BCSM is transferred via catadioptric system and acquired with Basler acA780-75gm camera, which is installed under concrete shielding of accelerator. Phase portrait rotation is performed by eight quadrupole doublets, located before BCSM (figure 2). They are powered by two independent current sources. Transfer matrix method is used for description of focusing structure of accelerator. Tomography software at INR is written mostly in LabVIEW, tomography kernel is written in Python. Image acquisition and calibration is based on luminescent diagnostics software for INR RAS Proton Irradiation Facility. Online tomography procedure includes preplanning, measuring and reconstruction steps. Tomography kernel is based on Simultaneous Algebraic Reconstruction Technique (SART) algorithm. It is taken from open-source code package called "scikit-image". Reconstruction results from tomography kernel are post-processed. Each phase portrait is split into 20 sub portraits so that intensity in each of them varies by 5 % of the total intensity of the original phase portrait. An envelope is calculated for every sub portrait, and this envelope is approximated by a phase ellipse (figure 3). Twiss parameters, emittance and center of each ellipse are calculated. All that data is displayed for user.

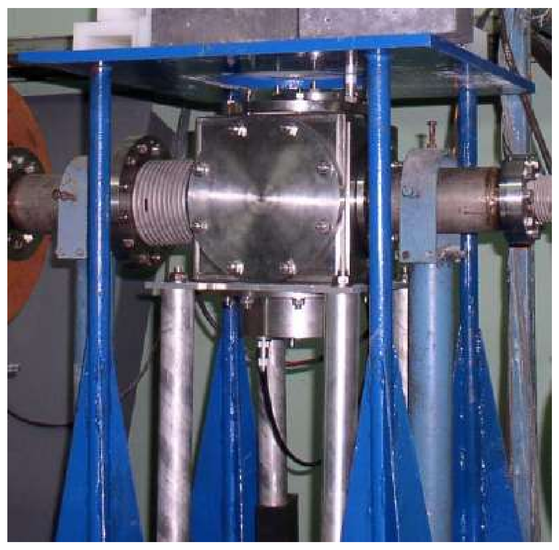

Fig. 2. BCSM appearance.

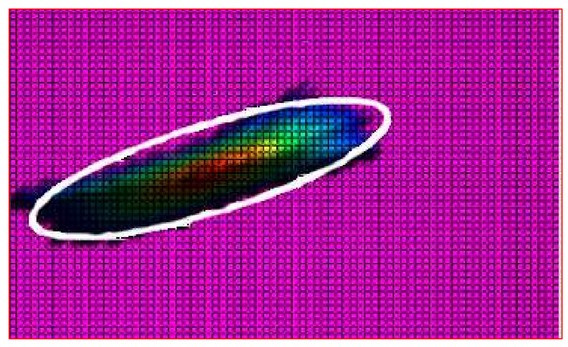

Fig. 3. An approximation of phase portrait by a phase ellipse.

Comparison of methods

Tomographic reconstruction was implemented as an alternative to a method of transverse profiles. A comparison between two methods was made, using previously obtained data (figures 6(a), 6(b)). Centres of ellipses were artificially combined. A simulation of beam transfer through elements, which were used for measurements, has been done for both methods (figure 7) to compare results from simulation with real values of beam size and position. Tomographic method showed to be better at reconstructing beam centre, while transverse profiles method is better at reconstructing beam size, however difference between measured beam size and reconstructed from tomographic reconstruction data is less than 1 standard deviation.

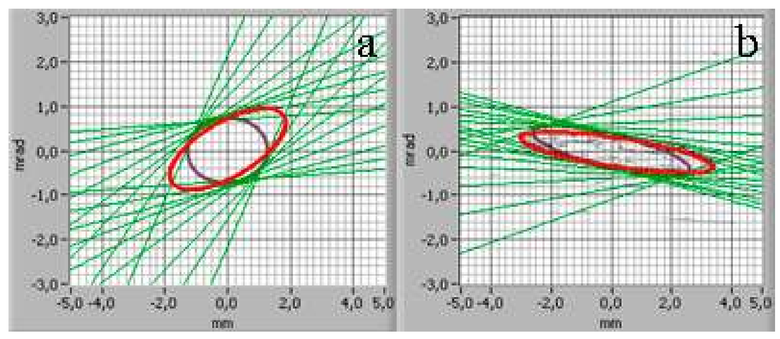

Fig. 6. results of tomographic (red) and transverse profiles (brown) methods: (a) for X-axis, (b) for Y-axis.

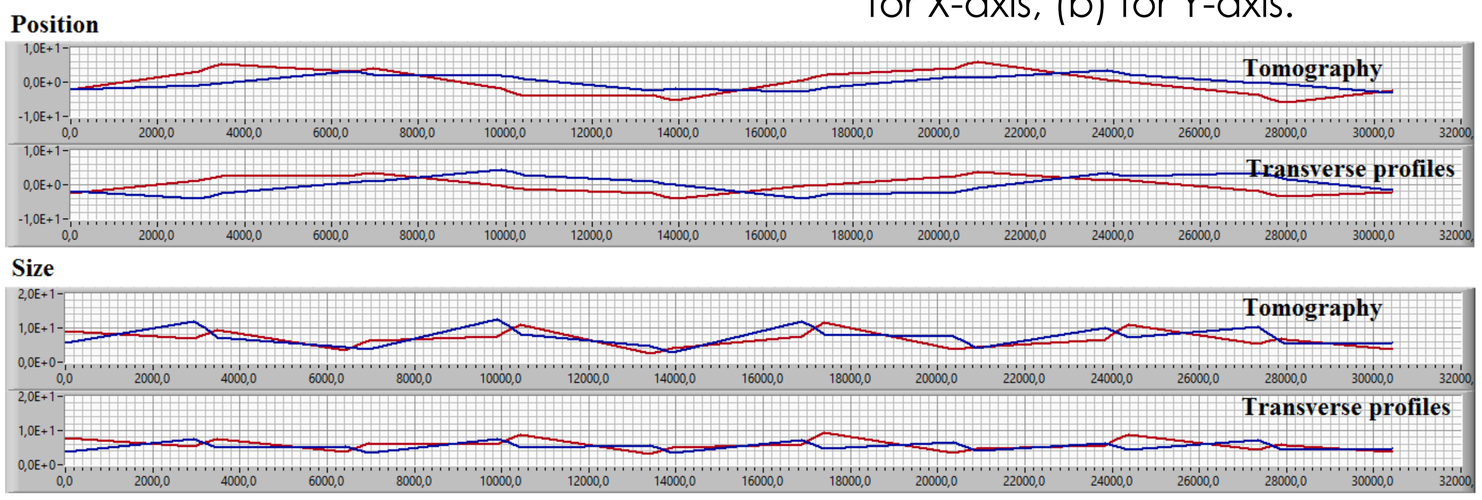

Fig. 7. Dynamics of beam position and size in modelled transfer line. Blue lines are for X-axis, red are for Y-axis.