BEAM TWISS MEASUREMENT WITH WS INCLUDING SPACE CHARGE EFFECT*

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Abstract

Wire Scanners (WS) are used to measure beam profile and calculate the transverse Twiss parameters at the entrance of MEBT1 in the CADS injector I test stand. As to data process, the traditional method with transfer map doesn't consider the space charge effect. But, as we know, space charge effect can't be neglected for high intensity accelerators. In this paper, optimization algorithm is used in beam emittance measurement.

INTRODUCTION

The traditional way and the way used in the paper to get the beam Twiss parameters from beam spot sizes are introduced in this section.

Lattice Layout

The MEBT1 lattice of CADS injector I test stand is shown in Figure 1. The WS2 is used to measure the Twiss parameters. We use quadrupole scan method with WS2 to measure Twiss parameters at the exit of RFQ. In order to minimize errors, the scan process should goes through beam waist, we scan Q1 for the x direction and Q2 for y.

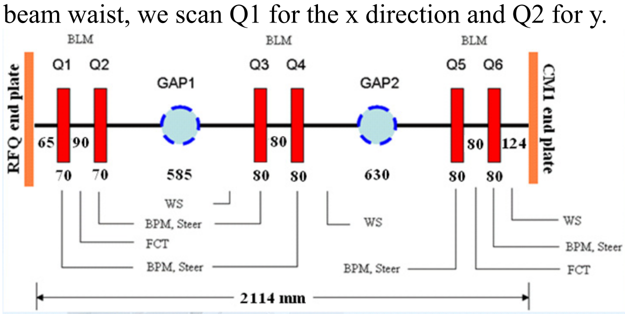

Figure 1: The lattice and diagnostic element layout of MEBT1 in CADS injector I.

Introduction to the Tradition Method

Usually, if we know the lattice, we know the transfer matrix M. With simple derivation we can get the relationship between input Twiss parameters and the measured beam size, as shown in equation 1.

$$\begin{pmatrix} \sigma_1^2 \\ \vdots \\ \sigma_n^2 \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} & R_{13} \\ \vdots & \vdots & \vdots \\ R_{n1} & R_{n2} & R_{n3} \end{pmatrix} \left((\beta\varepsilon)_0 \quad (\alpha\varepsilon)_0 \quad (\gamma\varepsilon)_0 \right) \tag{1}$$

In this equation, R is from the transfer matrix M that doesn't consider space charge effect, and σ_i is the spot size from WS, it. With least square method and the equation 2, the most suitable initial Twiss parameters σ_i can be found.

$$\varepsilon_0 = \sqrt{(\beta\varepsilon)_0(\gamma\varepsilon)_0 - (\alpha\varepsilon)_0^2} \tag{2}$$

Introduction to MOGA

The Multi Objective Genetic Algorithm (MOGA) is a widely used optimization method. This functions is based on evolutionary algorithm for finding the optimal solution for multiple objective [2].

I have two optimization objectives. One is

$$f(1) = \frac{\sum_{i=1}^{n} \left(\sigma_{i\exp} - \sigma_{isim}\right)^2}{\sum_{i=1}^{n} \left(\sigma_{i\exp}\right)^2 / n} \tag{3}$$

And the other one is

$$f(2) = \sum_{i=1}^{n} \left(\frac{\sigma_{i\exp} - \sigma_{isim}}{\sigma_{i\exp}} \right)^2 \tag{4}$$

Where n is the number of settings of the scanned quadrupoles, the footnote 'exp' means data from experiment, and 'sim' means data from simulation.

The optimization variables are Twiss parameters at the exit of RFQ, α_0, β_0, ε_0.

RESULTS

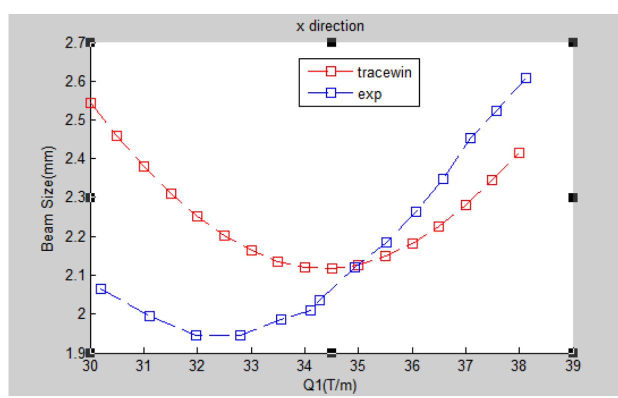

Figure 2: beam spot size in x direction, where the blue points are experiment data, and the red ones are gotten with Partran of TraceWin. During tracking, the Twiss parameters from traditional method are used.

Tracking the beam with multiparticle simulation code, like TraceWin, with initial α_0, β_0, ε_0 from traditional method [1], we can find that the beam size deviates a lot

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from the experiment spot size, as shown in figure 2 and 3. The solver seems to be unsuitable.

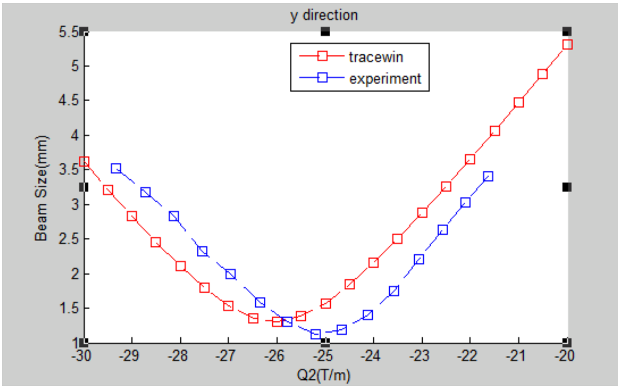

Figure 3: beam spot size in y direction, where the blue points are experiment data, and the red ones are gotten with Partran of TraceWin. During tracking, the Twiss parameters from traditional method are used.

With MOGA, I can get better result, as shown in figure 4 and figure 5. In y direction, I have tried to optimize 30 generations, then reduce the variable ranges and have another 30 generations again.

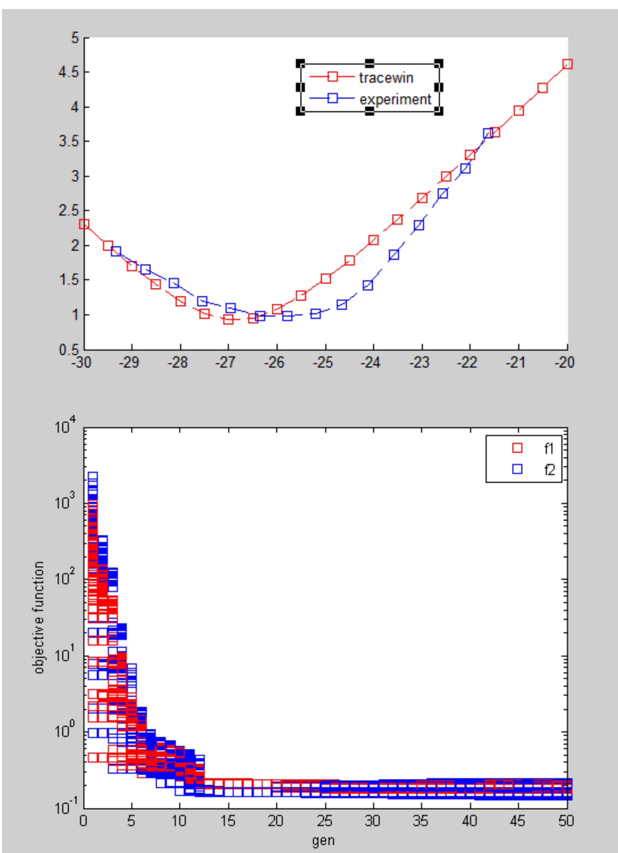

Figure 4: beam size data in x direction from experiment and simulation with 'Partran' code. The input Twiss parameters are from MOGA.

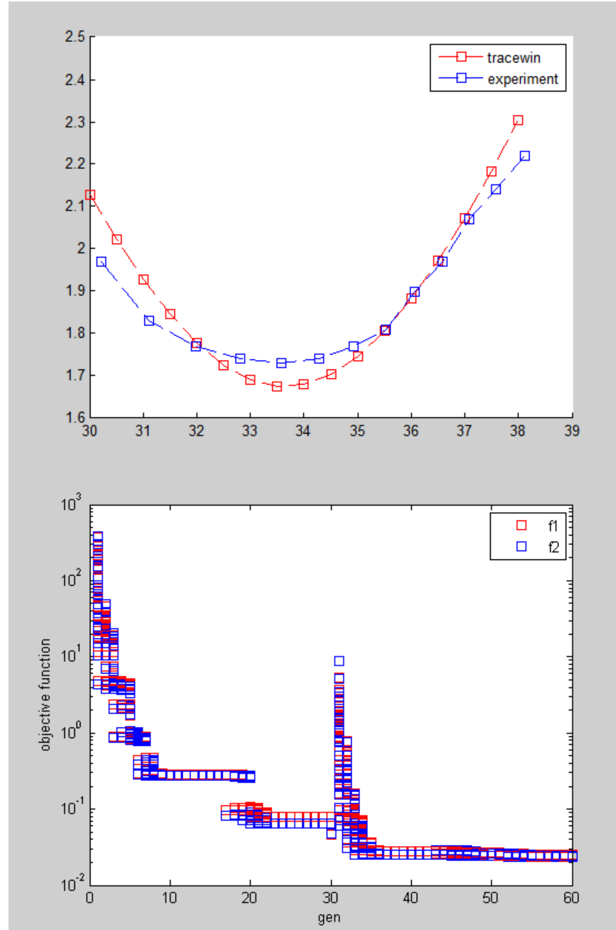

Figure 5: beam size data in y direction from experiment and simulation with 'Partran' code. The input Twiss parameters are from MOGA.

Twiss parameters from traditional and MOGA are shown in Table 1.

Table 1: Twiss Parameters at the Entrance of MEBT1

parameter	Tradition	MOGA
α_x	-1.22	-1.80
β_x(mm/mrad)	0.112	0.171
ε_x(mm mrad)	0.164	0.16
α_y	2.16	0.7169
β_y(mm/mrad)	0.194	0.0946
ε_y(mm mrad)	0.2	0.2066

CONCLUSION

Considering the space charge effect, optimization algorithm is a nature choice in data process of WS, and the traditional method result is unreliable. According to my experiment with MOGA, the range of variables, population size and number of generations are problems. This problem should be studied further more.

ACKNOWLEDGMENT

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REFERENCES

[1] Huiping Geng *et al.,* presented at IPAC'16, Busan, Korean, May 2016, paper MOPOY027.

[2] MOGA, http://www.iitk.ac.in/kangal.