MATCHING OF HIGH INTENSITY ION BEAMS TO AN RFQ: COMPARISON OF PARMTEQ AND IGUN SIMULATIONS

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Abstract

The classical way of matching an ion source to the low energy accelerator RFQ generally is performed by adjusting the matching optics of the LEBT to provide the rms ellipse twiss parameter requirements of the RFQ shaper section. By matching to the rms parameters (the equivalent rms beam method) the actual shape of the distribution plays a smaller role according to F. Sacherer. In many cases, however, the matching optics are creating not only aberrations to the ion beam but also a very non-elliptical shape of the emittance figure, and a more exact match may be required. As a way out, an ion extraction program (IGUN) has been modified to also take into account the rf-focusing of non-modulated RFQ vanes in the shaper section. This makes it feasible to use this program for the simulation from the ion source plasma until the beginning of modulation inside the RFQ, and it can also handle dc fields in the injection region of the RFQ. In order to demonstrate the differences of both approaches we apply them to well defined experimentally proved designs of RFQ shaper sections.

INTRODUCTION

We have shown [1], how the rf-focusing of the non-modulated entrance part of an RFQ (shaper) can be taken into account by the ion extraction program IGUN [2]. The necessity for this new option came from the “direct injection scheme” into an RFQ, as proposed and developed by Okamura [3]. In this application a 102 mA C^{4+} ion beam from a laser ion source is accelerated towards the vanes of an RFQ with exceptionel results for the acceptance and the transmission.

In this paper we will use the starting beam of classical RFQ-design with a waterbag distribution as an input beam to IGUN and compare the results with the corresponding results of PARMTEQ. This waterbag distribution, however, is very different to a thermal distribution, which is generally obtained from ion sources, as long as aberrations are not dominating the emittance at the RFQ entrance and a proper LEBT is provided with minimum emittance growth [4]. Therefore we also compute the RFQ-matching with a thermal distribution. A transverse thermal energy of 50 eV gives best agreement with the results when using the waterbag distribution.

SIMULATION OF THE WATERBAG DISTRIBUTION WITH IGUN

The classical RFQ matching procedure starts with a waterbag distribution in cartesian coordinates. A small computer program (XYRAY.FOR) has been written in order to convert the PARMTEQ input file for starting trajectories to a corresponding IGUN file in axisymmetric coordinates. This program also plots the distributions in different coordinates systems, as shown in Fig. 1.

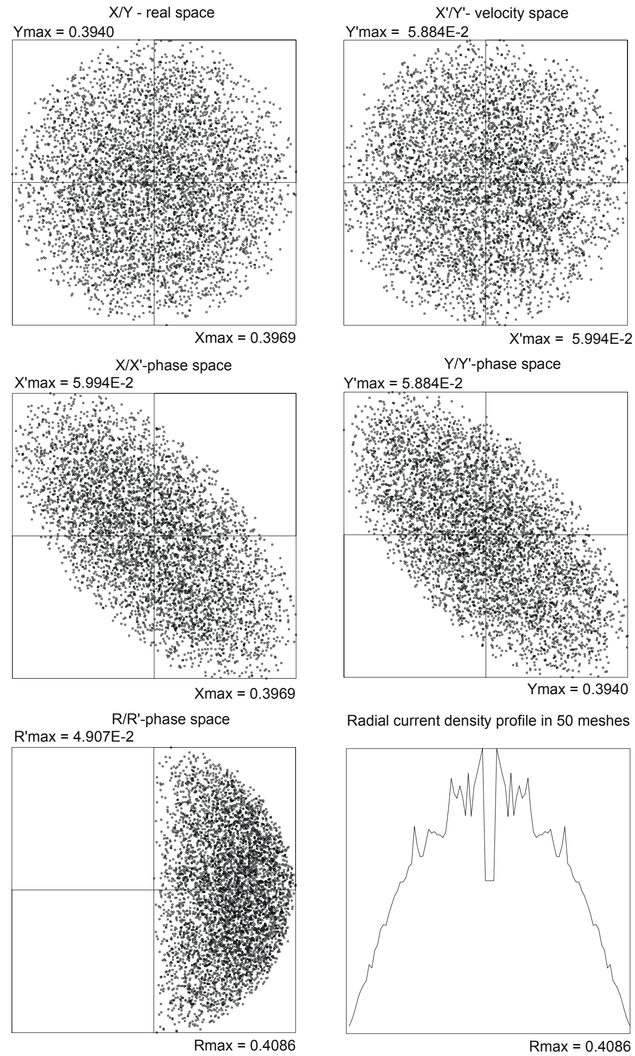

Figure 1: Distributions in x/y, x’/y’, x/x’, y/y’, r/r’, and radial space charge for a waterbag distribution.

The results of IGUN with the converted trajectory data of the waterbag distribution are shown in Fig. 2 for the behaviour of the trajectories and in Fig. 3 for emittances and beam profiles along the beam. This beam behaviour is almost identical with the calculation by PARMTEQ. The beam first expands and then reaches a waist at the end of the shaper section. The pseudo equipotential lines shown in in Fig. 2 are reflecting the influence of the space charge by the effective current, which is used to simulate the rf-focusing by IGUN. In regions, where the beam is smaller than the balance radius, the effective current is larger than the real one, in the central region, where the beam is larger than the balance radius, the effective current changes its sign in order to create potentials and fields, which cause radial focusing.

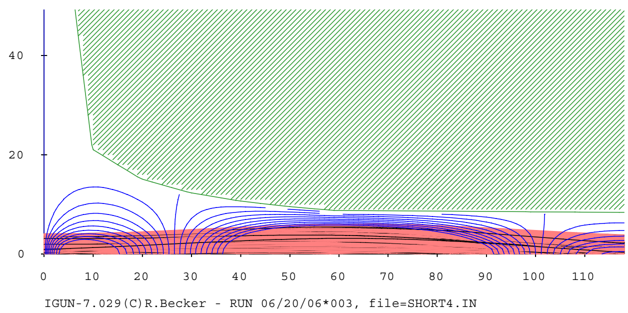

Figure 2: Trajectories and pseudo equipotential lines of an IGUN simulation of RFQ matching with a waterbag distribution.

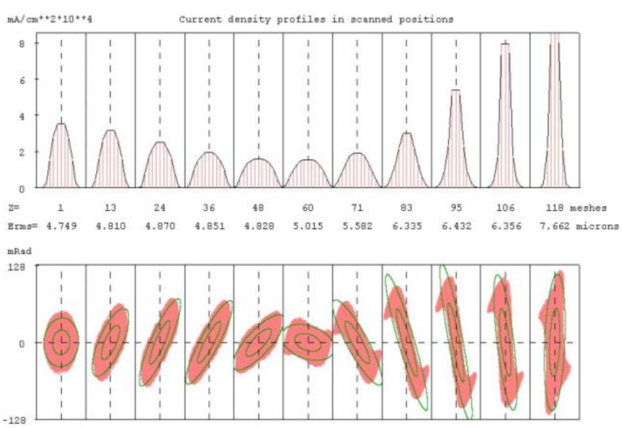

Figure 3: Current density profiles and emittances along the beam calculation of IGUN in Fig. 2.

SIMULATION OF THERMAL DISTRIBUTIONS WITH IGUN

The waterbag distribution shown in Fig. 1 for 5000 particles looks different to simulation results by the ion source extraction program IGUN. Therefore we have been looking into the distribution functions, which are created by "true" thermal starting, e.g. assuming a uniform distribution in x and y inside of a given radius together with a linear Maxwell distributions for x' and y'. This corresponds to distributions coming out of an orifice with thermallized particles, which is plausible for electron emitters as well as for the emission of ions from a plasma. In order to perform a meaningful comparison with the waterbag distribution, a transverse temperature of 50 eV has been used, giving very similar emittances as seen in Fig. 5, which is the corresponding IGUN plot to Fig. 3. The shape of the emittance in the beginning is almost a square, while the waterbag has an elliptical shape. During the matching the thermal emittance shape shows more pronounced abberation wings as compared to the waterbag distribution. The trajectory plot for this IGUN simulation does not show significant changes to Fig. 2, therefore it is not shown here.

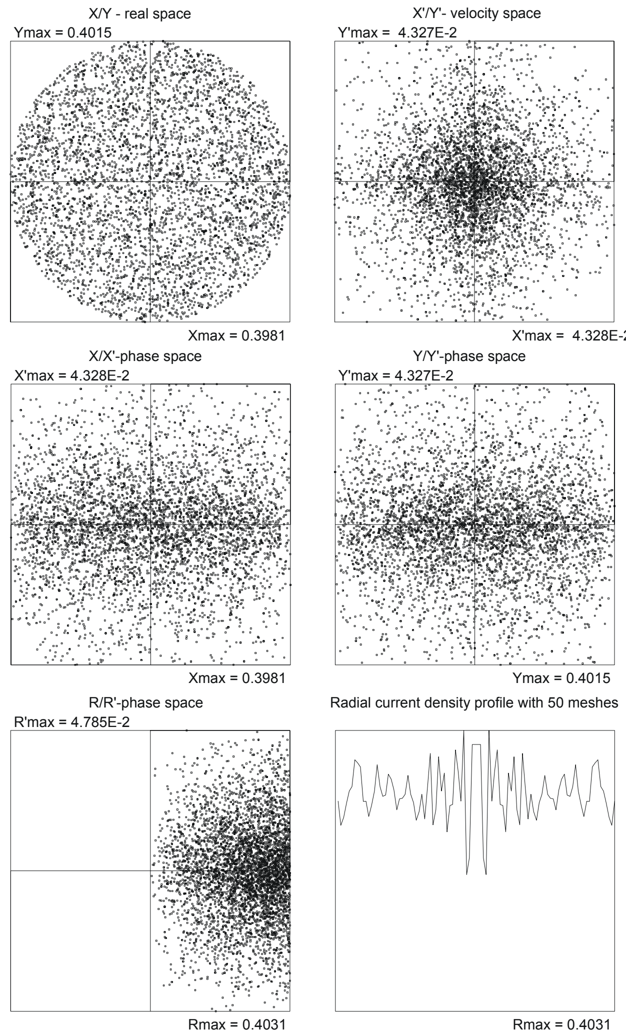

Figure 4: Distributions in x/y, x'/y', x/x', y/y', r/r', and radial space charge for a waterbag distribution.

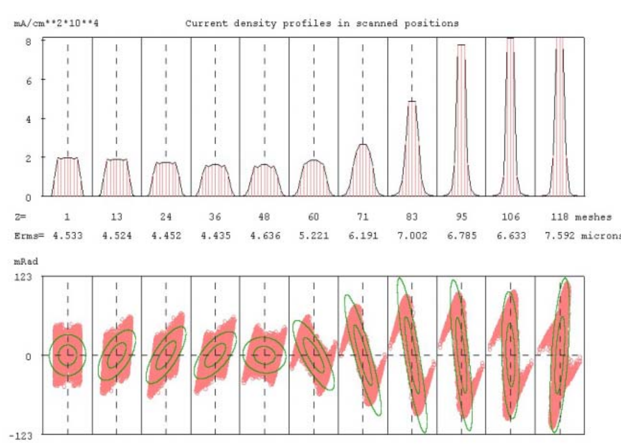

Figure 5: Current density profiles and emittances along the beam calculation of IGUN for a thermal distribution as shown in Fig. 4.

CONCLUSIONS

The matching of a high intensity C^{4+} ion beam of 102 mA and 60 kV to an RFQ has been compared by simulations with PARMTEQ and IGUN. For this the waterbag distribution, used for the PARMTEQ simulations has been transformed to axisymmetric coordinates, which are used by IGUN. In the r/r' – presentation this distribution looks different from usual results for ion sources as simulated with IGUN. Therefore we also generated a thermal distribution and performed IGUN simulations. Although the appearance of both distributions is very different, the corresponding beam profiles and emittance growth figures are close to each other. The reason may be that in high intensity applications the shaper is longer than ¼ of the plasma period, which will result in a gaussian like density distribution, similar to a waterbag one.

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