TRANSPORT OF THE 1.92 - 3.1 KA AIRIX ELECTRON BEAM

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Abstract

The AIRIX accelerator is running with a 1.92 kA (single pulse 60ns) electron beam for two years. The optimisation of the beam transport has to minimise the transverse BBU oscillations and preserve the quality of the 20 MeV electron beam at the end of the accelerator. This minimisation needs, first, a very precise alignment. Secondly, the use of a higher axial magnetic field minimise also BBU oscillations. In that way, we have installed new power supplies to generate those fields. We present in this paper the results we obtained.

We expose also the results we obtained with the adjunction of one more solenoïde between the injector and the accelerator.

Those two actions have to simplify the beam transport at the 3.1kA. The different experiment we made at this higher current are also exposed.

1 INTRODUCTION

The AIRIX accelerator is essentially used for flash X-Ray radiography, at Moronvilliers near Reims. During the different phases of use of this machine, we do some studies on the very specific electron beam that is delivered: 20 MeV, 1.92 kA, 60ns. Those studies have to ameliorate the performances of the accelerator but also to guarantee the quality of the focal spot. We present in this paper, some results obtained in beam transport that complete that was made one year ago [1].

The reliability of the machine is also crucial. During the long phases (several weeks), where the parameters of the machine are fixed, we have measured systematically the centroïde motion of the beam all along the accelerator. We expose those measurement of the beam stability.

We will speak also about the reliability of the accelerator and in particular the high voltage behaviour of the 64 induction cells and about the 32 high voltage generators that powered the cells.

This machine has been designed to transport a 3.5 kA electron beam. For instance, we use in routine, a 1.92 kA current, but we have begun to run the machine with a 3.1 kA. We present in a final part the characterisation of the injector at this higher current, and the first results we obtained for beam transport.

2 TRANSPORT OF THE 1.92 kA BEAM

2.1 Beam initial parameters

The determination of the beam initial parameters is made with two specific experiments. The first one establishes the abacus E=f(I), where I is the current measured with the BPM2 (Beam position monitor positioned @ 80 cm of the cathode), and E is the absolute mean energy measured with the time resolved spectrometer [2]. The energy spread along the 60 ns is better than ±1 % [3].

We use the same abacus for two years:

E (MeV) = 1.436.I (kA) + 1.083

The measurement of the beam radius, the slope of the beam envelope at the origin and the emittance is made with the classical three gradients method. In the Table 1, we have reported the different values obtained after two similar campaign, separated by one year. The analysis of the images obtained by Cerenkov radiation, with a gated camera (gate = 25ns), are made in the horizontal plane X and vertical plane Y.

Table 1: Beam initial parameters results
X (mm), Y (mm), ε (π mm mrad)

Date	X0	Y0	X'0	Y'0	εx	εy
09/99	19.5	20.1	70.1	70.0	404	233
07/00	19.8	20.2	73.1	74.2	565	532

The values obtained for X0, Y0, X'0, Y'0 are very closed with the one year delay. The differences obtained can be explained by several reasons: magnetic field stability of the first solenoïde, stability of the abacus and simply the accuracy of the measurement.

The most important is in the emittance evaluation. There is a difference of around 50% in the vertical plane. Because we have a space charge dominated beam, a big variation of the emittance value has a very low effect on the beam size.

The effect of those different beam parameters, on the beam envelope along the accelerator, is also not very important.

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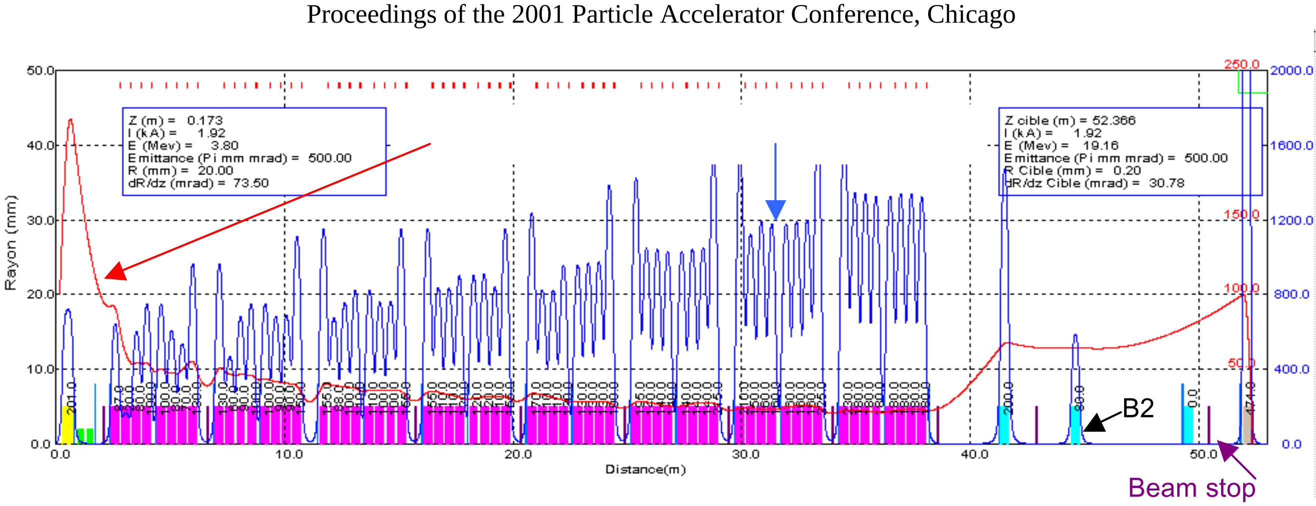

Figure1: beam transport calculated with ENV code

2.2 Beam transport

The beam transport is calculated with the ENV code [4]. The method used for this calculation has already been described [1]. The figure 1 shows the typical beam transport that was used recently.

We can notice that the envelope oscillations are quiet important at the entrance of the accelerator and in the two first modules of eight induction cells. This can be explained by the space charge effect and by the long distance without magnetic between the injector and the accelerator (≈1m). To correct that, we have installed but not yet tested a new solenoïde between the injector and the accelerator. The aim is to immerse the beam in a quasi-continuous magnetic field, and then minimise this oscillation. The objective is to transport most of the electrons present in the rise and fall time, as to delay the BBU oscillations.

The beam transport shows also that we have chosen to not use the B3 coil in the final section (at the end of the accelerator), and then create a very long drift space. In order to improve the beam transport calculations, we have made a specific campaign with the OTR diagnostic that is attached to the beam stop. The beam images are made with the fast gated camera (gate = 25 ns). The varying parameter is the current in the B2 coil.

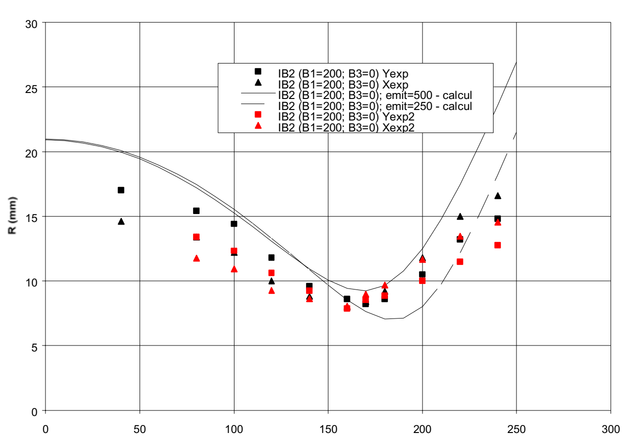

Figure 2: Beam radius variation versus I(B2) at 1.92 kA

This plot demonstrates the good prediction of the ENV code at this current. Two calculus have been made with 250 and 500 π€mm mrad for the emittance value and proves also the low influence of this parameter on the beam transport. For each point of this curve, we have made two shots not always consecutive. For low and high current in the B2 coil, we have a radius spread of the order of 10%. This can be explain by a variation of one or several parameter of the machine. The current and the energy of the electron beam are well controlled, but the axial magnetic field can have a small variation.

An image of the stability is the measurement of the beam position centroïde (X(t), Y(t)). Shot after shot we register this measurement. Over 7 consecutive weeks and more than 100 shots, we have seen that the centroïde of the beam is always included in a circle of 0.4 mm for diameter, at the end of the accelerator.

2.3 Reliability of the accelerator

The main risk for the beam perturbation is breakdown in the induction cells. This breakdown can be dramatic for the beam if it occurs near the gap. During the very long campaign (7 weeks) that has been made last year with the 1.92kA electron beam, we have enumerated 13 breakdown out to 472 shots realized. Only 4 of them had an incidence on the beam centering. We don't know in which part of the cell those breakdown appears, but most of them have no incidence for the beam and for the flash X-ray experiment.

The 32 H.V. generators [5] are also very reliable. The problem that appears sometimes, comes from the trigger unit installed on each generator. This unit can trigger the generator too late or too early for the beam. The consequence, when one generator is not well triggered is a modification of the total beam energy that becomes 18.6 MeV in comparison to the nominal value 19.2 MeV. We don't have seen very severe consequence on the beam propagation, but the focal spot can affected and the X-ray dose produced also. The problems that concern the 32 H.V. generator occurs 9 times over the 472 shots.

The analysis of all the 472 shots has provided the elements to evaluate the reliability of this machine, specially during this 7 weeks period. In total, we have encountered 24 shots that where the characteristics of the beam were not nominal. So, when a shot is initiated it is success in 95% of cases.

The problems that are mentioned here are today partially resolved in particular for the H.V. generator [5,6]. For the induction it is more difficult because it is a passive component of the accelerator. One way is to observe and analyse if there are some particular points on the electrical signal that announce the breakdown [8].

3 TRANSPORT OF THE 3.1 kA BEAM

3.1 Beam initial parameters

Running the machine with a higher current is important for specific uses. We have begun some studies to optimise the electron beam transport at 3.1kA. To operate with a 3.1 kA electron beam we used a 70 mm. diameter velvet cathode, with a velvet recess of 2.8 mm.

As usual, the first step is the injector characterisation. The time resolved spectrometer provides the useful measurement for the abacus establishment:

$$E\ (\text{MeV}) = 0.93\ I_{bpm2}\ (\text{kA}) + 0.99$$

The second step is the classical beam imaging campaign that permits the measurement of the beam initial parameters. The results we have obtained are the following:

Table 2: Beam initial parameters results for 3.1 kA
X (mm), Y (mm), ε (π mm mrad)

Date	X0	Y0	X'0	Y'0	εx	εy
07/00	26	26.5	77.7	78.2	500	347

We can see, as previously for the 1.92 kA electron beam, that the beam is quiet round. The emittance values are also quiet low, and the explanation given in the previous part is valid too.

3.2 Beam transport

The beam transport is made with the same ENV code and with the same method. The only difference is that we use higher axial magnetic field to contain the BBU oscillations. To do that, we have installed new power supplies to reach a maximum axial magnetic field in a cell around 2500 Gauss, instead the previous limitation of 1250 Gauss.

A beam imaging campaign has been made at this current on the beam stop (figure 3).

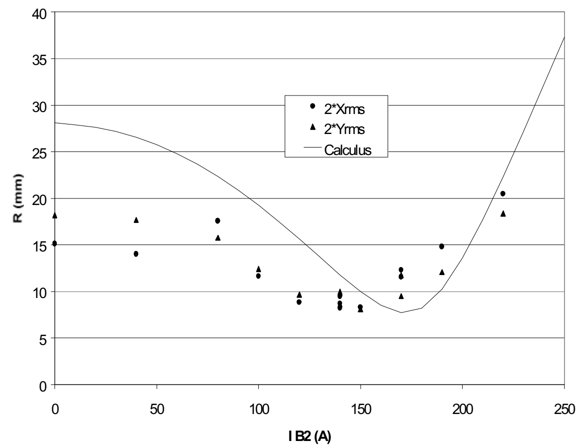

Figure 3: Beam radius variation versus I(B2) at 3.1 kA

In that case the differences between the calculation and the experiment are more important in comparison to 1.92 kA results. The BBU phenomenon is more important in that case and has probably an incidence on the beam radius that is measured. On the other hand, calculations don't take into account the probable 2D effects on beam propagation.

4 CONCLUSION

Now, we are working again with the 1.92 kA current. Changing the diode configuration needs 2 days, because of vacuum constraint. On the whole, 8 days have been sufficient to find again the running point of the entire machine, that proves the quiet good reproducibility of electron beam generation and transport.

AIRIX is used most of the time for flash X-Ray experiment. Nevertheless, the expertness of the physic of the electron beam will provide better performances and will ameliorate the reliability.

In that way studies are continuing on this installation and the results presented here are the first example.

5 REFERENCES

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