PROGRESS WITH THE 2-3 KA AIRIX ELECTRON BEAM

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Abstract

AIRIX is an induction accelerator designed for flash X-Ray radiography. It delivers a single pulse (60 ns, 2-3 kA, 20 MeV) electron beam. We present in this paper the different beam transport configuration that we use and the comparison with the experiment. We show the BBU amplification measured along the 64 induction cells. We speak also about the reliability of this machine that produces a single pulse electron beam 2000 times a year. The last part is dedicated to specific studies that we have made for predictive maintenance.

1 INTRODUCTION

The AIRIX induction accelerator dedicated for flash X-ray radiography is running in routine since the beginning of 2000. It has been designed to generate an intense electron beam pulse (2-3 kA, 20 MeV, 60 ns).

Now, this machine is essentially use for flash X-ray radiography. Nevertheless, we are still working on some evolutions of this accelerator, to make it more and more reliable and also we have to improve radiographic characteristics. There are two ways to obtain better performances of this installation. The first one is completely associated to electron beam – X-ray conversion and we don't speak about that here. The second one, concerns essentially the accelerator and the physic of the beam transport.

In this paper we present the status of the AIRIX accelerator. We tackle in particular evolutions made on the injector and the impact on the BBU that we are waiting for. We will see also that the beam centering is quiet repetitive.

2 THE INJECTOR

The injector can extract a 3.5 kA, 4 MeV, 60 ns electron pulse. Because of the evolution of the radiographic needs and to minimise the risks of ions desorption from the final target on the focal spot, we work, in routine at 2 kA [1]. In that way, the nominal value for the electron beam energy on the injector is 3.8 MeV.

The distance between the accelerator and the injector is quiet long (≈ 2m). The shape on the current profile changes along this drift tube (figure 1) because of the low energy of the electrons that constitute the rise and the fall time.

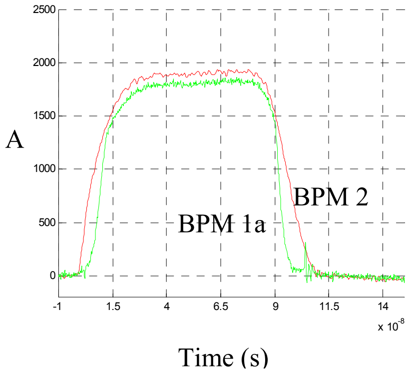

Figure 1: The evolution of the shape of the current between the injector and the accelerator.

One way to minimise the amplification of the BBU oscillations is to preserve this rise time at the entrance of the accelerator. To do that, we have installed, but not yet tested, a new solenoïde, that will minimise the electron losses. On the two next figures we have plotted the ENV code [2] calculation made for a current of 3.1 kA, with and without this coil. We can see that for the nominal value of the electron energy, the entrance of the beam in the accelerator is more smooth.

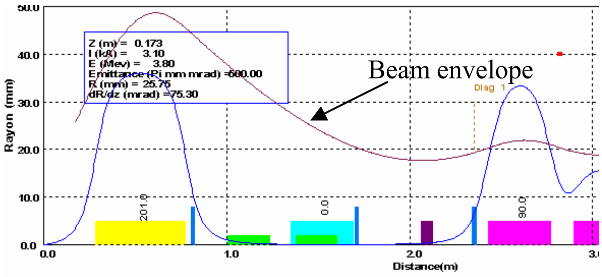

Figure 2a: beam transport between the injector and the accelerator

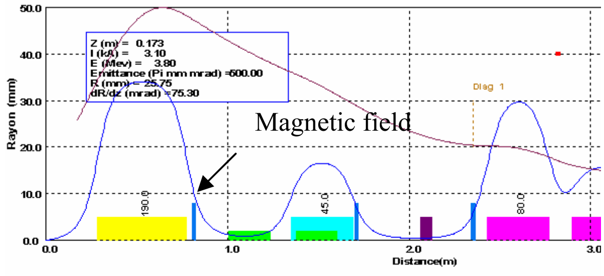

Figure 2b: beam transport between the injector and the accelerator, using the new coil (45 A)

3 THE ACCELERATOR

The accelerator has been also designed to accelerate the beam from 4 MeV up to 20 MeV. To prevent eventual breakdown on the induction cells, we use a 240 kV pulse per cell, instead of 250 kV. Finally the electron energy that is transported until the target, is 19.2 MeV.

3.1 Accelerator synchronisation

Day after day the trigger of the H.V. generator can sensitively change. So the acceleration along the machine can affect the electron beam spectrum that will be transported and focused (figure 3).

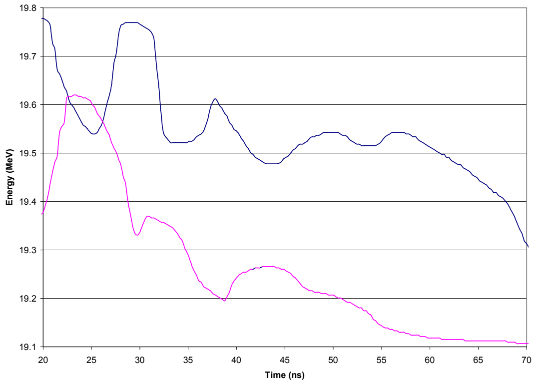

Figure 3 : Effect of H.V. generators Synchronisation on beam spectrum

To improve this synchronisation, we have defined a procedure based on the calculation of a time basis on which we can represent electron beam signal and induction cells signal.

Characteristics times [3] of each signal are determined with the time frequency representation. We have experimentally demonstrated, with an absolute time resolved spectrometer that the beam current signal has to be time centered with the H.V. cells pulse, as to ensure a monoenergetic spectrum ($E = \bar{E} \pm 1\%$ along 60 ns) for the beam pulse. In the procedure, now made in routine, we calculate the time shift between the beam and the H.V. generators, and minimise it by adjusting the trigger delay of the generators. That phase needs only five iterations to converge to an optimum synchronisation.

3.2 Beam centering reproducibility

To prepare a hydroshot, we need to run the machine each day. The total number of machine shots is arround 2000 per year. In this process, we ensure that the beam is well centered from the injector until the target. The reproducibility of this machine is quiet good and we have to use regularly our beam centering procedure at the entrance of the accelerator. On the next figure we can see the stability of the transverse position of the beam centroïde at the entrance and the exit of the accelerator measured with the beam position monitors (BPM). During those 109 shots plotted, that were made along 16 days, the beam is entering the accelerator at the position:

$$x = y = -0.3 \text{ mm} \pm 0.1 \text{ mm}$$

This is one image of the reproducibility of the injector. At the exit of the accelerator, the beam position is:

$$x = 0.7 \text{ mm} \pm 0.3 \text{ mm}; \quad y = 0.6 \text{ mm} \pm 0.2 \text{ mm}$$

This is also one measurement of the accelerator stability or the reproducibility of the 256 parameters of the accelerator: the axial and transverse magnetic fields and the cells high voltage.

Figure 4: position of the electron beam centroïde at the entrance and at the exit of the accelerator.

3.3 BBU amplification

The transverse oscillations caused by the Beam break up instability is intrinsic to this kind of accelerator. Those oscillations are more important if we work at higher current. On the figure 5, we have plotted the evolution of BBU amplitude oscillations measured by the BPM placed between each block of four cells. I those examples, the beam current is 3.1 kA. Between two shots, that are a priori equivalent (all the different parameters of the machine are equal), we can obtain substantial differences for this amplification.

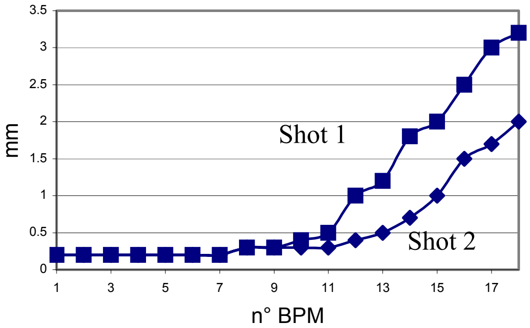

Figure 5: Growth of the amplitude of BBU oscillations

The differences that we have detected is the position of the beam centroïde from the third cell block of the accelerator. In the shot 1, the position of the electron beam centroïde is less than 1 mm in the first half of the accelerator and less than 2 mm in the second half. In the shot 2, the electron beam centroïde can reach 4 mm in the accelerator. Rather than centering the beam along the accelerator, we have to find a method to minimize the BBU oscillations as to obtain in routine, shots similar to the shot 2. Those oscillations can have a direct incidence on the focal spot.

4 THE PREDICTIVE MAINTENANCE

AIRIX is a machine used for flash X-ray radiography. This accelerator is only a tool for detonic experiments. Those experiment are unique and need a very reproducible focal spot as small as possible. When we initiate an hydroshot AIRIX must deliver the good focal spot at the good time. This is the illustration to say that there is a big effort done to survey this installation and to prevent each evolution or degradation each time that is possible [4].

To guaranty optimal performances during the experimentation, we must be able to characterize the functioning state of the installation. This is done by improving and developing the diagnosis tools and the available information analysis to optimize the functioning diagnostic and so the maintenance plan. On each shot, about 300 signals are recorded and they permit an efficient diagnostic of the machine. Using the different visualization mode of the signals (time, frequency and time-frequency), we extract the useful parameters for the functioning diagnosis. Generally redundant, those information are reduced with data mining algorithms (PCA, CCA) in order to track the most important part. With all the measurements realized during the first functioning year of the facility, we can create a learning base. We have developed a classifier based on a RBF neural net with an original approach of its construction. This one combines 2 unsupervised clustering algorithms, the fuzzy-c-means and a hierarchical tree. This two levels clustering strategy permits to construct and to initialize the RBF net from unsupervised data. This procedure is extended to take into account eventual new classes which are representative of new functioning states (correct or failure). The presented results show the improvement due of those methods on the installation operations such as performance optimization and development of a predictive maintenance for certain components.

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