NUKLEONIKA 2003;48(Supplement 2):S155–S158

Recent developments for high intensity beams at GANIL

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Abstract In December 2001, a 5 kW beam was accelerated for the first time at GANIL. This performance was achieved after the increase of SSC2 dee voltage from 170 kV to 200 kV. Moreover, several technical developments have been done, to improve the operation with high intensity beams, and a new electrostatic deflector is under construction in order to reduce losses and activation at the exit of SSC2. This paper presents an overview of these works and the main results on the last accelerated beams.

Key words cyclotrons • diagnostics • electrostatic deflector • RF system • high intensity beam

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Received: 26 November 2002

Introduction

In 2001–2002, several new results have been obtained and equipment development performed, in the frame of both projects: "6 kW beam acceleration" and "operation with 2 kW intensity beams":
- acceleration of a 5 kW argon beam for the first time at GANIL, in December 2001, with a SSC2 dee voltage of 200 kV (instead of 160 kV for the previous tests);
- operation of the SSC2 cavities at 230 kV in CW mode;
- installation of a new radial mobile probe in the compact injector cyclotron; it can support higher thermal powers, up to 200 W for a 1 MeV/A beam, in particular during machine studies with high intensity beams in the injector;
- development of a new chopper, due to the necessity of tuning the accelerator without modifying the peak intensity because of space charge effects, thus without pepper pots;
- construction of thinner pre-septum and septum for the SSC2 electrostatic deflector, in order to reduce both the losses on this equipment and its activation (replacement of copper pre-septum by a tungsten one);
- improvements of the accelerator security control system, and extension of high power beam transport towards some experimental areas.

Accelerator of a 5 kW beam

The argon beam profile presented in Fig. 1 has been registered in the extraction region of CSS2, and corresponds to the last accelerated turns, with a RF voltage of 200 kV. On the Figure both curves correspond to 2 different tunings for the rebuncher R2 (placed upstream of SSC2 to optimise the injected beam phase).

With this tuning, the overall transmission of the cyclotron is equal to 97% (the 3% losses are located on the

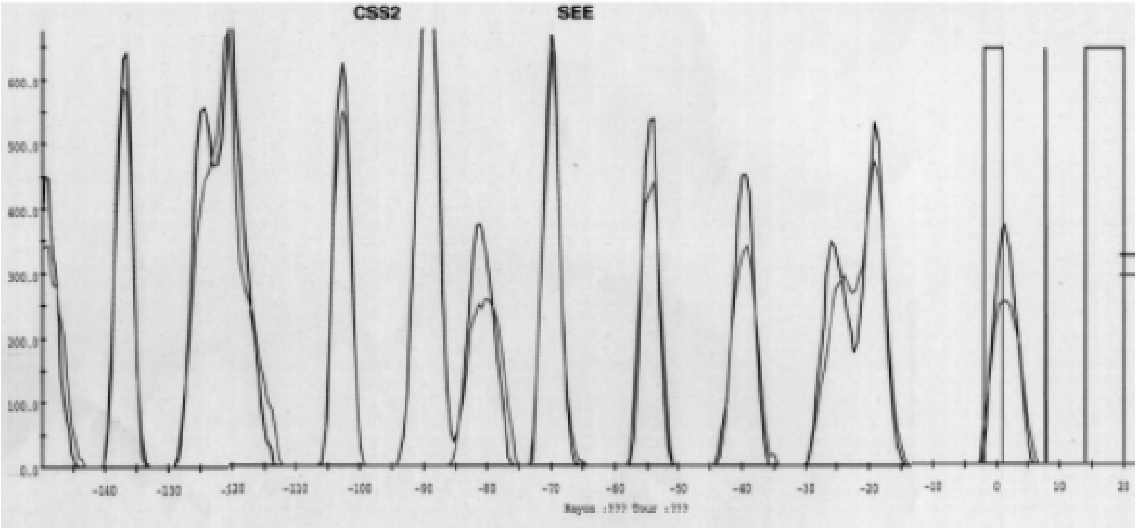

Fig. 1. Turn pattern of a 5 kW argon beam in the extraction region of SSC2.

electrostatic deflector pre-septum), and the ejected beam intensity equal to 26 μA, corresponding to a thermal power of 5 kW for a 95 MeV/A argon beam.

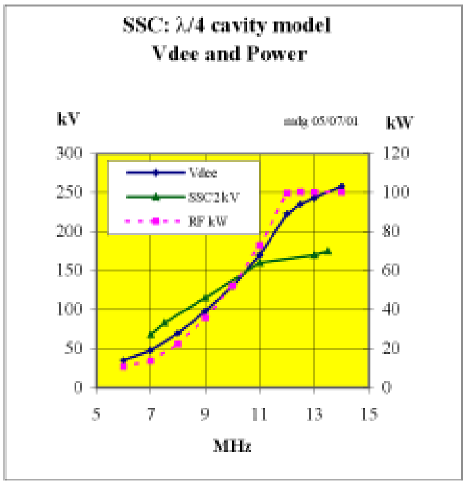

Fig. 2. Dee voltage law including the power limitations.

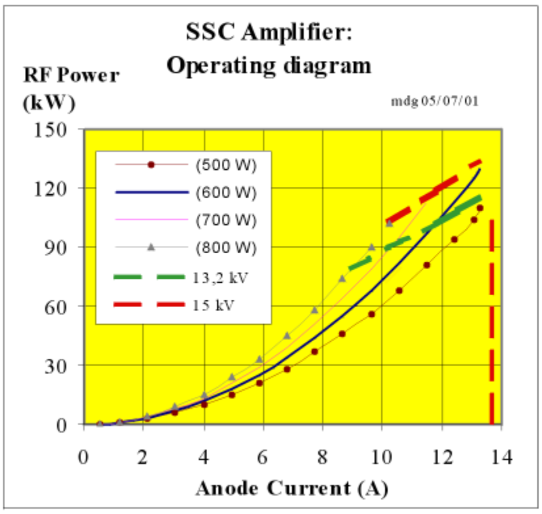

Fig. 3. Operating diagram of the 100 kW amplifiers.

Increase of the SSC2 dee voltage

The SSC2 dee voltage had been operated at 170 kV (@13.45 MHz), for many years, as there had been no need for higher values. When ion beam powers were increased up to several kW, space charge effects appeared in SSC2 [2], mainly due to turn overlap. Thus, an increase in the dee voltage was needed and a detailed study of the possible performances of the SSC cavities was done [3], which confirmed that they could reach voltages as high as 250 kV, at high frequency, 13.45 MHz (Fig. 2). Furthermore, the operating diagram of the 100 kW amplifiers (Fig. 3) was obtained in order to estimate the required RF power, with the available measurement points.

After a new tuning of the amplifiers on a 600 Ohm operating point, 210 kV were obtained on both cavities without any problem, which allowed to accelerate a 5 kW beam. Some tests were also performed at 230 kV during a few hours, value corresponding to the accelerating needed voltage for a 6 kW beam. Moreover, some X-ray measurements confirmed that the north cavity, that seemed to have a "strange" behaviour, had a real voltage 10–15% higher that the south one (which proofs that it can already be operated around 230–240 kV in CW operation).

The new chopper

Principle of the chopper

An action of the chopper on the beam is presented in Fig. 4.

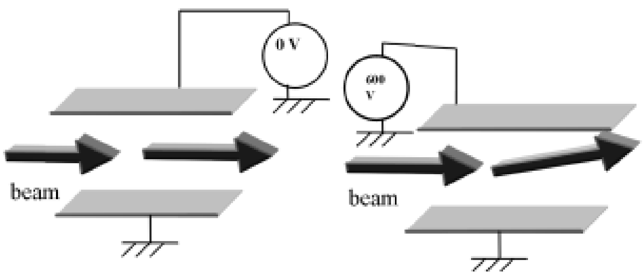

Fig. 4. Action of the chopper on the beam.

Former chopper principle

From 91% to 40%, T is constant (1.887 ms) and t varies. From 1/4 to 1/128, T varies (↗120.75 ms) and t is constant (943 µs).

Limited to 1/128, because incompatible with the diagnostics operation (Figs. 4 and 5).

The need of a new chopper appeared when space charge forces were put in evidence.

Low intensity beam tunings had to be performed with a chopper (and not with pepper-pots), and thus one had to

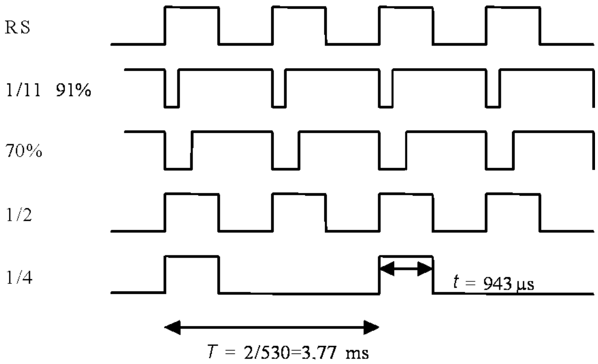

Fig. 5. Time structure of the former chopper.

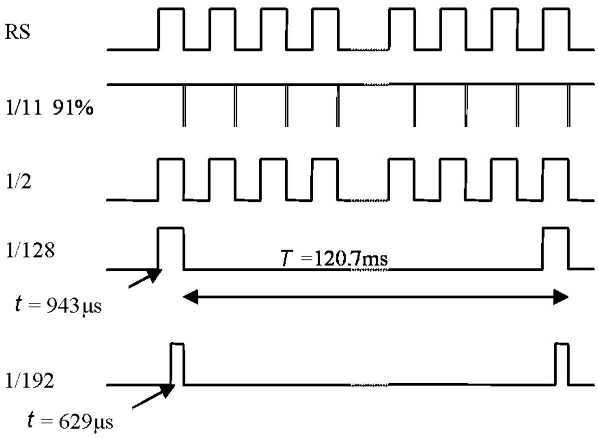

Fig. 6. Time structure of the new chopper.

decrease the chopping rate down to 1/1000, in order to insert wire beam profile monitors during the tunings.

New "mixed" chopper [4]:

– down to 1/128, works as the former chopper;
– from 1/128 down to 1/1024, T is constant (120.75 ms) and t varies (from 943 s) (Fig. 6);
– compatible with most of the diagnostics to 118 µ.

New radial probe in the injector cyclotron

The injector cyclotron radial probe has been redesigned (Figs. 7 and 8), in order to stand a higher thermal power, 200 W for a 1 MeV/A beam [1].

Moreover, 2 diagnostics have been added ("high" and "low"), in order to study the vertical oscillations and focusing of the beam, particularly with very high intensity beams. Nevertheless, up to now, the intensity which can be injected into the cyclotron is quite limited (V 50 µA), due to the lack of a rebuncher placed upstream of the inflector.

SSC2 electrostatic deflector modifications

The pre-septum has been redesigned to reduce beam losses (thickness = 1 mm instead of 2 mm), and the thin plate material has been changed from copper to tungsten, in order to reduce in particular the long term activation of this equipment. The cooling circuits have been redesigned (maximum beam losses will be of the order of 300 watts, but everything is designed for supporting 600 watts) as well as the whole mechanical supporting structure. The copper septum thickness had to be reduced at the entrance of the deflector (from 1 mm to 0.5 mm), while the thickness at the exit remains the same – 3 mm. A scheme of this new system is presented in Fig. 9.

Security control system

The security control system has been made more reliable during these last years, and has been extended to some experimental areas, where secondary beams are produced by different methods.

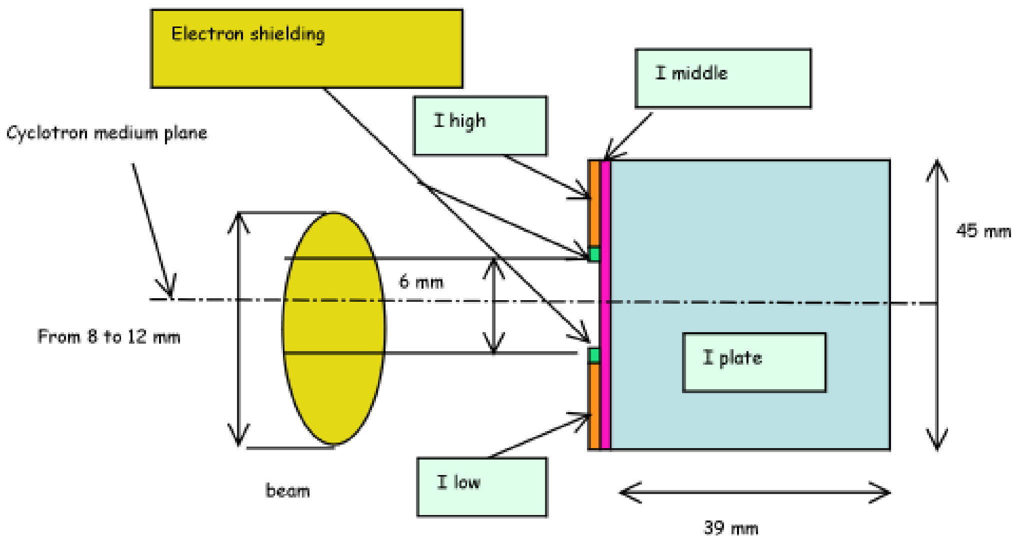

Fig. 7. Principle of the beam current measurements on the probe.

Fig. 8. Picture of the radial probe.

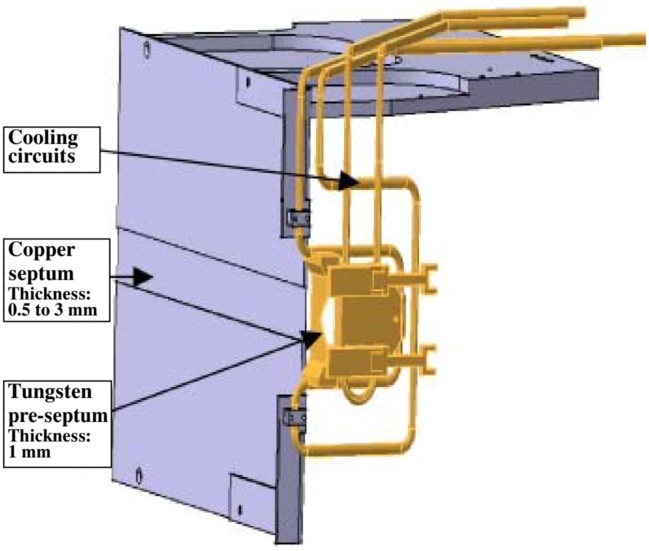

Fig. 9. Scheme of the new septum.

Loss detection diagnostics and differential intensity transformers (Fig. 10) have been added in these experimental lines, to get the possibility of transporting several kW of beam (this mode was not considered at all when the intensity increase project started).

Conclusion

During the last years, several technical improvements have been performed on the GANIL accelerators, for the transport of high intensity beams (2 kW), and the production of these beams is now a routine operation.

When Spiral was allowed to start, one year ago, a 1.5 kW beam was sent on the production target, from the very first days, with a very good stability and reliability.

Meanwhile, the SSC2 RF systems were tuned to obtain higher voltages, which gave the ability to accelerate a 5 kW beam.

As soon as 6 kW targets are ready for Spiral operation, a 6 kW beam will be produced, and the different measurements made both on the RF systems at 230 kV, and on the 5 kW beam, let think that no additional difficulty should be encountered.

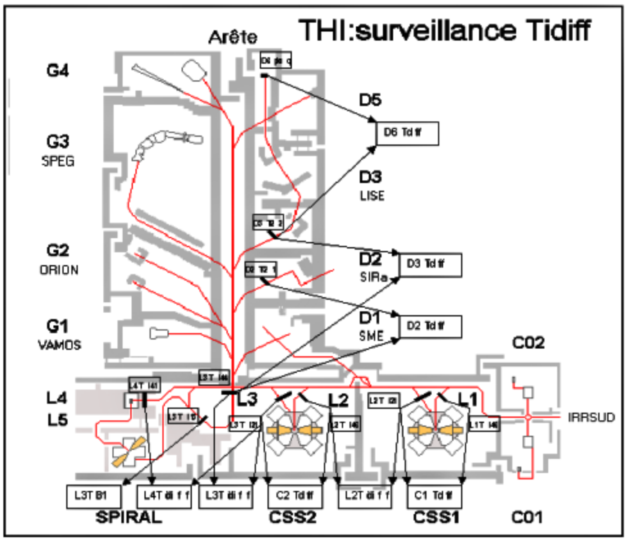

Fig. 10. Loss detection diagnostics and differential intensity transformers in the accelerator complex.

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