

First experience with the operation of the GTS-LHC ion source at 18 GHz

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Abstract

The GTS-LHC ion source delivers the heavy ion beam, in preparation for the ion collision experiments at CERN. The source was operating up to now with a microwave frequency of 14.5 GHz, in the afterglow mode, for the commissioning of the injector chain of the LHC. Tests have been made with injection of microwaves at 18 GHz, and the first results and experience are presented in this paper.

INTRODUCTION

Within the last years the ion injector chain for the Large Hadron Collider (LHC) was successful commissioned [1] with the so called “early” beam. This beam is ready to be used for the first heavy ion experiments at the LHC.

The goal of the frequency change was to ease the operation and have some margin for the “nominal” beam.

The main difference from the source and linac point of view between the “early” and the “nominal” beam is the number of shots need to be stacked in the following machine (Low Energy Ion Ring - LEIR). An increased intensity from the source reduces the number of shots necessary and simplifies the operation of LEIR.

OPERATION AT 14.5 GHz

For standard operation the source has used a microwave frequency of 14.5 GHz up to now[2]. All the commissioning of the ion injector chain for the LHC was done in this operation mode.

For the injection of the beam into the next synchrotron (LEIR) a flat top of approximately 200 μ s is needed. The source pulses at 10 Hz with 50% duty factor for the microwave heating and is tuned in an afterglow-mode of operation.

Beam intensity in an individual charge state is measured from the source using Faraday Cup 2 (see Fig. 1). For operational optimization of the source for the linac, it is critical to optimize firstly in Faraday Cup 3, after the RFQ. It is often the case that the optimization of beam on Faraday Cup 2 can be far from the best optimization on Faraday Cup 3 (even after thorough tuning of the intermediate elements). Finally the

real figure of merit is the beam intensity from the full Linac, into the final stripped ion (see also [3]).

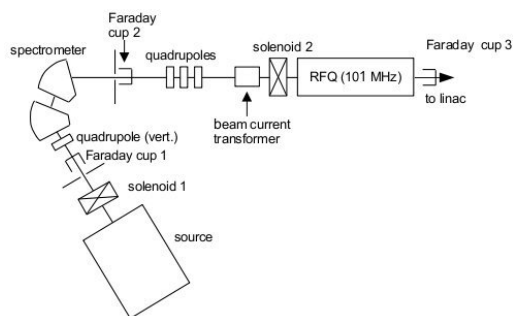


Figure 1: Sketch of the Low Energy Beam Transport (LEBT) of Linac3.

At the end of the linac, after a stripper and a spectrometer, the current is measured with a beam transformer.

Due to a better understanding and a careful tuning the source performance could be increased over the last years from around 100 e μ A of Pb²⁹⁺ to presently \sim 131 e μ A measured after the RFQ. This results at the end of Linac3 in a maximum current of \sim 31 e μ A of Pb⁵⁴⁺.

Figure 2 shows a charge state distribution when the beam was optimised into Faraday Cup 2. This was a peak performance, and did not deliver the maximum performance from the linac.

Typical conditions for operation at 14.5 GHz are: RF power of 540 W, bias disk voltage of -390 V (pulsed during the afterglow), extraction voltage of 18.52 kV, average drain current of 1.7 mA and solenoid settings of 1260 A/370 A/1200 A (injection/central/extraction coil) leading to a $B_{\max} = 1.3$ T at extraction.

Under this conditions a stable beam can be delivered for a period of up to two weeks. Then the oven has to be refilled. The overall intensity variation is in the range of 10%. The source has to be fine tuned several times per day to keep this level.

OPERATION AT 18 GHz

For the ECR ion sources several scaling laws are known and well tested [4]. One of them predicts that the extracted current for a certain charge state is proportional to the square of the frequency ($I_q \propto \omega^2$). If

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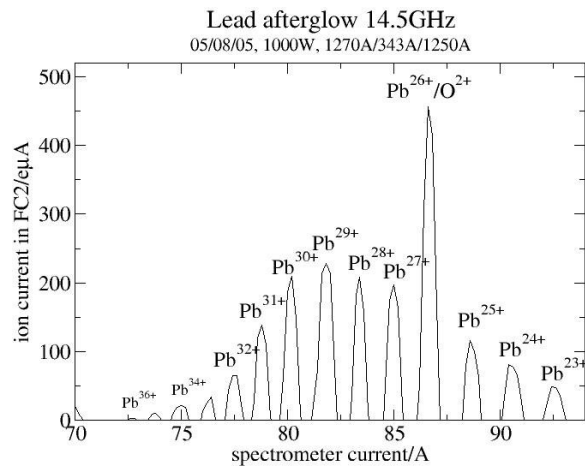


Figure 2: Lead charge state distribution from the source at 14.5 GHz operation (extraction voltage 20.07 kV).

one takes this into account the change from 14.5 GHz to 18 GHz should give than an increase of around 50%.

The magnetic structure of the GTS-LHC source was designed in a way that the source can run also with a microwave frequency of 18 GHz. In the first half of 2008 a short period was dedicated to test the source with 18 GHz. The results of this test are preliminary because they are the result of only one week of source operation.

In the start-up phase it was found that the HT break of the waveguide had to be modified for 18 GHz (see [5] for the theoretical background).

For the 14.5 GHz case the waveguide flanges are flat at both sides of the HT break and at this frequency the leakage of radiation is neglectable.

At 18 GHz the leakage was very high. One of the flat waveguide flanges was replaced with a grooved one, reducing the leakage to a acceptable level. But due to this modification now $\sim 10\%$ of the power is directly reflected at the HT break back to the generator. The addition of a tuner in this section of the waveguide could reduce this reflected power to nearly zero. This modification will be done in the future.

Figure 3 shows the resulting charge state distribution. Typical conditions for operation at 18 GHz are: RF power of 1994 W, bias disk voltage of -445 V, extraction voltage of 18.52 kV, drain current of 1.7 mA and solenoid settings of 1270 A/330 A/1260 A (injection/central/extraction coil). Compared to the 14.5 GHz case this is around 4-times the RF power, a higher bias disk voltage and a higher field in the extraction coil. Otherwise only minor changes.

With 18 GHz the source is a bit more difficult to tune to a stable mode of operation. Sometimes it jumps into a mode where the intensity varies very regularly between 0 and 100% with a period of several seconds. The reason for this mode is not understood and it is

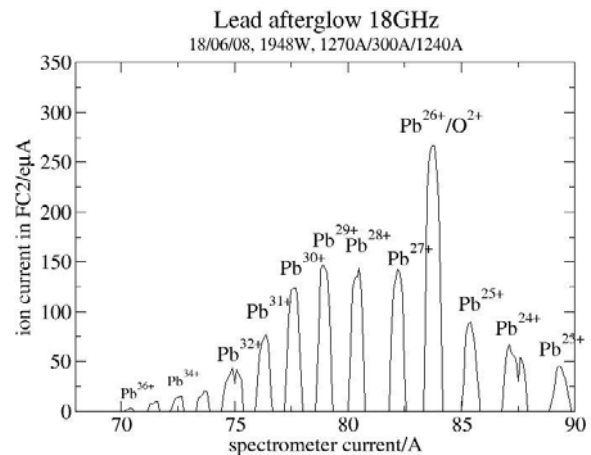


Figure 3: Lead charge state distribution from the source at 18 GHz operation (extraction voltage 18.52 kV).

very difficult to come back to a stable mode.

The maximum Pb²⁹⁺ current measured after the RFQ up to now is 136 μ A, only a small increase of the current compared to the 14.5 GHz case.

Quadrupole scan measurements of the emittance (the last quadrupole in the triplet before the RFQ was used for this, see Fig. 1) showed no appreciable difference of the emittance between the 14.5 GHz and 18 GHz case. But a scraping of the beam in the beam line cannot be excluded.

On the other hand not all source parameters could be optimised. One of the critical parameters is the position of the oven, relative to the plasma. The frequency change moves the plasma, causing additional heating of the oven, which changes the lead vapour pressure[6].

For a period of 8 hours the source showed a similar beam stability as for the 14.5 GHz case.

FREQUENCY MIXING

The use of two frequencies has increased the beam intensity of other sources[4].

The injection system of the GTS-LHC source includes two waveguides, in addition to a fixed power at 18 GHz a variable power at 14.5 GHz could be injected into the source.

Figure 4 shows the result of an small additional power at 14.5 GHz added to a fixed high power at 18 GHz. Already a small fraction of microwave power at 14.5 GHz reduced the intensity of the Pb²⁹⁺ ion beam. No setting with improvements could be found.

CONCLUSIONS

The GTS-LHC source can operate at 18 GHz. The expected improvements could not be found yet, but not all parameters could be checked in the limited

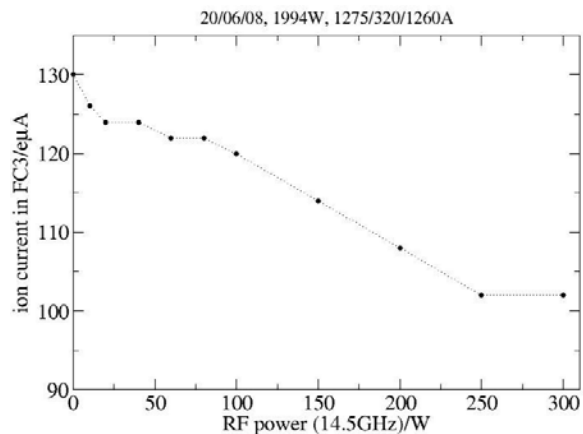


Figure 4: Mixing of a fixed power of 18 GHz (1994 W) with a variable power of 14.5 GHz.

time. In parallel with the setting up of the ion injector chain next year further source studies are planned to improve the present situation.

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