CHOPPER 500 STATUS REPORT

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Abstract

The production of consecutive accelerated bunches with a separation time of up to 200 ns and a width of 500 ps FWHM, is the goal of this new chopping beam system. The chopper 500 should be cut the present length of the accelerated beam bunches, delivered from the superconducting cyclotron, from 1.5э2 ns to 0.5 ns. Up to now all the components of the system are ready. The ¼ ς resonator, the coupling capacitor, the 3”1/8 coaxial line, the 50 kW final stage RF amplifier, the driver pre-amplifier, the DDS frequency synthesizer, are on site. Low and high power test are in progress on the components of the chopper system. All the technical performances, the experimental results, together with the numerical simulations, will be presented in this paper.

DESCRIPTION OF THE SYSTEM

Two deflecting plates, followed by a pair of selection slits placed along the output beam line of the cyclotron, are the core of the entire chopper 500 system[1]. The figure below shows the schematic of the chopper.

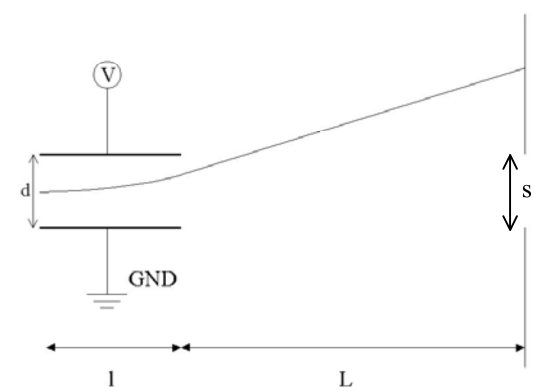

Figure 1: The schematic layout of the chopper 500

Currently delivering a beam bunch less than 0.7 ns FWHM costs a lot in terms of time and wasted beam current. The reduction of the total output current is more than factor 10 and the fine tuning of the phase slits, the adjustment of the axial buncher, the position of the electrostatic deflectors together with a fine setting of phase between the RF cavities are required. While the separation time of 200 ns is ensured by the already installed H.E. Chopper [2]. The new chopper 500 should resume in the same device both functions, cut the bunch tail and increase separation time. To design properly the chopper it was necessary to match the short time bunch lenght time with the high speed of the beam particle. To select a beam bunch of 0.5ns a high frequency voltage is applied to induce a fast variation of the electric field at a time interval of ±0.25ns during the passage of the particles. But the high frequency means short ης and therefore upper limit on the usable electrode length. The harmonic frequency between 2э4 is a compromise achieved between the need for an electrode length *l*=ης/2 as long as is possible and the highest frequency in order to minimise peak voltage. The ης is the usual product connecting the RF and ion speed. Assuming a typical phase acceptance of 30° RF for our cyclotron, means that a chopper performance in relation to this time interval is capable of sweeping the beam particles onto the collimator slits wich have to select a narrow phase interval between 3°-9° of the RF cyclotron. We assume an electrode lenght of 400mm, d=50 mm is the distance between the electrodes and the slit aperture a peak voltage of 200kV enough to sweep the unwanted beam on the slits, a distance L=3.5 m, a slit aperture of 6 mm. For all the above parameters the right frequency bandwidth for the cavity and the RF amplifier is between 65 and 110 MHz. The other goal of the chopper is increase the separation time between the bunches delivered to the users by suppression of the 1,2,3 or 4 unwanted bunches. Currently the superconducting cyclotron operates in harmonic 2. The radiofrequency range of the cyclotron, 15 – 48 MHz, gives a separation time between 20 and 66 ns, but if we want a separation time of 100-200 ns among the bunches, a suppression of some bunches is necessary. If we operate the chopper at an integer harmonic respect the cyclotron frequency we are able to cut each bunch at 0.5 nsec. This is the first goal. The solution to achieve the second goal is to choose a harmonic not integer multiple of the fundamental RF cyclotron. In fig. 2, an example of this choice is given.

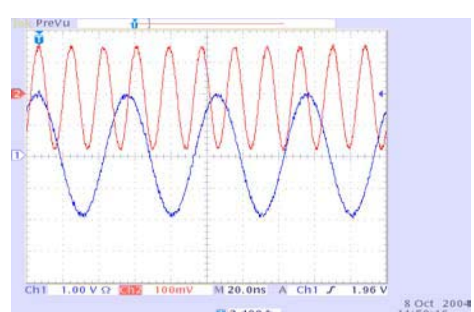

Figure 2: Cyclotron and chopper sinusoids

The blue sinusoidal signal is the RF of the cyclotron, the red sinusoid is the chopper harmonic. The red one is 3.25 times higher than the blue one. This means that there is a common subharmonic frequency wich is the subharmonic 4 and 13 of the cyclotron and chopper frequency respectively, in every four periods of RF cyclotron the two waves cross at the same phase. In the other three periods the following bunch will cross with a phase difference which increase of 90° per RF cyclotron period. So the chopper is able to remove one bunch over two. In order to reach the right separation time we can decide this multiplication factor in the frequency operative range of the chopper.

MAIN COMPONENTS OF THE SYSTEM

All the main components of the system are on site. The final composition of the system is shown in fig. 3. Each module has been tested and the results are given in the following paragraphs.

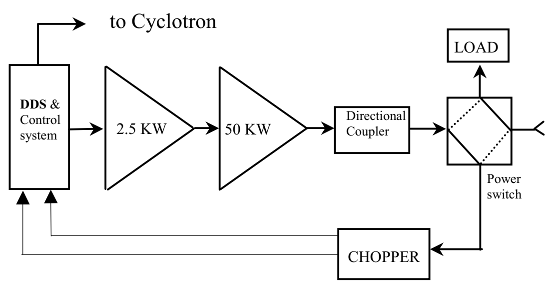

Figure 3: Block diagram of the chopper 500 system

DDS frequency synthesizer

This synthesizer is a multiple frequencies generator based on the direct digital synthesis technique. The DDS generator allows the generation of sinusoidal output signals, highly stable in frequency, phase and amplitude respectively, without any problem between integer or non integer harmonic. For two years a first DDS prototype has been successfully installed to drive the RF cyclotron, the axial buncher and the present H.E. chopper. The system, based on the AD9852, a commercial electronic component, is very versatile. The extremely low switching time together with the possibility to modulate the output sinusoid in amplitude and phase, makes the DDS as a complete control RF system too [3].

RF amplifiers

The chains of amplification take the few milliwatts of the DDS synthesizer signal to the 50 kW of the final stage RF amplifier. This final power should be enough to reach the right voltage on the electrode of the cavity in order to accomplish 0.5ns of beam bunch and 200 ns of separation time. The first stage, is a broadband linear amplifier. The frequency range is between 10kHz and 220 MHz, the gain is 64dB, the maximum output power is 2500W (1750W, linear @ 1dB compression). Another choice for the driver is a dedicated 1kW solid state amplifier. It is an adapted FM commercial amplifier. It will be used for most of the time when it is not necessary to reach the maximum 50kW power. The final stage come from the FM broadcast experience also. It was assembled at home to adapt range of frequency and main characteristics to our purposes. The bandwidth becomes 60϶110 MHz, the gain is 16dB, the available output power CW is 50kW. The open cabinet of the final stage, based on the Thomson TH535 tetrode, is shown in fig. 4.

Figure 4: the internal view of final stage amplifier

All the amplifiers have been tested at full power on the dummy load and on a prototype of RFQ cavity. The RFQ is part of the new project known as SPIRAL2 [4]. The test of this RFQ prototype was been done in our laboratory during September 2004. For four weeks the RFQ prototype cavity was been conditioned at 89 MHz from few watts to 50 kW. The experience was carried out thanks to a collaboration between the LNS-Catania, CEA-Saclay and GANIL-Caen Institutes. The test fully accomplished the targets. On our side we tested the amplifiers to a proper cavity load, before the installation of the chopper cavity. On the CEA-Ganil side the test was a practical starting point to verify the project design of the RFQ and test the RF join.

Between the load and the output stage of the final amplifier there is a power coaxial switch. It is a four port device with two operative positions. One position connects the amplifier to the cavity, the other allows the connection between the same amplifier to the dummy load and, through a coaxial adapter the input cavity directly to a network or spectrum analyser or other instrument to study the cavity without any other component before it.

Cavity and coupling capacitor

The cavity of the chopper 500 is the last component to be tested. We have already finished the low power test and we are confident to begin the full power test soon. Between the real measuring campaign and the simulation data of the cavity there is a good agreement. Different calculations have been made, from the sophisticated 3 dimensional electromagnetic simulators such as H.F.S.S. and MicroWave Studio [5] to the more simple Mathcad. A certain trend of convergence to the practical test bench results has been achieved. In the relation between the measurement and simulation we need to consider the weight of the real mechanical machinery. An example of the simulation result is given in figure 5. The mesh of the cavity structure is given, together with the longitudinal electric field distribution at 106 MHz. The coupler capacitor takes part also in these simulations.

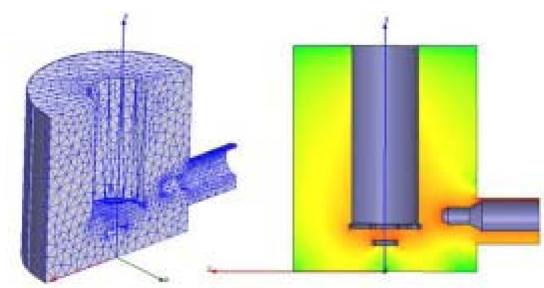

Figure 5: Mesh and distribution electric field.

The chopper 500 cavity is a ς/4 copper made coaxial resonator. It is inside a steel tank to avoid the vacuum stress pressure along the copper wall. The coupling with the final stage of the amplifier is capacitive. The position can be changed by 50 mm, enough to cover the matching for all the frequency range between 65 to 110 MHz. The simulated and measured VSWR, along the frequency range of the system, are shown in fig. 6.

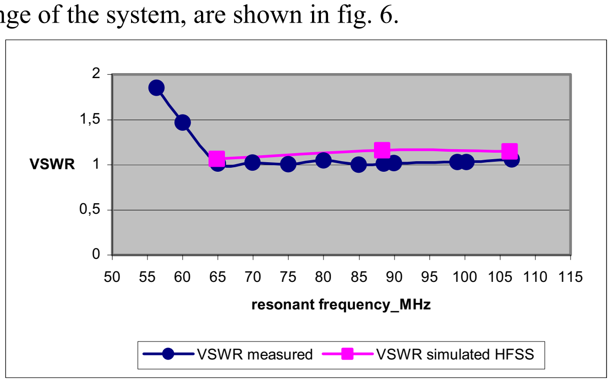

Figure 6: The measured and simulated VSWR

The measurement of the shunt resistor, using the perturbation method has been carried out at different frequencies along the bandwidth of the chopper. These results together with the available power from the RF amplifier allows 200kV on the electrodes along the entire frequency range. Fig 7 shows R_{shunt}, Q_o and RF power.

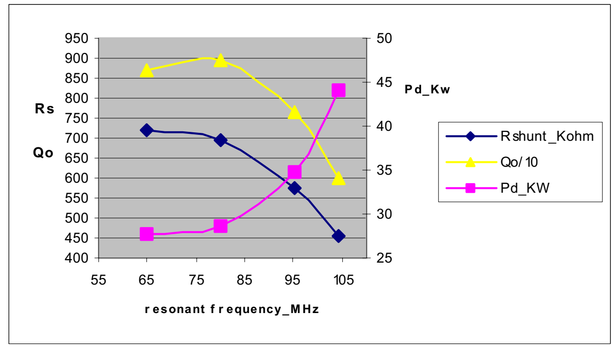

Figure 7: relation between R_{shunt}, Q_o and RF Power

The main parameter measurements of the cavity, after the tests, are summarized in table1.

Table 1: Main parameters and values

Parameters	**Value and limits**
Maximum Peak Voltage	200 kVolts
Frequency range	65϶110 MHz
Qo	6000϶9000
R shunt	450϶720 kT
Power dissipated	27϶45 kW
VSWR	< 1.1
Coupling	capacitive
Input impedance	50T on 3"1/8

CONCLUSION

All the components of the chopper 500 system are ready. The amplifiers, the drivers, the DDS generator have been tested successfully at low and full power. After the low power test also the cavity will be tested at high power. We are confident to install the chopper 500 along the extraction beam line from the cyclotron, soon.

REFERENCES

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