DEVELOPMENT OF A NEW BROADBAND ACCELERATING SYSTEM FOR THE SIS18 UPGRADE AT GSI

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Abstract

This paper describes the development of a new rf accelerating cavity based on novel magnetic alloy materials (MA-materials) for operation at harmonic number h=2 (f=0,43- to 2,8 Mhz) to provide the necessary accelerating voltage for SIS18 injector operation with high intensity heavy ion beams in a fast operation mode with three cycles per second. The acceleration system consist of three units which are able to operate independently from each other. That is important, since each ion for FAIR has to cross the h=2-rf-system and in the case of a damage a reduced operation has to be ensured. Since the cavities are filled with lossy MA-ring-cores, which are iron based Finemet FT3M ring cores from Hitachi, the cavities show a broadband behaviour and thus no cavity tuning during the acceleration ramp will be necessary. Due to the high saturation field strength of Finemet (1,2 T) the overall length of all three cavity units can be very short. This is an important feature since due to many insertions which were additionally inserted into the synchrotron ring SIS12/18 in the meantime, the available length in SIS12/18 for the cavity units is with 4 m very short.

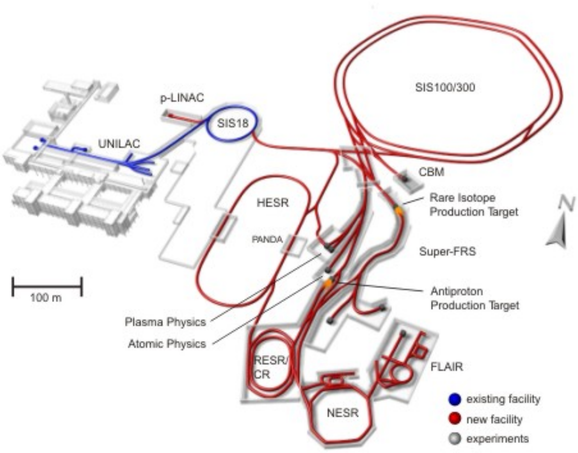

Figure 1: A schematic overview of the FAIR-facility

INTRODUCTION

The GSI Helmholtzzentrum für Schwerionenforschung GmbH Darmstadt is planning a new powerful facility named FAIR (**F**acility for **A**ntiproton and **I**on **R**esearch) [1] which includes an upgrade of the old synchrotron SIS18.

Presently the SIS18 rf – system operates at the fourth harmonic. At the end of the SIS18 upgrade program the harmonic number two system will replace one of the old cavities in order to enable a double harmonic rf operation with the remaining cavity. It is important to point out that the existing SIS18 rf system does not provide enough bucket area in order to accelerate intense bunches in the 3 Hz SIS12 mode.

REQUIREMENTS

As it was already mentioned above, due to the many insertions which were additionally implemented into the synchrotron ring SIS12/18 in the meantime, the available length in SIS12/18 for one cavity is very short.

The required length for all three units is 4 m. It is mandatory that each rf-unit can be operated and mounted independently from the others. That is important, since the reliability of the whole system should be as high as possible.

The gap voltage requirement with a bucket filling of 2/3 with space charge compensation and under beam loading is 40 kV in the frequency region of 0,43-1,6 MHz (11.4 – 200 MeV/u).

In order to leave a safety margin we demand a total voltage of not less than 50 kV without beam.

The aforementioned requirements are realizable with MA-ring-cores only, since it was carefully proved that the required length for a ferrite-system would be more than 7 m.

TYPE OF RF CAVITY

The general arrangement for one cavity unit is based on four quarter-wave magnetic-alloy-loaded coaxial lines. Two of them are excited in push-pull mode respectively and both push-pull units are connected in parallel as shown in Fig. 2.

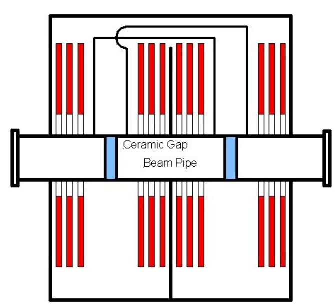

Figure 2: The scheme for one cavity unit

This arrangement is necessary due to two essential requirements. First by the resonance frequency of a half gap should settle in the region of 1,2 MHz. Second by the cavity bandwidth must be as broad as possible since the more ring cores are stringed together the more parasitic capacitances will be enclosed between the cores. The parallel connection of two gaps avoids the formation of large ring core packages. The disadvantages are the necessity of two ceramic gaps and a shunt impedance seen by the tetrode half as high as one gap without parallel connection.

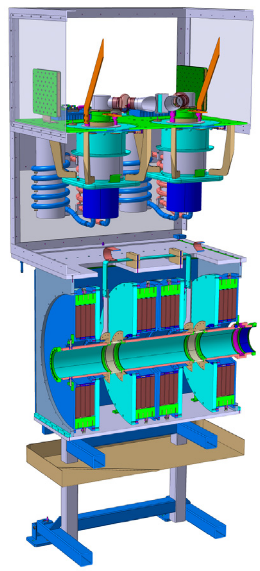

Figure 3: Broadband cavity with its power amplifier on top

Table 1: Cavity parameters for one unit

Duty cycle	100%
Frequency range with the hardest requirements	0,429 MHz – 1,6 MHz (full range 0,4-2,7 MHz)
Overall voltage	16.7 kV
Number of gaps	2
Number of ring cores per unit	16
Shunt impedance R_p per half gap (one stack of 4 ring cores) at 429 kHz	440 Ω
Parallel inductance L_p per half gap at 429 kHz	308 µH
Parallel capacitance C_p per half gap	50 pF
RF dissipation power per unit	80 kW
RF dissipation power per ring core	5 kW

As already mentioned above one cavity unit consists of two ceramic gaps and four short stacks of four Finemet FT3M ring cores from Hitachi. The stacks of cores are enclosed in pressure resistant stainless steel tanks which are closed at the gap-side by strong plates made of fiber-reinforced resin. The ring cores are cooled by mineral-oil which flows between adjacent cores. Two core stacks are connected in parallel respectively by a busbar which is directly connected to the gaps. RF-power is fed into the cavity via the busbars. Due to space problems in the synchrotron tunnel the power amplifier is mounted directly on top of the cavity. This solution keeps the service path free.

RF-POWER-APLIFIER

A schematic view of the rf power stage and the cavity is displayed in Fig. 4. The rf power is generated by two TH 537 (300 kW) tubes from Thales operating in push pull mode. During the rf pulse, both tubes will be set from C- into A-operating point by a fast MOSFET-switch. The tube stage is driven by a broadband 1 kW solid state amplifier and the power is transmitted via a ferrite loaded toroidal transformer. The grid voltage is fed to the secondary of the toroidal transformer. The transformer ratio is 1:2 and therefore a capacitively coupled resistance of 100 Ω between grid and cathode is necessary to match the secondary to the primary side. To provide safe operation during the switching time from class C- to class A-mode two grid bleeder resistors of 20 kΩ are connected between grid and ground. Balancing of both tubes can be performed individually by adjusting the voltage of the separated screen grid power supplies.

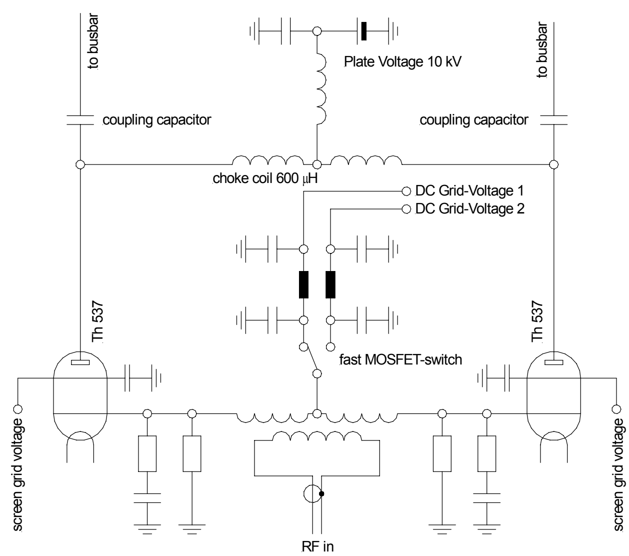

Figure 4. Schematic view on the power amplifier

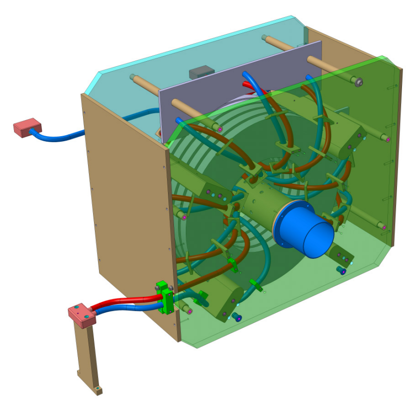

Figure 5. The design of the choke coil. The DC-current from both tubes cancel each other due to windings in opposite directions

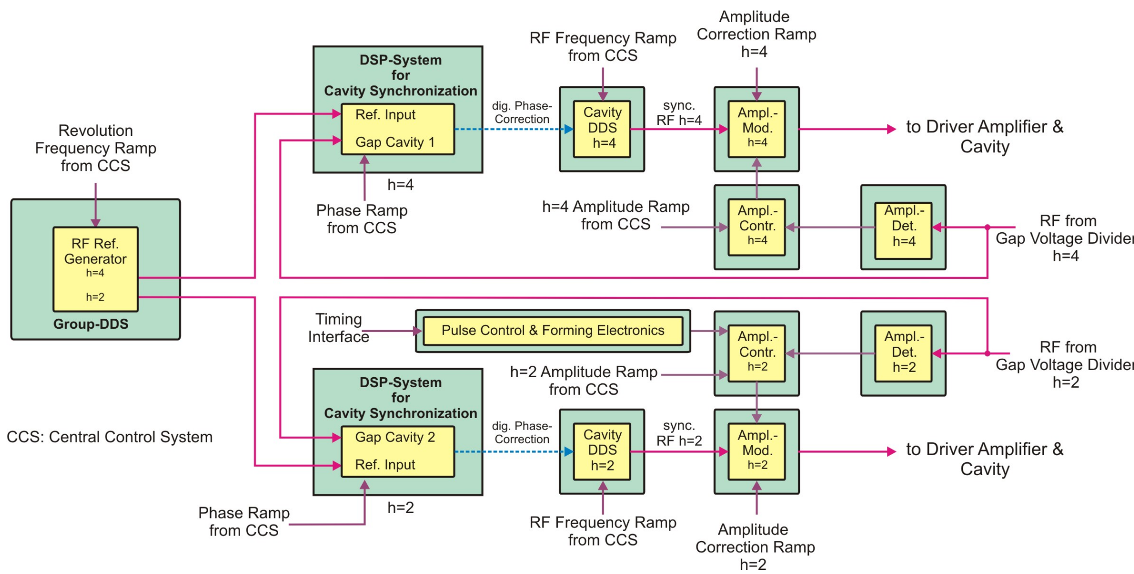

Figure 6. Low level rf system to allow double harmonic operation of h=2 broadband- and h=4 narrowband rf system

Some parts of the power amplifier are difficult to realize due to the low starting frequency of 429 kHz. For example to achieve the required inductance of 600 μH at 429 kHz for the choke coil five ferrite ring cores of large size (Ferroxcube from Phillips, ∅ 500 mm, thickness 25 mm) are necessary (see Fig. 5). Another example is the design of the screen grid capacitance. In order to get rid of unwanted rf voltage from the screen grid one has to provide a screen grid capacitor which is sufficiently large to ground the rf-currents over the whole frequency range. The capacitance must be 500 nF to ground the rf-currents safely at the lowest frequency beeing 429 kHz. The capacitor must have an intrinsic inductance as low as possible which means the capacitor should turn into an inductance at frequencies of several hundred MHz. A foil capacitor for example would turn into an inductance at a frequency of several MHz which would lead to a parasitic resonator together with the screen grid plate capacitance in the tube socket. This resonator would have a resonance frequency of several MHz and could be excited by fluctuations of the DC-current in the tube leading immediately to an instability in the power amplifier. Thus our design is a parallel arrangement of 100 ceramic barrel style capacitors of low inductance with a capacitance of 5 nF each and which are clamped between large copper plates.

LOW LEVEL SYSTEM FOR DUAL HARMONIC ACCELERATION

In Fig. 6 a schematic setup of the low level rf system is shown. From a group DDS (Direct Digital Synthesis) the rf signals for the h=2 and h=4 DSP-systems ([2], [3], [4]) (Digital Signal Processor) are distributed. These DSP-systems compare the phases of the rf-signals taken from the cavity gaps with the rf signals of the group DDS and synchronise the cavity DDS with the group DDS. Additionally phase ramps are applied to the h=2- and the h=4 DSP in order to insure the double harmonic operation. Each cavity DDS signal is fed to amplitude control unit which consists of an amplitude modulator, -controler and -detector.

Additionally the h=2-cavity system may be used as a bunch rotator which requires, compared to the usual cw-mode, a pulsed operation. Therefore a pulse control and forming electronics acts on the amplitude control of the h=2 cavity which can be activated by the timing event system.

CONCLUSION AND OUTLOOK

The design of cavity and power amplifier is finished. The supply unit was ordered in November last year at OCEM and will be delivered in October 2010. Measures to provide the required infrastructure to install the first unit is currently an ongoing task.

Machine development experiments took place at GSI in the responsibility of the GSI RF Department to run performance tests of the newly designed control loop topology for the existing SIS 18 and for the future synchrotron and storage rings at FAIR. The measurements clearly confirmed the proof the principle as well as the technical capabilities of the technical setup and the approach of generating dual harmonic buckets.

REFERENCES

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