The AGS Booster low frequency RF system*

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Abstract

An RF system has been designed to accelerate all the desired species of ions up to Gold, which will be available at β=0.048. The system will run on different harmonic numbers (h). It will start from h = 12 at injection and jump to h = 3 during the cycle. The beam will then be transferred to the high frequency RF system that will bring it to the extraction energy. The low frequency system consists of two single gap cavities that sweep from 0.6 to 2.4 MHz, with gap voltages up to 17 kV. The cavities are loaded with TDK SY7 high permeability ferrite rings. Tuning will be accomplished by changing the permeability of the ferrite with dc bias currents as high as 200 A flowing in two "figure of eight" windings. The cavity will be driven by a 200 kW push-pull tetrode power amplifier, which will be driven by remotely located solid state drivers.

Introduction, system description and parameters

The AGS Booster has two RF systems covering a frequency range from 600 kHz to 4.2 MHz. The low frequency system, also called Band II, operates on a frequency range from 600 kHz to 2.4 MHz and consists of two single-gap cavities, each capable of 17 kV. It will be used in the initial part of the heavy ion acceleration cycle. In this mode the Booster will sweep in less than one second.

The system will run two different harmonic numbers. The ions arriving from the Tandem Van de Graaff will be captured on h=12 from the Band II system and accelerated until the highest frequency available on the Band II cavities is reached. It will then be debunched, while the system is being reset to the starting frequency, recaptured on h=3 and accelerated again.

	C	Cu	Au	
A	6	63	197	
Z	6	29	79	
Q	6	21	33	
E_{inj}	7.5	2.85	1.06	MeV/u
E_{ext}	966	854	350	MeV/u
β_{inj}	0.12	0.078	0.047	
β_{ext}	0.87	0.85	0.68	
$\Delta P/P$	0.15	0.24	0.40	%
B_{inj}	0.576	0.531	0.645	kG
Bunch Area	<0.05	<0.05	<0.05	eV/u-s
P. total	54	10	3.2	10^9 part
Acc. time	< 620	< 620	< 620	ms

Table 1 - Rf parameters for a few cases of the AGS Booster Heavy Ion cycles.

The final part of the cycle will be done by Band III, which also provides for the acceleration of both polarized and non-polarized protons [1]. The latter is already installed in the Booster tunnel and it is described, together with the "bench" test results, in another paper in these proceedings [2].

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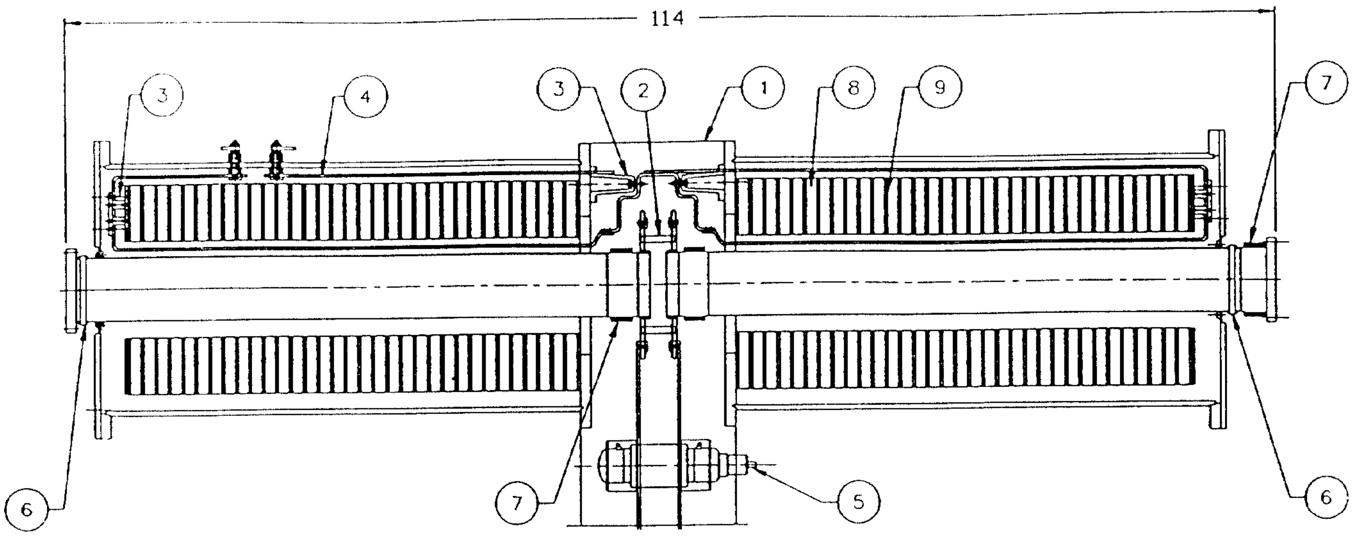

Fig. 1 - The Band II cavity. 1. RF tight enclosure; 2. Ceramic gap insulator; 3. Ceramic bias winding support; 4. DC bias winding; 5. Tuning vacuum capacitor; 6. Ceramic insulator; 7. Bellows; 8. Ferrite; 9. Cooling plate.

The Booster rf parameters are listed in Table 1. The parameters listed for Gold are in the case of the AGS fixed target program. The dB/dt is of the order of 3 T/s, whereas df/dt can be as high as 35 MHz/s. The momentum spread is induced by the rf during the non adiabatic injection. Studies on this scheme are still underway and a final set of parameters will be developed in concurrence with the results of the "bench" tests of the system. Results such as dynamic losses in the cavity, tuning system reset time and maximum tuning range available, are extremely important in choosing the best solution. Table 2 summarizes the high level system configuration.

N. of cavities	2
N. of accelerating gaps	2
Peak rf Voltage/gap	17 kV
Rms rf power/pa.	200 kW
Frequency range	0.6 - 2.4 MHz
Harmonic number	12 - 3
Duty cycle	20 %

Table 2 - Band II rf system parameters.

Cavity design

The Low Frequency RF cavity is a single gap, ferrite loaded resonator. It is not evacuated, since a ceramic gap is sealed on the beampipe. The gap also has a variable tuning capacitor that can adjust the tuning range, if needed.

Following a complete testing and evaluating program [3], the ferrite chosen for this application is the TDK SY7. Each cavity uses 66 rings of this Ni-Zn ferrite, with a relative permeability of 1100. Tuning is accomplished by saturating the ferrite to a relative permeability of 85 with a dc field applied through two buss bars, which cross-couple the two sides of the cavity, guaranteeing the push-pull operation of the system even at very low Q and decoupling the rf from the bias supply [4]. The rf field in the ferrite can be as high as 170 G, with losses up to 300 mW/cc. The rings are therefore sandwiched between water cooled copper plates. The total expected static losses are about 170 kW and due to the relatively long dimensions of each ferrite stack, the stacking order is particularly chosen trying to keep the losses in each of the rings as uniform as possible.

Since the need for ultra high vacuum ($\approx 10^{-11}$ torr) imposes the requirement for the vacuum chamber to be bakeable in the Booster ring at 200° C, the design provides electrical heaters and thermocouples built into and around the beampipe [5]. Insulating blankets are used to protect the ferrite rings from high thermal gradients and stresses. The Band II cavity is shown in Fig. 1.

Power Amplifier

The power amplifier is located in the Booster ring directly below the cavity and it is designed to deliver over 200 kW rms on a 17 kV peak accelerating voltage. It uses two EIMAC Y567B tetrodes capable of plate dissipations up to 150 kW. They are used running class AB_1 in a push-pull configuration, with grounded cathodes. The plate peak current is about 50 A, when the tubes are running at an anode voltage of 12 kV, with the screen grid at 1.1 kV and 3 A of quiescent cathode current.

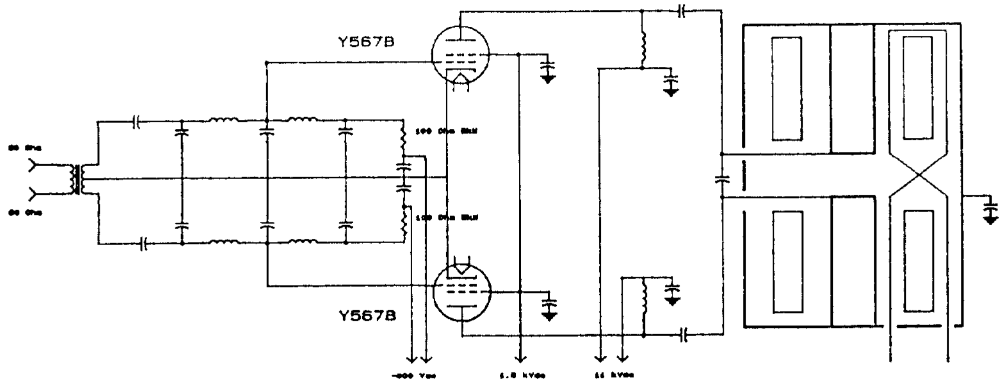

Fig. 2 - The Band II power amplifier

In the case of heavy ions, the power delivered to the beam is negligible compared to the losses in the cavity: all the power is dissipated in the ferrite.

1 kW drive power is delivered by two solid state class A amplifiers into a cross coupling and matching transformer. They are located away from the Booster ring to protect them from radiation damage. The transformer is part of the input filtering network, which is a broadband low-pass filter that includes the tube input capacitance and is terminated into two water cooled 100 Ohms dummy loads. The simplified schematic of the power amplifier and cavity system is shown in Fig. 2. The coupling to the cavity is done via DC blocking capacitors and the B^+ is brought in the amplifier through an RF blocking choke to eliminate the rf voltage affecting the anode power supply

The power amplifier is also equipped with a local control system that allows the amplifier to be operated either from the AGS main control room, the Booster ring or the building where most of the equipment is located. In the last two sites, the system can be run both in manual or automatic mode, which in sequence energizes the filament step-start, the grid, anode and screen supply and eventually tuning supply and rf drivers. The control system includes all of the required safety features and interlocks.

The cavity tuning system is designed to provide up to 200 A into the two turn bias winding. Two signals are used to perform the task: the first is an open loop program obtained from a function generator that uses a frequency-to-voltage converter as its input to create the drive signal from the low level frequency program; the second is a feedback signal coming from the output of a phase detector that compares the rf phases of the plate and grid signals. These signals are used to drive a bank of water cooled power transistors paralleled to provide the required currents.

Status

Commissioning of the Booster is underway at present with proton beams. In this phase the Band II system is not being used. The first cavity is being assembled and assembly of the first amplifier should start soon. Full development of both cavity and amplifier, their testing and installation is scheduled to be completed before the end of the year.

Acknowledgments

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