RF Accelerating System for TARNII

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Abstract

An RF accelerating system for TARN II is now completed. It produces the accelerating voltage of 2 kV for the frequency range from 0.62MHz to 7.5MHz. Several feedback loops for the control of beam capture and acceleration are prepared. In this paper, outlines of the system are presented as well as the preliminary operational results.

Introduction

At the Institute for Nuclear Study, University of Tokyo, a heavy-ion cooler synchrotron TARNII is being constructed.1 It aims the beam acceleration up to 1.1 GeV for proton and to 370 MeV/u for heavy ions of q/A=0.5. An electron cooling device and a slow extraction channel are also prepared for various beam experiments. An RF accelerating system which captures the injected beam from the injector cyclotron and accelerates the beam from the injection energy to the top energies, is now completed. Main parameters of RF systens are given in Table 1.

Table 1 RF accelerating parameters

Injection Energy	> 2.58 MeV/u
Acceleration Energy	< 1.1 Gev
Momentum spread at injection	<±0.5%
Revolution frequency	0.31- 3.75 MHz
Harmonic number	2
Acceleration frequency	0.62- 7.50 MHz
Maximum RF accelerating voltage	2kV

The lowest injection energy is 2.58 MeV/u of 20Ne4+ ions among the various ions from the SF cyclotron, corresponding to the revolution frequency of 0.307 MHz. At the top energy of 1100 MeV for protons, the revolution frequency is 3.75 MHz, thus the ratio of the lowest to the highest frequencies is thirteen. The harmonic number was chosen to be 2 and the designed acceleration frequency is 0.6 MHz to 7.5 MHz. An acceleration voltage of 2 kV is enough for the beam with 0.5 % momentum spread within the acceleration period of 3.5 sec.

RF Cavity

The RF cavity is a single-gap structure which consists of two ferrite-loaded quarter-wave coaxial resonators. In order to produce an accelerating voltage at the gap, a push-pull mode excitation of two resonators is achieved by the help of a "figure of eight" configuration of ferrite-bias windings. Choice of a ferrite material with high incremental permeability is important to realize a cavity with a very wide frequency range. We have chosen a ferrite material, TDK SY-6. The initial permeabilities of 48 ferrite rings distribute from 969 to 1214 and the average is 1093. These 48 rings are alternately stacked in the two resonators according to the order of the permiability to balance two resonators electrically. Measurements of the cavity with SY-6 ferrites rings show that a resonance frequency changes by a factor of 15.5 from 0.59 MHz to 9.18 MHz when a bias field changes from 0 AT/m to 2.59 kAT/m. The frequency of fundamental resonance, shunt impedance and Q factor are measured as a function of bias current.2

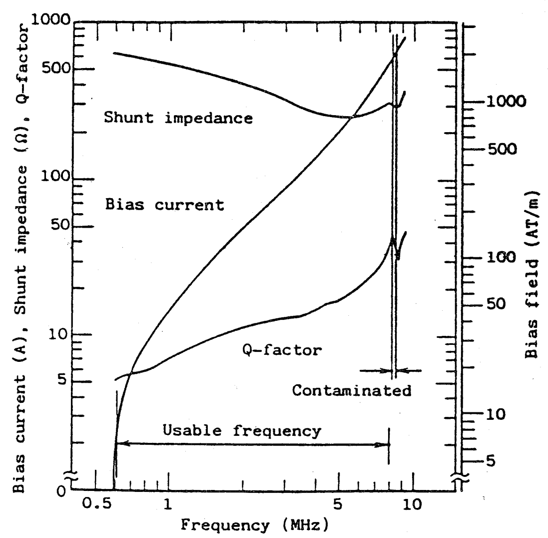

Fig. 1 Resonant frequency, shunt impedance Q-factor of cavity as a function of bias current.

(Fig. 1) The lowest value of the shunt impedcance is obtained at 250 Ω at around 5 Mhz.The final power amplifier consists of a tetrode, RS 2012 CJ of Siemens, which is capable of an anode dissipation of 18 kW. Typical operation parameters of the tube are; Anode dc is 4.7kV, Screen grid 1.2kV and control grid -100 V, and filament 7.2V, 80A, respectively.

Low level RF system

The low level RF electronic system is composed of a voltage controlled oscillator (VCO) and several feedback loops(Fig. 2). Three menory modules store the forms of frequency, voltage and bias current to be produced as a function of the magnetic field strength of the bending magnets. At every increment of 1 Gauss of the magnetic field, measured at the 25th dipole magnet for field monitoring, the calculated values of RF parameters are read from memory modules and converted into analog voltages through DAC's. These voltages are fed into a voltage controlled oscillator, an amplitude modulator and a bias current power supply, respectively. The error of bias current or equivallently the degree of detuning of cavity is detected as the phase difference between the RF signals at the grid and the plate of final power tube. It is used for the correction of resonance frequency of cavity via a hardware feedback loops (AFC). In addition, the signals of beam position (ΔR) and of the phase error ($\Delta \phi$) between beam bunch and acceleratition RF field, are fed back to the voltage controlled oscillator through several amplifiers and switching elements which determine the period of feedback control. The output RF signal of this oscillator is fed to the driver and power amplifiers through the amplitude modulator and phase shifter. On the other hand, at the injecton period the VCO is phase locked

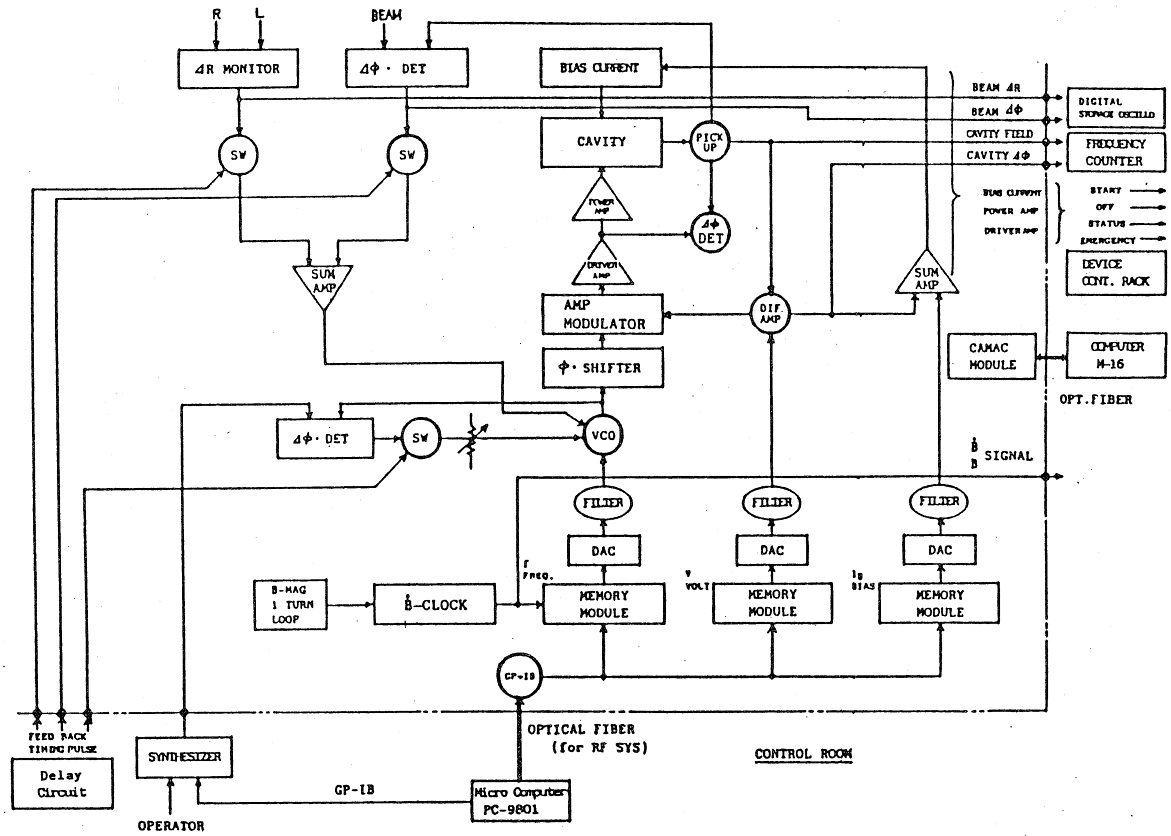

Fig.2 Block diagram of RF system for TARNII

with the RF signal from a frequency synthesizer. The frequency and voltage at this injection period are finely adujusted manually to get the maximum capture efficiency.The, block diagram of low level RF system is given in Fig. 2.

Electrostatic beam monitors are used for the measurement of beam bunch and position.3 In order to correctly detect the shape of beam bunch, an FET probe with input impedance of 100 kΩ are used as the first amplifier. With the capacitance of 100 pF beam monitor itself between the monitoring plate and the earth plate, the time constant is 10 μ sec, sufficient to reproduce the bunch shape. In Fig. 3, bunch shapes of 20 MeV proton beams captured by 1.578 MHz RF fields, are given for two RF voltages. The number of protons in one bunch is around 10^7

Timing of RF control

The timing chart of RF control is given in Fig. 3. A master pulse triggers all the start pulses of aparatus of time dependent operation through adequte delays. Examples are the start of pattern generation of bending and Q magnet currents, bump magnets for the multiturn injection and RF function generation. Three functions for RF frequency, voltage and bias current, are generated by the pulse trains from a Voltage Frequency Converter (VFC) which produces a pulse every 1 Gauss increment at the bending magnet. B start pulse triggers the generation of these pulse trains. After the generation of the pulse trains , of which the number is just adjusted to be equal to the difference of bending magnetic fields at injection and flat top (Btop-Binj), B stop pulse is created. Memory modules are reset at 9 sec after the start pulse and the values are set to the initial ones. Injection feedback gate is applied at the flat bottom period and the beam phase control(Δ φ) and position control(ΔR) are started after beam bunches

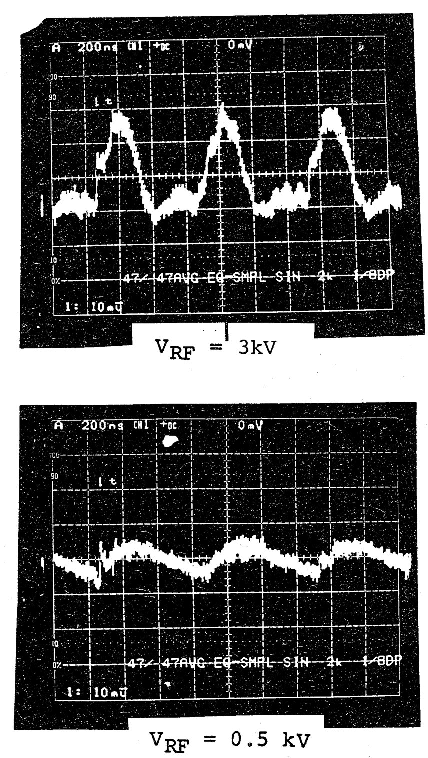

Fig. 3 Beam bunch signals from electrostatic monitors for two RF voltages, 2kV and 0.5 kV,respectively.

are created.The feedback loop gain of $\Delta\phi$ is adjusted to be much larger than that of injection feedback loop.
Then, the RF frequency is changed to be phase locked to the beam bunch itself , and the RF frequency is synchronized to the revolution frequency of the beam.

In Fig. 4, the output voltages of two phase detectors in the injection feedback loop and the $\Delta\phi$ loop are given, where we can see the phase locking condition are moved from injection loop to the $\Delta\phi$ loop at the overlapping period.

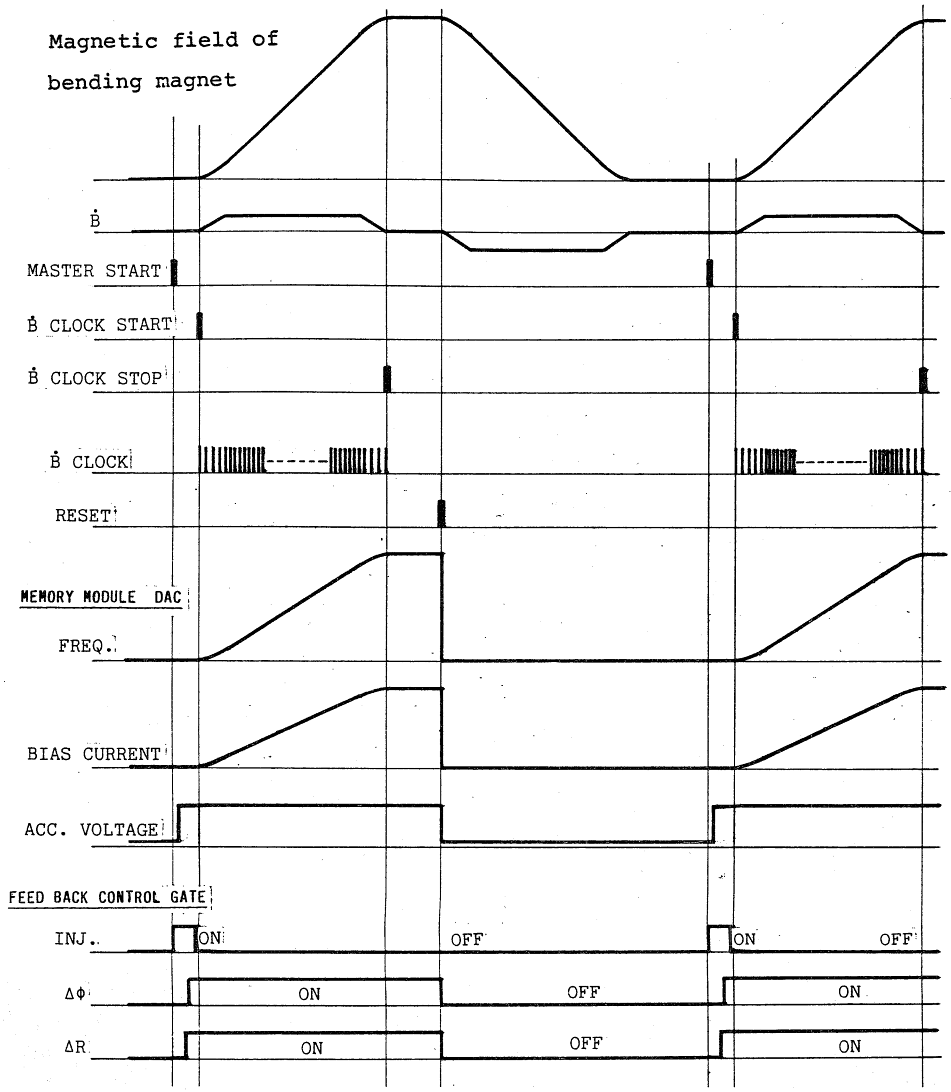

Fig.4 Timing Chart of RF Control

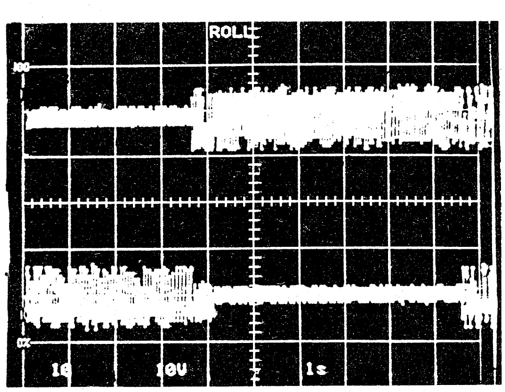

Fig.5 Output voltages of two phase detectors in injection loop and $\Delta\phi$ loop. Locking condition is changed from the former to the latter at the overlapping period.

Acknowledgement

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