RF STATION FOR ION BEAM STAKING IN HIRFL-CSR

V.S.Arbuzov, Yu.A.Biryuchevsky, A.A.Bushuev, N.F.Vajenin, E.I.Gorniker, A.N.Dranichnikov, E.K.Kendjebulatov, A A. Kondakov, S.A. Krutikhin, M. Kondaurov, Ya.G.Kruchkov, G.Ya.Kurkin, L.A.Mironenko, S.V. Motygin, V.N.Osipov, V.M.Petrov, A.M. Pilan, A.M.Popov, V.V.Rashenko, A.N. Selivanov, A.R.Shteinke.

Budker Institute of Nuclear Physics of Siberian Branche of Russian Academy of Sciences, 630090, Novosibirsk, Lavrentiev ave, 11

Abstract

BINP has developed and produced the RF station for Institute of Modern Physics (IMP), Lanzhou, China, for multipurpose accelerator complex with electron cooling. The RF station will be used for accumulation of ion beams in the main ring of the system. It was successfully tested in IMP and installed into the main accelerator ring of the complex.

The RF station includes accelerating RF cavity and RF power generator with power supplies. The station works within frequency range 6.0 - 14.0 MHz, maximum voltage across the accelerating gap of the RF cavity - 20 kV. In the RF cavity the 200 VNP ferrite is utilized. A residual gas pressure in vacuum chamber does not exceed 2,5E - 11 mbar. Maximum output power of the RF generator 25 kW.

The data acquisition and control of the RF station is based on COMPACT – PCI bus and provides all functions of monitoring and control.

INTODUCTION

HIRFL-CSR is the new accelerator complex that nowadays undergoes commissioning at Center for heavy ion study (HIRFL) in Lanzhou city, China. It is a multipurpose accelerator complex, consisting of the main accelerating ring (CSRm) and an experimental ring (CSRe). Bunches of heavy ions with an energy of 10-50 MeV/u will be stored, accumulated, cooled, and then accelerated up to 400 - 900 MeV/u by accelerating ring CSRm.

RF STATION PARAMETERS

RF station №2 is destined for accumulation (RF staking) of ions in CSRm before acceleration cycle. The acceleration station (№1) during this time is to be switched off. Parameters of staking station №2 are given in Table 1.

A newly injected bunch is captured in RF separatrix, and then a frequency of driving oscillator of station is changed in special way to make orbit of newly injected particles motion come closer to the orbit of previously accumulated particles circulating in the ring. RF voltage of the RF station №2 is switched off after that, and the injected bunch is attached to circulating particles with an aid of electron cooling. Then the cycle is repeated.

The injected bunch has a short length but a wide energy spread. In order to capture such a bunch in separatrix a high accelerating voltage is needed.

Table 1: Main parameters of RF station №2

Frequency range		6.0 - 14.0	MHz
RF voltage amplitude		20.0	kV
Harmonic number		16, 32	
Operation vacuum in RF cavity		$< 3.5 \cdot 10^{-11}$	mbar
Ferrite type		200 VNP	
Max. RF power of generator		25	kW
Cycle duration		50	ms
Repetition frequency		20	Hz
Installation length of RF cavity		2300	mm
Height	Orbit plane		mm
Aperture	horizontal	200	mm
	vertical	200	mm

At that time while new injected bunch approaches the circulated particles, and the frequency of RF voltage and circulation frequency become closer, high accelerating voltage would disturb the motion of circulating particles too much.

Moreover, the cooling efficiency will also decrease at large initial energy dispersion of the bunch. That is why the bunch is injected when the gap accelerating RF voltage equals to 20 kV in accepted scheme. The RF voltage is quickly decreased to value 1.0 – 1.5 kV after period of time equal to quarter of synchrotron oscillation (some tens microseconds), when energy spread of particles is minimal. This voltage is sufficient for keeping particles in separatrix and this voltage is maintained constant till the end of cycle.

RF station consists of accelerating RF cavity, RF power generator and control system (see fig. 1).

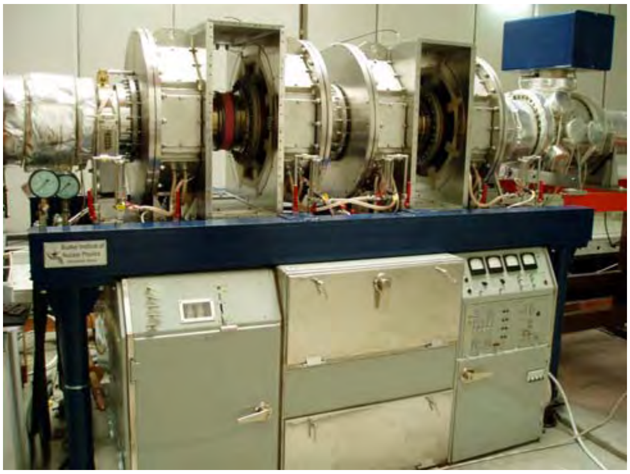

Fig.1: RF cavity and RF power generator of station

RF cavity, RF power generator with power supplies are assembled in single module, the control system is mounted separately in radio rack.

RF CAVITY

RF cavity has two gaps into which a ceramic insulators are welded in (see fig. 2). Maximal voltage on each insulator – 10 kV. This voltages are summed up at single accelerating gap inside vacuum chamber.

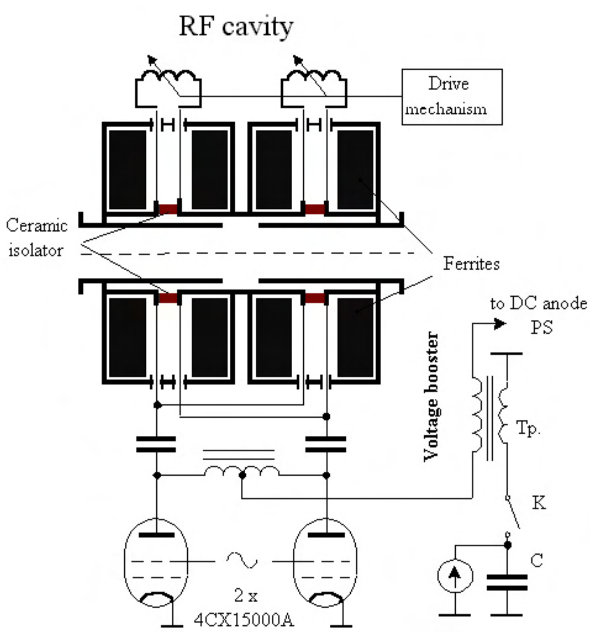

Fig.2: Block diagram of RF station

Resonant frequency of RF cavity is not tuned during operation cycle because the range of generator frequency tuning lies within resonant frequency band of RF cavity for the given type of ions. Change for another type of ions and compensation of the thermal or any other instabilities is accomplished by RF cavity tuning with an aid of electro-mechanically driven variable inductivity (see fig. 2).

The RF cavity is tuned in such a way that it is accurately at resonance when the gap voltage is maximal (20 kV). Later (during cycle) when RF voltage is small, the operation frequency moves away relative to the resonant frequency of RF cavity, and required RF voltage at detuned cavity is maintained by increasing of excitation of output stage of RF generator.

In RF cavity of station the ferrite of 200 VNP type is used. It is produced by “Magnetron” plant, St.Petersburg. Ferrite was delivered from plant in form of tiles, which were than mechanically treated and glued into octagonal rings. Inner diameter of the ring – 340 mm, total length of rings assembly – 500 mm. The heat, dissipated in ferrite, is removed by copper discs inserted between rings. The discs are cooled with water. For improving the thermal contact between ferrite rings and copper plates, mechanical stability of elements as well as for increase of the electric strength of insulation, a free space in the cavity is filled with a sealing compound. Maximal induction in ferrite at 6 MHz and gap voltage 20 kV – 90 Gs.

Vacuum chamber with ceramic insulators was backed at temperature 350ºC for achievement of high vacuum 3.5 10^{-11} mbar.

RF POWER GENERATOR

Two air-cooled vacuum tetrodes 8281/4CX15000A are utilized in output stage of RF power generator. The tubes are connected into push-pull scheme with common cathode, and their anodes are connected directly to accelerating gap via high frequency.

The output stage is fed by 2.5 kV rectifier. Boosting device provides increase of anode voltage up to 6.5 kV during 150 microseconds at the beginning of each operation cycle when RF voltage at cavity gap is 20 kV. The pulse transformer Tp is connected in series to anode power supply circuit for this purpose. The switch K connects storage capacitor C to primary winding for the time ~ 150 mc.

A water cooled broadband preamplifier is based on transistors and drives the tetrodes in the whole frequency range without tuning. Maximum output power of the preamplifier is 0.9 kW in CW mode. The input power of the preamplifier is 0.25W max.

CONTROL SYSTEM

The Control System is based on the Compact PCI bus and provides for a complete control and monitoring of all parameter of RF station. The control system provides regulation of the operating frequency of RF station by a given program, controls amplitude and phase of accelerating voltage of RF cavity and fine tuning of its resonant frequency.

The Main Control Module is installed in the Compact PCI crate and contains the Master Oscillator of RF station using DDS technology, the DACs providing DC reference signals for RF cavity amplitude and ADC for monitoring of RF station parameters during the cycle. The AD9854 DDS is functioned with EP1K30QC208 FPGA in parallel connect mode to achieve high updating of signal frequency. The DDS supplies frequency resolution less then 1 Hz and frequency update less then 1μs. RF system is locked by phase feedback loop to compensate phase deviation between the DDS and cavity voltage. 16 bit of amplitude date and voltage feedback from the cavity are applied to amplitude modulation unit. Digital frequency date through linearization table is also converted to analog signal. This voltage is added with the signal from phase meter between cavity voltage and feeder current and put to unit tuning the cavity.

The RAM section of the module stores the information, which determines the key parameters during the operating cycle: the output frequency of DDS, amplitude of accelerating voltage of RF. The station can be controlled from the Central Control Room of the CSRm through Ethernet or/and from a local monitor and a keyboard.

RESULTS OF RF STATION TEST

After shipment of RF station to Lanzhou it was reassembled there and the required vacuum in the cavity was obtained. The commissioning testing of the cavity was made during 72 hours non-stop. The RF cavity voltage instabilities was measured to be within 0.2%, accuracy of the cavity tuner was inside 5 degree. After successful completion of the test the RF station was moved into CSRm ring, installed there and now is ready for operation.

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