# RF SYSTEM OF THE MINOR STORAGE RING FOR TECHNOLOLICAL SR SOURCE TNK-1

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## Abstract

The status of the commissioning of the RF system of the minor storage ring for Technological SR source is discussed. This minor storage ring is designed as independent SR source and as injector for major storage ring of the Technological SR source complex. The component parts of RF control system, RF power amplifier 34.52 MHz 5 kW and RF cavity are described. Initial results of measurements and tests are presented.

## **INRODUCTION**

The Technological Storage Ring Complex being constructed in Institute of Physical Problems (Zelenograd, Moscow region) is designed to be a specialized SR source for technological applications. It should include two electron storage rings – smaller and greater ones. Physical commissioning of the smaller ring was accomplished by the end of 2005.

In future the minor ring (MSR) with energy 450 MeV and stored bunch current up to 0,2 A will serve as injector for the big ring. The same time MSR may be used as independent SR source in UV and mild X-ray bands [1]. The storage ring was designed and manufactured in BINP. Assemblage and commissioning of MSR was performed jointly by staff members of BINP and of the Institute of Physical Problems.

# **DESCRIPTION OF RF SYSTEM**

Revolution frequency in MSR - 34,52 MHz. Accelerating RF cavity works at the same frequency. Required RF power from RF generator - 4 kW.

RF system consists of electronic blocks allocated in control rack "Vishnya" standard, RF power generator, coaxial cable feeder and capacitive loaded coaxial accelerating RF cavity.

#### RF Cavity

Copper capacitive loaded coaxial accelerating RF cavity (Fig.1) is not evacuated, it consists of two halves, embracing ceramic insertion in vacuum chamber of the storage ring (9). The ceramic insertion (4) in accelerating gap is made of 22XC ceramic. Inner conductor of the coaxial cavity and metallic ferrules of the ceramic insulator are cooled with water. Frequency tuning is attained by elastic deformation of a side wall (5) of the resonant cavity in longitudinal direction. The side wall and capacitive disc (6) of inner coaxial conductor are electrically connected to the ferrules of the ceramic insertion by flexible copper foil sectors (3). Tuning

mechanism (1) is driven by step motor of  $\amalg \square \square$ -5 type (10).



Figure 1: Scheme of RF cavity and it's lower part mounted on storage ring.

## Test Results

After mounting of RF cavity on storage ring some measurements and high power operation test had been accomplished.

Cold measurements results are

- Unloaded quality factor  $Q_0 = 7850$ ,
- Loaded quality factor  $Q_L = 2065$
- Shunt impedance  $R_{oe} = 128 \ kOhm$
- Characteristic impedance  $\rho = 16, 4 Ohm$
- Operational resonant frequency F = 34,525 *MHz*
- Frequency tuning bandwidth  $\Delta F = -293 \div +360 \ kHz$ .

During high power test the maximal accelerating voltage 15 kV was kept during 3 hours. At that time an end of the ceramic insulator unit was heated up to 60°C. Feeder current was 3,6 A (in equivalent cross section), cavity gap voltage 15 kV, and power dissipated in RF cavity 880 W. Feeder current was increased up to 10 A with the gap voltage 13 kV by detuning of RF cavity. When gap voltage was in range 0,9-1,2 kV it was observed some deterioration of vacuum from  $6.5 \times 10^{-6} Pa$  to  $1.5 \times 10^{-5} Pa$ , but after training during 10-20 min vacuum reestablished itself. It can be explained as secondary electronic discharge in vacuum volume inside of the ceramic insulator. Measurements of vacuum quality were accomplished by manometric tube situated at distance about two meters away from ceramic accelerating gap. Automatic cut off of RF power was

observed three times during tests, when pressure exceeded protection set point level  $1,8 \times 10^{-5} Pa$ .

Hardware protection constrains after finishing of tests were set at feeder current level 9 A and accelerating gap voltage level 15.5 kV.

## **RF** Power Generator

RF power generator consists of several modules cased in single rack – power supply block, air cooling fan block, Control, Interlock and Signal crate and two amplifying vacuum tube stages in stainless still casings.

RF chanal of power generator realizes doubling of frequency 17.26 MHz  $\times$  2 = 34.52 MHz and amplification 5 W  $\rightarrow$  5 kW. In both stages of RF chanal an air cooled vacuum tetrodes are applied in circuits with common cathode. Tetrode GU-34B in 1-st stage frequency doubler and amplifier - is used. Its anode is connected to narrow - band resonant oscillatory circuit tuned on second harmonic 34.52 MHz. Tetrode GU-36B-1 in 2-nd stage – amplifier - is used in regime A-B with cutoff angle more than 90°. Characteristic impedance of resonant oscillatory circuit 50 Ohm, loaded quality factor  $Q_I = 40$  for power 5 kW to active matched load 50 Ohm. Loading and resonant frequency of anode circuit is widely adjustable by variable vacuum capacitors. RF power output from variable vacuum capacitor is connected to inner wire of coaxial cable PK50-44-17. Electrical length of connecting line between anode of RF power tube and accelerating cavity is chosen 4,762  $\Lambda$  some 0.1 m longer when nearest half wave length to provide decrement to synchrotron oscillations of electron bunch in storage ring.

#### Control System

RF control system (Fig 2) is designed to keep control over amplitude and phase of accelerating voltage in RF resonant cavity and to provide synchronization for injection from linear accelerator and injection to main major storage ring. Modulator block of the control system adjusts RF power yield from generator using three feed back loops in different operation modes relying on RF cavity voltage, feeder current (coupling loop current) and generator tube anode power dissipation. RF signals come from measuring loops in feeder and resonant cavity arrive to amplitude detectors. Detected voltages are compared with reference levels of excitation current and accelerating cavity voltage. Amplified difference signals provide correction of output power of controllable amplifier CA.

Beside this in modulator block there is an analog device which produce a signal proportional to the power dissipation on output stage power vacuum tube. If that signal exceeds a reference level, the output signal from PV decreases.

Control system accomplishes RF cavity tuning in two different operation modes – 1st mode relies on phase difference between excitation current and feeder and RF voltage in RF cavity – for detunings smaller then resonance bandwidth, and 2nd mode relies on ratio between RF voltage in resonant cavity and feeder current – for greater detunings – up to 15 bandwidth. In first mode the signals from measuring loop of feeder excitation current and measuring loop of RF cavity voltage come to phasemeter 2. If phase shift differs from set point it turns on the step motor of tuning mechanism to appropriate direction.

In the second operation mode the autotuning system compares signal from cavity voltage loop with reference voltage from digital to analog converter which is set to a certain proportion to the reference level of the excitation current signal from loop in feeder. At this mode the excitation current signal is stabilized by modulator. Amplified difference of these signals goes to the servoamplifier to attain desired cavity voltage by



Figure 2: Block diagram of RF control system.

appropriate detuning. Decrease of the reference voltage from digital to analog converter causes decrease of cavity voltage by increase of the cavity detuning.

In the control system there is a circuit for autophasing of RF cavity voltage to reference RF signal from master oscillator which is used for injection syncronisation also. This circuit includes phasemeter 1 which measures phase difference between RF cavity voltage phase and the reference RF signal. The output voltage from phasemeter controls a phaseshifter in main RF tract.

This phaseshifter consists of two separate phase shifters connected in series so that their phaseshifts are summarised. One of them applies connected resonant LC circuits tuned by varicaps. This phaseshifter has a shift range  $\pm 90^{\circ}$  and works in feed back circuit continuously compensating the phase instabilities of RF generator. The second phaseshifter accomplishes phaseshifts by steps of  $45^{\circ}$  in full range  $360^{\circ}$  and applies two balanced modulators with input RF signals shifted one from another upon  $90^{\circ}$ . It is possible to move a phase of the output signal around a circle altering input signal amplitudes in proper sequence

When working point of the first phasesifter comes close to limit, a threshold device turns on the step phase shifter and it makes a smooth phaseshift in proper direction upon 45° to return the working point into the middle of its operation range.

The control system realizes the synchronization of electron bunch output from injector linear accelerator with RF cavity voltage in storage ring, the phasing of RF voltages between minor and larger storage rings before injection of bunch from one to another, and forms a signals for deflector and inflector launching in both storage rings. The detailed description of synchrization system is given in [3]. The synchronization, RF caviti tuning and voltage regulation can be done automatically by a computer program.

In injection regime the RF cavity resonance frequency is detuned down for some 5-10 bandvidth and the cavity voltage is set on 1-2 kV. In this regime the control system works in the second operation mode as described above. While electron energy raising according to computer program the detuning decreases and and then the tuning control proceeds to the first operation mode relaying on phasemeter signal. Accelerating voltage gradually increases while tuning process and then voltage regulation proceeds from feeder current stabilization to automatic stabilization of RF cavity voltage.

# **SUMMARY**

- Designed parameters of RF system are obtained.
- RF system and minor storage ring THK-1 is succesfully commissioned.

# REFERENCES

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