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THE RF GUN FOR THE SIBERIAN CIRCULAR LIGHT SOURCE "SKIF"

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Abstract

The Siberian Circular Light Source is a new medium-energy high brightness synchrotron light facility which is under construction on the Budker Institute of Nuclear Physics (BINP) in Russia, Novosibirsk [1]. The accelerator facility for convenience is divided into three components; a 3 GeV storage ring, a full-energy booster synchrotron and a 200 MeV injector linac with a thermionic gridded RF gun electron source. This paper describes the RF gun design and plans for operation.

INTRODUCTION

The prototype of the RF gun presented in this paper is the RF gun constructed for Novosibirsk Free Electron Laser facility [2] and the RF gun for VNIIEF [3] that have been extensively tested and operated at BINP and Sarov. The differences are the pulse regime of work instead the continuous one and the higher beam energy (800 keV).

It has an oxide thermionic gridded cathode mounted into the RF gun cavity. A trigger pulse with 1 ns width came to the cathode-grid gap at the moment when RF phase voltage in the cavity becomes 40 degrees in order to emit an electron bunch. This bunch is accelerated by the cavity field up to 800 keV. This energy is less than those maximal one that occurred at the launch phase of 70 degrees. So, the 40 degrees bunch has the specific energy distribution of particles that led to bunch longitudinal compress of up to 20 ps at the end of some drift space distance. In order to get the desired 4 ps width bunch, there must be additionally used a special third harmonic cavity.

Hereby, the RF gun generates an electron beam suitable for velocity bunching of it down by 250 times on a 3-metre-long drift space containing a third harmonic cavity, a pre-accelerator, and a diagnostic and focusing equipment. Respective cavity resonance frequencies are 178, 534 and 2856 MHz. All works in a pulse regime with 1 Hz repetition frequency. There is the possibility to use a higher repetition frequency, e.g., of 20 Hz, to make a conditioning of the cavities.

The main requirements to the RF gun are the phase and amplitude field stability of about 1° and 1% respectively. This is followed from the requirement for the electron beam at the linac exit to have no more than 1% of energy spread and energy deviation suitable for injection through the linac-to-buster transfer line into the booster synchrotron.

All these cavities together with the linac accelerating structures must be accurate synchronized within 2 psec by the *Libera* electronic system equipment with master generator frequency of 178 MHz. The temperature of all cavities is stabilized accurate within 0.1 K. Their resonance frequencies, except the pre-accelerator one, are controlled by a precision feedback control system equipped with piezoelectric tuners.

Two modes of operation are planed; short-pulse mode, in which a single 1 nC electron bunch is injected into one buster RF bucket and long-pulse mode in which a train of single bunches with the total charge of 16.5 nC is injected into the booster working at an operational frequency of 356 MHz.

Such value of charges leads to a beam loading effect those results in voltage drop of cavity acceleration. Simulations show that the maximum voltage drop is less than 1%. Furthermore, a possible phase shift of the voltage due to the sound or thermal impact of the RF power pulse into the cavity is estimated as slow enough to compensate the both by the vector modulator equipped feedback control system. The amplitude and phase of the RF master generator signal is controlled by the vector modulator and drives a solid-state preamplifier. A second 0.7 MW solid state amplifier equipped by built-in circulators, amplifies the signal which is connected to the RF gun by a 6 1/8" coaxial feeder and an RF power coupler.

The trigger pulses with 1 ns width and the variable 0÷150 V amplitude are formed by a special transistor scheme displaced into a mobile block inserted into the RF gun and connected to the cathode-grid assembly through a set of collets. The trigger signal is phase controlled by the reference signal of the master generator through electronic equipment made by BINP.

The detailed RF parameters of the RF gun are listed in Table 1.

The RF gun now is manufactured on the BINP experimental production that will be lasted for 1 year and then will be tested at a special stand-prototype consisting from the third harmonic cavity, pre-accelerator, the first accelerating section of the linac, and the diagnostic equipment in order to test the system during a building structure for the SKIF facility is constructed and made.

RF GUN DESIGN

The RF gun schematic view is presented in Figs. 1 and 2.

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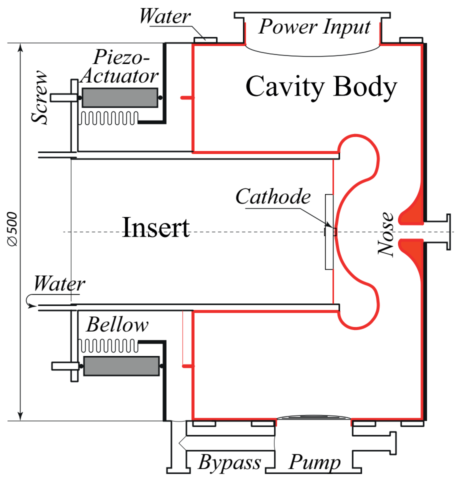

Figure 1: Schematic view of the RF gun.

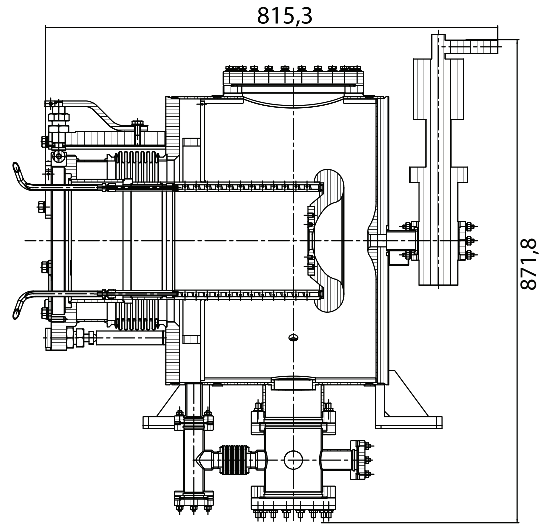

Figure 2: Structural drawing of the RF gun.

Table 1: RF Gun Parameters

Parameters	Designa-tion	Value
Resonance frequency	MHz	178.47
Loaded quality factor	Q	14700
Characteristic time	µsec	13.1
Effective impedance	Ohm	57.4
Transit factor	T	0.995
Max. axis electric field	MV/m	11
Stored RF energy	J	4.26
Dissipated pulse power	kW	325.2
Beam pulse power	kW	38
Input pulse power	kW	363.2
Loaded quality factor		6580
Coupling coefficient		1.39
Average power	W	<50
Injector beam energy	MeV	0.71
Max. surface E field	MV/m	22.7
E field at the grid	MV/m	2.7
Launch phase	grad	40
Bunch train charge	nC	16.5
Loading by the beam	%	0.14
Amplitude stability	%	<1
Phase stability	grad	<1.0
Piezo tuner stroke	µm//kHz	116//88
Handle stroke	mm//kHz	±0.5//±380

The body of the cavity is made from bi-metall. The inner layer is made from copper supporting a good electrical conductance. The outer layer is from stainless steel which proved the body stiffness and vacuum tightness.

The special cathode insert ("Insert" in Fig. 1) is fixed into the cavity. At the center of its front end there is the gridded cathode unit that is attached by a conflate flange at the inner side. The cathode is used from the domestic tube GS-34 and can be replaced by usual YU-171 of EIMAC firm.

The insert front end has a spherical form which produces a strongly focusing electric field such that the operation can be made without of external focusing solenoids. Furthermore, the electric field at the cathode is reduced by 10 times down to 2.3 MV/m in order to use no more than 100 Volt of the control cathode-grid signal. Due to the low cathode E field the dark current is absent there. The maximum electric field is concentrated at the outer edge of the insert front end and at the Nose. So, the dark current trajectories lie far from the beam channel and the beam does not contaminated by the parasitic particles. In order to decrease the field emission at the insertion edge surface and at the nose it is treated by a diamond tool to the mirror glare.

There is the cylindrical hollow in the insert at the tail end that is used for the mobile unit having the collet at its front end in order to connect it to the cathode-grid unit and to control the cathode. The tubes at the insertion tail are used for water cooling of the insert.

The insert is fixed at their middle part into the cavity copper wall having 8 mm thickness. The tail part is fixed in transverse direction by three screws displaced symmetrically in azimuth. It is used for adjusting the cathode to the cavity axis. These screws are connecting to the insert through the bearing which does not prevent the insert to the longitudinal movement by another three screws with piezo-actuators in consecutive order included. By these piezo-actuators the efficient adjusting of the cavity resonance

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frequency is made in the range of 120 microns and the handle adjusting by screws is in the range of 1 mm.

At the cavity top there is aperture for the RF power input, and at the bottom there is the aperture for the vacuum pump.

TECHNOLOGIES

Electron Beam Welding

In the cavity there is widely employed the vacuum electron beam welding (EBW) technology – the cavity inner end and tail seams, the insert to cavity seam, and other ones. Some of its examples are shown in Figs. 3-5.

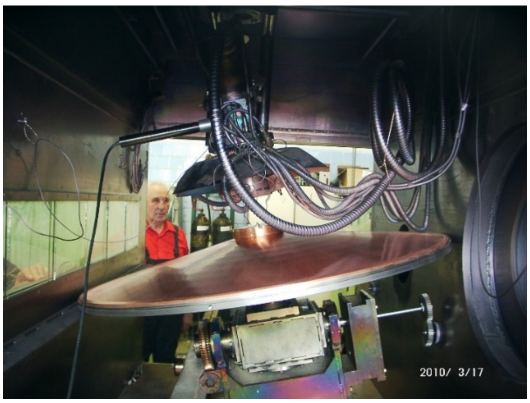

Figure 3: Example of the beam welding of the cavity wall center with the Nose [2] (that is shielded by a cover).

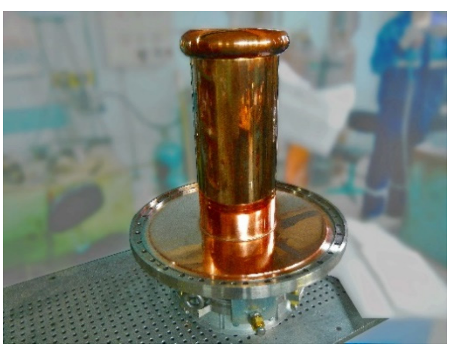

Figure 4: Example of the beam welding of the Insert with the cavity wall [3].

Figure 5: Example of the beam welding of Insert edges for water channels [2].

Bi-metal Production

Some examples of bi-metal production for previous RF gun cavity [3] are shown in Figs. 6-8.

Figure 6: Outer stainless-steel cylinder covered by copper metal.

Figure 7: Inner copper cylinder covered by argentum metal.

Figure 8: Inner copper cylinder, after its cooling by liquid nitrogen, is inserted into the outer cylinder.

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