SOURCE OF HIGH ELECTRON CURRENT FOR INJECTION INTO ACCELERATORS

N.A. Vinokurov, P.A. Golubev, V.E. Karlin, E.I. Kolobanov, S.A. Krutikhin, G.Ya. Kurkin, V.K. Ovchar, S.S. Seredniakov, S.V. Tararyshkin,
Budker Institute of Nuclear Physics, Russia.

Abstract

A pulsed source of electron current with an oxide cathode has been developed and implemented, with adjustable average current from 0 to 110mA and pulse duration of 0,5 nanosecond. The pulse charge can be adjusted from zero to 1,5 nanocoulombs

The source was created for the second stage of the free electron laser, implying making the average current of the microtron-recuperator as high as 150 mA at an electron current pulse duration of approximately 0,5 nanosecond. We have been using the oxide cathode from the RF triode till now; other cathodes can be applied, the scheme for generation of pulses to activate the cathode current staying the same.

Previous publications devoted to this issue (1-3) followed the principle of generation of short electron pulses via summation of even harmonics, without due account of factors influencing the coherence of the phase of electron bunch birth and the phase of voltage across the accelerating resonators as well as on the amplitude of the electron current of the cathode. Fig.1 presents a scheme elucidating the principle of generation of short pulses of electron current.

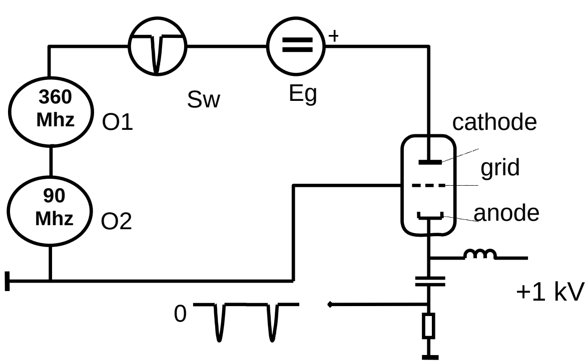

Figure 1: Basic diagram of current pulse generation.

Switch Sw selects a required pulse sequence from the half-sinusoids of the 360 MHz harmonic that are repeated with a frequency of 90 MHz. The pulse base duration does not exceed 22 nanoseconds, which is the doubled value of the period of the 90 MHz oscillator. The switch is a capacitor that is charged in 10 to 11 nanoseconds to a negative potential of 100 V and discharged down to zero in the same time. The capacitor value is chosen so that the potential does not change significantly when a 1.5 nanocoulomb charge is emitted from the cathode. The maximal operating frequency of the switch is 7MHz, because of insufficient recuperation of the capacitor energy, which results in heating of the switching transistor (ST913A).

The oscillators in Fig.1 are toroidal-shaped resonators. When there is no signal on switch K, bias driver E_g ensures a complete cutoff of the cathode current. In the mode of injection of 90 MHz electron pulses, voltage across the power source decreases smoothly down to 50 V, which corresponds to an average cathode current of 110 mA.

In the variant presented, the computer automatically tunes the resonators to resonance, from maximal values of voltage across each of the cavities. Each resonator is tuned with the help of a short-circuit frame rotated by a step motor driven by the controller SMC-485.

A scheme of the autotuning mechanism is presented in Fig.2.

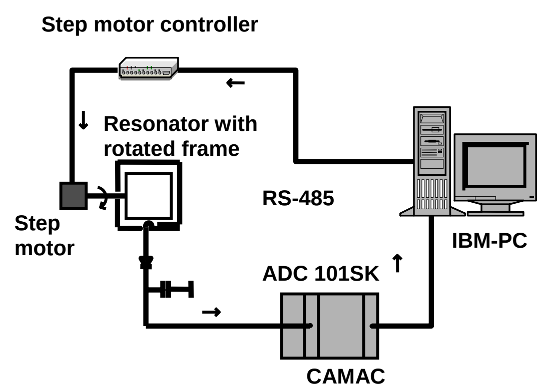

Figure 2: A scheme of the mechanism for resonator autotuning.

The program measures voltage across the resonator as long as the oscillator is working. If the voltage falls below the initial value more than by 5%, the autotuning begins, i.e. the maximal voltage across the frame is found via changing the angle of turn. In so doing, the program changes the frame position by one step of the motor (~1.5 degrees) and measures voltage across the resonator after each step. The cycle is continued until the voltage maximum is found. Since changing voltage across the resonator is a rather slow process and autotuning begins even at very small deviation of voltage, this process runs close to resonance.

The cathode unit and those of the scheme of short pulse generation are under a static voltage of 30 kV, and optical communication links are used for controlling and monitoring (Fig.3). Two RF channels are used to synchronize the electron pulse of cathode current with the voltage across the resonators of the accelerator. A slot antenna, designed so that it does not disturb the electrostatic field, transmits a 180 MHz phase-controlled signal from the "earth"; a signal transmitted to the "earth" has a frequency of 90 MHz. The coherence of 180 MHz and 90 MHz signals is provided by phase detector II and amplifier phase shifter. Stability of a predetermined phase of beam birth relative to the phase of voltage across the accelerator resonators depends a lot on the quality of the optical RF communication.

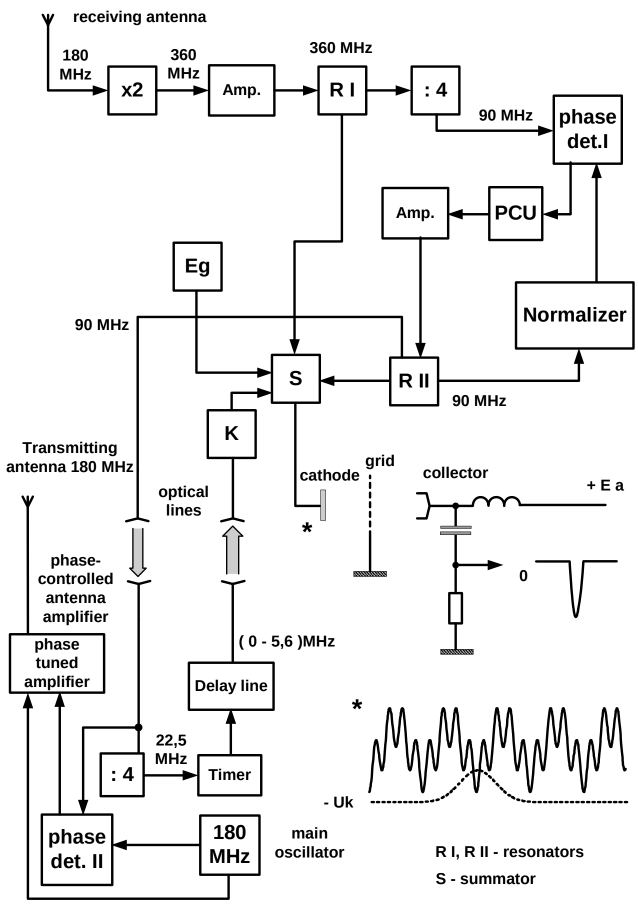

Figure 3: Scheme of links of main elements of the electron source.

We have applied a multi-mode optical cable with a HFE4190-541 laser and HFD3141-102 photodetector, which provide a modulation bandwidth within the interval from 10 kHz to 2,5 GHz, as an optical link for 90MHz signals.

The signal from the reception antenna (2,5 V) is doubled against frequency, amplified (a transistor in the output stage of the KT934B amplifier) and is transmitted to resonator RI (360 MHz) by 50 Ohm cable with the length λ/2. The counter divides the signal from resonator RI by 4 (IE7A), and a 50 Ohm cable with the length λ/2 passes the signal to resonator RII (90 MHz) through the amplifier (a transistor in the output stage of the KT934B amplifier).

From resonator RII (90 MHz), the signal, which has been normalized against amplitude, arrives to phase detector I. Phase detector I and the phase-controlling unit (PCU) provide the required phase relationship for both resonators.

If the source is working at a low rate of current pulse repetition (up to 5,6 MHz), frequency of the 90 MHz signal of the optical link is divided by 4 (IE7A) and arrives to the computer-controlled timer. The signal from the timer goes to the switch by a variable delay line. The time of delay is set so that the pulse in the cathode current detected has maximal amplitude. The delay is set one time and does not depend on the rate of operations of the switch.

Fig.4 shows the appearance of the electron source. Fig.5 shows an oscillogram of a current pulse on the collector (the anode of the tube GS-34) made with the help of a sampling oscilloscope.

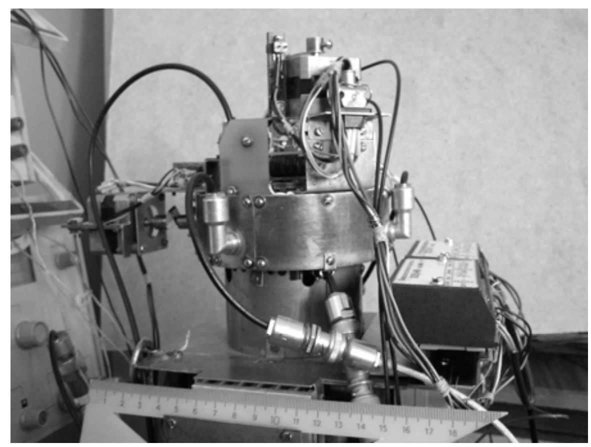

Figure 4: Appearance of the device.

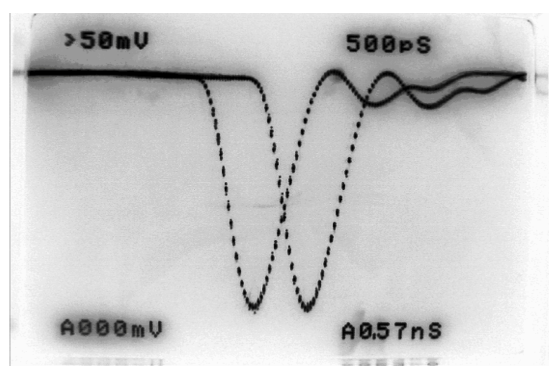

Figure 5: Oscillogram of a current pulse in the collector circuit (the same pulse is depicted with a 0,57 ns shift in order to define the time-response characteristic).

REFERENCES

[1] E.I. Kolobanov. Patent 2148296.
[2] E.I. Kolobanov. IET, 1994, N 3, 126.
[3] E. I. Kolobanov, S. A. Krutihin et al. Subnanosecond pulse driver, 13th International Conference on High-Power Particle Beams, Japan, 2000.