NANOSECOND PULSE ELECTRON GUN WITH WIDE RANGE OF REPETITION FREQUENCY

V.M.Borovikov, A.N.Kerginsky, V.V.Kolmogorov, G.S.Krainov, A.M.Kryuchkov, E.A.Kuper, A.V.Madorsky, A.S.Medvedko, E.G.Miginsky, A.M.Molokoedov, V.K.Ovchar, I.N.Sorokin, M.A.Tiunov, G.I.Yasnov
Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia

Abstract

Design and experimental results gained on the thermionic tetrode electron gun developed for a free electron laser [1] are presented. The main parameters are: a wide range of the electron bunch repetition rate, 0 - 22.5 MHz, high peak current ~ 1.8 A, pulse duration of 1.3 ns, small emittance of the electron beam with an energy of 300 keV. The small emittance is provided by the tetrode type of the grid-cathode assembly. An electron beam with an average current of 40 mA has been obtained. Electron bunch 'jitter' measured is less than ± 100 ps.

1 INRODUCTION

An electron gun with a thermocathode at a high potential has been developed and started to operation, for the free electron laser that is under construction at the Photochemical Research Center in Novosibirsk.

2 SYSTEM DESCRIPTION

A general view of the electron gun manufactured at BINP SB RAS is presented in Fig.1.

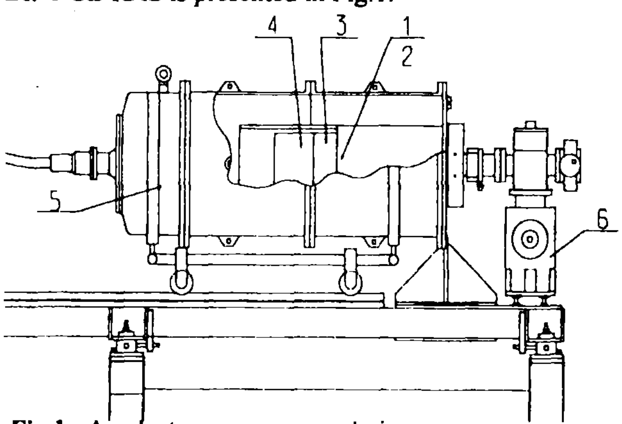

Fig 1. An electron gun , general view.

The electron gun is subdivided to several components:

1. Grid-cathode assembly and microwave collets.
2. Accelerating tube.
3. Modulator
4. Power source for the modulator
5. Tank.
6. System of vacuum pumping.
7. Fiber-optical isolating system

2.1 Grid-cathode assembly and microwave collets.

The electron beam source is the thermionic grid-cathode assembly, which is a metal-ceramical construction with cylindrical electrode leads, an oxide-coated dispenser cathode and two control grids. The pulses from modulator be received by the cathode but all two grids have a constant voltage and guarantee the modulator output protection during HV discharges in the accelerating tube. Activated cathodes of this type shouldn't be at air for a long time, since they loose significantly their emission properties. That is why, before being installed into the gun, the cathodes were stored in a sealed volume , filled with nitrogen. But experiments demonstrated that cathode emission may be practically restored if at the moment when air got into the vacuum part the cathode was in the inoperative state, i.e. the filament was switched off. If air got into the vacuum part when the filament was switched on, cathode emission may be restored only to 30-40% of the original value. The microwave collet of the grid-cathode assembly is designed so that to provide minimal additional inductance and capacitance between the cathode and grids. It also eliminates the necessity of forced cooling of the ceramics. Excessive heat is removed from the ceramics by a special radiator with small parasite capacitance.

2.2 Accelerating tube

An accelerating tube manufactured at BINP was used as a system for electrostatic focusing and accelerating the electron beam. It was the first time when such a tube was used in the horizontal version. The accelerating tube is a vacuum tight warming-up metal ceramical unit, ~ 350 mm in height and ~ 285 mm in diameter. It consists of individual sections, each 20 mm in height. Inside the vacuum part there is a system of focusing electrodes for gaining necessary beam parameters. Outwards (the gas part) there is high-voltage divider, which sets uniform distribution of voltage over the sections of the accelerating tube (~20 kV per gap at total quantity of sections of 16), the shielding electrodes, which smooth electrostatic field at the surface of the accelerating tube. To protect the accelerating tube against full and partial breakdowns, leading to a decrease of electrical strength of the vacuum and gas gaps and a destruction of the isolator body or of its surface, gas-discharge arresters have been used. They are situated on the outside electrodes of the accelerating tube. So, at a total voltage of 300 kV across the accelerating tube electric intensity at the surface of the ceramics is 10 kV/cm. The gap between the arresters is 2 mm and electrical intensity in the gap is, correspondingly, ~ 100 V/cm.

2.3 Modulator

The modulator is used, together with the grid-cathode assembly, to form short electron bunches. The modulator is a former of strong and short voltage pulses with a wide range of repetition rate on the cathode . The modulator is started by the leading edge of a 10 ns long pulse from the fiber-optical cable. The optical receiver consists of a HFBR2524 microcircuit and an AD9696 TTL comparator. The leading edge of a TTL signal from the comparator exit starts two sequential pulse formers, made on 1554TM2. The formers form a 10ns pulse and, after a 5 ns delay, a 5 ns pulse. The first pulse switches on current key K1 with a current of 4A. This key provides charge accumulation in a step recovery diodes (SRDs). Switch K1 having been switched off, switch K2 is switched on. With this a polarity reversal and energy accumulation in the accumulation line L1 takes place. After a clean-out of minor charges in the SRD there is occurs a sharp restoration of SRD resistance and the energy accumulated in line L1 is sent to the load (the cathode). Pulse duration is determined by the length of line L1 and pulse amplitude is determined by the amplitude of the current accumulated in line L1. For the purpose of current increase the non-symmetrical values of the supplying voltages of keys K1 and K2 were chosen. The main parameters of the modulator are :

- Output pulse voltage 120-150 V
- Output current 2.4-3 A
- Pulse duration 1.3 ns
- Repetition rate 0-22.5 MHz
- Power consumption is 50 W at a maximum operational frequency of 22.5 MHz.

2.4 Power source for the modulator.

The power source is intended to feed the modulator and grid-cathode assembly of the injector, under computer control. Remote adjustment is used for : filament voltage, cathode bias voltage , voltage of the grid 2 and positive voltage of the modulator. Remote measurement is applied to : all the voltages of the power sources and currents of the grid 2 and cathode. The power source is located in the immediate vicinity of the grid-cathode assembly and modulator and is at a potential of -300 kV. Power decoupling is executed through a high-voltage isolating transformer, to which a current of a 20 kHz frequency is applied from the inverter. The necessary current value is set by a DAC. The source is controlled through a communication block and two optical cables. The control board provides monitoring and control over the power sources with the help of a 4-channel DAC and a 16-channel ADC through the computer.

2.5 Tank

The tank is a divided construction, consisting of several shells. For operation of the high-voltage units of the electron gun the role of an isolating medium is played by SF_6 at 1.3 ati.

2.6 The system of vacuum pumping

Forevacuum pumping is prosecuted through an angle valve. Vacuum pumping of the accelerating tube is prosecuted with the help of a vacuum pump of the PVIG type (post-vacuum ion-getter type) . Productivity of the pump is 150 l/min, which makes it possible to keep vacuum in the accelerating tube at a level of $10^{-7} \div 10^{-8}$ Pa. Vacuum in the electron gun is measured with a vacuum transducer. Vacuum of the electron tube is cut off from the main line with the help of a vacuum gate.

2.7 The fiber-optical isolating system.

The fiber-optical isolating system is used for sending control signals from the control cables to the high potential of -300 V and back. To input signals from the control cables to the tank with increased pressure of the SF_6 gas (1.3 ati), a glass vacuum-tight 2PMGP24B19S1E2 connector is used. Adjacent to this, inside the tank there is the optical converter, which converts electrical signals to optical ones and vice versa. From the converter along the accelerating tube there are placed 3 plastic optical cables . To eliminate break-downs over their surface, voltage is smoothed over the surface of the cables, from the sectionalized divider of the accelerating tube. The starting signal for the modulator is transmitted with a special care, to provide minimal signal delay and minimal delay instability. The summary delay at a transmission into the tank is 15 ns .

2.8 High-voltage rectifier and (IGBT) inverter.

High-voltage power supply of the electron gun is made from a high-voltage sectionalized transformer-rectifier «Malyutka», through a high-voltage co-axial cable with multilayer insulation. Each section of the secondary winding is constructionally combined with the voltage doubling diode rectifier. For the purpose of high-voltage strength a not closed magnetic circuit is used . Therefore, the connection factor doesn't exceed 0.6, which determines requirements for the primary voltage generator. The main element of the generator is a transistor bridge inverter with width-pulse control.

Between the output of inverter and the primary winding of «Malyutka» a circuit for impedance matching and forming sinusoid voltage is connected. The inverter is provided with fast protections against over current and over voltage of the high-voltage rectifier and with interlocks, monitoring presence of water flow in the primary winding of the high-voltage rectifier, availability of sufficient pressure of SF_6 in the high-voltage rectifier and electron gun.

The main parameters of the high-voltage supply:

- Primary supply voltage 3 phases -380 V
- Supplying mains frequency 50-60 Hz
- Frequency of the inverter 400-500 Hz
- Rectifier output voltage 0-300 kV
- Maximum rectifier output current 50 ma

3 RESULTS OF THE EXPERIMENTS

After the experiments the following parameters of the electron beam from the current have been obtained:

- Electron energy 300 keV
- Peak current ~ 1.8 A
- Average current ~ 40 mA
- Bunch repetition rate 0...22.5 MHz
- Pulse duration ~ 1.3 ns

4 References

[1] N.G.Gavrilov et al, «Status of the Novosibirsk project for a high-power free electron laser» in Free-Electron Laser Challenges, Proceedings of SPIE, 2988, 185(1997)