Abstract – A high-current electron accelerator for pumping of the Xe₂ lamp is developed. It is intended for injection of the electron beam into cylindrical gas cavity (diameter of 400 mm, length of 1600 mm, pressure up to 3 bar). Two parallel electron diodes are used in the accelerator, each of them connected to linear transformer driver with vacuum insulation of a secondary turn. The next parameters of the accelerator have been obtained: diode voltage – 550–600 kV, diode current – 276–230 kA, current rise time – 160 ns, maximum power of the electron beam – 130 GW, pulse width on half maximum – 160 ns, electron beam energy at power level not less than half of maximum value – 20 kJ, mean specific power of energy input into gas cavity ~ 330 kW/cm². Design of the accelerator and test results are presented and discussed in this report.

1. Introduction

High-current, large-area electron beams are used to energize large gas lasers for inertial fusion research and other applications. The electron beams are usually generated from a field emission cold cathode and extracted into the lasing gas through thin metallic foils. The cathodes are driven by pulsed power generators of 500–700 kV voltage and of hundreds of kiloamperes, with pulse duration of up to 1 μs. Maximizing the electron-beam energy deposited in the gas is required to maximize the pump efficiency, as well as minimizing the electron-beam energy deposited in foils and anode ribs to ensure the survivability of the foils and to minimize the heat dissipation requirements. A high average power KrF laser, Electra, is being developed for inertial fusion energy research. This system produces two counter-propagating electron beams, each of a 500 kV, 100 kA, 150 ns and area 30 × 100 cm² at repetition rate of 5 Hz [1, 2]. The Nike laser amplifier produces opposing 750 kV, 500 kA, 240 ns, 60 × 200 cm² electron beams [3]. In both these installations (Electra and Nike) each electron beam is produced by its own Marx pulse forming line system. Linear Transformer Driver (LTD) technology is actively developed in the Institute of High Current Electronics (IHCE) in Tomsk, Russia [4, 5] and could be quite competitive with traditional Marx generators. Recent development of high voltage low inductance capacitors and low inductance switches enabled to achieve ~ 100 ns rise time of the LTD output pulse. This technique allows one to eliminate intermediate pulse forming elements.

In the Linear Transformer Driver technology, capacitors and switches are directly incorporated in the individual cavities (named stages) to generate a fast output voltage pulse which is added along a vacuum coaxial line. A high-current accelerator, based on linear transformer driver technology, for pumping of the 200-L excimer laser was developed at the IHCE, providing electron energy of 550 keV, a diode current of 320 kA, and an e-beam current of 250 kA [6]. The present report describes a new electron accelerator, driven by two generators, each of them consisting of 12 LTD stages. This accelerator is intended for pumping of the Xe₂ lamp for hybrid femtosecond XeF (C–A) laser system [7]. Implementation of new technology enabled us to increase rate of the diode power rise from 0.5 GW/ns in [6] to 1 GW/ns in present work at almost the same level of the output power.

2. Design of the accelerator

Block scheme of the generator is given in Fig. 1. At command from the control computer capacitor blocks of 12 stages of two linear transformers are charged from the HV power supply up to 90–100 kV. The same power supply charges a capacitor block of the triggering generator. Capacitors of the Marx generator are charged up to 20 kV from the thyratron generator. A delay block forms signal for triggering of the premagnetization generator, which premagnetizes in correct direction the stages inductors of both linear transformers. At ~ 100 μs after triggering (at maximum of the premagnetization current) signal from the delay block triggers the thyratron generator, which in turn triggers the Marx generator. Voltage from the Marx generator output is delivered for triggering of the capacitor block switch of the triggering generator. Voltage from the triggering generator output fires switches of the capacitor blocks of the linear transformer stages.

Voltage from the linear transformer outputs is delivered to the cathodes of a vacuum diode, placed on both sides of a gas cavity. Electrons beams, generated in each diode, are injected into the gas volume through Ti foil, fixed on the anode ribs, and pump the working gas of high pressure.

General view of the electron accelerator is given in Fig. 2. Two HV pulse generators, made on scheme of a linear transformer with vacuum sealed secondary turn, are used to drive the electron diode. Each generator consists of 12 air insulated LTD stages, with capacitor GA35426 (100 kV, 40 nF) in each stage. Dry
Fig. 1. Block scheme of the installation

Fig. 2. General view of the generator: 1 – charging bus; 2 – transformer stage; 3 – vacuum chamber; 4 – triggering bus; 5 – vacuum pump; 6 – support; 7 – capacitors of the premagnetization block; 8 – triggering cables; 9 – air purge system of the transformer stage switches.

Air is used both as working gas in the switch and as insulation in the stages. The switches are purged by dry air permanently during operation.

HV pulse generators are placed on both sides of vacuum chamber 3, where the vacuum electron diode and pumped gas volume are installed. Vacuum chamber and HV generators are mounted on supports 6. These supports are used also for alignment of the generator and vacuum chamber elements. On one side of one of the HV generators the thyristor block of the premagnetization generator is mounted in support 6, from the other side the charging block of the premagnetization generator is mounted in opposite support 6.

Vacuum pumps 5 are placed under the vacuum chamber.

Cross section of the electron accelerator is given in Fig. 3. Transformer stages are connected in between, hermetically sealed, through the insulator and are tightened by fixing element 5. Central conductor 6, placed inside the stages, serves as part of the secondary turn for all 12 LTD stages. One end of this conductor is connected with the cathode of the electron diode, the other one is fixed on a flange of the last stage of the linear transformer. Central conductor 6 is made as cylinder with variable diameter of 160/140 mm.
3. Design of the transformer stage

Capacitor block is a main structural element of the generator. It incorporates two capacitors GA 35426 (40 nF, 100 kV) and multichannel multigap gas switch. Switch operates in voltage range 70÷100 kV without any changes in inter-electrode gaps and gas pressure. Detailed description of the capacitor block and its tests are given in [8].

Module of the transformer stage is assembled from two capacitor blocks, connected in parallel. Blocks are placed on basement from the No. 12 Π-shaped channel (base 120, leg 56 mm) and fixed by plate from delta-wood through 3 caprolon rods. Charging voltage is supplied to the top block in the module through the transition insulator. Transition insulator is also installed between blocks for transferring of charging voltage to the other block.

The high-voltage wire in polyethylene isolation is passed consistently through all electrodes of the second row with holes in all blocks for the triggering pulse delivery.

Transformer stage (see Fig. 4) consists of two modules, connected in parallel on secondary turn of the linear transformer and inductor section. The modules are placed at one side of the mounting plate symmetrically relatively to the plate center and are fixed to the plate from low voltage side on basement 9. Acryl insulator sheet of 15 mm thickness is placed between modules and mounting plate. Terminals of the capacitor blocks are connected with current bus by spring contacts. Inductor of the transformer stage is mounted outside of outer conductor of the vacuum coaxial line. It consists of three cores, that are cast in the epoxy compound. Each core is wound up by 18 mm transformer steel strip ET 3425-0.05 mm with insulating by 10 μm mylar tape between turns. Current pulse from the premagnetization generator comes to the current bus from the bottom through the spring contact. Synchronization and triggering system provides synchronous firing of all 24 LTD stages of the accelerator. The triggering generator is made on base of the capacitor block, which is the same as in modules of the transformer stage. At moment of the switch breakdown capacitors are discharged on transmission cables (type KVI-120), which deliver the triggering voltage to modules of the transformer stages.

4. Diode design

Anode-cathode block is shown in Fig. 5. Vacuum chamber has cylindrical form with inner diameter of 740 mm and length of 1440 mm. The chamber has two prolonged hardening ribs in type of vertical plates for fixation of the anode block. These ribs also serve as return current bus of the diode. Diameter of side flanges is 780 mm. Four sleeves are welded to the vacuum chamber: two horizontal sleeves with inner diameter of 200 mm in central part of the chamber are intended for delivery of HV from pulsed generators on the cathodes and two vertical sleeves with inner diameter of 200 mm in bottom part of the chamber are used for pumping of the vacuum volume.
5. Experimental results

Diagnostics. Active voltage dividers were used for measurement of a voltage on each stage. Total voltage is calculated taking into account inductance. The load and inductor currents were measured by inductive probes, installed in the last stage on each side of the generator. Typical waveforms for different voltages are given in Fig. 7.

References