

PROJECT OF SEMICONDUCTOR HIGH-POWER HIGH-REPETITION RATE COMPACT ACCELERATOR

E. Galstjan*, L. Kazanskiy, MRTI,
 Warszawskoe Shosse 132, Moscow 113519, Russia

Abstract

The paper describes project of a compact accelerator (120 kV, 2 kA, 15-25 ns pulse duration, 1 kHz - repetition rate). To attract an attention of accelerator community to abilities of modern power fast semiconductors, this device is suggested to create by using modern high-power super-fast semiconductor switches.

1 INTRODUCTION

The tendency of the last years in the field of development of high-power pulse and accelerating facility is the maximum extension of possible areas of its application. It demands development simple in circulation, reliable in maintenance, and, principal, whenever possible of compact devices. On the other hand, for the last two decades of research in the field of a solid state physics have resulted in creation of semiconductor devices [1-2], which parameters have allowed to create generators of high-voltage high-power impulses working in a repetitive mode [1, 2]. However, till now these semiconductor devices have not found the place directly in development of accelerating facility. The presented paper is devoted to exposition of idea of possible usage of modern semiconductor devices [2] for creation of a compact accelerator device, which, on our opinion, can find rather broad application. In the basis of this device the principle stating lies that the inductive storage of electrical energy combined with possibilities of modern semiconductors, is most perspective for creation of high-power pulse devices working with a high repetition rate. Instead of gas discharges, which limit a pulse-repetition rate and have enough wide jitter in a response time, it is offered to use new semiconducting switches. These switches are capable to reconnect for extremely short time (0,1 - 1 ns) currents by magnitude 1 - 10 kA at an operation voltage 10 - 100 kV [2]. In addition, the process of switching is controlled with split-hair accuracy, as the jitter in operation of keys does not exceed 20 ps. Thus the repetition rates of switching limits only by conditions of heat rejection from the device and can reach tens of megahertz.

*) E-mail address: galstjan@aha.ru

2 ACCELERATOR PROJECT

Let's consider more in detail principle of operation of the accelerator. In Fig. 1 one section of the device is shown. A toroidal inductor L_p is inserted in a transmission line

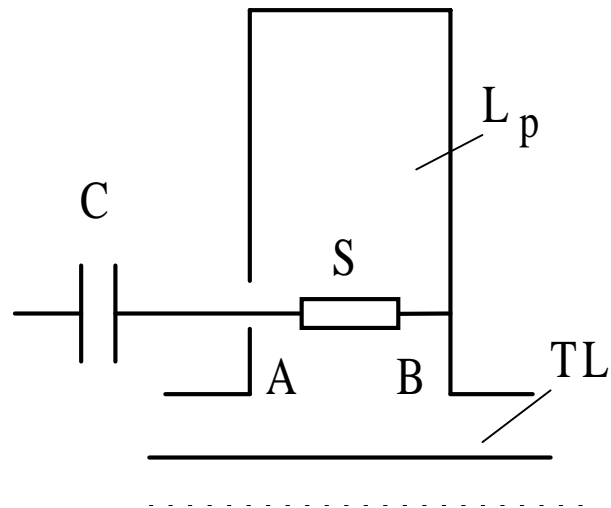


Figure 1: Principal schematic of the accelerator section

TL, which generally can be a coaxial line or can be loaded with a beam of charged particles. Originally capacitor C is charged by an external source up to primary voltage U_1 , reaching several kilovolt, then it starts to be discharged through walls of the inductor connected by a semiconducting switch S . There is a transfer of the energy, accumulated in the capacitor, in an energy of a magnetic field of the inductor and at reaching a maximum value of a current in the inductor, when the voltage on the capacitor C becomes equal to zero, the switch S is turned off, switching the inductor on a load. Thus on the gap AB there is a high voltage U_2 , which generates electric pulse in a coaxial line or accelerates charged particles of a beam.

The simple estimates display, that at small time of switching Δt the maximum voltage on the gap AB has magnitude $U_2 = U_1 \cdot t_1/t_2$, where $t_1 = (L_p \cdot C)^{1/2}$, $t_2 = L_p/Z$ - reference times of charging and discharging of the inductor. The front of high-voltage impulse is determined by time of a rupture of a current Δt , and its duration - discharge time of the inductor t_2 . Thus, though scheme of the section reminds to section used in linear electron accelerators, actually it works

completely in another way. In usual linear accelerator the energy, transforming in accelerating impulse, is stored in capacitors, and in our accelerator - directly in the inductor of the section, that allows effectively generating short (10 - 15 ns) high-power electric pulses. Besides it is possible to shape very short impulses (3 - 5 ns) of rectangular form by using matched radial lines as the inductors.

However incarnation of all these ideas in actual devices requires a solution of a lot of engineering problems. For this purpose now in Institute of Experimental Physics (Sarov, Russia) in cooperation with the authors the construction of an accelerator grounded on the above-described principles is developed. This accelerator is designed to operate with the cold explosive-emission cathode, for which it is necessary to create an operation voltage not less than 100 kV. Therefore, a series connection of several described above sections is supposed. As the first variant it is supposed to connect sequentially such three sections. At primary voltage $U_1 = 4$ kV and the relation $t_1/t_2 = 10$, the output voltage on the cathode should be 120 kV at pulse duration about 15 - 25 ns, working current up to 2 kA and repetition rate of working impulses 1 kHz. On this accelerator it is supposed to decide engineering problems, bound up with a construction, an electrical circuit, matched operation all sections etc.

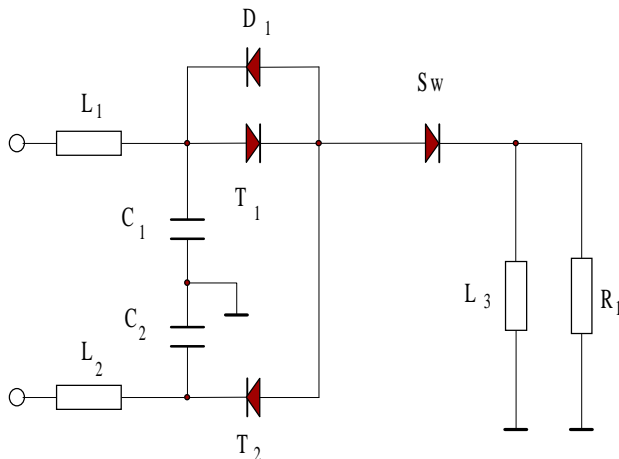


Figure 2: Electrical circuit of the section.
($C_1 = C_2 = 0.4 \mu\text{F}$, $L_1 = L_2 = 30 \mu\text{H}$,
 $L_3 = 0.2 \mu\text{H}$, $R_1 = 10 \text{ Ohm}$)

In fig. 2 one of possible variants of the principle electrical circuit of a section of the above-described accelerator is shown. A semiconductor switch, first of all, defines the view of this circuit, as it demands initial pump by electrical carriers in a forward direction, and the rupture of a current happens at opposite direction of a current, when it reaches a maximum value. In addition, the charge, which is flowing past through the switch in a forward direction, should coincide with the charge that has flowed past

in the opposite direction. This condition also determines choice of the circuit. The circuit operates as follows. Originally the capacitors C_1 and C_2 , connected in series, are charged through inductances L_1 and L_2 up to the primary voltage. Further capacitor C_1 is used for direct pump of the semiconductor switch. For this purpose the thyristor T_1 is turned on at a closed thyristor T_2 , and the capacitor C_1 is completely recharged through the inductor and the switch. After the recharge process is over, the thyristor T_2 is turned on and, as a result, capacitors C_1 and C_2 are connected in parallel. It results in that the above-stated condition of equality of an amount of the flowed past charges is fulfilled for a quarter of phase of oscillation of a reverse current. At a maximum value of a current in the inductor L_3 , the switch produces cutoff of this current and the voltage pulse is shaped on a load resistance R_1 .

It is necessary to mark that the selected operational mode of semiconductor switches in the given circuits is far from limiting on output voltage. For this reason, expected rate of acceleration can reach only moderate magnitude ~ 0.2 MV/m, but this value may be gained. Besides it is known, that an electron beam generated by a cold cathode with an explosive emission, has no enough high quality. It limits its applications, for example, in Free Electron Lasers. In our variant of the accelerator the generated beam could be additionally accelerated up to a necessary energy in a set of the same sections, loaded on the beam. In this case, quality of the beam could be essentially improved.

Thus, usage of modern semiconductor switches allows creating the compact device both a generator of power electric pulses, and an accelerator of charged particles. The generator of electric pulses can be used in medicine and biology, where a possibility of selective action of short electric pulse on a cell now is researched [3].

The accelerating devices, assembled from above described sections, are good sources of charged particle (electrons, protons, and ions) bunches, which can be used for generation of electromagnetic radiation, for surface treatment, in an ecology etc. Besides it is possible to gather classical Linacs with a possibility of acceleration of bunches up to large energies.

3 REFERENCES

- [1]. Lyubutin S. K., Mesyats G. A., Rukin S. N., et al. In Proc.: XI Int. Conf. on High Power Particle Beams. Prague, Czech Republic, 1996. V.1. P.1211-1214.
- [2]. Efanov V.M., Karavaev V.V., Kardo-Sysoev A.F., Tchashnikov I.G. Fast ionization dynistor (FID) - a new semiconductor superpower closing switch. // In Proc.: XI IEEE Int. Pulsed Power Conf. Baltimore, USA, 1997. P. 988-991.
- [3]. Schoenbach H. et al. The effect of pulsed electrical fields on biological cells. // In Proc.: XI IEEE Int. Pulsed Power Conf. Baltimore, USA, 1997. P. 73-78.