IOP Conf. Series: Materials Science and Engineering **124** (2016) 012029 doi:10.1088/1757-899X/124/1/012029

High-frequency trigger generators for CuBr-laser high voltage pumping source

S Torgaev[1,3,4], O Kozhemyak[1], E Yaroslavtsev[1], M Trigub[2,3], I Musorov[1] and D Chertikhina[1]

[1] Department of Industrial and Medical Electronics, National Research Tomsk Polytechnic University, 30, Lenin ave., Tomsk, 634050, Russia

[2] Department of High Voltage Engineering and Electrophysics, National Research Tomsk Polytechnic University, 30, Lenin ave., Tomsk, 634050, Russia

[3] Laboratory of Quantum Electronics, V.E. Zuev Institute of Atmospheric Optics SB RAS, 1, Academician Zuev Square, Tomsk, 634050, Russia

[4] Computer Science Laboratory, National Research Tomsk State University, 36, Lenin ave., Tomsk, 634050, Russia

E-mail: torgaev@tpu.ru

Abstract. In this paper the circuits of high frequency trigger generators of pulses of the nanosecond duration are presented. A detailed study of a generator based on the avalanche transistor with the use of a coaxial cable instead of a capacitor is described. This circuit showed advanced characteristics of the output pulses. A circuit of a generator built on high-speed digital components is also considered. The basic advantages and disadvantages of both generators are presented in this paper.

1. Introduction

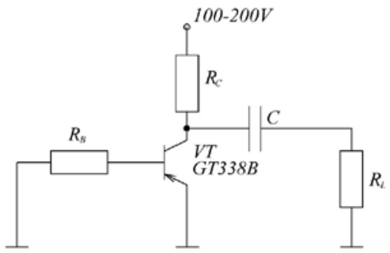
There is a multitude of various scientific papers devoted to the study of copper and a copper halides vapor laser [1-5]. The advantages of this laser are: high gain of the laser medium, high average and peak power, a narrow spectral range, etc. This laser radiates two wavelengths: 510 nm (a green line) and 578 nm (a yellow line) and it is widely used in various fields of science and technology [1]. However, using this laser in high speed optical systems [6-8] requires obtaining a high pulse repetition rate (up to 1 MHz and above). Also, a high pulse repetition rate is needed to study the physics of a repetitively pulsed discharge in the laser medium in order to identify the parameters which impair the frequency and energy characteristics of the laser. Today, the maximum frequency of the copper bromide vapor laser is 700 kHz.

In [3, 8] it was shown that for the high pulse repetition rate it is necessary to ensure a low energy input in the mode of a discharge. The low energy input into the discharge can be achieved in various ways: reducing the pump pulse amplitude, an operation of the laser in the low-current mode, reducing the duration of the pump pulse. However, the first and second methods lead to a decrease in pumping efficiency. Therefore, for pumping supply applications the generator of pulses with small duration (about tens of nanoseconds) and high frequency (more than 1MHz) must be designed.

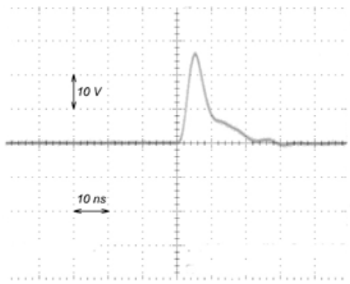
In previous studies [9], we investigated the parameters of the generator circuit built on an avalanche transistor ‘GT338B’. This circuit could provide a pulse repetition rate up to 1.3 MHz with pulse duration of 20 ns (FWTM) and of 6-7 ns (FWHM), but these pulses had an oscillation on the falling edge. Besides, during experiments the increase of the fall time of the pulse was observed. This all had a negative effect on the performance of the circuit as a whole. Consequently, it was necessary to study the pulse generator circuit with a better pulse shape. This paper presents results of the experimental study of the pulse generator based on the avalanche transistors, and the other one – with the use of high-speed logic circuits.

2. A generator based on avalanche transistors

Figure 1, *a* shows a typical circuit diagram of the pulse generator based on avalanche transistors [10, 11].



a



b

Figure 1. The typical circuit of the pulse generator based on the avalanche transistor (a) and the output pulse of the generator based on the avalanche transistor ‘GT338B’ (b).

Figure 1, *b* shows the waveform of the voltage across load RL with the following parameters of the circuit: RL=100 Ohm, RB= 470 Ohm, RC=33 kOhm, C=33 pF. Registration of voltage and current pulses, as well as pulses of generation was done with the use of the oscilloscope ‘Tektronix 3054C’. Such circuit topology allowed pulse generating with the duration of 6-7 ns (FWHM). However, the output pulse has sufficiently long fall time – more than 10 ns.

To improve the parameters of the output pulses of the generator (to decrease the pulse duration and fall time) various coaxial cables (RG59, RG64, DG113, RG174) were used instead of capacitance C (Figure 2). The parameters of the cables are shown in Table 1.

Table 1. Parameters of coaxial cables.

Parameter	RG59	RG64	DG113	RG174
Impedance, Ohm	75	75	75	50
Capacitance, pF/m	51	67	52	92.1
Copper lead diameter, mm	0.81	0.72	1.13	0.48
Cable diameter, mm	6.02	7.04	6.8	2.55

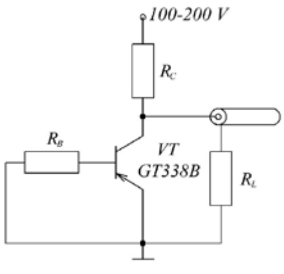


Figure 2. A circuit diagram of the generator based on the avalanche transistor with use of the coaxial cable as a capacitance.

Experimental studies have shown that the use of coaxial cables as a capacitor allows obtaining pulses with a better shape (with shorter fall time) and of short durations. Figure 3 shows the experimental waveforms of output pulses with use of various coaxial cables. The parameters of the circuit elements correspond to those in the experiment presented in Figure 1.

a) b)

Figure 3. The output pulses of the generator based on the avalanche transistor with use of coaxial cables of 10 cm length: a) RG59, b) RG174.

An experimental data show that the use of coaxial cables allows obtaining output pulses of about 2 ns duration (FWHM). At the same time, due to changes in the length of the coaxial cable, it is possible to adjust the frequency range of the generator. Figure 5 shows the waveforms of the output pulses obtained with use of coaxial cable RG174 of 5 cm and 10 cm lengths.

a) b)

Figure 4. The output pulses of the generator based on the avalanche transistor with use of coaxial cable RG174 of various lengths: a) 5 cm, b) 10 cm.

From the diagrams (Figure 4) it is obvious that with increasing length of the coaxial cable the repetition rate of output pulses decreases. Continuous adjustment of the frequency can be implemented by introducing a variable resistor into a collector circuit of the transistor. Figure 5 shows the dependence of the repetition rate of the output pulses on the value of the resistor placed in the collector circuit.

It is seen that an increase in the resistance in the collector circuit decreases the repetition rate of output pulses, and the dependence of the frequency on the resistance is almost linear. As it can be seen from the diagrams shown in figures 3 and 4, the voltage amplitude of the output pulses varies from 22 to 30 V. When using this generator for control of power transistors it is necessary to provide a possibility of adjustment of the amplitude of output pulses. This is due to the fact that the operating voltage on the gate of MOSFETs and IGBTs does not exceed 20 V. The adjustment of the amplitude of the output pulses in this circuit can be implemented by varying load resistance. Figure 6 shows the dependence of the amplitude and frequency of the output pulses on values of the load resistor.

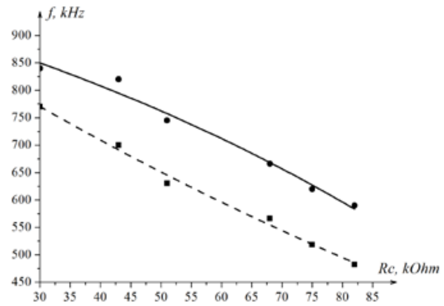


Figure 5. The dependence of the frequency of the output pulses on the value of the resistor in the collector circuit with use of coaxial cable RG64 of various lengths: 5 cm (solid line ●), 10 cm (dashed line ■).

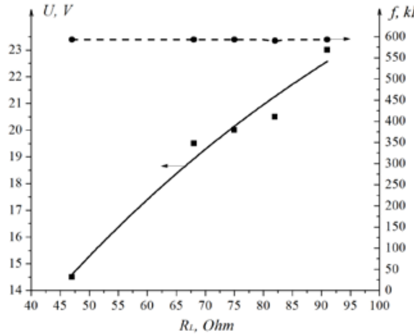


Figure 6. The dependence of the frequency (dashed line, ■) and the amplitude (solid line, ●) of the output pulses on the value of the load resistor with use of coaxial cable DG113.

Presented in Figure 6 the dependence shows the possibility of adjustment of the amplitude of output pulses in a rather wide range. Due to the small value of the load resistor the pulse repetition frequency remains nearly constant, i.e. time constant of the circuit of charge of cable capacitance does not change. However, the change of the load resistance leads to the change of the output pulse duration. One of the ways to eliminate this disadvantage is to build a high-frequency pulse generator on the base of high frequency logic elements.

3. A generator of high frequency pulses based on logic elements

In this part, a high-frequency generator of nanosecond pulses on the base of logic elements was built in the form of the block diagram shown in Figure 7.

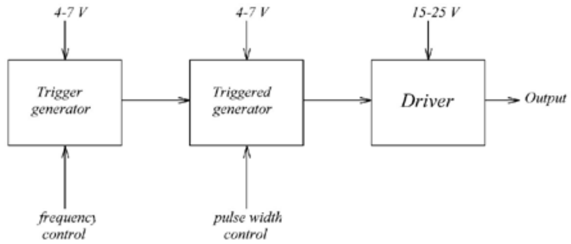


Figure 7. A block diagram of the high frequency trigger generator.

The trigger and triggered generators were built on standard generator circuits with logic elements. The high-frequency logic elements - SN74LVC1G00DBVR – were used in the circuit of the generator. They have a CMOS structure with maximum supply voltage of 5 V. Figure 8 shows the output voltages of the trigger and triggered generators with maximum frequency and the minimum duration of the output pulses.

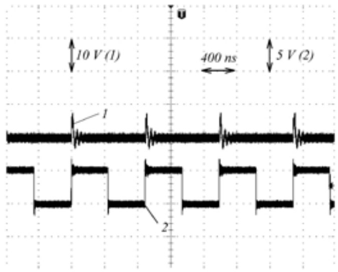


Figure 8. The waveforms of the output pulses of a trigger generator (2) and a triggered generator (1).

Since it is necessary to generate the output pulses with an amplitude of up to 20 V, the generator circuit includes high frequency driver IXDN630CI. This driver allows generating the output pulses with an amplitude of up to 25 V and duration of 10-12 ns (FWHM) (Figure 9).

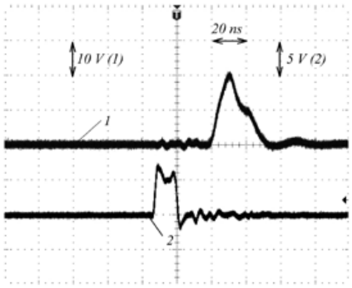


Figure 9. The waveforms of the output pulses of the triggered generator (2) and driver IXDN630CI (1).

Diagrams (Figures 8 and 9) show the possibility of generating the output pulses with frequency greater than 1 MHz and pulse duration less than 20 ns for the circuit of the pulse generator based on logic elements. Such circuit topology allows independent adjustment of the frequency and duration of the output pulses.

4. Conclusion

Generators of high-frequency trigger pulses considered in this paper allow generating control signals for high voltage pumping of the CuBr-laser. Presented generators provide output pulse repetition frequency above 1 MHz with pulse duration of about 4-12 ns (FWHM).

The generator circuit based on the avalanche transistor is the most simple and cheap. The main disadvantage of this circuit is an extremely large variety of transistors parameters (up to 300%). Therefore, the replacement of the transistor will cause the required circuit debugging. The generator circuit based on logic elements eliminates this disadvantage, however, due to the use of high-speed digital circuits and the driver such circuit high frequency generator has substantially greater cost.

Acknowledgment

The work is supported by the Russian Science Foundation, project No 14-19-00175.

References

[1] Little C E 1998 *Metal Vapor Lasers: Physics, Engineering & Applications* (Chichester, UK, John Wiley & Sons Ltd.)
[2] Boychenko A M, Evtushenko G S and Torgaev S N 2011 *Phys. of Wave Phenom.* **19** 189–201
[3] Boychenko A M, Evtushenko G S, Nekhoroshev V O, Shiyanov D V and Torgaev S N 2015 *Phys. of Wave Phenom.* **23** 1–13
[4] Shiyanov D V, Trigub M V, Sukhanov V B, Evtushenko G S and Vlasov V V 2015 *Technical Physics* **60** 571–4

[5] Trigub M V, Shiyanov D V and Evtushenko G S 2013 *Russian Physics Journal* **55** 1152–6
[6] Evtushenko G S, Trigub M V, Gubarev F A, Evtushenko T G, Torgaev S N and Shiyanov D V 2014 *Review of Scientific Instruments* **85** 1–5
[7] Trigub M V, Shiyanov D V and Vlasov V V 2014 Brightness amplifiers with PRF up to 100 kHz Proc. Int. Conf. of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM 6882534
[8] Nekhoroshev V O, Fedorov V F, Evtushenko G S and Torgaev S N 2012 *Quantum Electronics* **42** 877–9.
[9] Chertikhina D S, Musorov I S, Torgaev S N and Yaroslavtsev E V 2014 *Proc. Int. Conf. of Young Specialists on Micro/Nanotechnologies and Electron Devices, EDM* 23254173
[10] Diyakonov V 2010 *Components and technologies* **8** 49–58
[11] Zbigniew B and Krzysztof C 1996 *Opto-Electronic Review* **4** 58–61