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Features of pulse discharge formation in the trigger units of sealed-off cold cathode thyratrons

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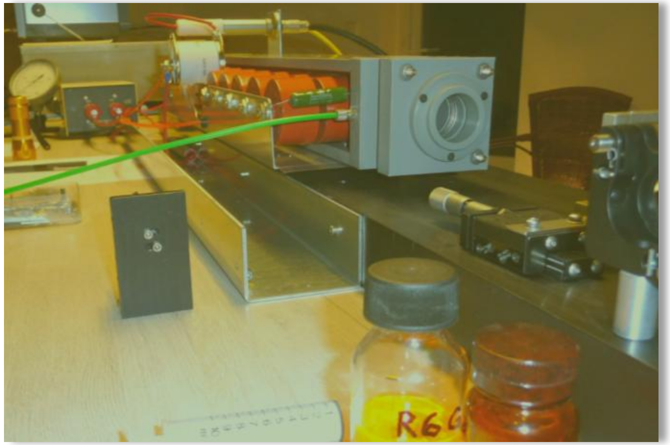
Applications of cold-cathode thyratrons

- Medicine

A lithotripter “Medolit” where cold cathode thyratrons used

- Laser pumping



Pulse generator with a cold-cathode thyratron for laser pumping

- Accelerators

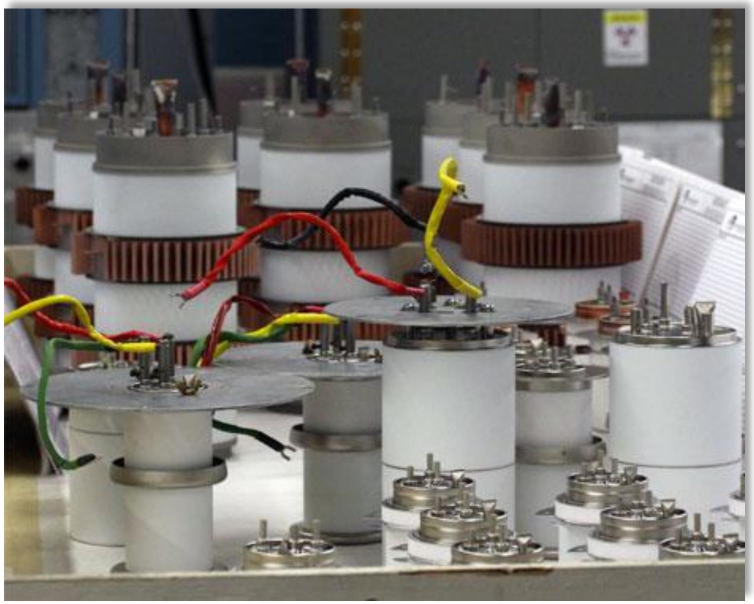
Pulse generators of linear accelerator LIA-2 with an assembly of 48 modulators with the thyratrons

"ETIGO-III“, an inductive pulsed electron beam accelerator

- And other fast switching applications

Problem of nanosecond jitter

There is a common issue associated with providing nanosecond jitter of commercially produced thyratrons.

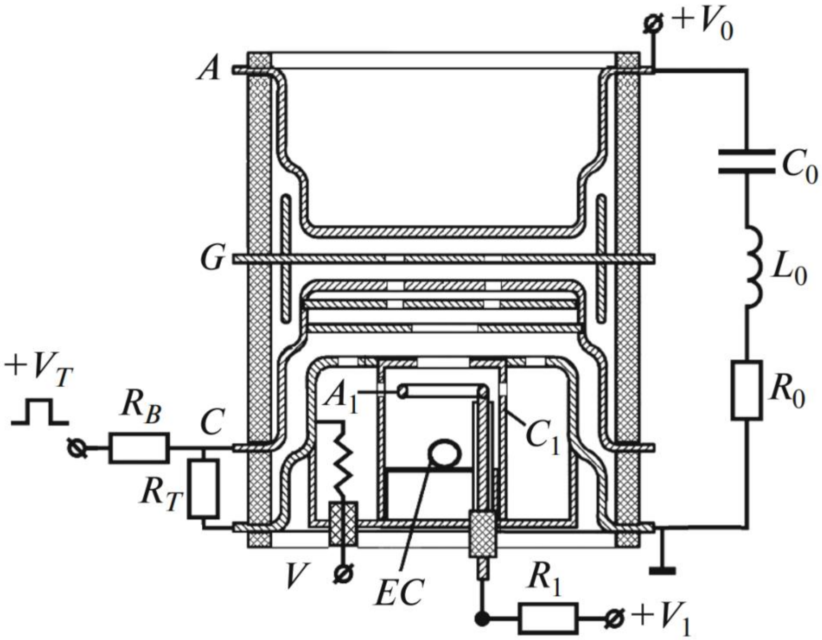


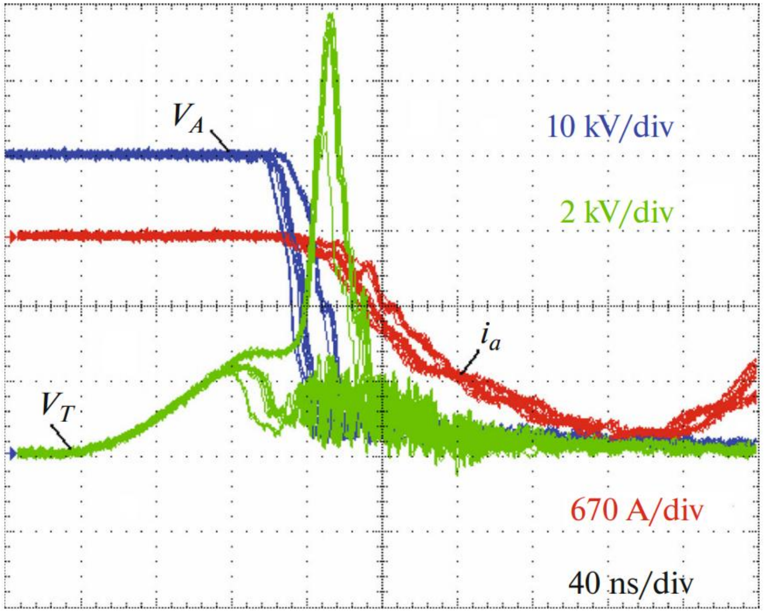
The problem, in particular, is of a great importance in the systems where a large number of switches operate onto a common load.

An example - the linear accelerator LIA-2 with an assembly of 48 modulators with the thyratrons.
LIA-20 accelerator is being developed, where more that 900 thyratrons are to operate simultaneously.

Reason of increased jitter

In case of the TPI1-10k/50 thyratrons, the trigger units based on auxiliary glow discharge.
The auxiliary discharge provides pre-ionization inside the trigger unit,
in order to facilitate development of the trigger discharge.



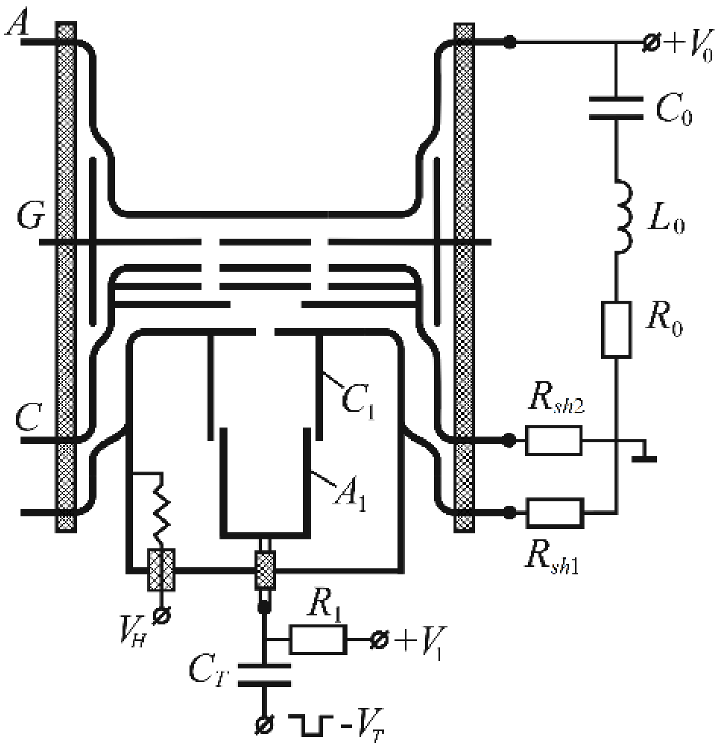


In the commercially produced thyratrons jitter depends on the regime of sustaining of the auxiliary discharge.

The so-called high emissivity tablet (***EC***) used in the trigger unit in order to initiate the auxiliary discharge at a low voltage. However, the tablet makes the auxiliary glow discharge unstable, i.e. the spontaneous transitions from one mode of the discharge to another are occurring.

Changing of the initial conditions of triggering affects the delay time to breakdown of the main gap.

Primary upgraded version of thyratron



A – anode of the thyratron,

C – hollow cathode of the thyratron,

G – gradient electrode,

A_1 – anode of the trigger unit,

C_1 – hollow cathode of the trigger unit.

The main electrode system (*A, G and C*) is the same as in the commercially produced thyratron. The electrodes of the upgraded trigger unit: A_1 and C_1.

The thyratron is intended to switch the capacitance C_0 onto the load R_0. Before triggering, the auxiliary glow discharge sustains in the trigger unit. The main fraction of the auxiliary discharge current flows to the cavity C_1 via the shunt R_{sh1}.

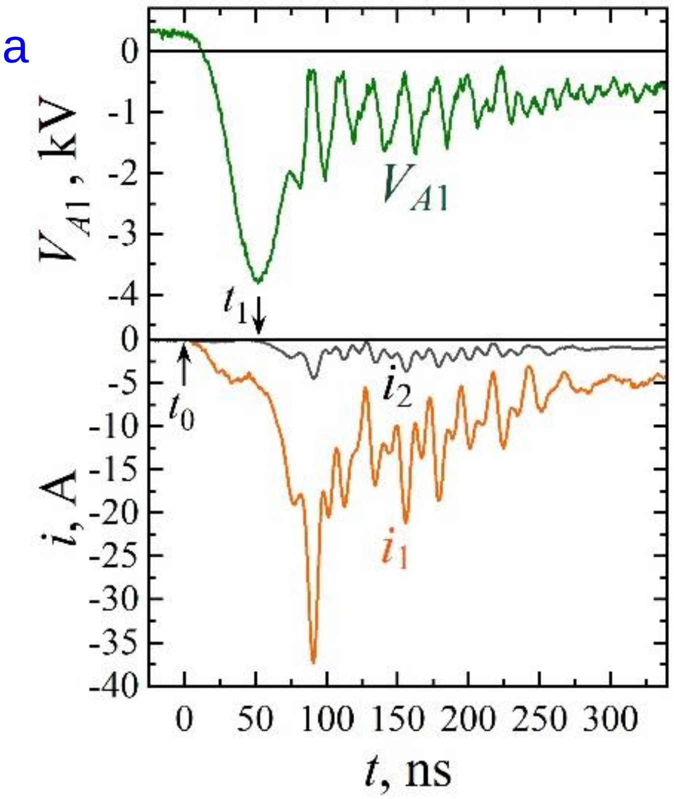
A small fraction of the auxiliary current flows to the electrode *C* via the aperture in the electrode C_1.
This is the so-called parasitic current, flowing via the shunt R_{sh2}.

Applying the trigger pulse $-V_T$ initiates the trigger discharge in the trigger unit.
The discharge current flows to the cavity C_1 and to the main cathode cavity *C*.

As the trigger pulse is negative, the hollow-anode plasma is generated inside the cavity *C*.
The electrons from the plasma are extracted into the main gap, and the main gap breakdown occurs.

Correct trigger discharge formation mode

It is necessary to generate the trigger discharge plasma inside the cavity ***C*** for triggering a thyratron.



A negative trigger pulse applied to the electrode A_1 at the point t_0. Prior, the auxiliary glow discharge sustains in the trigger unit. The current of the discharge i_1 = 20 mA and the parasitic current i_2 = 0.3 mA.

Trigger pulse application turns A_1 into a hollow cathode. The interval $t_{d1} = (t_1 – t_0)$ is the delay time to breakdown in the trigger unit. Though the current i_2 does not exceed 5 A, such a value is sufficient to provide triggering of the thyratron with nanosecond stability.

This trigger discharge formation mode is related to a correct regime of operation of the trigger unit.

Yet, deviations from this correct operating mode have been observed in some samples of the thyratrons. It is associated with the specific design of the trigger system. There is a space between the outer surfaces of the electrodes A_1 and C_1. The discharge can sustain not only inside the cavities A_1 and C_1 but also over a long path, between the outer surface of the electrodes.

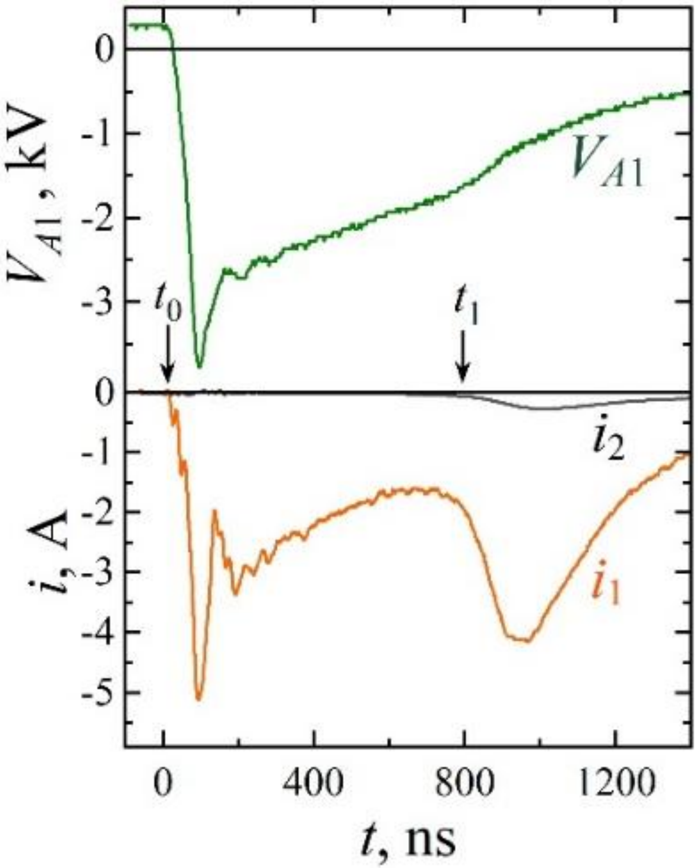
Incorrect trigger discharge formation mode

The initial conditions are similar to the previous case: the auxiliary discharge current i_1 = 20 mA.
The parasitic current i_2 here is nearly absent.

Presumably, only a small fraction of the current flows inside the cavities A_1 and C_1.
The major fraction flows between the outer surfaces of the electrodes A_1 and C_1.

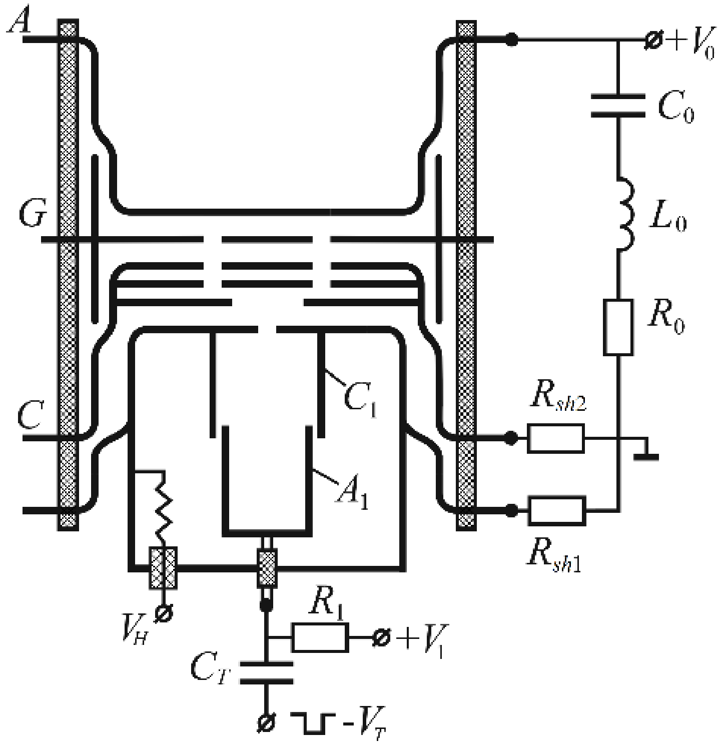
The point t_1 associated with the breakdown between the cavities of the electrodes A_1 and C_1, as there are drop in voltage V_{A1} and rise of the current i_1.

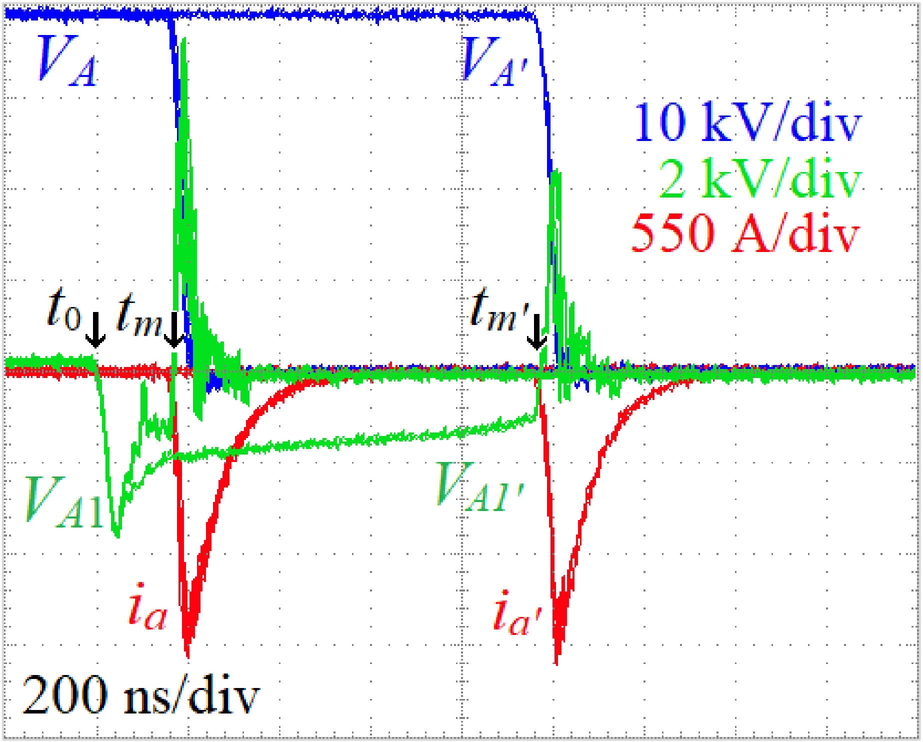
Here the delay time to breakdown in the trigger unit t_{d1} = 800 ns unlike it was 50 ns in the correct mode.
In the thyratron design under discussion, both regimes of the auxiliary discharge sustaining are occurring spontaneously.



Triggering in the presence of high voltage

In this experiment, the shunts R_{sh1} and R_{sh2} were shortened. Anode voltage V_A, anode current i_a and the trigger pulse voltage of V_{A1} were measured. Ten sets of the waveforms are superimposed.



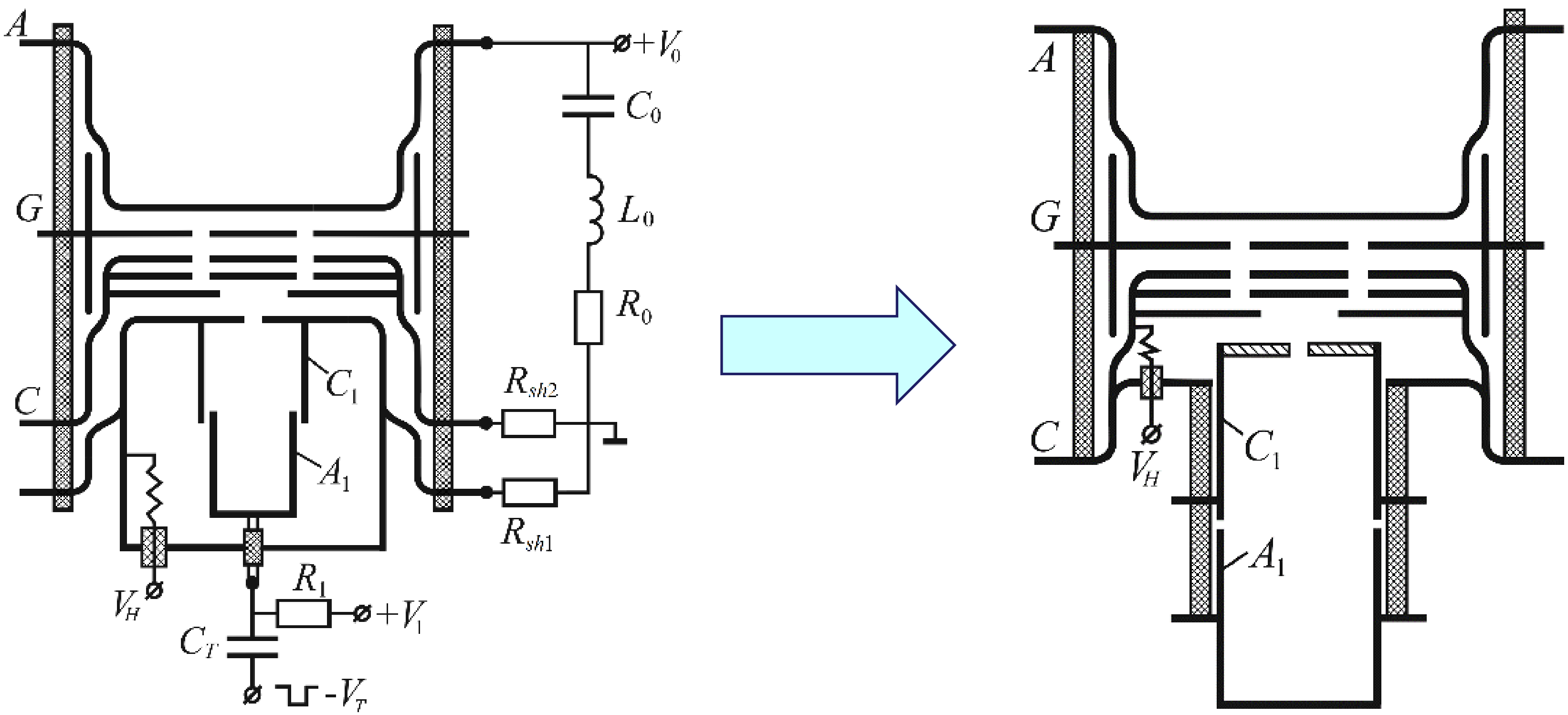


Point t_m corresponds to sharp decreasing of V_A and rise of i_a.
The interval $t_m - t_0$ is the total delay time to triggering. It includes the delay time to breakdown in the trigger unit $t_1 - t_0$ and the interval $t_m - t_1$ from the beginning of breakdown in the trigger unit.

Some of the pulses correspond to the correct regime of the auxiliary discharge and the total delay time t_m = 160 ns. For the incorrect regime $t_{m'}$ = 960 ns.

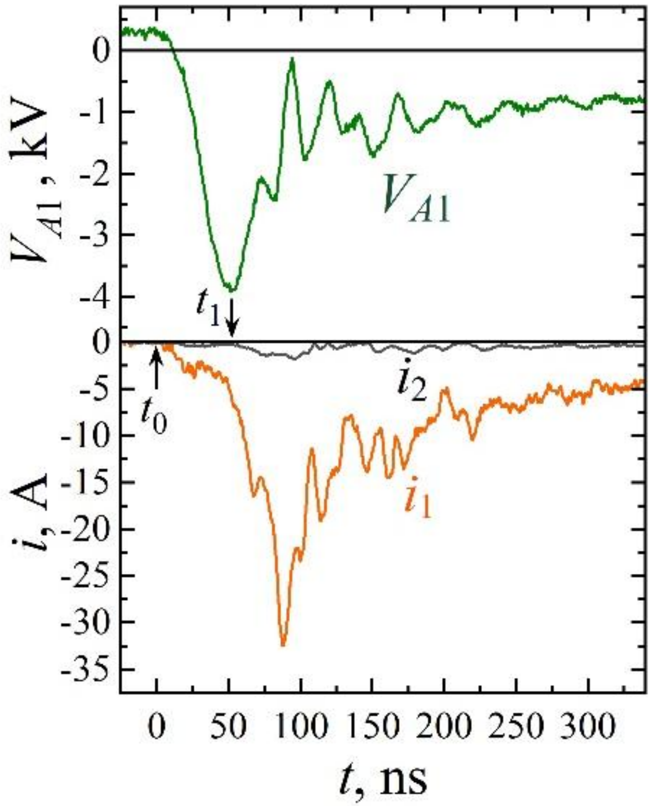
Upgraded thyratron

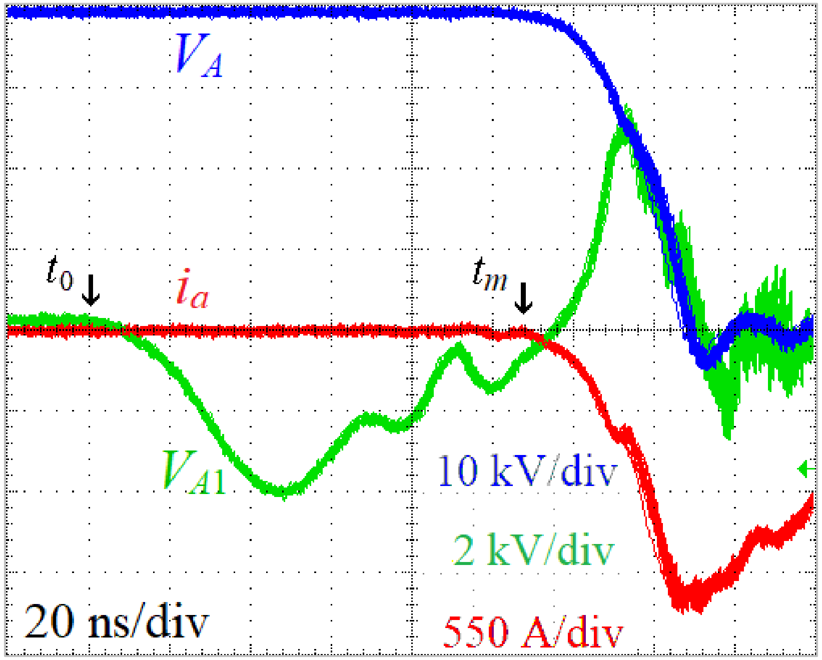
To avoid spontaneous changing of total delay time, the trigger unit was upgraded. The main gap electrodes left unchanged.



The electrodes A_1 and C_1 of the new trigger unit placed inside the insulators.
A narrow slit between the outer surface of the electrodes and the inner surface of the insulators prevents from discharge developing between the outer surfaces.
The auxiliary discharge and the trigger discharge forcedly initiate inside the cavities of the electrodes *A* and *C*.

Trigger discharge formation and triggering characteristics





In the upgraded thyratron there is only correct mode of the trigger discharge formation. Total delay time to triggering amounts 108 ns, and jitter is 4 ns.

Summary

- The auxiliary glow discharge may ignite in different modes spontaneously in case of the primarily upgraded thyratron,
- The spontaneously occurring modes of the trigger discharge worsen triggering characteristics of the thyratron,
- The newly upgraded thyratron has an improved design of the trigger unit. The trigger discharge ignites stably, providing nanosecond triggering stability of the device in the proposed electric circuit.