

# SHORT PULSE ELECTRON ACCELERATOR FOR PULSE RADIOLYSIS STUDY

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## Abstract

Electron accelerator dedicated for pulse radiolysis experiments has been constructed with nominal parameters: electron energy 10 MeV, pulse duration 10 ns, peak current 1 A. Traveling wave type accelerating structure powered by klystron operated at a frequency 1818 MHz has been applied. It consists of a cylindrical diaphragmatic waveguide with a prebunching part at the beginning. The loading properties of this structure provide acceleration capability in stored energy mode up to 10 A of pulse current with typical energy spread and 10 ns pulse length. The high power klystron pulse modulator was designed and build according to the scheme with delay line and thyatron switch. Pulse duration 2  $\mu$ s, repetition rate 50 Hz and amplitude up to 250 kV can be obtained. The original nanosecond electron gun with small value of the cut-off voltage (-1.3 kV) has been developed. The intensity of emitted current was tested with the rotationally symmetric and with the mesh grids. HV gun modulator was designed and build to provide 80 kV, 200 ns pulses. Thyatron switch triggered by fast transistor was used to obtain low jitter (<100 ps) necessary for precise synchronisation between high voltage and nanosecond pulses which are used to operate the electron gun. The nanosecond grid modulator has been build using ultra-fast transistor switch with the rise and fall time <3 ns

for pulses with an amplitude 4 kV. The accelerator and experimental halls and auxiliary rooms cover a total surface area of 220 m<sup>2</sup>. The experimental room has independent shielding and grounding systems to avoid distortion produced by high power, high voltage modulators and protect the measuring set up used in pulse radiolysis experiments.

## 1 INTRODUCTION

A new electron accelerator LAE 10 has been constructed at Department of Radiation Chemistry and Technology, Institute of Nuclear Chemistry and Technology (INCT) in Warsaw. This facility is dedicated to pulse radiolysis and related experiments in the field of radiation chemistry. The first electron linac LAE 13/9 type was installed at INCT in 1971 and has been successfully applied in the field of radiation chemistry and technology [1]. The growing demand for use of the accelerator and opposite requirements for both experimental and radiation processing applications changed the situation significantly after some years of facility exploitation. It was recognized that more suitable at present time are specialized units. Accordingly, other accelerator facilities were planned and built [2]. The main parameters of accelerators installed are shown in Table 1.

Table 1. Accelerator facilities in Department of Radiation Chemistry and Technology INCT

Facility		Type of accelerator				
Parameters	Units	LAE 13/9	AS-2000	ILU 6M2	Elektronika	LAE 10
Producer/country		NIIIEFA Russia	HVEC USA	INP Russia	NPO Toriy Russia	INCT Poland
Energy	MeV	5-13	0.1 – 2	0.7 – 2.5	10	10
Pulse current	A	0.8	D.C.	0.5	0.5	1
Average beam power	KW	9	0.2	20	10	0.2
Pulse duration	$\mu$ s	5.5	-	400	4.5	0.01
Repetition rate	Hz	150, single pulse	-	60	400	25, single pulse
Frequency	GHz	1.818	-	0.12	1.863	1,818
Power consumption	KW	150	10	100	120	55
Year of installation		1971	1987	1988	1993	1999

## 2 ACCELERATOR LAYOUT

The block diagram of LAE 10 linac is shown in Fig. 1. The accelerating section of the LAE 10 linac was built as a cylindrical diaphragmatic waveguide with

$2\pi/3$  modes with a prebunching part. The traveling wave accelerating structure of LAE 10 was made in NIIIEFA, Russia and it is the same type as the LAE 13/9 linac. Accelerating structure is powered by klystron KIU-15 operated at a frequency 1818 MHz.

The pulse power at the output of the klystron is 20 MW. A low power klystron KIU-17 with a suitable modulator is used to drive a high power amplifier. A rectangular waveguide  $120 \times 57 \text{ mm}^2$  in cross section filled with nitrogen at a pressure of 5 at is used to feed the accelerating structure with microwave energy. The waveguide is separated from the vacuum system by ceramic windows. The not used portion of microwave energy is taken away by water cooled microwave load. The accelerating section is under pressure  $< 5 \times 10^{-6}$  Torr, which is secured by two titanium vacuum pumps and a forevacuum oil pump. The KIU 15 pulse modulator was designed and built to operate according to the scheme with delay line and TGI-2500/50 ceramic thyatron high power switch. Pulses with

duration  $2 \mu\text{s}$ , repetition rate 25 Hz and amplitude up to 250 kV have been obtained.

The original nanosecond triode electron gun with impregnated cathode has been developed and used as a source of electrons. The gun initially designed with the grid rotational symmetric finally was constructed with the mesh grid to obtain bigger current at the output of the accelerator.

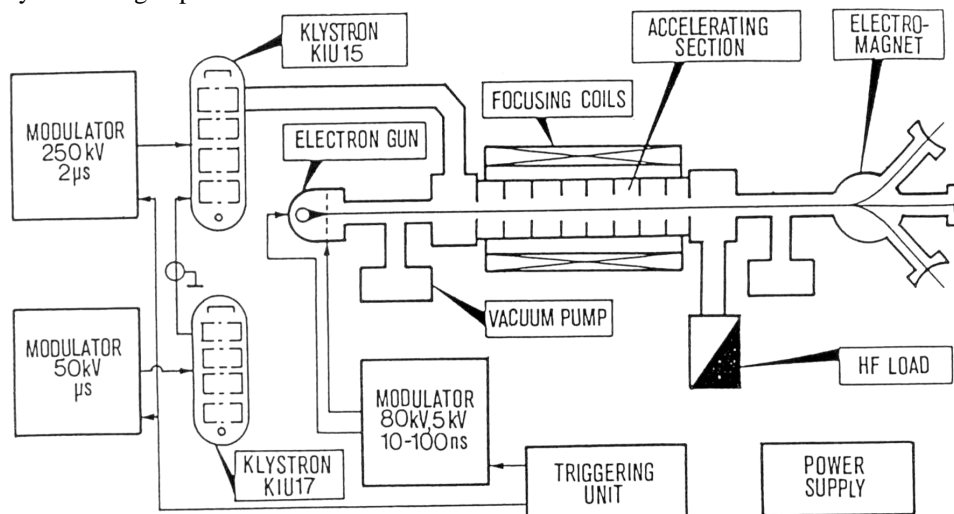


Fig.1. Block diagram of LAE 10 linac.

The gun is operated in a pulse regime at a voltage of 80 and 4 kV respectively. Pulses with fixed duration 10 ns are formed. The electron beam is extracted in one of three directions through  $50 \mu\text{m}$  air cooled titanium foils. The first output is designed to measure electron energy. Two other outputs are applied in separate experimental stands where pulse radiolysis instrumentation are located.

The original nanosecond electron gun and gun modulator have been developed to fulfil specific requirements [3]. The acceleration process requires certain initial parameters of the electron beam at the input of accelerating section of LAE 10 linear accelerator. The electrons should have velocity  $v = 0,5c$  what corresponds electron energy 80 keV and such pulse amplitude should be used to operate the electron gun. The circuit consist of triode gun, high voltage modulator, nanosecond grid modulator, negative biasing.

High voltage pulse modulator was designed and build to provide pulses with amplitude 80 kV and pulse duration 200 ns. The main high voltage circuit is based on TGI-1000/25 ceramic thyatron as a powerful

switch. It is triggered by HTS 31 fast transistor switch which can deliver strong pulses without any pulse transformer [4]. This fast switch is energised during 80 ns what is sufficient to charge storage capacitor. The stable trigger pulses with an amplitude 800 V were obtained due to diode forming circuit. Such configuration may accept relatively high supply voltage fluctuation ( $\pm 15\%$ ) without significant change of trigger amplitude. The delay between trigger and output pulses is approximately 700 ns. The trigger pulse has very low jitter less then 100 ps. It allows to obtain precise synchronisation between high voltage and nanosecond pulses which are used to operate electron gun.

The nanosecond grid modulator has been designed and build. Good quality R and C components were used to improve time performances of the modulator. Ultra-fast transistor switch HTS 80-12-UF was applied. The rise and fall time are not higher than 3 ns respectively. The rise time  $t_n$  was measured on the output of the generator. It depends on the total load capacitance  $C_0$  ( $C_0 = \text{load capacitance } C_0 + \text{coaxial cable capacitance } C_{cc} + \text{montage capacitance } C_m$ ) and

on coaxial cable parameters ( $Z_f = 50 \Omega$ ) and load resistance  $R_0$ . The load capacitance was found to be  $C_0 \leq 38 \text{ pF}$  for desired rise time  $t_n \leq 3 \text{ ns}$ . Some distortion of the pulse shape has been observed which are caused by stray inductance  $L_p$  related to the connections between circuit components. When the current rise is high ( $di/dt \leq 50 \text{ A/ns}$ ) 10mm long wire (what corresponds to  $L_p = 10 \text{ nH}$ ) may introduce the distortion signal with amplitude several hundred volts.

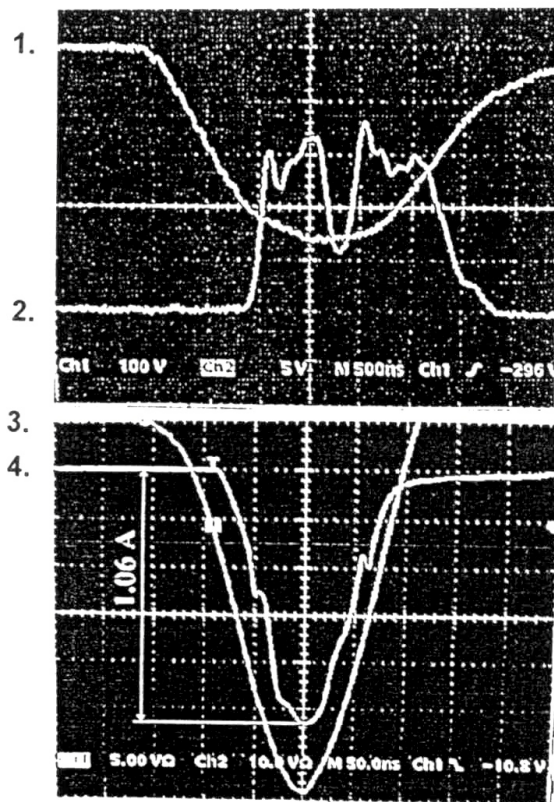


Fig. 2. Selected pulses: output of KIU-15 klystron modulator (1), microwave envelope loaded by electron beam (2), output of gun modulator (3), 100 ns pulse of electrons (4)

A LAE 10 accelerator was located in specially developed building equipped with adequately shielded rooms. The accelerator and experimental halls and auxiliary rooms cover a total surface area of 220 m<sup>2</sup>. The experimental room itself will have a surface area of 15 m<sup>2</sup> and is equipped with independent shielding and grounding systems to avoid distortion produced by high power, high voltage modulators. The console and auxiliary control system are placed in a separate room located in existing building.

### 3 ELECTRON BEAM CHARACTERISTICS

Due to electron gun power supply system there are two modes of operation. In the first mode the nanosecond gun does not provide pulses. The Fig. 2 shows selected pulses: output of KIU-15 klystron modulator (1), microwave envelope loaded by electron beam (2), output of gun modulator (3), 100 ns pulse of electrons (4). The second mode is related to nanosecond time scale. Fig.3 shows the electron beam current pulse shape in ns time scale.

### 4 FINAL REMARKS

The electron accelerator type LAE 10 is an instrument for research in the radiation chemistry field which provides 10 MeV, 10 ns electron pulses with an amplitude over 1A. This facility is solely dedicated to pulse radiolysis experiments and related work in the field of radiation chemistry. The construction and performances of this specialized linac are complementary to existing at INCT various types of accelerators with different technical parameters and applications. The gathered experience will also allow to introduce necessary modification of the accelerator and measuring set up to fulfill scientific work programs in the future.

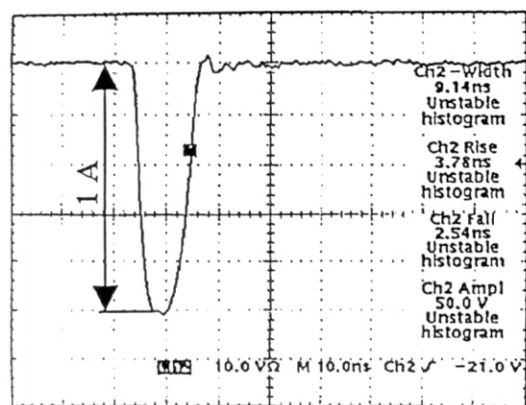


Fig. 3. The shape of electron beam pulse in nanosecond mode of operation

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