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Klystron pulse modulator of linear electron accelerator: test results

Z. Zimek, Z. Dźwigalski*, S. Warchoł, K. Roman, S. Bułka
Centre for Radiation Research and Technology, Institute of Nuclear Chemistry and Technology, ul. Dorodna 16, 03-195 Warsaw, Poland
* Corresponding author: E-mail address: dzwigal@orange.ichtj.waw.pl

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Analysis and modelling

ABSTRACT

Purpose: The purpose of the paper is to describe Klystron pulse modulator of linear electron accelerator.
Design/methodology/approach: TH-2158 klystron modulator experimental model is based on semiconductor switch HTS 181-160 FI (acceptable current load 1600 A, and voltage up to 18 kV). The results of test measurements carried out during modulator starting up period are presented in this work. TH-2158 klystron was used as a load. The klystron was connected to the second winding of the pulse HV transformer with 1:10 windings turn ratio. The examined modulator is equipped with safety shutdown circuitry for protection against current overload that may appear at IGBT switch in the case of short-circuiting happened in klystron and waveguide system.
Findings: Linear electron accelerator type LAE 10/15 with electron energy 10 MeV and beam power up to 15 kW was designed and completed at Institute of Nuclear Chemistry and Technology. This accelerator was installed in facility for radiation sterilization single use medical devices, implants and tissue grafts. The standing wave accelerating section was selected. Microwave energy used for accelerating process is provided by klystron type TH-2158 working at frequency 2856 MHz.
Practical implications: Described HV pulse modulator which designed and constructed for klystron TH-2158 was preliminary tested to evaluate the quality of the klystron HV and load current pulses and optimized selected component parameters. Obtained experimental results are better than those which were predicted by computer simulation method.
Originality/value: Description of Klystron pulse modulator of linear electron accelerator.
Keywords: Klystron pulse; Linear electron accelerator; HV pulse modulator

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1. Introduction

High voltage, pulse modulator was designed and constructed to provide pulses with amplitude up to 135 kV, duration 20 μs and repetition rate up to 330 Hz. The partly discharged capacitor bank is applied and semiconductor switch is used to form certain pulse time structure. The TH-2158 (modulator load device) is supplied through 1:10 pulse transformer. The modulator was tested recently and first experimental results were obtained. The measurements were performed with driving pulses duration t_p<12μs and repetition frequency rate f_f <1Hz. Capacitor bank „C" [1] was charged to maximum voltage 12kV what corresponds with pulse amplitude 120 kV. The primary objectives of performed experiment were evaluation of wireing quality and evaluation of certain components parameters on pulse shape. The obtained results are sufficient base for optimization circuit parameters for final modulator construction [1-4]. registered by capacitor divider with transformation ratio 10 000:1.

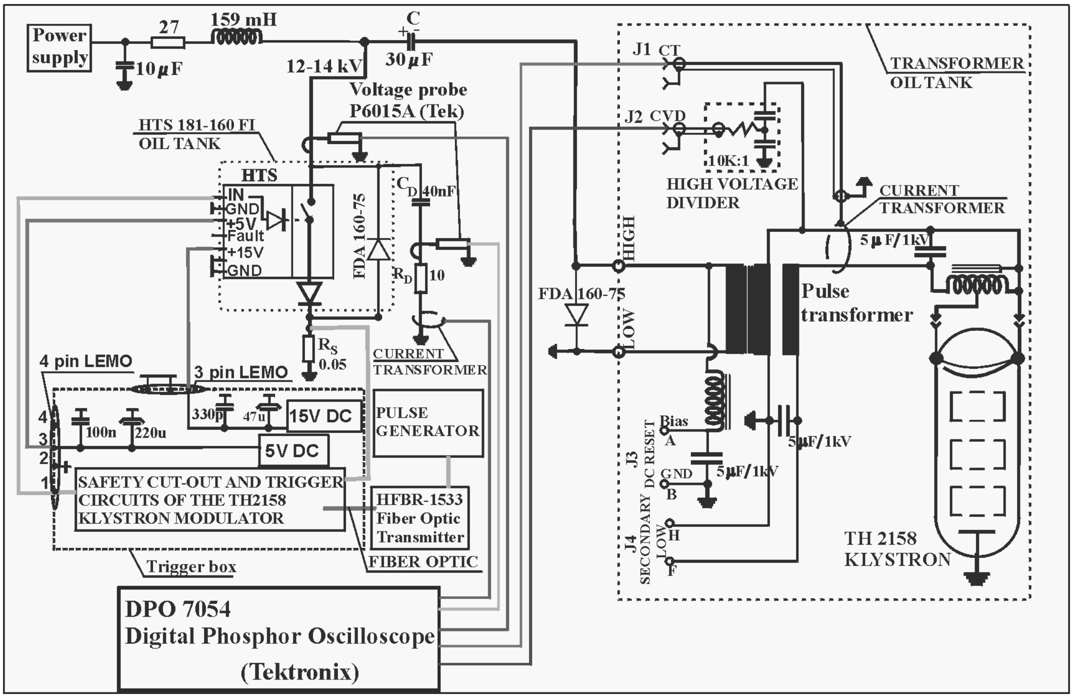

Fig. 1. Simplified scheme of the TH2158 klystron modulator and measuring circuit

a)

b)

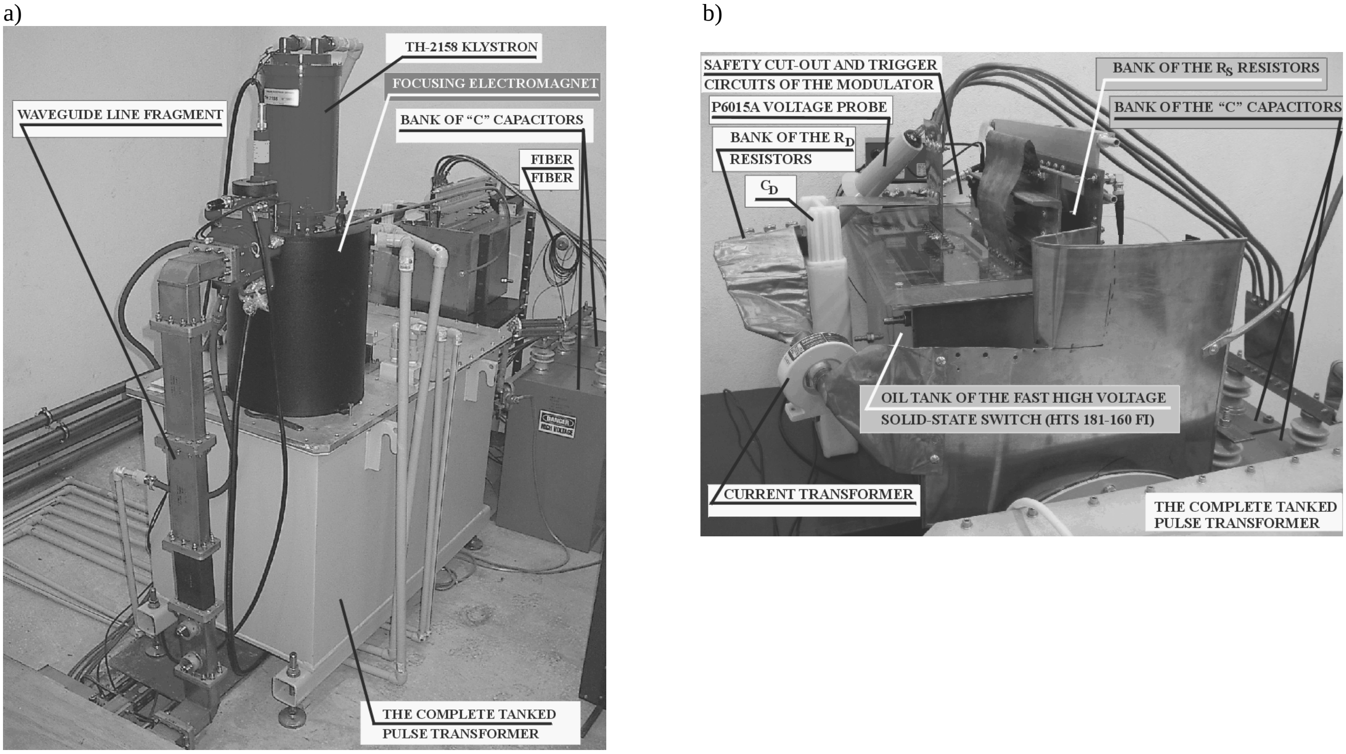

Fig. 2. a) Overall view of the modulator, b) Wireing of semiconductor switch and location of HV and current sensors

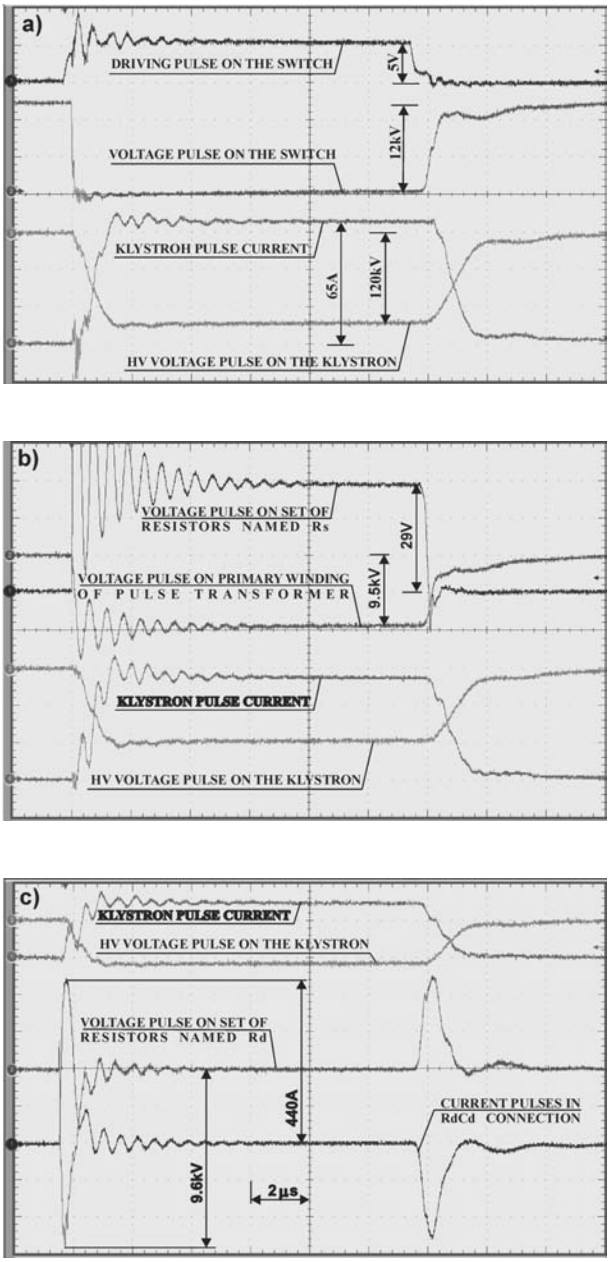

Fig. 3. Oscillograph records

Additionally pulse current in parallel to HTS 181-160 FI (semiconductor switch) R_DC_D connections was registered. Current transformer type 2-0.1W, provided by Stangenes Company, with sensitivity 0,1A/V0 was used as current sensor. Voltage pulse amplitude on resistivity R_D was captured by high voltage zound P6015A. The same type of sensor was used to measure the DC voltage level on capacitor bank “C”.

The shape of voltage pulses on HTS 181-160 FI (semiconductor switch) and primary winding of pulse transformer were measured as well. The shape of current pulses in primary winding of pulse transformer and semiconductor switch was measured as voltage drop on ceramic resistor R_S with resistivity 50mΩ [4].

2. Experimental arrangement

Simplified modulator circuit with measurements sensors is show on Fig. 1. Modulator overall view is presented on Fig. 2.a.

Wireing of semiconductor switch responsible for transmission high level current pulses and location of HV and current sensors can be seen on Fig. 2.b.

Four channels digital oscilloscope type DPO 7054 (manufactured by Tektronix Company) was used to measure simultaneously pulse shape in different circuit points. Two high voltage probe type P6015A (1000:1) and two probe type P6139A were use to capture voltage signals. Klystron load pulse current shape was measured by current transformer with sensitivity 10A/V. The shape high voltage pulses were

3. Experimental results

Structures of arc discharge operating on titanium cathodes, typical for investigated sources, recorded at different exposure times in the same process conditions (I_{ARC} = 100 A, p = 8.0×10^{-3} mbar, 90%N_2 + 10%C_2H_2) are shown in Fig. 2. At the exposure times applied in the experiments (21 µs and 10505 µs) cathode spots of the Type 2 [5] were recorded (with average lifetime of 0.5 - 1.5 ms).

Oscillograph records presented on Fig. 3.b show the shape of the following pulses: HV pulse on klystron, voltage pulse on primary winding of pulse transformer and voltage pulse on set of resistors named R_S and load klystron pulse current with rise time around 1.6 µs and amplitude 78A. Pulse current amplitude was higher than that which was presented on Fig. 3.a due to higher value of provided to klystron cathode heater. The oscillation amplitude observed in front part of voltage pulse observed on primary pulse transformer winding should be decreased because of their influence on the shape of klystron HV pulse shape and particularly rise time. The observed oscillations have also influence on the shape of driving pulse of semiconductor switch and destroying properties of safety cut-out and trigger circuits of the TH-2158 klystron modulator [3].

Oscillograph records presented on Fig. 3.c show except HV and current klystron pulses, the shape of the voltage measured on set of ceramic resistors R_D and current pulses in R_DC_D connection.

These measurements provide necessary date to evaluate power which will be dissipated by resistor R_D for certain frequency pulse repetition rate f_f . When f_f =300Hz this power will be around 1kW.

4. Conclusions

Described HV pulse modulator which designed and constructed for klystron TH-2158 was preliminary tested to evaluate the quality of the klystron HV and load current pulses and optimized selected component parameters. Obtained experimental results are better than those which were predicted by computer simulation method.

Acknowledgements

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