ON LENGTHENING THE VOLTAGE PULSE DURATION OF A LINEAR MODULATOR

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Experiments were made to investigate the operation of the modulator in combination with the storage capacitor, using the nonlinear properties of the core material of the pulse transformer for the formation of long pulses. Studies were made on the parameters of voltage pulses at the secondary winding of the pulse step-up transformer. We have considered the influence of the PT core demagnetization current and voltage on the shape of the output signal.

PACS: 41.75.Fr, 87.50.Mn

1. INTRODUCTION

Powerful electron beams present one of the effective means for modifying the surface properties of materials. This is currently central for strengthening reactor structural materials, improving their wear resistance, and increasing the service life of reactor components. Being exposed to the beam, the material surface is quickly heated up to the transformation temperatures to a depth of about the range of particles in the given material, and then it is allowed to cool. It has been demonstrated in refs. [2,3] that the optimum parameters of the electron beam for modification of material surfaces are as follows: electron energy 100…400 keV, power density on the material surface under treatment 1…5 MW/cm^2, pulse duration 5…50 µs.

In recent years, consideration has been given to magnetron guns with cold secondary-emission cathodes in crossed fields [3]. These guns have a number of advantages: they are simple in design, retain emission after letting to air, and their service life may attain 100,000 hours. They hold promise for their use as electron sources for modification of material surfaces. For power supply of these guns, it is necessary to have a pulse modulator with long pulse duration (up to 100 µs). The generation of such pulses is a rather complicated task. It appears reasonable to make use of the nonlinear properties of the core material [4] of the pulse transformer for the formation of long pulses in the modulator with the use of a storage capacitor and a pulse transformer. The present paper is concerned with the studies into the possibility of creating the pulse modulator for energizing the magnetron gun with a secondary-emission cathode.

2. THE EXPERIMENTAL SETUP AND THE RESEARCH TECHNIQUES

The experiments were performed at the setup schematically presented in Fig.1. The figure gives the circuit of the pulse modulator with the storage capacitor C =1.5 µF (load resistance R_l = 880 Ω). At discharge of the storage capacitor to measure the generator resistance, additional resistors R_{add} = 12 Ω, 21Ω, 36 Ω were connected in series with the storage capacitor. Studies were made on the parameters of voltage pulses at the secondary winding of the pulse step-up transformer (PT) for the discharge of the storage capacitor through the PT, at different currents of PT core demagnetization (I_{dem} = - 20A…+20A) and different output voltages. The signals are taken from the secondary winding of the PT via the potentiometer-type voltage divider and are supplied to the attenuator unit, which makes it computer-assisted measuring system [5].

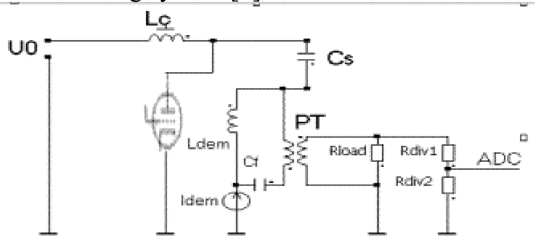

Fig.1. Measurement circuit

The pulses were registered by means of a possible to match the signal amplitudes for their further transformation and processing in the ADC and PC. The signals are registered in the digital form in steps of 200 ns. The measuring error ranges within 1 to 2%.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The output voltage pulse is substantially influenced by the current of PT core demagnetization. By varying the demagnetization current I_{dem} it is possible to vary the working point position on the hysteresis loop with its shift into the nonlinear region of the loop, where the magnetizing inductance of the PT decreases, and hence, the pulse shape changes.

The effect of demagnetization current, and correspondingly, of the PT working point position on the parameters of the pulse was investigated for the modulator with the storage capacitor. We have considered the influence of the PT core demagnetization current on the shape of the output signal at a constant output voltage (Fig.2). It can be seen from the figure with a decrease in the current I_d the voltage pulse duration in the secondary winding of the PT also decreases. For example, at I_d = + 20 A the pulse duration makes 14 µs, while at I_d = - 20A the pulse lasts 4.5 µs.

Fig.3 shows the pulse duration in the secondary winding of the PT as a function of the output voltage at a demagnetization current of + 20A (the demagnetization current value was chosen from the consideration of the PT operation in the linear part of the hysteresis loop). At low voltage amplitude values the voltage pulse falls off practically linearly. At high voltage values, two stages may be distinguished in the voltage drop: at the

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2006. № 2.
Series: Nuclear Physics Investigations (46), p.120-122.

first stage the voltage drops slowly, while at the second stage it drops quickly. In the first case, this is due to the operation in the linear part of the hysteresis loop, and in the second case the working point is shifted to the nonlinear part of the hysteresis loop, and the sag of the pulse becomes more abrupt.

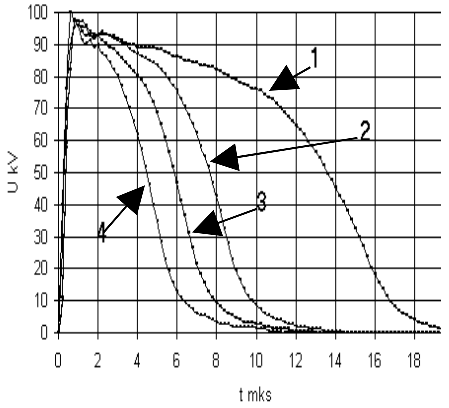

Fig.2. Output signal shape versus demagnetization current. 1 – I_d = + 20A; 2 – I_d = + 5A; 3 – I_d = 0; 5 – I_d = - 20A

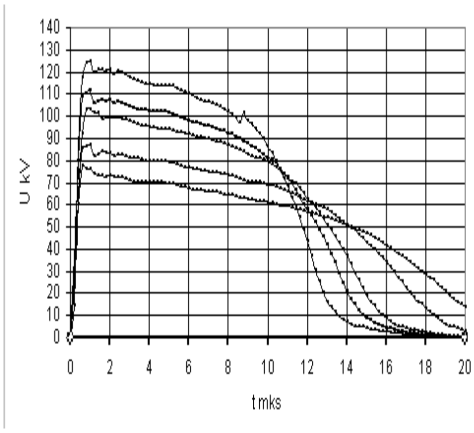

Fig.3. Pulse length as a function of output voltage amplitude

The wave resistance of the discharge circuit of the modulator with the storage capacitor (measured with the use additional resistor R_{add}) has been determined to be ~ 1.5 Ω. This result is necessary for calculating the parameters of the modulator.

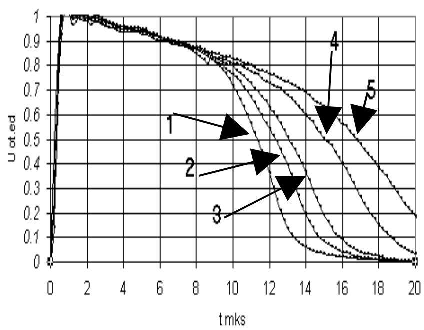

Fig.4. Normalized output voltage pulses of amplitudes: 1 – 120 kV; 2 – 107 kV; 3 – 100 kV; 4 – 85 kV; 5 - 75 kV. The demagnetization current is 20 A

Figure 4 shows the voltage pulses of different amplitudes at the PT secondary winding, which were normalized to their maximum value. It is seen that up to a certain moment of time (for 9 μs) all the pulses drop by the same law; the sag of the pulse for 9 microseconds makes 17%.

The sag of the pulse can be reduced by connecting an additional inductor L_{add}, in series with the storage capacitor [6]. Calculations were made to find the dependence of the pulse shape on different values of additional inductance. Results of calculations ousted in the Table, which gives the following pulse parameters: the maximum amplitude U/U_0, front time $\boldsymbol{\tau}$, duration at a 20% sag of a pulse $\tau_{0.8}$. It is clear from the table that with a series connection of the additional inductor the pulse duration increases, and the sag of the pulse gets reduced. But in this case the pulse amplitude also decreases, while the pulse rise time increases.

The pulse parameters

L_{add} ,μH	t, μs	$\tau_{0.8}$,μs	U/U_0
0	0.7	9	0.77
40	2.7	11.4	0.67
60	4	12.1	0.65
100	6	13.6	0.61

4. CONCLUSION

The present measurements and calculations have demonstrated that nonlinear properties of the pulse transformer core material may be used for the formation of long pulses in a modulator. This leads to a decrease in the pulse decay time. By introducing an additional inductor it appears possible to form the shape of the pulse peak so as to obtain nearly a rectangular voltage pulse.

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К ВОПРОСУ ОБ УВЕЛИЧЕНИИ ДЛИТЕЛЬНОСТИ ИМПУЛЬСА НАПРЯЖЕНИЯ ЛИНЕЙНОГО МОДУЛЯТОРА

В.В. Закутин, Н.Г. Решетняк, В.П. Ромасько, И.А. Чертищев

Проведены эксперименты по исследованию работы модулятора с накопительной емкостью, с целью использования нелинейных свойств материала сердечника импульсного трансформатора для формирования импульсов большой длительности. Изучались параметры импульсов напряжения на вторичной обмотке импульсного трансформатора. Рассмотрено влияние тока размагничивания сердечника импульсного трансформатора и напряжения на форму выходного сигнала.

ДО ПИТАННЯ ПРО ЗБІЛЬШЕННЯ ТРИВАЛОСТІ ІМПУЛЬСУ НАПРУГИ ЛІНІЙНОГО МОДУЛЯТОРА

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Проведені експерименти по дослідженню роботи модулятора з накопичуваною ємністю, з метою використовування нелінійних властивостей матеріалу осердя імпульсного трансформатора задля формування імпульсів великої довжини. Вивчалися параметри імпульсів напруження на вторинній обмотці імпульсного трансформатора. Розглянуто вплив струму розмагнічування та напруги на форму вихідного імпульсу.

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2006. № 2.
Series: Nuclear Physics Investigations (46), p.120-122.