HIGH-CURRENT STANDING WAVE LINAC WITH GYROCON POWER SOURCE

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Abstract

A gyrocon together with high-voltage 1.5 MeV accelerator ELIT-3A represents a power generator at 430 MHz serving for linear electron accelerator pulse driving. The facility description and results of calorimetric measurements of ELIT-3A electron beam power and accelerated beam at the end of accelerator are presented in the paper. 2.2 amps of pulsed current have been obtained at electron energy of 20 MeV. The achieved energy conversion efficiency is about 55%.

INTRODUCTION

The high-current (up to 20 A) 50 MeV linear accelerator (linac) operated in energy accumulating mode [1] is used as an electron and positron source at the VEPP-4 storage facility at Budker INP SB RAS. Making such accelerator has been made possible by development at BINP of a high-power RF power source – gyrocon [2]. The gyrocon uses a non-bunched relativistic electron beam form the high-voltage direct action accelerator ELIT-3A [3]. The linear accelerator has been operating as a part of the VEPP-4 facility since 1978. Availability of the high-efficiency (>75%) RF power source and safely operated linac enabled us to carry out experiments on study of relatively low-voltage (1.5–1.7 MeV) high-power electron beam energy conversion into the energy of electrons accelerated up to energy of 15-20 MeV. Such investigations are still actual because of availability of effective accelerator projects for applied applications and future linear collider projects, operated at the same concept.

EXPERIMENTAL SETUP

Figure 1 represents the scheme of the experimental setup and its main parts.

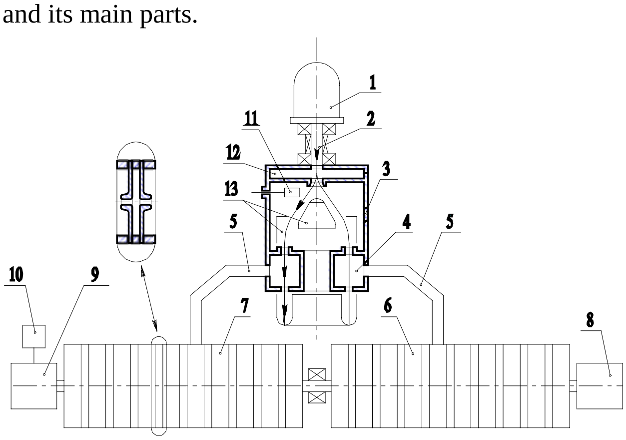

Figure 1: Experimental setup scheme.

1.5 MeV electron beam formed by ELIT-3A accelerator (1) is injected via electron-optic channel (2) into gyrocon (3). Conversion of the electron kinetic energy into RF power at 430 MHz takes place in the gyrocon output cavity (4). Two vacuum-proof waveguides (5) serve for RF power output from the gyrocon. Length of these waveguides is divisible by integer number of the half-wavelength and provides the resonant coupling between the RF power source –gyrocon and linac.

The linear accelerator consists of two sections (6,7), each of them is a biperiodic chain of coupled cavities. $\pi/2$ type oscillations are excited in the structure with $\mathbf{TM_{010}}$ field distribution in the cavities. Each section contains 10 accelerating and 9 coupling cavities. The coupling coefficient of the accelerating cavities is about 10% and provides short transition time of linac oscillations comparing with RF feeding pulse length.

A diode gun serves as an electron injector (8) in linac. The gun is installed into the center of the end wall of the first accelerating section (6). The gun anode is realized as a grid with transparency coefficient of 0.8 and has a galvanic coupling with the end wall. The negative voltage pulse of 40–60 kV with duration up to 10 μs is formed by the gun modulator and is applied to the cathode through the step-up transformer, thus providing injection of the electron current into linac. In the first cavity, bunches of ~2 radians length are formed from the electron flow, then they are accelerated in linac sections, are focused, and hit the cooled target (9) connected to the calorimeter (10).

A general view of the experimental setup is shown in Fig. 2. Figure 3 represents a time diagram, which clarifies the device operating. Efficiency η of low-energy ELIT-3A beam power conversion into high-energy linac electron beam power is determined by the ratio of the average during a pulse beam power at linac output $\mathbf{P_u}$ to the beam power exciting the gyrocon $\mathbf{P_g}$, i.e. $\eta = \mathbf{P_u}/\mathbf{P_g}$. To measure these values, the method of calorimetrical calibration has been chosen. Such a method is preferred because of the electrons are injected into the linac without pre-bunching. Pulse forms were controlled by automated system, which simultaneously carried out the functional dependence processing. The target (Fig. 1 pos. 9) which absorbs the beam from linac is made of aluminium and lead. Its dimensions has been chosen to absorb more than 98% of the beam power for 40 MeV electron beam. The target is heat-insulated and is cooled by water pumped through the calorimeter. The calorimeter contains the heating element, which is used for calibration by heating the water up to the fixed temperature difference by alternate current of low frequency. It allowed us to eliminate inaccuracies of water current speed measurements and thermal couple calibration, as well as to decrease error of power measurement down to ±2-3%.

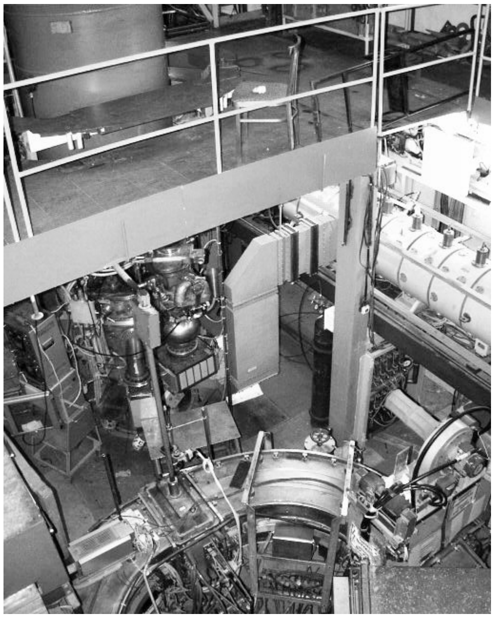

Figure 2: Experimental setup: a general view.

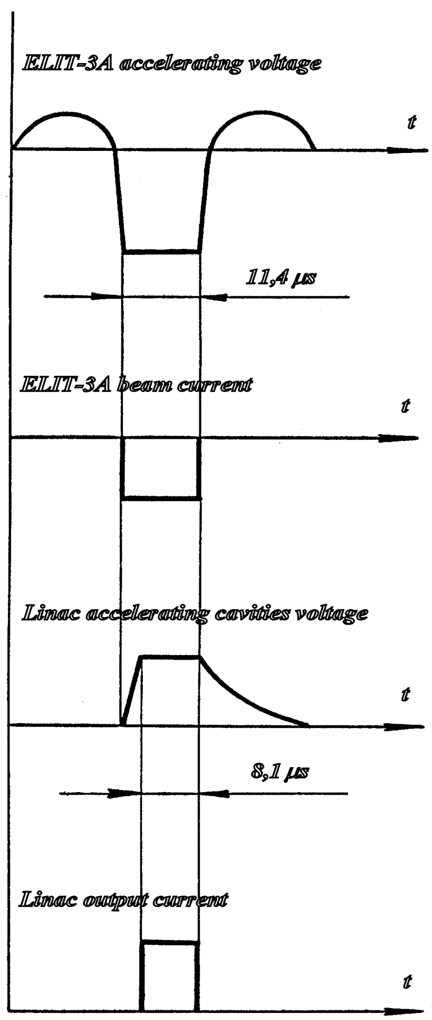

Figure 3: Pulses time dependencies.

The distantly replaceable gyrocon central probe (Fig. 1 pos. 11) is used as an absorbing target to measure an average beam power excited the gyrocon. This probe is made as a cooled Faraday cup, which can be connected to the calorimeter. The probe is located between the gyrocon input cavity (Fig. 1 pos. 12) and deflecting systems (Fig. 1 pos. 13). To measure the beam average power, which excites the gyrocon, the central probe is positioned on the axis, and the drive cavity is not excited. In this case, the direct beam from ELIT-3A is absorbed in the Faraday cup, so heating it, and the calorimeter allows us to measure an average consumed power.

STUDY RESULTS

The maximal beam power at the linac output has been obtained by thorough gyrocon tuning, adjusting the coupling between the output cavity and linac sections, and choosing the parameters of the beam injected into the linac (such as voltage, current, duration, and moment of injection). The main parameters of ELIT-3A and linac are correspondingly listed in Tables 1 and 2.

Table 1.

ELIT-3A accelerating voltage, MV	1.75
ELIT-3A pulsed current, exciting the gyrocon, A	42
Beam energy, J	848
ELIT-3A current pulse duration at 0.5 power level, μs	11.4
ELIT-3A average per pulse beam power, exciting the gyrocon, MW	74.4

Table 2.

Operating frequency, MHz	429.5
Type of oscillations in the structure	$\pi/2$
Coupling coefficient of accelerating cavities, %	10.6
Accelerating section quality factor Q	20000
Shunt impedance R, MOhm/m	12.5
Accelerator output electron energy, MeV	~19
Beam pulsed current, A	2.2
Beam energy, J	335
Beam current duration at 0.5 power level, μs	8.1
Average per pulse beam power, MW	41.4

CONCLUSION

A current of 2.2 A at an energy of 20 MeV in 8 μs pulse was obtained as a result of work carried out. The experimental efficiency **η=0.55±0.03** of electron beam energy conversion at the gyrocon–linear accelerator setup has been obtained. The experiments were realized at a facility not optimized for the maximal efficiency obtaining: linac and gyrocon cavities were made of duralumin, coupling cavities in linac sections are located along the beam motion direction, etc.

REFERENCES

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