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MODELING OF THE ENERGY COMPRESSION SYSTEM SLED FOR THE LINAC-200 ACCELERATOR

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Abstract

This paper is devoted to the research of the possibility of increasing the output energy of an electron beam at the LINAC-200 linear accelerator by using the SLED (Stanford Linac Energy Doubler) [1] energy compression system with constant parameters of the storage cavities [2].

In order to select the necessary parameters and characteristics for the successful creation of this system on the accelerator, the SLED system (Fig. 1) structure simulation and the characteristics of cylindrical hollow resonators [3] calculation were conducted using the CST MICROWAVE STUDIO program [4].

INTRODUCTION

The LINAC-200 linear electron accelerator operating at a frequency of 2856 MHz can currently increase the energy of particles to 200 MeV. We continue to build up energy by installing accelerating sections, which according to plans can raise energies up to 800 MeV. However, further increasing the size of the accelerator is difficult, so other approaches have been explored.

Figure 1: SLED energy compression system design from IREN (JINR, LNP).

An energy compression system can be used to increase the energy of an electron beam in a linear accelerator without increasing the size of the installation. In our case, the power multiplication system SLED was chosen [2]. This system consists of several components shown in Fig. 2.

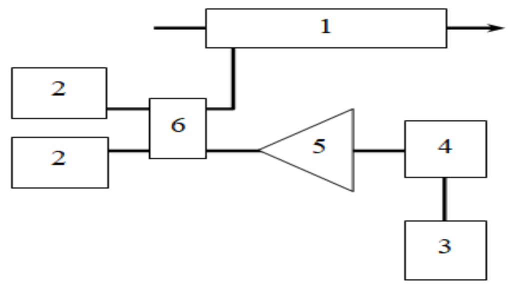

Figure 2: Block diagram of LINAC with an energy compression system SLED (1 - accelerating section, 2 - storage resonators, 3 - master oscillator, 4 - high-speed phase shifter, 5 - power amplifier, 6 - high frequency bridge).

To analyze the structure and obtain results, it is sufficient to consider the process of excitation of a single cavity [1].

PARAMETER ESTIMATION AND CAVITY MODELING IN THE ENERGY COMPRESSION SYSTEM SLED

Pulsed klystrons of the 10 centimeter range are used as microwave power amplifiers, the operating frequency of which corresponds to 2856 MHz. Information on klystrons is specified in the Table 1.

Table 1: Parameters of Klystrons

Type	**TH 2129**
Company manufacturer	TTE (Thomson Tube Electronics)
Peak power:	
input, W	100
output, MW	20
Average power:	
input, W	0.7
output, kW	20
Pulse duration, μs	4
Frequency of repetition (max), Hz	500

There are 2 types of accelerating sections: short and long (Fig. 3). They have the characteristics specified in the Table 2.

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Table 2: Parameters of Accelerating Sections

	short	long
Amount of sections	3	18
Amount of cells in a section	105	210
Length at accelerating intervals, cm	3.673	7.346
Amount of uniform segments per section	11	11
Frequency, MHz	2856	
Type of wave	TW	
Oscillation mode	2π/3	
Acceleration rate, MeV / m	5 (I=40mA) – 7 (I=0)	
Filling time, µs	1.3	
Beam load (total over the entire accelerator), MeV / mA	2.6	
Group speed range velocity, V_γ/c	0.0093 – 0.0389	
Shunt impedance, MOhm	56.5 – 48	
Iris aperture: diameter, mm	32	
thickness, mm	5.84	

Figure 3: Long accelerating section A3A.

A high Q factor in copper cavities, at room temperature, can be obtained by using higher-order resonant modes. Taking into account the mechanical stability and frequency separation of higher modes, it can be concluded that the mode with the smallest cavity volume will be the most desirable mode.

Mods from the TE_{01N} family satisfy these requirements. The specific ratio of the diameter D to the length L of the cavity is chosen on the basis of calculations, optimizing the achievement of the maximum frequency resolution between adjacent modes at the highest Q-factor. With an increase in the number of variations N along the length of the cavity, the Q-factor increases, but at the same time, the frequency resolution between adjacent modes decreases. It was decided to use N = 5 [3], the field distribution of which can be seen in Fig. 4.

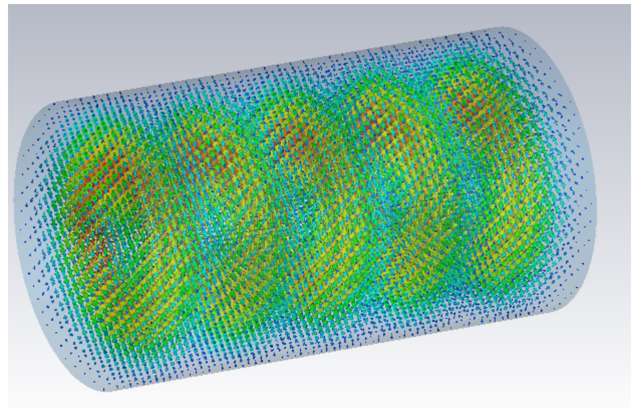

Figure 4: Cavity e- field distribution at selected size.

A cavity was modeled for the well-known structure of the LINAC-200 accelerator, the parameters of which correspond to our needs [1, 2]. The values of the characteristics obtained in the analysis of the SLED system are shown in Table 3.

Table 3: Estimation of the Parameters of the Energy Compression System

Type of wave	$2\pi/3$
Frequency, MHz	2856
Filling time, µs	1.3
Pulse duration, µs	4
Field decay time in section, µs	1.5
Time of pumping out the stored energy, µs	2
Coupling coefficient	4
The coefficient of increase of the collected energy	2.002

The simulation in the CST MICROWAVE STUDIO program resulted in the physical dimensions of the cavity (L = 33.59cm, D = 20.52cm) and its Q factor (Q = 1.002 * 10^5). These data were selected from the obtained modes 1 and 2 (Fig. 5 and Fig. 6) for different cavity sizes.

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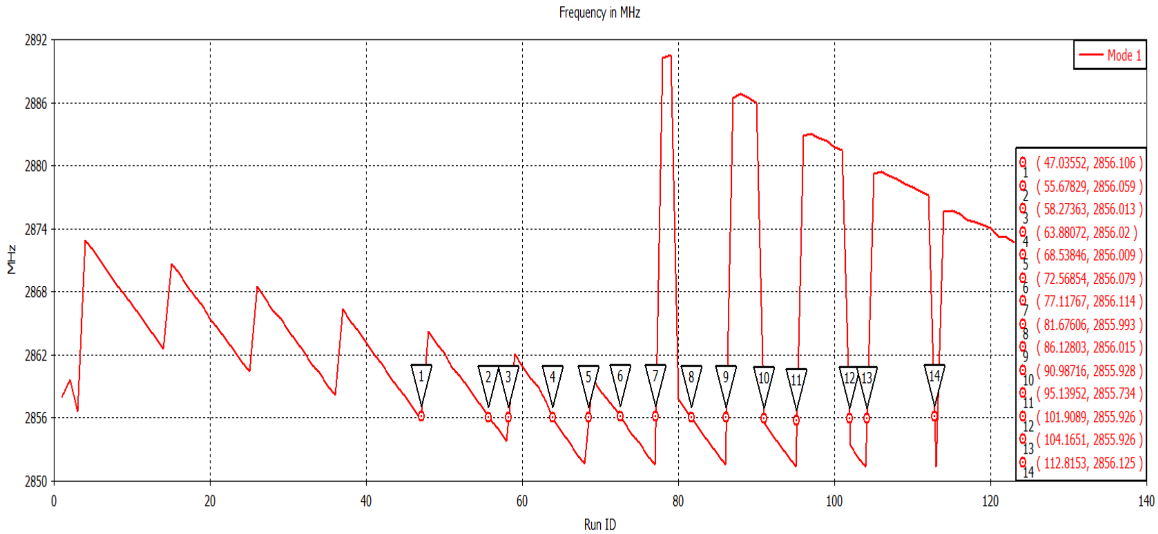

Figure 5: Modes for different cavity parameters (cylinder proportions change).

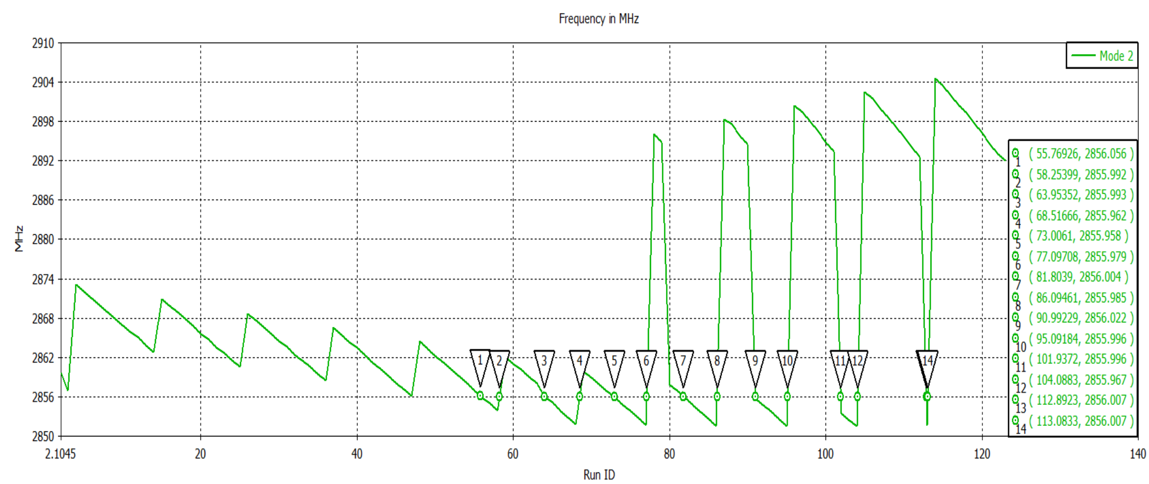

Figure 6: Close modes for different cavity parameters (cylinder proportions change).

CONCLUSION

In the course of the work done, the cavity for the SLED system was modeled, parameters (such as: field decay time in the section, characteristic time of pumping out the stored energy, coupling coefficient, gain of the accumulated energy, Q factor, wave type, resonator diameter, resonator length, material (oxygen-free copper)) which will be suitable for the LINAC-200 accelerator. Based on these values, it can be assumed that an increase in the electron beam energy at the output is possible up to 280 MeV.

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