PARALLEL COUPLED CAVITY STRUCTURE WITH CONSTANT MAGNETS FOCUSING SYSTEM

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Accelerator for intensive electron beam (average current up to 2 A) from energy 50 keV up to energy 3-5 MeV is offered. Accelerating structure consist of a few resonators fed parallel from one waveguide. Focusing system contains constant radial magnets located between accelerating resonators and creating the axial alternating-gradient focusing magnetic field.
Geometry and results of beam dynamics calculation such kind accelerator are presented.
PACS number: 29.17.+w

The development of an electron accelerator on low energies $\beta \cong$ (0.4-1) with pulse current more than 0.1 A represents some difficulties due to influence of the space charge on beam dynamics. To retain a beam the magnetic field of the order 0.05 - 0.2 T is necessary. The weight a focusing solenoid is significant, the DC power sources and cooling system are necessary. All these essentially increase the weight and cost of such kind of accelerators.

The focusing of a beam by a sign-alternating magnetic field allows reducing the weight and cost of the focusing system [1]. Permanent magnets with a large remanence are attractive for producing strong magnetic fields. The focusing of a beam, for example in powerful klystrons, is carried out by Sm-Co permanent magnets keeping on axes of beams an alternating field with maximum induction 0.1-0.2 T [2]. However such fields, capable of retaining a beam current of several ampere, in making injector -accelerators are not utilized. The reason is simple: due to the construction of usual accelerating structure, in which the accelerating cavities are located close to each other, or the intervals are occupied by coupling cavities [3-5].

In parallel coupled structure [6] the creation of an alternating magnetic field on the axis of a beam with the help of radially magnetized magnets is possible. In such a structure the accelerating cavities are located sequentially one after another and are excited from a wave-guide through a common wall [6, 7]. If for excitation a rectangular wave-guide is used, the condition of a travelling wave with the phase velocity v_φ > c is fulfilled. The cavities should be installed at the distance $L = \lambda_0 / \left(c/v + \lambda_0 / \Lambda_g \right)$ apart, where λ_0, Λ_g - wavelengths of the accelerating field in free space and in the wave-guide respectively. The direction of particle motion in the structure must be opposite to the direction of the wave-guide phase velocity. Under these conditions the synchronous acceleration of particles with variable velocity v is possible. The intervals between accelerating cavities are free and can be used for installation of focusing magnets.

The sizes of cavity coupling slots become considerable even if cavity quality-factor is equal to 10^5 [8]. That can result in the appearance of asymmetric field components in the accelerating cavity. In our case at quality-factor of accelerating resonators $Q \cong 10^4$ the sizes of coupling holes can be essentially reduced by exciting accelerating cavities through the transmission-type cavity.

The scheme of such a structure with built-in magnets is shown in Fig. 1. The accelerating cavities (1) are excited from the transmission-type cavity (6) through coupling slots (3) in the common wall. Excitation of the whole system is carried out through a coupling hole (7). The cavity (6) represents a cut of the rectangular wave-guide, operated on H_{104} -mode. The wave-guide is loaded by capacity protuberances (2) to reduce the wavelength.

In the transmission-type cavity (6) the standing wave with a period $L = \lambda_o/2$ is settled. The distance between the neighboring coupling holes (3) is also $\lambda_o/2$. Therefore accelerating cavities are exited by the transversal component of the magnetic field of cavity (6) with a phase shift π.

The wave-guide-fed slots of all cavities (1) are in identical conditions. They are connected in series and can be considered as one equivalent cavity. Thus the structure can be described as a system of two coupled cavities [9, 10].

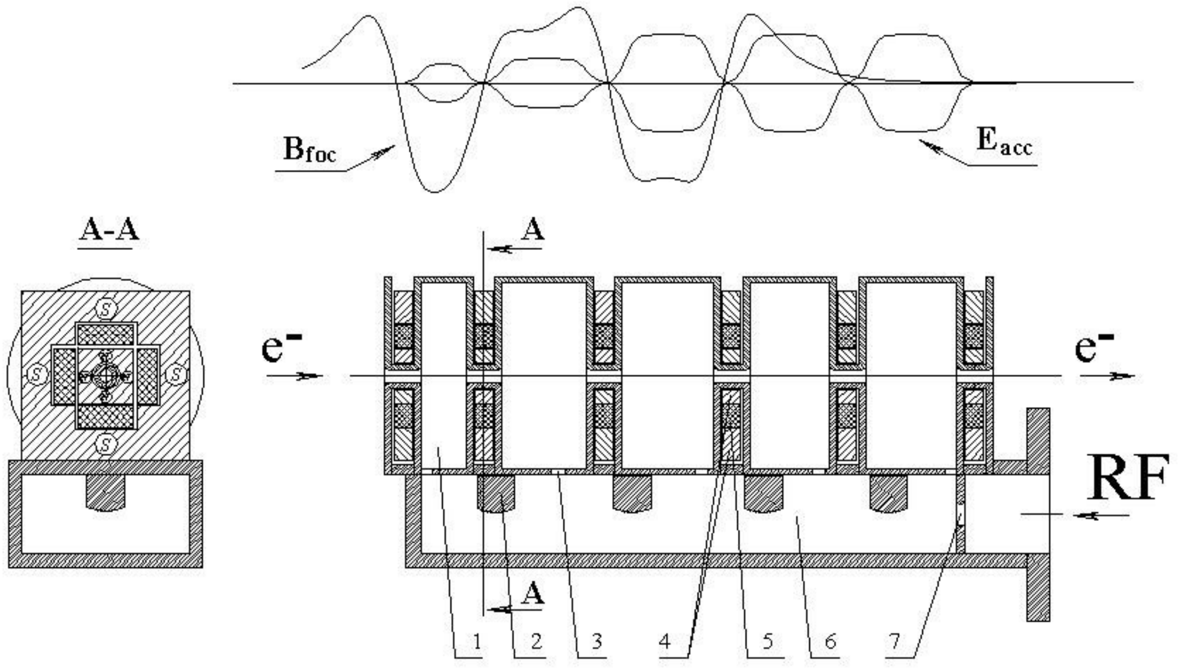

Fig. 1. Scheme of the accelerating structure.
1 – accelerating cavity, 2 – capacity protuberance, 3 – coupling slot, 4 – symmetrized magnetic circuit, 5 – magnets, 6 – transmission-type cavity, 7 – input coupling hole.

In such a system the coupling coefficient between cavities (final and intermediate) can vary over a wide range. The ratio of stored energies in final cavity W_1 and intermediate cavity W_2 depends on coupling coefficient k between the cavities and the quality-factor of the final cavity Q_1: $W_1/W_2 = k^2Q_1^2$. The system is matched, if the entering coupling coefficient is chosen from the requirement: $k_o = 1 + k^2Q_1 \cdot Q_2$.

Thus, increasing the amplitude of the field in a transmission-type cavity with keeping the input matched reduces the coupling coefficient between the cavities and, hence, decreases the sizes of the coupling holes. This reduces the influence of coupling slot on the distribution of fields in the accelerating cavity.

To create radially magnetized system four rectangular Nd-Fe-B magnets (5) are used. The aperture magnetic field is symmetrized by Fe- bushes (4) with a round hole. Magnets (5) are located inside the intervals between cavities (1). The magnets are magnetized alternately - from axis and to axis of structure. This produces an alternating longitudinal magnetic field on beam axis. The adjusting accessories of magnets are demountable, that allows to remove them if the structure must be heated.

The optimum sizes of accelerating cavities depend on the current of the beam and power input. When a large current is accelerated, the influence of longitudinal wake fields becomes essential. The voltage variation of the beam U on an single cavity with length L and effective shunt impedance Z taking into account radiation is determined by the expression: $U = (PZL)^{1/2} - IZL/2$, where P – input RF power and I – average accelerating beam current. At given P and I, U as the function of (ZL) has maximum at $(ZL)_0 = P/I^2$, and is equal to zero at $ZL = 4(ZL)_0$ and unsignificantly (about 20 %) varies when changing ZL from $(ZL)_0$ up to $2(ZL)_0$. The power P is always restricted by employed RF source, therefore ZL should be chosen from the requirements: $(ZL)_{opt.}=1.5 \cdot P_{max}/I^2_{max}$. In this case at a variation of a power level the effective acceleration of currents up to I_{max} is possible.

As an example one of the variants of beam dynamics calculation is presented. Basic data:

Operate frequency	2856 MHz,
Injection energy	50 kV (input energy spread 2%),
Average beam current	1.95 A ,
Number of particles in bunch	$0.36 \cdot 10^{10}$,

Pulse duration of input current is according to π injection,

Diameter of input beam	4 mm,

Phase shift between cavities equal to π,

Input RF powers (without current load) 0.025, 0.15, 0.25, 0.35 and 0.45 MW respectively.

The distribution of accelerating field of E_{010} cavities and its parameters were calculated previously using program SLANS [11]. The diameter of aperture is equal to 10 mm. Cavity diameter 80 mm, (operating frequency 2856 MHz). Length of cavities: 18, 22, 32, 36 and 36 mm respectively. Cavities are assumed not coupling.

The magnetic field of radially magnetized permanent magnets was modelled by the field of thin close located solenoids with opposing current [1]. The lengths of magnets located between the cavities are 8 mm.

The results of calculations are shown in Fig. 2.

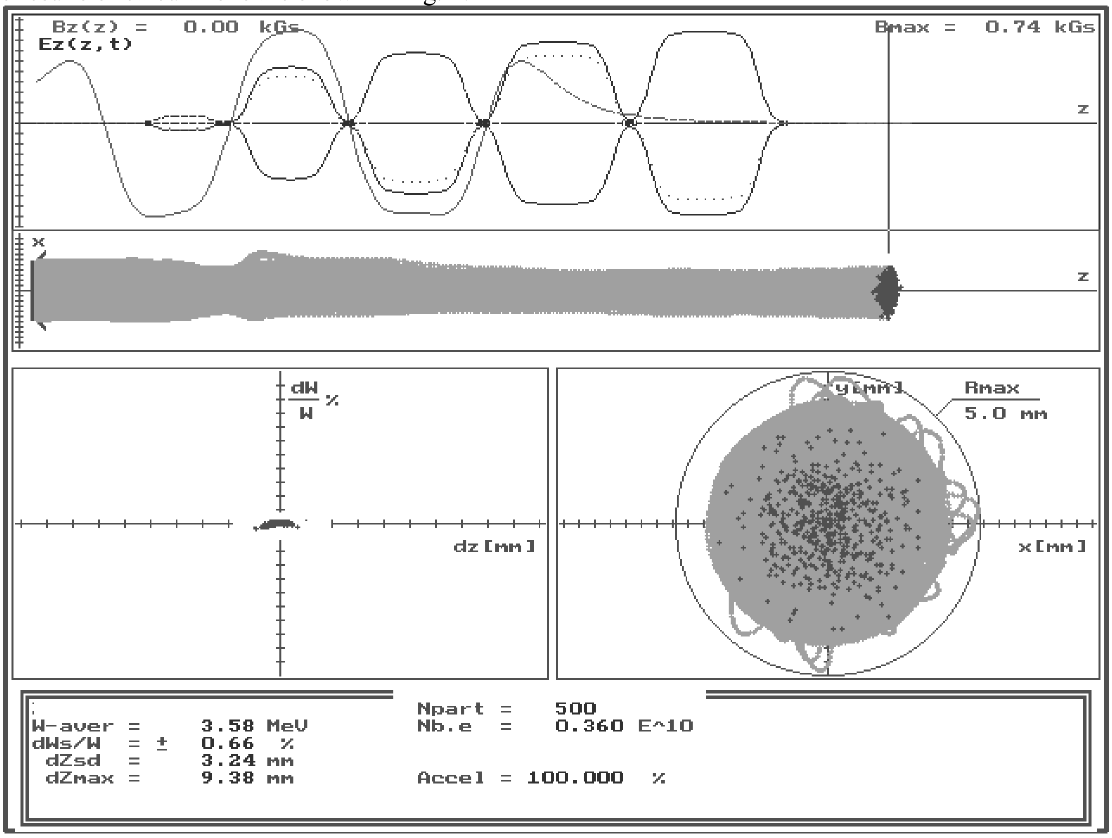

Fig. 2. The results of calculation.

There one can see the distributions of focusing magnetic field, relative amplitude of accelerating RF field in the cavities and results of calculation:

Average output energy 3.6 MeV,
root-mean-square deviation of energy ±0.7 %,
Electrons capture 100 %.

Calculated normalized emittance of accelerating particles is less than 33 π·mm·mrad for both x and y axes.

At present time the model of accelerator on parallel coupled cavity is in progress.

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