LOCALISATION OF THE RF BREAKDOWN IN THE PARALLEL COUPLED ACCELERATING STRUCTURE

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Abstract

Parallel coupled accelerating structures (PCAS) [1,2] with parallel RF power feeding of accelerating cavities have some features and advantages vs. conventional TW - traveling wave and SW - standing wave structures with sequential (serial) RF power feeding. Parallel feeding of accelerating units - individual cells or accelerating substructures provides normal regime acceleration of the beam by all cells and minimizes the RF power flows via coupling slots and determines individual behavior of each cell in the regime of RF breakdown. These features can be used for developing low energy linear accelerators as well as high gradient accelerating structures. The experimental data of the breakdown regimes in the PCAS are presented in this paper.

INTRODUCTION

The main idea of the PCAS is the feeding of accelerating cells in parallel from the rectangular waveguide [1,2]. Parallel feeding of accelerating units – individual cells or accelerating substructures, provides normal regime of acceleration of the beam by all cells [1], minimizes RF power flows via coupling slots, and as shown in this paper, determines individual behavior of each cell in the regime of breakdown and minimizes absorbed RF energy in each accelerating cavity. These inherent characteristics and features of the PCAS are helpful for developing of low energy linear accelerators [1-3] and as noted in the papers [1,2,4] can be used to overcome difficulties when elaborating a high gradient accelerating structures.

A breakdown violates normal work of the accelerator, destructs the surface of the cells. The damage accumulates and as a result the RF property of separate cells and accelerating structure changes. Numerous investigations are devoted to study of this phenomenon [5-9]. The phenomenon is rather complicated and the processes involved are not clear yet. Nevertheless in recent years some evidence has been found that the RF power flow in particular determines the maximum sustainable gradient in an accelerating structure [6,7]. Using a parallel feeding in the PSAC handles and solves the issue of high level of RF flows in the structure.

Feeding line delivers electromagnetic energy to accelerating sells of the PCAS, it works on TW [1,2,4] or SW [2,3] mode. In the case of TW-mode it is difficult to provide the necessary amplitude and phase distributions of microwaves along the accelerating structure. For these goals it is necessary to employ variable coupling coefficient of cells with feeding line [1,2,4] which reduces advantages of the PCAS. The most straightforward means to solve this problem seems to be the use of SW-mode in the feeding RF line. This mode gives π-phase shift between the accelerating cavities as well as provides required amplitude distribution of an accelerating field along the structure [2,3]. The experimental data of the breakdown in the PCAS [3] which consists of an individual accelerating sells feeding via common exciting cavity – segment of rectangular waveguide working in the SW regime are given below.

EXPERIMENTAL SETUP

A conceptual scheme of PCAS is shown in Fig.1. The Accelerating (Accel.) Cavities are fed in parallel by common Exciting Cavity connected to feeding RF Power line thru Input Diaphragm. Exciting Cavity is shorted at

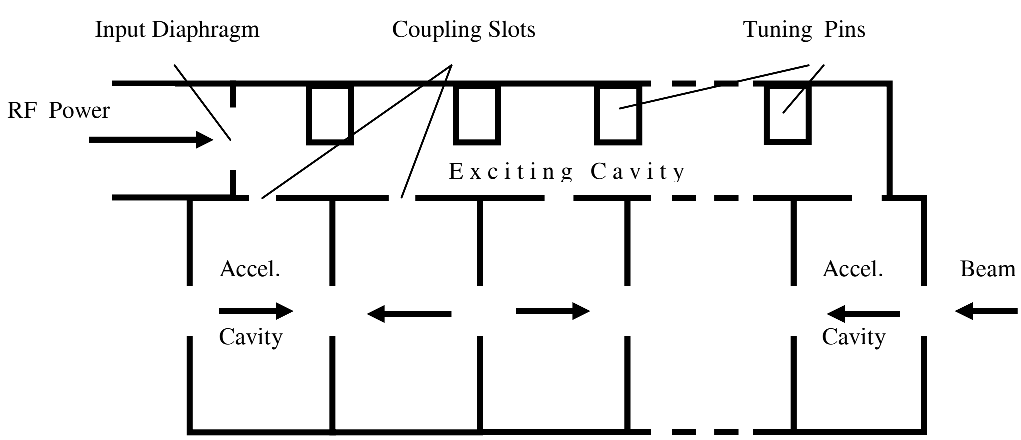

Figure.1: Conceptual scheme of the PCAS

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the ends a segment of rectangular waveguide operating on TE_{10N-1} – like SW mode, N – quantity of accelerating cavities. It is loaded by Tuning Pins to reduce the wavelength. Due to the Pins in the Exciting Cavity standing wave with period of $\lambda_0/2$ is settled, where λ_0 is the wavelength of accelerating frequency in the free space. The distance between the neighboring Coupling Slots is also $\lambda_0/2$. Therefore accelerating cavities are excited by the transversal component of the magnetic field of exciting cavity with a phase shift π, which provides regime of acceleration of electron bunches with velocity of light C by all accelerating cavities.

RF power delivers to all accelerating cavities by individual Coupling Slots in parallel. This feeding system minimizes RF power flows via all Coupling Slots as well as optimizes stored RF energy in every sell of PCAS.

The Coupling Slots of all accelerating cavities are under the identical conditions. Due to the parallel connection all accelerating cavities can be considered as one equivalent cavity. Thus the accelerating structure can be described as a system of two coupled cavities [10] – exciting cavity and common accelerating cavity. In such a system the coupling coefficient between cavities (first and second) can be varied over a wide range. Employing exiting cavity installed in front of the accelerating cavities permits to decrease the sizes of the coupling slots [11].

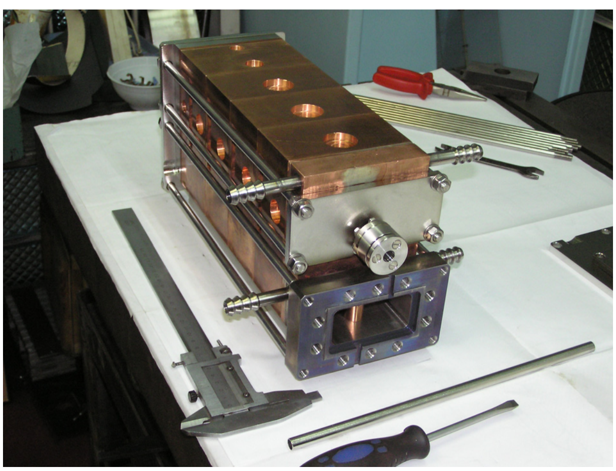

Figure 2: 5-cavity model of PCAS.

The experiments in the regime of breakdown were done on the experimental model of PCAS shown in Fig.2. Model contains 5 accelerating sells [3].

MESURMENT OF BREAKDOWN

Experimental data characterizing the breakdown processes during RF processing are represented in Fig. 3a-3c. Measured value of RF power was 1.6 MW, calculated amplitude of surface electric field reached up to 0.7 MV/cm. Incident, reflected RF power and stored RF energy in the fifth accelerating cavity were measured at the experiments. In Fig.3 one can see signals: incident RF power (F1) – yellow; reflected RF power (F3) – blue; RF signal from fifth accelerating cavity, proportional to stored energy in them (F4) – green. In normal regime (without breakdown) all signals are of the proper form, without any singularity. Incident RF power (F1) has rectangular form. Reflected RF signal (F3) characterizes transients in the system of two coupled cavities – accelerating and exciting cavities. Signal (F4) with exponential form represents stored energy in the fifth cavity.

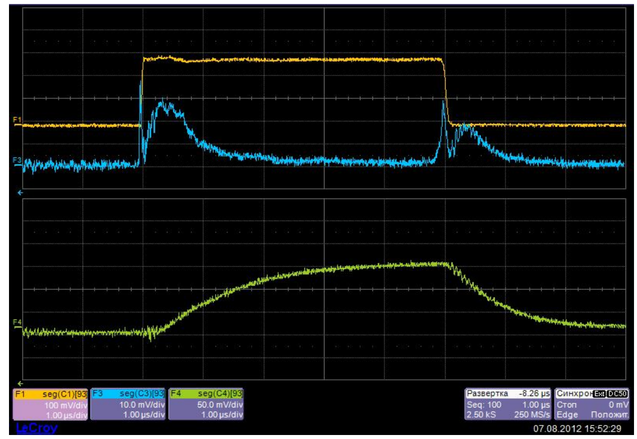

Figure 3a: Regime without breakdowns.

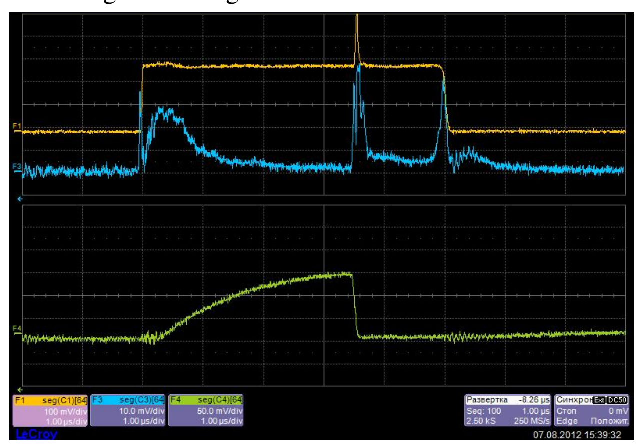

Figure 3b: Breakdown in the 5-th accelerating cavity.

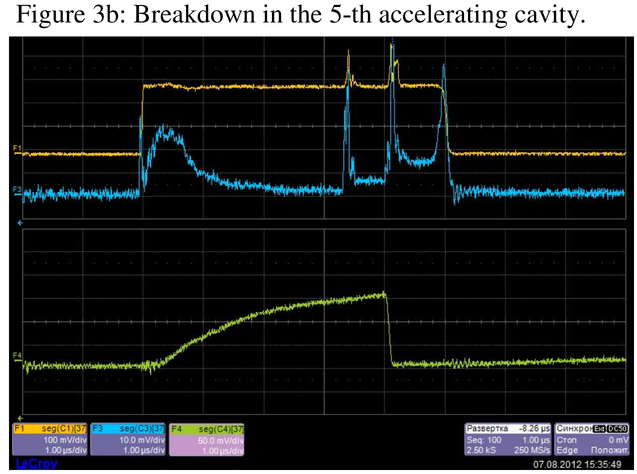

Figure 3c: Regime with breakdowns in several accelerating cavities. F1 – RF power from klystron, 1.6 MW, pulse duration 5 μs; F3 – reflected signal; F4 – stored RF energy in 5-th accelerating cavity.

The processes change under breakdown. If a breakdown takes place in the single accelerating cavity, a

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part of the stored RF energy dissipates in this cavity, some fraction radiates to exciting cavity and then thru Input Diaphragm to external RF Power line. As a result on the reflected signal one can see short pulse burst - Fig.3b, line (F3). Let's note that there are no sizeable reflections from accelerating structure which could affect the RF generator. So, PCAS almost doesn't ″notice″ the breakdown in the separate cavity. In Fig.3c behavior of the system when the breakdowns take place almost simultaneously - during one RF pulse in some accelerating cavities – a very rare event is shown. In this case accelerating cavities are disconnected one by one, reflected RF signal increases – Fig.3c, line (F3).

THE SUM OF OBSERVATIONS AND DISCUSSION

At high level of RF power breakdowns occur in the well-established SW and TW structures as well as in accelerating cavities of PCAS. In the case of SW accelerating structure in the regime of breakdown the reflection coefficient becomes close to unit and almost all incident RF power of the generator is reflected [4]. Nevertheless total RF energy stored in the whole structure can dissipate in the cavity where breakdown takes place. For the case of TW in the regime of breakdown the reflection coefficient remains close to zero and RF energy, stored in the structure, and almost all RF power of the generator feeding the accelerator dissipates in the cavity with breakdown.

Character of processes at the regime of breakdown in the PCAS seems to be as follows. Breakdown process in the PCAS localizes in a single accelerating cavity. If a breakdown occurs in some cavity, stored RF energy dissipates and amplitude of RF field in this cavity decreases. The neighboring accelerating cavities are isolated one from another by Exiting Cavity, therefore stored RF energy and amplitude of RF field remains invariable in them. The breakdown in the separate cavity does not change the property of accelerating structure on the whole. Electron beam accelerates almost up to its previous energy. Only one cavity where breakdown occurs is eliminated of this regime. External RF generator ″sees″ the exciting cavity of PCAS with practically constant amplitude. After the breakdown RF field and stored energy in the accelerating cavity restore with time constant $\tau \sim Q/\omega$, where Q is quality factor of the cavity and ω is the frequency of accelerating field. Let's note that additional reflection from the structure practically doesn't arise.

CONCLUSIONS

Parallel feeding of accelerating cavities in the PCAS determines individual behavior of each cell in the regime of breakdown. Breakdown process in the PCAS localizes in a single accelerating cavity. If a breakdown occurs in an accelerating cavity of PCAS, stored RF energy of this cavity dissipates only in this cavity.

Breakdowns occur in the accelerating cavities with sequential (serial) RF power feeding violates normal work of the accelerator, destructs the surface of the cells. In the case of PCAS a breakdown does not change acceleration regime in the accelerating structure. RF energy destroying the surface of accelerating cavity of PCAS due to breakdowns, as compared to SW and TW structure with sequential RF power feeding is at least N times less, where N is a quantity of accelerating cavity of the structure. Therefore the damages are alike smaller.

Certainly the method of feeding of accelerating sells in parallel from a rectangular waveguide [1,2] will help to create the robust high gradient accelerating structures [4].

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