ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E9-96-199

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LIGHT RADIATION AT THE EXIT OF RFQ AND RF-FIELD CONTROL

Submitted to the Fifth European Particle Accelerator Conference,
June 10—14, 1996, Sitges, Spain

1996

Introduction

For many practical applications of ion RFQ linacs, for example implantation, one needs the high accuracy of repeatability of a beam main parameters from a set to a set of irradiation. A qualitative run of the proposed designs depends on operative field-control in an RF cavity. It is of prime importance for accelerators with focusing by the accelerated field that determines both the longitudinal and transverse beam characteristics. Experimental investigations show that the ion energy spectrum at the exit of RFQ- structures essentially depends on the RF field amplitude and its departure from the optimal value. For example, as the RF power decreased to some value, the beam component with basic energy disappeared and a number of spectrum lines from the injection energy (about 100 keV) up to 0.7 of the regular value of this structure (about 1.4 MeV) appeared. The widths and the ratio between the amplitudes of the lines are defined by the RF field value. This effect in combination with the magnet separator at the exit of the accelerator was used in ref. [1] for studying the features of the gas target radiation that is produced by the H^- beams with different energy. The possibility of simultaneous using a number of different energy ion beams, with the suitable RF field change and control, in a single acceleration structure is of great interest for ion implantation. The development of a simple and reliable procedure for operative and nonperturbative control of the accelerated field is an essentially actual problem for the recently proposed implanters with varying of the resonant frequency of the structure and changing of the RF field value in a suitable algorithm [2,3]. In that case, the traditional method of the RF field amplitude control by using the loop for the RF power measurement, is a problem because of the complicated frequency dependence of the cavity shunt impedance in a wide range of frequency variation.

Secondary particles, which are produced and leave the cavity under the RF field, can be used for the optimisation run of the linac cavities unloaded by a beam. In particular, some information about the cavity operation condition can be obtained by secondary electron fluxes which are produced between drift tubes in the longitudinal [4] and transverse [5] directions. The complicated character of the cavity RF fields strongly affects the initial energy distribution of the electrons and their flux time-dependence. As a result, information about the RF field at the electron production point is distorted. In this connection, the use of photons with different wave-lengths for transfer of this information is of interest. Photons can be produced by both autoelectron emission [6] and electron bombardment of nearest electrodes. The proved in [7] method of the RF voltage amplitude estimation by the bremsstrahlung spectrum from the electrodes (see in [8]), which is produced by the autoemission electrons, needs very long time for the information storing ≈ 0.5-3 hours, depending on the

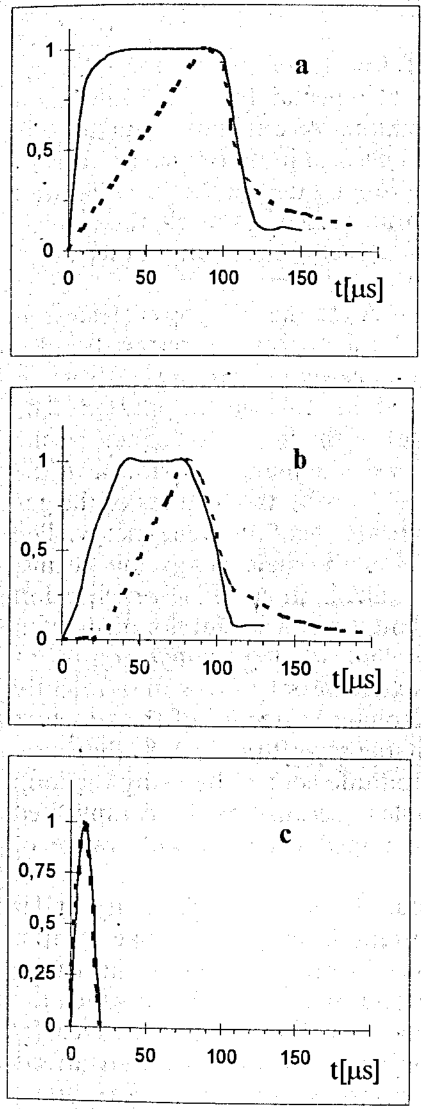

Fig. 1. The normalised current signal from photomultiplier (dashed line) and RF power signal (solid line) time-dependencies for two types of cavities: space homogeneous (a) and space inhomogeneous (b) RFQ;
c - the signal from photomultiplier followed by control beam pulse.

RF power level in the cavity. However, the absence of the interaction between the photons and the cavity field and the possibility of separation of the most interesting near-electrode areas by appropriate optics [9] allow the photons to be used as an effective tool for nonperturbative control of RF cavities.

Light radiation at the exit of RFQ

The nature of the light radiation at the exit of RF linac was studied in [10]. The investigations have been performed with cavities of two types of accelerators: space homogeneous [11] and space inhomogeneous [12] RFQ. The light radiation was detected by a photomultiplier placed at $L \geq 20$ cm from the exit hole of the accelerator. The photocathode plane was in parallel with the accelerator axis. This measurement geometry didn't hinder the normal run of the accelerator with a beam and practically eliminated registration of light immediately from the cavity. The RF power in the cavity was controlled by a loop. Both the signals - from the loop and from the photomultiplier - were digitised with a 1 μs separation interval and entered into the computer for processing.

The experiments show that the RF power pulse causes light radiation in the beam transfer line at the exit of the cavity. The shape of the normalised current signal from the photomultiplier and the RF power signal from the two types of cavities for different materials of the vacuum chamber wall in the region of the registration are plotted in Fig 1. The wall of stainless steel was used, or the wall was covered by aquadag.

The presented results are typical for a wide range of the input RF power levels. For comparison, the current signal from the photomultiplier (in the same conditions of its run) followed by the light radiation of the residual gas with a shorter control beam pulse from ion injector, when RF power was switched off, is plotted in Fig 1 c.

The light radiation intensity (I_γ) , which accompanies RF pulse, essentially depends (see Fig 2) on the input level of RF power (U_a is the loop signal), on the wall material in the region of registration and decreases (under other equal conditions) with moving away from the cavity exit hole. For elucidation of the light radiation nature, the transverse magnetic field ($H \leq 100$ Erst) was switched on immediately behind the cavity exit hole. In the control experiment it didn't perturb photomultiplier. This field caused great decrease or even total disappearance of the photomultiplier signal. The signal amplitude was restored by switching off the magnetic field. The signal did not change after the vacuum pressure increased ten times in the cavity and few hundred of times at the photomultiplier location. In this connection, it can be deduced that the registered light radiation is not associated with electron-atom interactions in the residual gas. At the same time, the signal time-dependence with respect to the RF power signal (fig 1a,1b) is in good agreement with the corresponding time-dependence of the high energy component ($E_e \geq 50$ keV, $E_{e\,max} \approx 90$ keV) of the electron flux at the exit of the similar cavity [4].

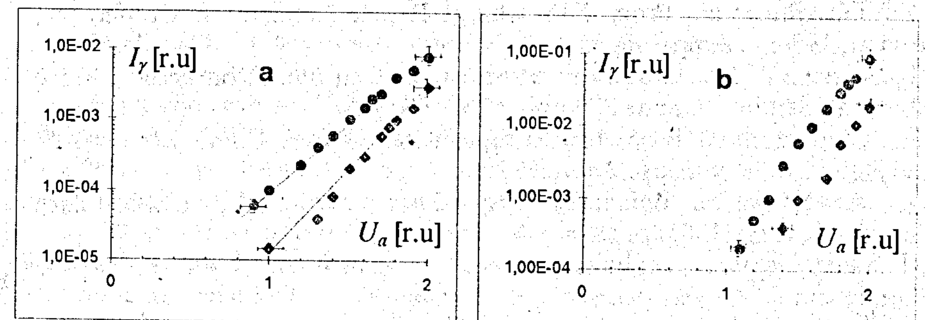

Fig.2. The light radiation intensity (I_γ) vs RF power (U_a is the loop signal) for two types of cavities : space homogeneous (a) and space inhomogeneous (b) RFQ.
• - the vacuum chamber wall of stainless steel,
♦ - the wall covered by aquadag

The results show that the light radiation at the exit of the cavity is mainly caused by the electrons with energy $E_e \leq 10^5$ eV, which is in good agreement with the calculated RF field amplitude. These electrons are produced at the electrodes by autoemission, leave the cavity in the centreline direction, scatter by the electrical lens at the exit hole, and cause light radiation as a result of the vacuum chamber wall bombardment. In this case, , the major contribution to the registrated light in the wave-length area of the photomultiplier sensitivity probably comes from the transition radiation [6,13,14]. The fact that the RF power- dependence of the radiation intensity is strong (fig 2) demonstrates the prospects for further investigations of light photons produced at the electrodes inside and outside the cavities which can be used for RF field diagnostics and nonperturbative control of the beam parameters stability at the exit of the accelerator. After preliminary testing, this control can be operatively realised by irregular switching off the ion injector.

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Received by Publishing Department

on June 7, 1996.