BEAM PULSE SHORTING PHENOMENA IN A RF ELECTRON GUN

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Abstract

The phenomenon of beam pulse shortening phenomenon associated with the rf electron gun is firstly reported. The author believes that the beam loading effect take an important role in it, the interaction between the electron beam and the deflecting mode is another important reason.

Introduction

The classical type of beam pulse shortening, or beam break-up (BBU) phenomenon, were observed in many short, high current linacs[1-2]. In our rf gun experiments similar phenomenon was observed.

The basic manifestation of the beam pulse shortening phenomenon is illustrated in Fig.1. The current

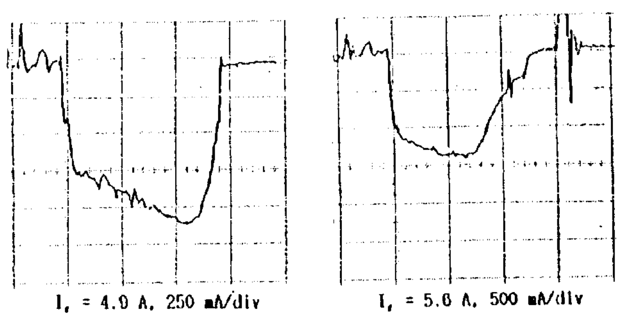

Figure 1: Beam pulse shortening phenomenon, beam current I_{bct1} at different filament current I_f (2 μs/div, P_{in} = 1.7 MW)

pulse was viewed and plotted with a digitizing oscilloscope. The ripple came from the noise and the parasitic oscillation in the beam current transformer toroid. As can be seen from the figures that the beam macropulse length is shortened when the beam current increased above certain levels.

Fig.1 shows a series of the electron pulses for several filament currents under fixed input rf power. With the increase of filament current, the cathode temperature increases and more current is emitted. When emitted current is above a threshold, an increasingly large fraction of the electrons are lost, the output current is reduced.

The beam pulse shortening in high current linacs is not new, and the phenomenon has been conclusivly associated with the excitation of transverse deflecting modes[3-4]. However, we should clearly recognise that we are dealing with more complex case here because of: 1) the cathode is in the cavity, the electron emission is determined by the temperature, the field and the space charge. 2) the electric field in the cavity is strongly modified by beam loading effect. 3) the electrons are accelerated from zero to about 1 MeV, the interaction between the beam and fields of deflecting mode is much different from that of highly relativistic electrons in the accelerators.

We try to explain the experimental results qualitatively from these two effects: beam loading and deflecting mode.

We know the emitted current from the cathode is higher at the tail than at the head within a macropulse due to back bombardment. With back bombardment, the current can go up by more than 50 percent. This current gain takes an important role on the beam itself. Firstly, electric field will go down because of beam loading, thus less part of emitted current can get out of the cavity, i.e. the output current reduces[5]. Also larger part of emitted current go back to hit the cathode, which will cause the cathode emitting more current. This further reduces the electric field. So does the output current. As a result the output current at the tail of the macropulse will change from larger to smaller value than the head level of the current. This process can be observed once the beam pulse shortening begin to happen.

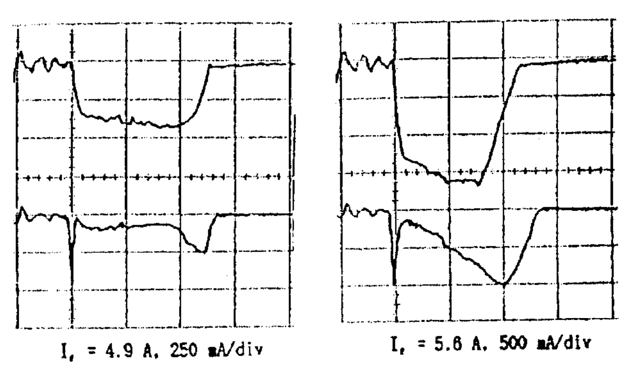

Figure 2: Observed reflected power P_{re} pulse (lower curve) and I_{bct1} pulse (upper curve) (2 μs/div, P_{in} = 2.0 MW)

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Secondly, the current will affect the rf power coupling. When the current is high, less rf power is coupled into the cavity, thus the electric field will be smailler. This will help to realize the above process. Fig.2 is the reflected power pulses and the output current pulses observed in the experiment. When the current is not high (about 500 mA in our case), the reflected power is very small. With increment of the filament power, the back bombardment increases and the emitted current goes up, then the reflected rf power increases. The reflected rf power is larger at the tail of the macropulse which is coincident with the beam current. To increase the filament current again, the beam pulse shortening occurs but the reflected rf power keeps increasing. This is the evidence that the current emission is more but the output current is less than before, which is the result of less field strength.

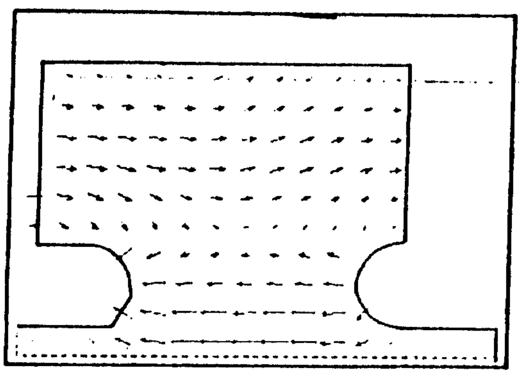

Figure 3: Electric field distribution of TEM_{111} mode of the cavity

With the code URMEL[6] we learnt about high order modes existing in the cavity. The resonant frequency of TEM_{111}-like mode is 5410 MHz, and its field distribution is plotted in Fig.3. The fields can be excited by interaction with the head part of the electron beam, then it deflects the electrons off the axis at the late part of the macropulse.

The interaction is complicated because the back electrons take part in it. It is believed that the interaction between electrons and the deflecting field indeed exsits. Because we find the threshold of beam current when beam pulse shortening could happen is inversely proportional to the length of macropulse: for 6 μs, the threshold is about 1300 mA, for 4 μs it is about 1600 mA.

Reference

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