Proceedings of the 23rd Linear Accelerator Meeting in Japan (September 16 - 18, 1998, Tsukuba, Japan)

〔F18p23〕

Characteristics of a beam acceleration on TWRR at PNC

Shin'ichi Tōyama

Power Reactor and Nuclear Fuel Development Corporation (PNC)
4002, Narita Oarai Ibaraki pref., Japan 311-1393

Abstract

There are lots of accelerators for electrons which employ traveling wave accelerator structure including TWRR. The comparison with traveling wave and standing wave are mentioned in the points of the energy gain, energy conversion to beam power, the difference of each structures and operation. The behavior of RF power, its transmission, accelerator gain and beam loading are examined by parameters of the attenuation for accelerator structure for TWRR.

I. Introduction

The development of a high power electron linac is in progress and its test linac is settled in Quantum Technology Development Facility (QTF) in PNC Oarai Engineering Center in order to study the feasibility of high efficient acceleration for transmutation and other applications as well. The Traveling Wave Resonant Ring (TWRR) for an accelerating structure and CW RF power supply are the main features of the linac.

In this report, the design principle for beam stabilization associated with TWRR compared with basic accelerator characteristics is evaluated by means of analytic calculation for various types of accelerator structures.

2. Comparison of accelerator structures

2.1 Traveling wave accelerator structure

The power into the dummy is calculated changing the length of accelerator wave guide. Fig. 1 shows the result from the calculation for an accelerator structure length dependence of the power at the dummy load for constant gradient type. The calculation is executed for the case of constant value input RF power P_0 800 kW, shunt impedance r_s 40 MΩ/m and beam current I_0 100 mA which are design parameters for PNC accelerator respectively, changing the attenuation τ in the range from 0.05 to 1.0 in neper/m. Solid lines and dashed lines correspond to the power fed into the dummy loads without and with beam loading. It is obvious from Fig. 1 that the loss power gets small less than 20% from initial value, when the length of the accelerator structure gets longer than 2 meters and τ is less than 0.5. Fig. 2 shows the energy transmission from input RF to beam power. It is clear from Fig. 2 that higher attenuation more than 0.5 neper makes it possible to get approximately 100 % power transmission in 2 m.

The total gains for PNC accelerator are summarized in Fig. 3 in which the gradients are calculation parametrized by the attenuation mentioned above paragraph. The gain in Fig. 3 is the case for the average beam current of 100 mA. It is seen that the optimum length for the gradient shifts to about 7 m as the attenuation gets smaller. Typical traveling wave structure for S band linac has the gain more than 10 MeV/m with a few tens MW RF which attenuation is around 1.0 nepers/m, and the optimum length is shorter than 2 m. Higher attenuation is of course favorable to achieve higher gradient. Nowadays usual value for t is 0.4 to 0.7 after the compromise against the RF energy conversion to beam power.

Fig. 4 shows the result from the calculation for the current dependence of the gradient with 1 m long accelerator structure which has various attenuation parameter. The RF power and shunt impedance employed are the same as the case of Fig. 1. The current limit to be accelerated is higher in lower attenuations, while the gradient is totally smaller. Morever, it is seen that the vias of a beam loading gets affected mild to the gradient when structures have lower attenuation.

2.2 Standing wave accelerator structure

The high shunt impedance of a standing wave accelerator structure is favor to get high gradient. The shunt impedance for π mode is up to 100 MΩ/m, which is one of highest among various structures. The cavity structure for standing wave is complicated in order to reduce transit time factor and get high gradient almost equal to one from π mode. The small diameter for the iris in each cavities is preferable to realize stronger electric fields and get higher effective shunt impedance.

The transit time effect essentially causes the phase slip between beam and RF which results in the energy spread in accelerated beam. The dimensions have not large difference between standing wave structures and traveling wave structures. The specific phenomenon for standing wave cavity is a detune dependent of the beam current. Tuners are equipped to each cell to cancel the induced voltage caused by beam bunches.

Circulators are equipped between RF source and cavity in many case. This device is certainly larger because it generally consists of wave guide and high power Faraday rotation device which needs cooling circuit even though there is no power loss in an ideal case. The circulators for L-band was not applicable at the first stage of development of PNC accelerator.

3. TWRR accelerator structure

3.1 Advantage of TWRR accelerator structure

The attenuation of accelerator structure is lower than the value between 0.4 and 0.7 which range is usual case for traveling wave structures. Low attenuation makes it possible to keep larger beam irises. The large aperture has the advantage that the beam has less possibility to hit accelerator structure.

TWRR structure can accumulate RF power which is recirculating inside TWRR structure. The inside power is determined by the energy conservation of RF power fed into recirculator and dissipation energy to wall of TWRR structure. This power multiplication compensates the intrinsic low shunt impedance of traveling wave accelerator and identically power recirculation can achieve the same acceleration gain from standing wave structure.

Another advantage to choose this type is simple characteristics for RF feeding to accelerating structure because there is no RF reflection at the input coupler of the accelerator structure by the change of a beam loading. Moreover, there is no detuning effect in TWRR because beam is accelerated in a traveling wave which causes no RF resonance inside the structure.

3.2 Beam loading in TWRR

The charge of the beam bunch creates the induced field which causes the longitudinal BBU. The dynamics on each particles are evaluated microscopic calculation which is rather complicated in actual cases. Beside, total induced voltage can be calculated by means of the loss factor which is attainable from the result in previous reports [1].

The relationship between the induced voltage *V*in and the loss factor k_l is mentioned as follows,

$$V_{in} = 2\ k_l\ q \qquad (1)$$

where, q is a single bunch charge. The loss factor for TWRR structure is calculated by ABCI [2] and shown in previous report [1]. The maximum induced voltage is 1.8 kV and it is clear that the induced voltage is almost negligible small compared with acceleration whose magnitude is 1 MV.

4. Conclusion

The TWRR can accelerate electron beam with high energy conversion (70% or more) from RF to beam. The TWRR structure is simpler than the standing wave structure which has high shunt impedance. The accelerator gain is increased almost the same magnitude as much as the accelerator gain from π mode standing wave structure. TWRR has more advantages to stable beam acceleration because it can have wider beam irises and less induced field and no beam detuning effect which causes BBU. The longitudinal BBU is quite small compared with acceleration voltage. Then total BBU is expected small as the results from previous reports.

References

[1] S. Tōyama et al; Proceedings of the 21st linear Accelerator Meeting in Japan, 1996
[2] Y.H. Chin; LBL-35258, 1994

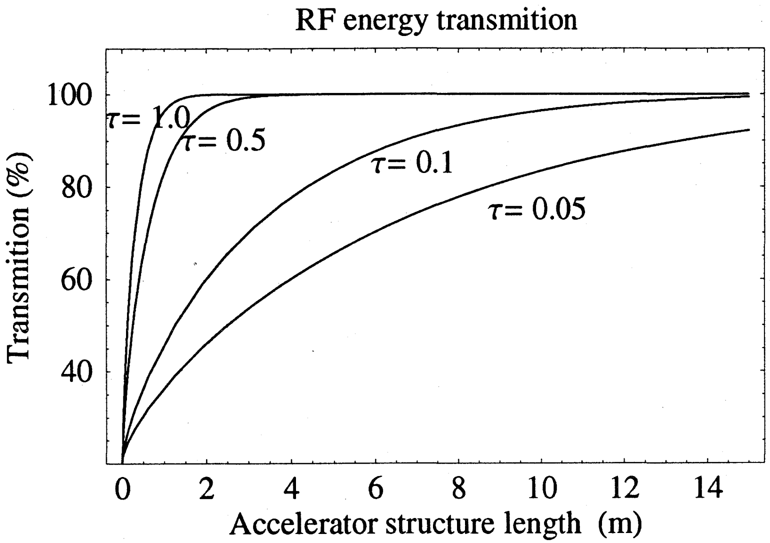

Fig.1 Power at dummy load with various attenuation parameters.

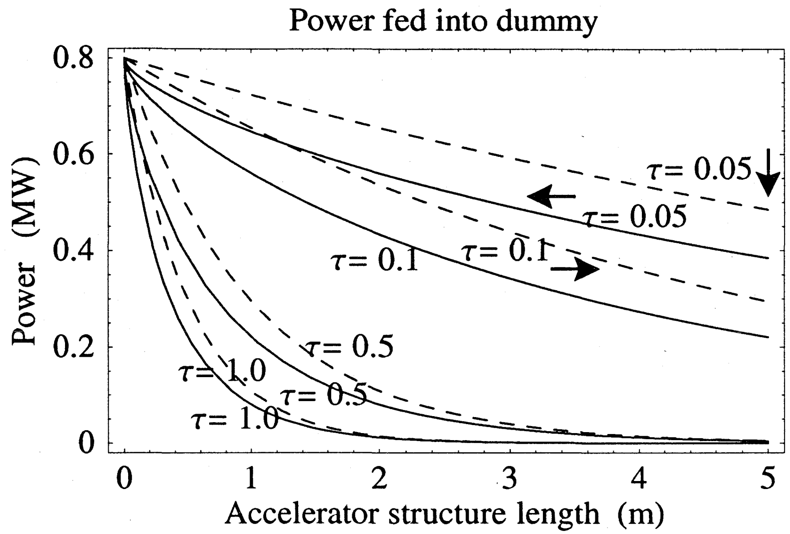

Fig. 2 Energy transmission from input RF to beam power.

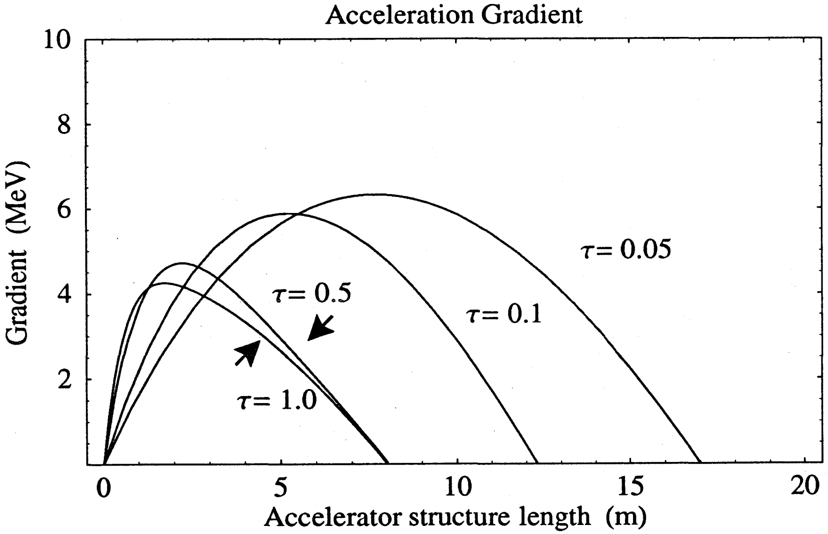

Fig.3 Accelerator gain with various attenuation parameters.

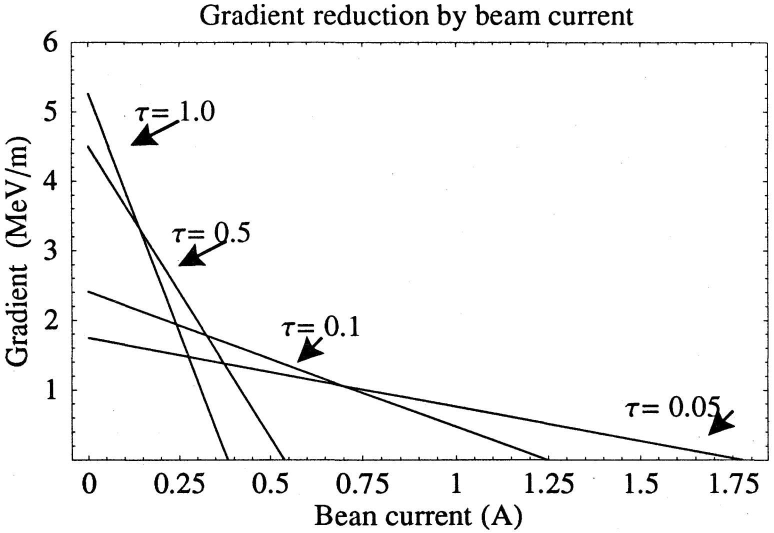

Fig. 4 Current dependence of the gradient with 1m long acdelerator structure.