Particle Accelerators, 1990, Vol. 30, pp. 237–242
Reprints available directly from the publisher
Photocopying permitted by license only

PROPOSAL FOR A HIGH-GRADIENT AND HIGH-EFFICIENCY LINAC

ISAMU SATO AND YUAN LIN WANG *
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305 JAPAN
* Joint Researcher of KEK and
Department of Physics, Nanjing University
Nanjing, The People's Republic of China

Abstract A proposal for a linac with traveling-wave resonant ring is introduced. The proposed linac would have both a high accelerating field strength and a high efficiency. The accelerating field strength would be more than 100 MV/m. The length of the 1 TeV linac would be 10 km.

1. INTRODUCTION

Experimental results regarding RF breakdown for a disk-loaded accelerating structure have already been reported by SLAC.[1,2,3] In the SLAC experiments an S-band traveling-wave linear accelerator section was excited in a standing-wave mode and an equivalent traveling-wave accelerating field of 146.7 MV/m was attained. The theory and experimental results regarding linear accelerators with traveling-wave resonant rings have been reported.[4-9] It has a high accelerating field strength and high efficiency. Both are important for the design of a TeV linac. It is necessary to use very high RF power in order to use ordinary linac technology to obtain an accelerating field as high as 100 MV/m. For example, in the electron-positron linear collider R&D program at KEK a test accelerator facility will be built.[10] The main part of the facility would be a 1-GeV S-band linac. It would comprise three sections of a 3.3m structure unit. Hence, the required peak RF power per unit section would be 840 MW for the average accelerating gradient 100 MV/m. According to this scale, a 1-TeV linac would require 2,400,000 MW of RF power.

In our proposal we adopt every accelerator guide with a traveling-wave resonant ring in which RF power can repeatedly go through the guide in the same direction so that the accelerating field strength can reach more than 100 MV/m. The length of a 1-TeV linac would be 10 km and it would only require 1,800,000 MW of RF power

2. DESCRIPTION OF THE LINAC

A part of the 1-TeV linear accelerator is shown in Fig. 1. The linac design comprises 30,000 accelerator guides, each of which has a traveling

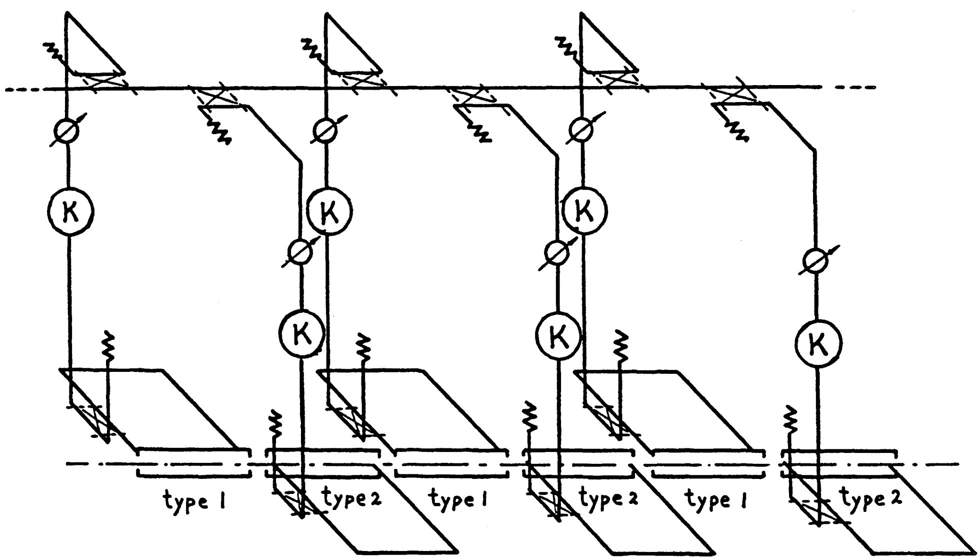

Fig. 1 A part of the proposed 1-TeV linear accelerator

wave resonant ring of its own, being fed by a 60 MW klystron. There are two types of accelerator structures: one is the $2\pi/3$ mode; the other is the $\pi/2$ mode. They would be arranged alternatively. The parameters of the accelerator structures are given in Table 1.

TABLE 1 Parameters of the two types of accelerator structures

	type 1	type 2
Operating frequency (MHz)	2856	2856
Phase shift per cavity	$2\pi/3$	$\pi/2$
Length of a guide (m)	0.35	0.34
Number of cavities	10	13
Shunt imperdance R ($M\Omega/m$)	71.89	65.06
Attenuation α (nepers/m)	0.4128	0.434
Factor of merit Q	14230	11640
Group velocity Vg/C	0.005092	0.00506
Diameter of disk hole 2a (cm)	1.65	1.65
Disk thickness t (mm)	5	5

An accelerator guide with a traveling-wave resonant ring is shown in Fig. 2.

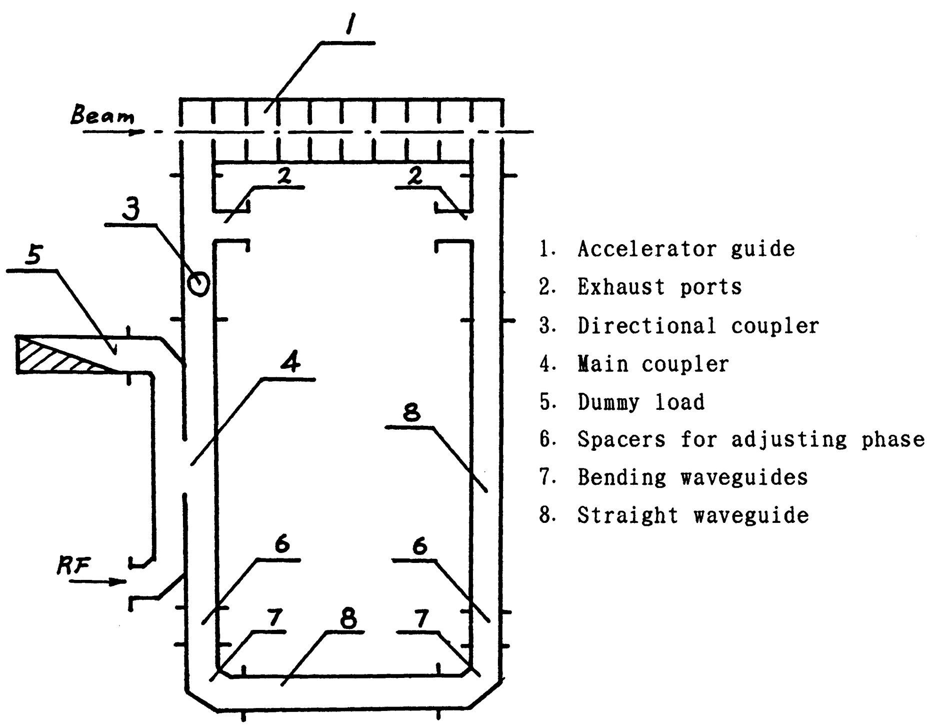

Fig. 2 An accelerating guide with a traveling-wave resonant ring

3. PHASING SYSTEM

In the proposed linac with traveling-wave resonant rings the phasing system would have two parts. One of them would be used to adjust the phase of each klystron so as to make the beam bunch be in suitable phase with the wave in the accelerating guide. The other would be used to adjust the phase of each resonant ring so as to meet resonance conditions. If one uses a phase shifter in every traveling-wave resonant ring to adjust the phase, it would not only increase the investment but would also increase the lose which causes the field multiplication factor to decrease. For increasing the accelerating field strength we would rather use two spacers than one phase shifter to adjust the phase in the ring.

4. DESIGN OF A LINAC WITH TRAVELING-WAVE RESONANT RINGS

For the design of a linac with traveling-wave resonant rings under optimal coupling we can use the following formulae:[4,5]

$$V_i = ME_0L\frac{1-e^{-\tau}}{\tau} - IRL\left(1-\frac{1-e^{-\tau}}{\tau}\right), \tag{1}$$

$$M=\frac{\sqrt{\frac{I^2R^2}{E_0^2}(1-e^{-\tau})^2e^{-\tau'}-(1-e^{-2(\tau+\tau')})}-\frac{IR}{E_0}(1-e^{-\tau})e^{-(\tau+\tau')}e^{-\tau'}}{1-e^{-2(\tau+\tau')}}, \tag{2}$$

$$C=\frac{1}{M}, \tag{3}$$

and

$$E_0=\sqrt{2P_0\alpha R}, \tag{4}$$

where V_i is the energy gain for every accelerating guide, M the field multiplication factor in the traveling-wave resonant ring, C the voltage coupling coefficient, E_0 the accelerating field strength in the beginning of the accelerator guide (actually, $E = ME_0$), P_0 the input power, α the attenuation of the accelerator guide per unit length in nepers, R the shunt impedance of the accelerator guide per unit length, L the length of one accelerator guide, τ the attenuation constant of the one accelerator guide, $\tau = \alpha L$, τ' the attenuation constant of the waveguide of the traveling wave resonant ring except accelerator guide and I the beam pluse current.

To prevent BBU appearance the accelerator guide is designed to be as short as possible and to use two types guides arranged alternatively.

SLAC's 5045 klystrons were selected as RF power source. The output power of one klystron is 67 MW and pulse width is 3.5 μs. The power build-up in the ring is a step-wise process with intervals between steps equal to the filling time. In the ring the power builds up to 95% of the steady state value after ten transits through the ring. Thus, the beam pulse width is about 1.5 μs (Fig. 3).

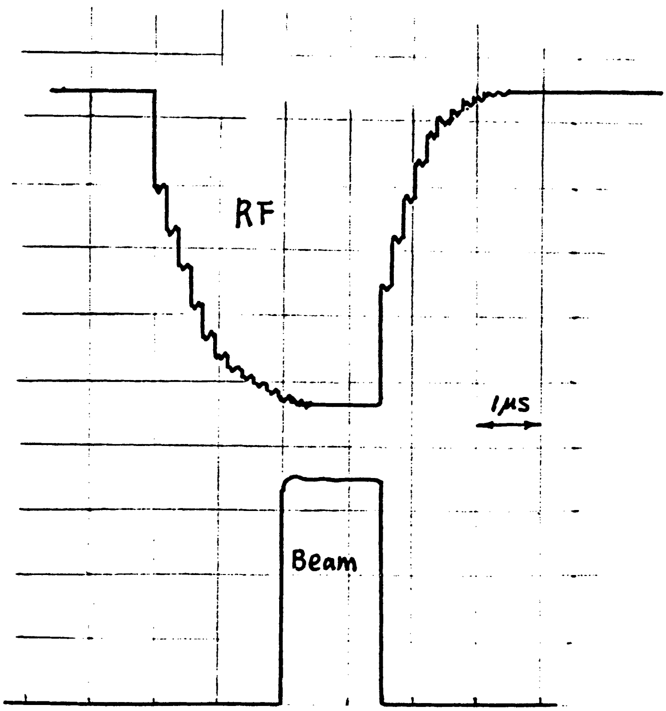

Fig. 3 Pulse shapes of the RF envelope and beam

For short pulses in the accelerator guide with the traveling-wave resonant ring, the stored energy can be written as

$$W = M^2 P_o T f_t \frac{1-e^{-2\tau}}{2\tau}, \quad (5)$$

In each guide W = 24 J; thus, a 20 A, 3ns (10 bunchs) beam current takes only 10% of the stored energy away.

The total energy gain V equals NV_i, where N is the number of accelerator guides. The parameters of the design are listed in table 2.

Table 2 The results of the design

Operating frequency (MHz)	2856
Length of the linac (km)	10.4
Beam energy (TeV) for 20A 3ns	1.10
for 0.2A 1.5μs	1.08
for 0.4A 1.5μs	1.02
Total RF power (MW)	1,800,000
Number of accelerator guides	30,000
Number of klystrons	30,000
Power of one klystron (MW)	60

REFERENCES

1. J.W.Wang, G.A.Loew, SLAC/AP-26 1985
2. J.W.Wang, G.A.Loew, SLAC/PUB-3597 1985
3. J.W.Wang, V.N.Tuong and G.A.Loew, SLAC-PUB-3940 1986
4. Y.L.Wang, IEEE Trans. Nucl. Sci. Vol.NS-28, No.3, 3526 1981
5. Y.L.Wang, IEEE Trans. Nucl. Sci. Vol.NS-30, No.4, 3024 1983
6. Y.L.Wang, Proceedings of The Second CHINA-JAPAN Joint Symposium on Accelerator for Nuclear and Their Applications, 1983 P.159
7. I.Sato et al. Proceedings of The 6th Symposium on Accelerator Science and Technology, 1987 Tokyo Japan P.95
8. I.Sato et al. Proceedings of The 5th Symposium on Accelerator Science and Technology, 1984 P.415
9. H.Matsumoto et al. Proceedings of 1987 IEEE Trans. Particle Accelerator Conference P.1654
10. Y.Kimura and K.Tanata, Proceedings of The 6th Symposium on Accelerator Science and Technology, 1987 P.313