Plasma Wakefield Acceleration Experiment By Using Twin Linac System

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A new plasma wakefield acceleration experiment by using two 10 ps electron pulses from 28 MeV and 18 MeV linacs (the twin linac system) has been planed. One pulse makes the wakefield in the plasma, and the other pulse is used for a testing pulse. By changing the time difference between the two pulses, the timing of testing pulse can be matched to the phase of the wakefield. The estimated accelerating gradient is 200 keV / m. When a pulse train is used for the driving pulse instead of the 10 ps pulse, the maximum gradient of 8 MeV / m will be achieved.

1. Introduction

Plasma wakefield produced by high energy charged particles has been paid attention as a new accelerating mechanism for future high gradient accelerators. Recently, the theoretical and experimental studies on the plasma wake field acceleration have been progressed.

Argonne group did the first experiment on the wakefield acceleration by using a L-band linac.[1] They got an accelerating gradient of a few tens keV / m by using a very unique experimental system which divided one pulse into a driving pulse and a testing pulse. KEK group attained the high accelerating gradient of 12 MeV / m by using a 500 MeV nanosecond pulse which had a several bunches from a S-band linac.[2]

It is important for the high accelerating gradient to attain a high transformer ratio (increment of energy of test pulse / decrement of energy of driving pulse), and a high density plasma. For that purpose, more detailed experiments are necessary.

In this paper, a new plane on plasma acceleration experiment by using two 10 ps electron pulses from 28 MeV and 18 MeV linacs (the twin linac system) at University of Tokyo is reported.

2. Twin Linac System

Both 28 MeV and 18 MeV S-band (2856 MHz) electron linacs (28L & 18L) produce various kinds of pulses from 10 ps to 4.5 μs. Single electron pulse with pulse width of 10 ps is produced by a 1/6 sub harmonic buncher (SHB). Fig 1 shows the schematic diagram of the twin linac system. In the twin linac system,[3] both linac can be operated simultaneously. The timing of the two pulse can be changed by controlling the three phase shifters inserted in the trigger line of the electron gun of 18L, the 467 MHz SHB line of 18L, and the 2856 MHz line of 18L. The time zitter between the twin pulse is less than 10 ps.

In the plasma wakefield acceleration experiment, a 10 ps big pulse (28 MeV, 500 pC) is used for the driving pulse, and a 10 ps small pulse (18 MeV, less than 50 pC) is used for the testing pulse. The timing of the testing pulse can be matched the phase of the wakefield by changing the time difference between the two pulses.

In some cases, a pulse trains (pulse period is 350 ps.) is used for the driving pulse to attain high wakefield. The pulse width of the macro pulse is from 2 ns to 4.5 μs.

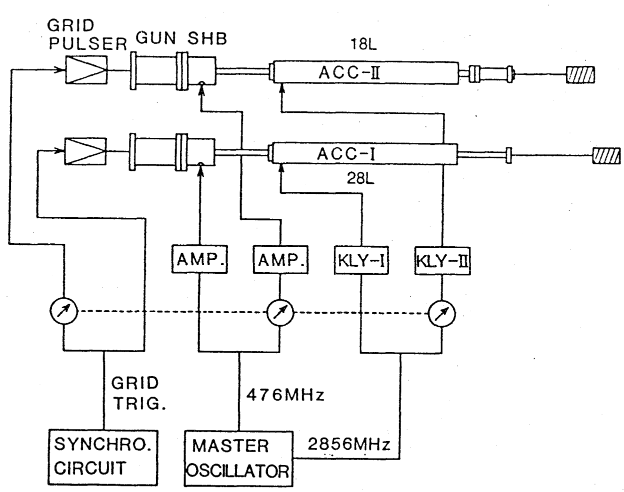

Fig. 1 Schematic diagram of twin linac system at university of Tokyo.

3. Experimental Setup

Fig. 2 shows an experimental setup of the plasma section. Two pulse beams from 28L and 18L overlap on a coaxial line in a plasma chamber by an achromatic beam line system which consists of three bending magnets and two Q-magnets. An argon plasma is produced in the chamber (147 mm in inner diameter and 360 mm in length) by a discharge between a LaB_6 cathodes and the chamber in synchronism with the linac pulse. The maximum plasma density is 10^{12} cm^{-3}. The detail of the plasma chamber has been reported elsewhere.[4]

The change of the energy of testing beam is detected by an energy analyzer. It is easy to distinguish the testing beam from the driving beam, because the difference of the energies of two beams is much large.

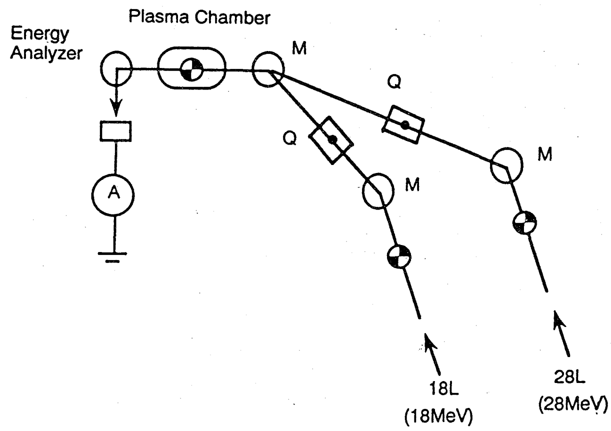

Fig. 2 Experimental setup of plasma section.

4. Estimation of Accelerating Gradient

The wakefield E caused by an impulsive bunch with charge σ is expressed by following equation:

$$E + 2\beta E + \omega_p{}^2 E = E_0 \delta \qquad [1]$$

where ω_p and β are the plasma frequency and the damping frequency, respectively. By using parabolic approximation, its solution is given by

$$E = 4 r_e m_e c^2 N / a^2 \, [2K_2(k_a) + 1 - 4(k_a)^{-2}] \qquad [2]$$

where a and K_2 represent a beam radius and the Bessel function, respectively. By using a 10 ps driving pulse (500 pC), the accelerating gradient is 2 MeV / m at the plasma density of 10^{12} cm^{-3}.

In order to attain higher gradient, a pulse train should be used for the driving pulse. In the condition that ω_p is equal to integral multiple of the bunch frequency, ω_l (2856MHz), the wakefield becomes higher. The ratio of wakefield caused by an infinite pulse train, $W(\infty)$, to that caused by a pulse, E_0, is given by

$$W(\infty) / E_0 = \omega_p / 2\pi\beta \qquad [3]$$

A 50 pC driving pulse gives the gradient of 200 keV / m at the plasma density of 10^{12} cm^{-3}. From the result of the predominant experiment, the ratio was about 40 in the case of a 50 pC driving pulse. Therefore, the achieved gradient by the pulse train will be 8 MeV / m.

References

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