VELOCITY MONITOR FOR THE KEK 40MEV PROTON LINAC

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Abstract

At the KEK 40MeV proton linac, beam velocity monitors were designed, constructed and then installed in the beam transport lines in order to measure the velocity of negative hydrogen and deuterium beams, nondestructively. It comprises a pair of bunch sensors (one turn toroid with an amorphas core), 201MHz band-pass filters and a phase detector. The measured results are consistent with those of the conventional magnetic analyzing system. This monitor is very useful to tune an accelerating field strength in the tank and to control the phase difference between two tanks.

Introduction

At KEK, a conventional magnetic analyzing system has been installed at the 40MeV transport line in order to measure the momentum spread and the energy of negative hydrogen beams accelerated with the 40MeV proton linac. This system comprises a pulsed bending magnet, a DC bending magnet, a slit, an analyzing magnet, a foil (for stripping electrons) and 94 charge collectors. The relation between the slit and the collector was fabricated based on Barbahr's law. The system is thus big and very complicated.

Further, to measure the momentum of accelerated beams, almost all of the beams transported to the analyzing course were stopped on the slit and collectors. Therefore, the residual radio activities around the system have been increased.

The KEK 40MeV proton linac comprises a pre-buncher, the first tank, the second tank and a de-buncher. In general, the momentum and its distribution are very sensitive to the accelerating field in the cavities. It is therefore very important to control the accelerating field strength as well as the phase differences between the cavities. It is very useful to nondestructively measure the velocity of the beam accelerated with each of the cavities.

We designed a velocity monitor system, and have installed it at the transport lines.

TOF (time-of-flight) method

In general, in order to measure a velocity of the beam particles, the time-of-flight method is used.[1), 2)]

The velocity (β) divided by the velocity of light is given by

$$\beta=L/(\tau\times c),$$

where L, c and τ are the distance between two bunch sensors, the velocity of light and the time of flight, respectively.

A pulse beam accelerated with the KEK 40MeV proton linac is beam bunched with a repetition rate of 201.068MHz. Therefore, it would be very difficult to measure the time of flight at a repetition rate of 201MHz. We thus measured the phase differences between the beam bunches and ones travelling at a distance of L instead of the time of flight.

It is considered that the beam bunches are combined by several frequency components with a multiple of the main frequency of 201MHz. In general, after the beam travels a distance of L, the shape of the beam bunches varies because of the momentum spread in the bunches. Therefore, although the higher frequency components included in the beam bunches vary, the main frequency component remains constant if there is no beam loss. We thought that an investigation of the 201MHz component in the bunches would yield much information concerning the behaviour of beams accelerated with the cavities. The amplitude corresponds to the intensity of the beam bunched and the capture efficiency in the last cavity. The phase difference between bunches corresponds to the momentum of the center of bunches. On the other hand, the variation of the higher frequency components would be due to debunching of the beam bunches.

We measured the phase difference of the 201MHz component in order to observe the beam velocity . It is given by

$$\beta=(L\times 360)/(\phi\times\lambda),$$

where λ is the wave length (201.068MHz) and ϕ (degree) the measured phase difference.

Velocity Monitor System and Test

A block-diagram of the velocity monitor system is shown in Fig.1.This system comprises two bunch sensors, 201MHz band-pass filters and a phase detector.

In order to observe microscopic beam bunches, a bunch monitor with a wide frequency range of above a few GHz would be required.

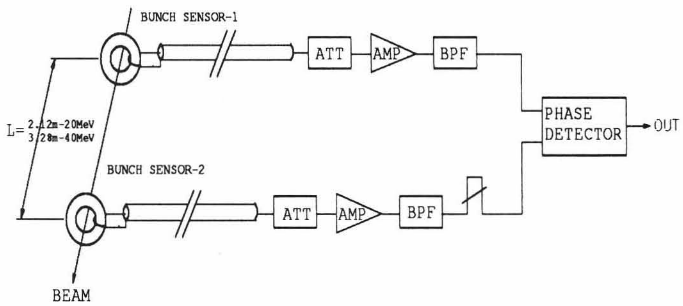


Fig.1 Block diagram of velocity monitor

Therefore, we designed two types of bunch monitors. One of them is a one-turn toroid with an amorphas core (type NA-40, TDK ctd). Fig.2 and 3 show the frequency characteristics and the pulse response.

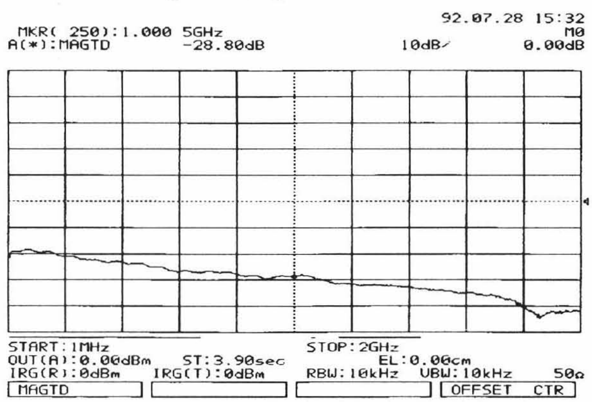


Fig.2 Frequency characteristics of one turn toroid

The other is a pick-up electrode type, which comprises a cylinder split into four electrodes. This split prevents the electromagnetic waves induced by bunched beams from propagating tangentially, and a higher frequency response would thus be expected. The pick-up electrodes will also be used to measure the position of the beam bunches. These monitors have been installed on the beam transport lines.

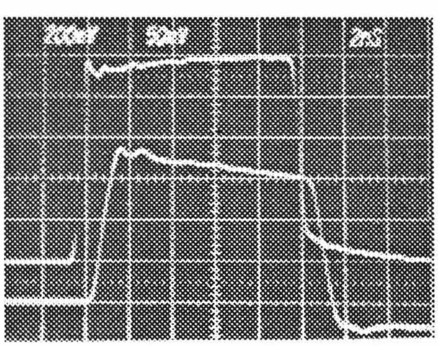


Fig.3 Pulse responce of one turn toroid
(upper: input, lower: output)

As can be seen in Fig. 2 and 3, although the one-turn toroid does not have such a wide frequency range to measure microscopic beam bunches ,it was sufficient to pick up the 201MHz frequency component from the beam bunches. The toroidal monitors were thus used as a bunch sensor against the velocity monitor system.

The signals picked up by the bunch sensors are transmitted through a phase-stable coaxial cable ($\sim 10^{-5}/°$ C, Mitsubishi cable ctd) into the local control room.

Then, the signals through the 201MHz band-pass filters are divided into two paths in order to detect the amplitude of the 201MHz component and to measure the phase difference.

In the phase detector, the input signals are down converted to 1MHz and then into the logic signal level (ECL). Phase detection is carried out under the logic signal. The dependence of the phase on the amplitudes of the input signals were observed. The accuracy of the velocity monitor was less than ±1°.

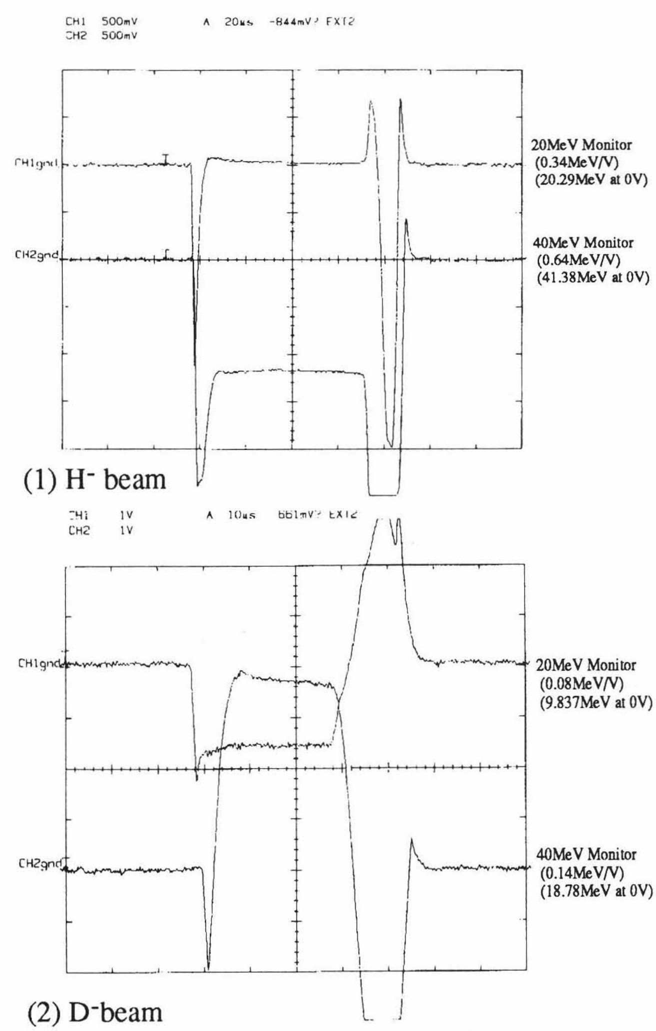
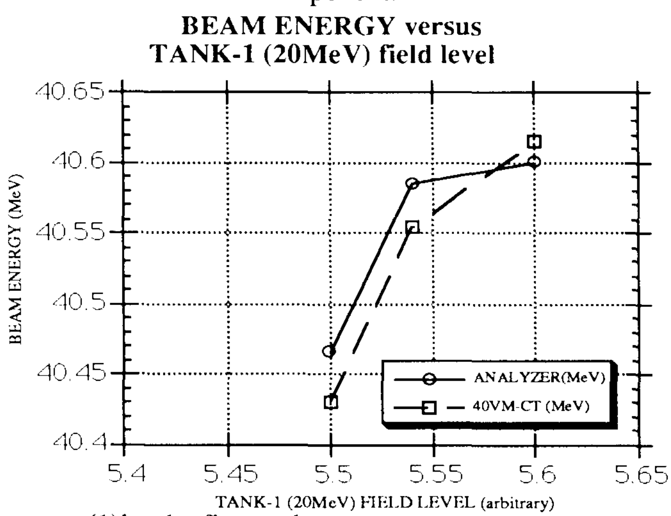


Fig.4 The measured results using Velocity Monitors
(1) H^- beam, (2) D^-beam

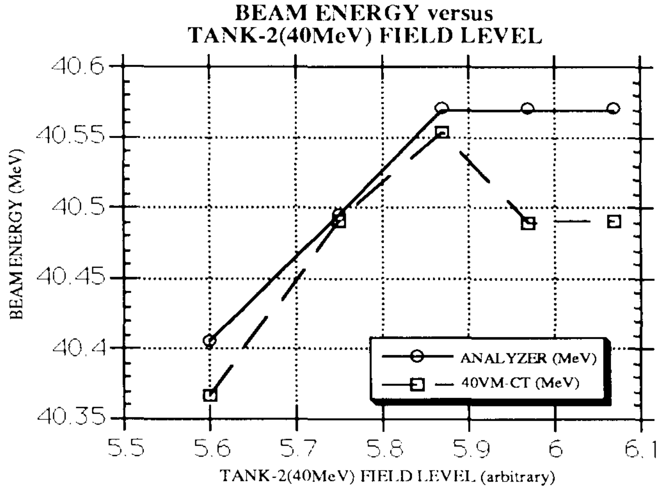
The developed velocity monitors were installed on the 20 and the 40MeV transport lines. The variation in the velocity in the beam pulse duration was measured with these monitors. The measured results are given in Fig. 4.

To compare the energies measured by the velocity monitor with those measured by the conventional magnetic analyzing system, the energy of the beam was changed with the accelerating field strength in the cavities.

Fig.5 shows the measured result. The open circles in Fig.5 indicate the center of mass in the momentum distribution measured by the conventional analyzing system. The results measured with the velocity monitor were consistent with those measured with the analyzing system within ±0.1%. The disagreement between the two data given at the ends of Fig.5 might be due to the limits to the sensitivity of the collectors and/or a decrease in the amplitudes of the 201MHz component.



(1)by the first tank



(2)by the second tank

Fig.5 Comparison the results of a velocity monitor with those of the analyzing system.
(1)Energy changed by the first tank
(2) " by the second tank

Conclusion

We designed a new velocity monitor and installed at the transport lines. The velocity monitor comprises very simple one-turn toroids, 201MHz band-pass filters and a phase detector. The filter and the phase detector are necessarily used to control/tune the pulse high power RF-field.This monitor system is thus very simple and inexpensive; the measured results using this system were consistent with those determined using the conventional analyzing system.

At the beginning of routine operation, this monitor system was used to adjust the accelerating field in the cavities.

References

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