LINAC UPGRADING AND P TO H^- CONVERSION

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ABSTRACT

The second linac tank is designed and negative hydrogen ions are to be accelerated from 20 MeV to 40 MeV. It is equipped with post couplers and ALNICO permanent magnets in its drift tubes. Some characteristics of post couplers in a model cavity and some results on a permanent Q magnet are presented.

INTRODUCTION

To increase beam intensity in a synchrotron and/or to decrease beam loss at injection, a charge-exchange injection system is spreading in accelerator community[1,2,3,4]. It is well known that the higher injection energy is preferable because of lower energy loss and smaller multiple scattering caused by a charge-stripping foil. As an injection energy of 20 MeV seemed not enough, some possibilities were examined using the present linac room[5]. However, it is very difficult now to extend the building for an additional RF high power system, because construction of the TRISTAN tunnel is going and it will pass through under the area where the building is to be built. The cavity-exciting RF power is about 1 MW for the 20 MeV tank, and the linac beam is 130 ∿ 160 mA in routine operation. For beam loading compensation, the tank is driven by two TH516 amplifier systems. If H^- beams are accelerated instead of protons, the beam intensity is 30 mA or less and the beam power is 0.6 MW at most. Consequently, it is possible to drive the 20 MeV tank by one TH516 amplifier system and the other can be used for the second tank. As the output power of each amplifier is limited to 2 MW by its modulator capacity, the excitation power of the second tank should be around 1 MW, which determines the output energy to be 40 MeV. This is still lower than the injection energies of the operating machines. However, the multiple scattering angle and energy loss due to a stripping foil decreases to about a half of the 20 MeV beam's. Since the 500 MeV beam intensity was slightly improved by 20 MeV H^- injection into the Booster synchrotron, the upgrading of the linac ensures successful operation of the charge-exchange injection system for polarized and unpolarized H^- beams.

40 MeV LINAC TANK

Fig. 1 is a layout of the 40 MeV linac with the operating 20 MeV linac. Main parameters of the 40 MeV tank is shown in Table 1. Computer codes are SUPERFISH and PARMILA. The average accelerating field is somewhat higher than that of the 20 MeV tank. Most of mechanical design is similar to the first tank[6] except a tuner and post couplers. As the present linac is a single cavity, the master oscillator follows the resonant frequency of the tank. Thus the new tank always should be tuned to the first tank, and this is done by a tuner with negative feedback loop. To reduce effect of tuning on the field distribution, some kind of stabilizer is needed.

Two tanks are separated by 2.5 m for installation of a polarimeter and other monitors.

MODEL CAVITY

A 400 MHz model cavity was made to confirm stabilization of the field by post couplers[7]. (Fig. 2) It has 15 cells. Its Brillouin diagram or dispersion curve is shown in Fig. 3. The parameters are post coupler lengths and lower two curves corresponds to the stem mode. Confluence of the TM_{010} and post modes occurred at 13.5 cm. Fig. 4 shows relations between post coupler lengths and resonant frequencies of the cavity with perturbations which were made by shifting both end plates by 1, 3, 5 mm in the same axial direction. They

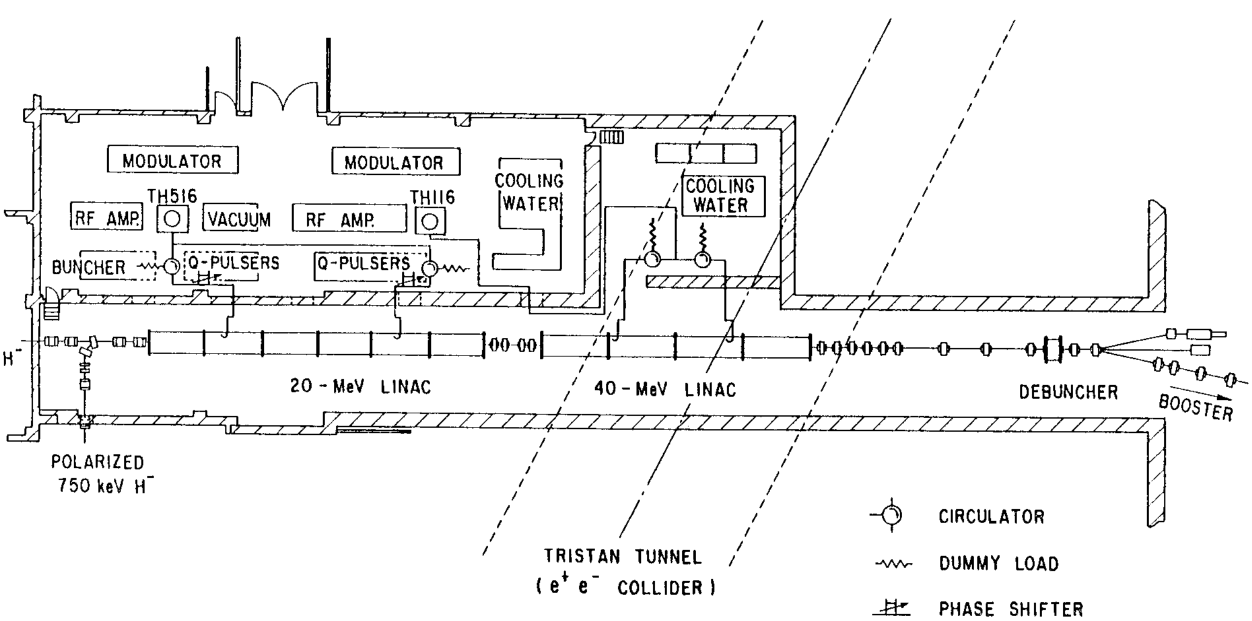

Fig. 1 Layout of KEK 40 MeV injector linac with modified RF system.

Table 1

Main parameters of 40 MeV linac tank

Energy	20.60 – 40.46 MeV
Frequency	201.070 MHz
β	0.2062 – 0.2846
$\beta\lambda$	0.3091 – 0.4226 m
$\beta^2\gamma^3$	0.04537 – 0.09190
Tank	Steel, copper plated
Length	12.84 m
Inside diameter	0.90 m
Number of cells	35
Drift tube	Stainless steel, copper plated
Length	23.32 – 28.79 cm
Outer diameter	16 cm
Bore diameter	3 cm
Stem diameter	3.6 cm
Quadrupole magnet	Permanent (ALNICO-9)
Aperture	3.4 cm
Length	16 cm
Outer diameter	13.5 cm
Field gradient	2.0 – 2.05 kG/cm
Synchronous phase	- 30°
Average axial field	2.2 MV/m
Shunt impedance	70.33 – 68.71 MΩ/m
Transit time factor	0.8699 – 0.8143
Effective shunt impedance	53.22 – 45.56 MΩ/m
Excitation power	1.078 MW
Beam power (for 30 mA)	0.596 MW
Total RF power	1.674 MW
RF coupling	Loop, two feeds
Stabilizer	Post couplers
Post diameter	3.0 cm
Vacuum system	Ion pump (500 ℓ/s x 8)
	Thurbomolecular pump (500 ℓ/s x 2)
Temperature regulation	± 0.1 °C

scarcely affected the resonant frequency at the confluence. Field distributions were measured by the bead perturbation method. The post couplers stabilize the field as shown in Fig. 5. The perturbation was made by shifting both end plates, the lowest energy cell was shortened by 5 mm while the highest one was extended by the same length as in the case of Fig. 4. Although the perturbation is unreally large, the field is disturbed in the both end cells only.

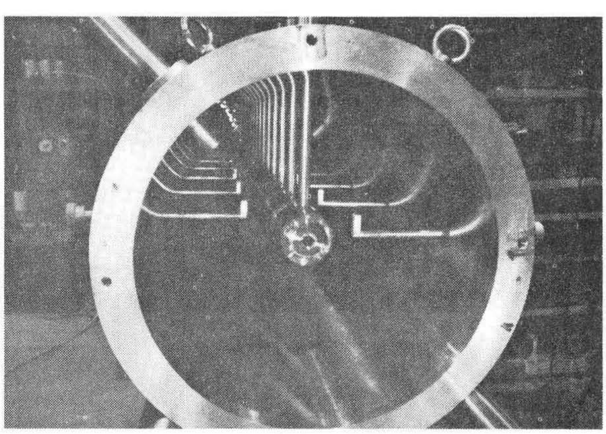

Fig. 2 400 MHz, 15 cell model cavity.

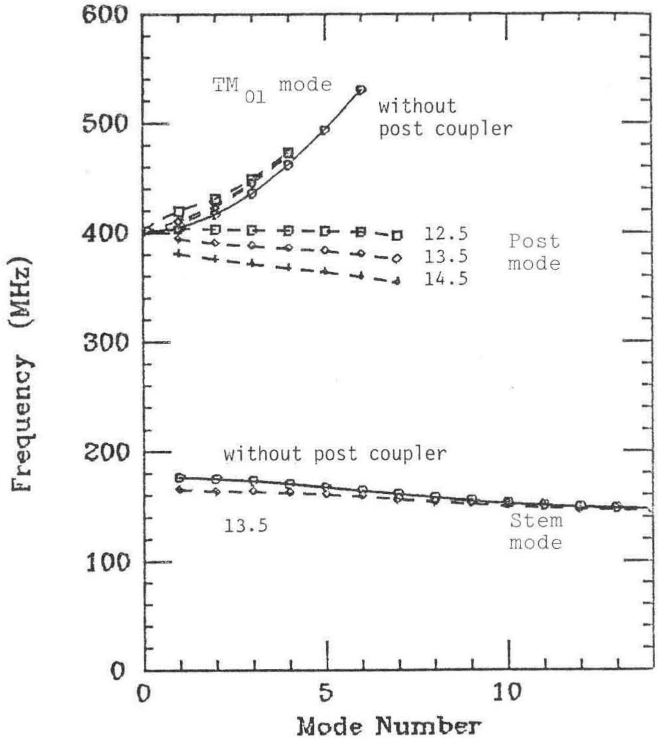

Fig. 3 Dispersion curves of model cavity. Parameters are post coupler lengths in cm.

PERMANENT QUADRUPOLE MAGNET

Permanent quadrupole magnets require no sophisticated pulsed power supplies and simplify operation and maintenance of the linac. An ALNICO-9 magnet can yield necessary field gradient of 2.0 ∿ 2.05 kG/cm for drift tubes of 20 ∿ 40 MeV. Although windings are inevitable, the ALNICO magnet has following advantages: the field gradient is variable in some region, the polarity can be changed after installation into the tank and electron beam welding can be applied without special precautions. Fig. 6 shows a test model of ALNICO Q magnet[8]. Its pole tips and yoke are made of low carbon steel. Discrepancy between the dipole-minima and the geometrical axis of the Q magnet has hysteresis as shown in Fig. 7. Fortunately, it is small in an operating region where the magnetic property is stable. An ALNICO Q magnet has been put into the last drift tube of the 20 MeV linac. It worked already for one year. No appreciable change in the beam was detected.

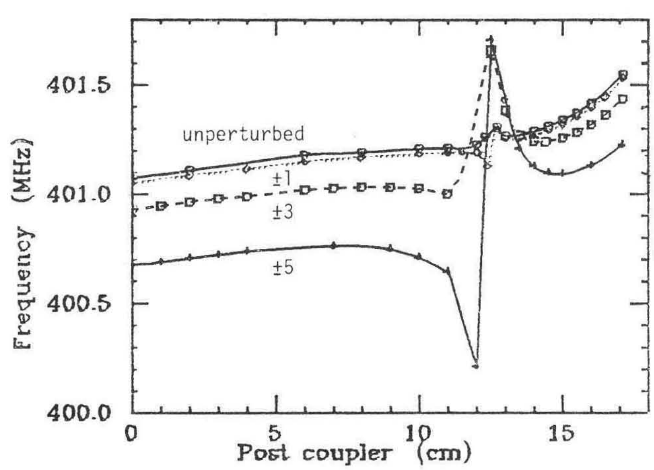

Fig. 4 Post coupler length vs. resonant frequency. Parameters are shifting of both end plates in mm.

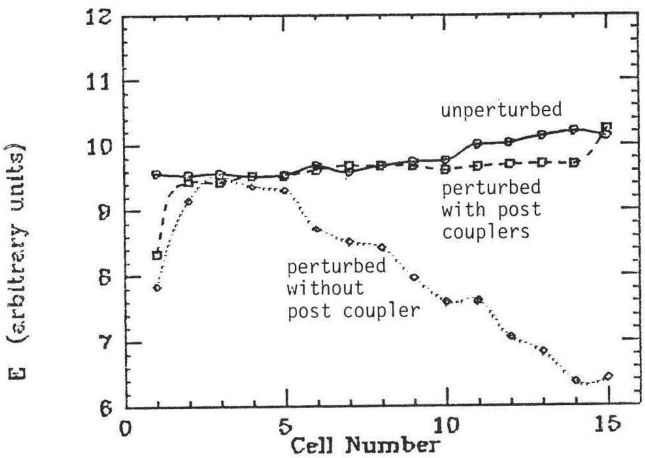

Fig. 5 Field distribution with and without the post couplers.

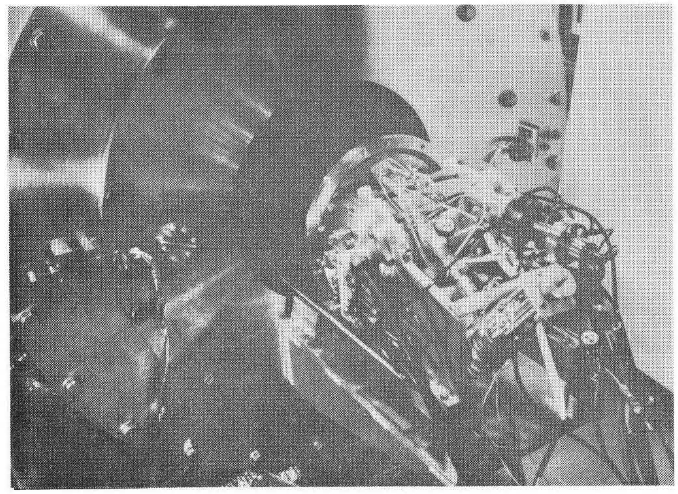

Fig. 8 Multicusp H^- ion source, ready for installation into the high gradient accelerating column.

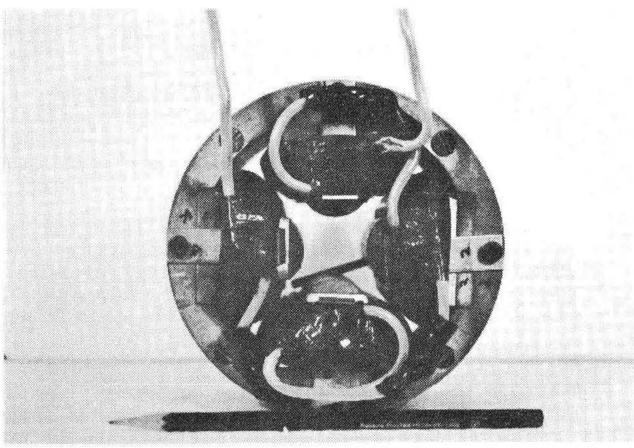

Fig. 6 ALNICO quadrupole magnet.

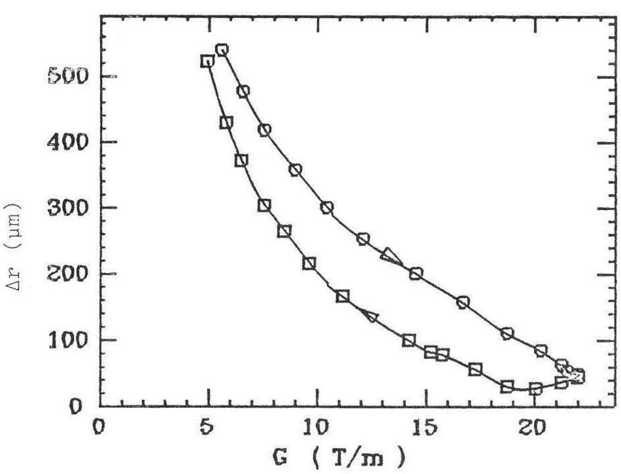

Fig. 7 Discrepancy between the dipole-minima and the geometrical axis of the Q magnet.

H^- ACCELERATION TRIAL

A multicusp H^- ion source[9] was installed into the high gradient accelerating column of the 750 kV pre-accelerator. (Fig. 8) A beam of 20 mA was injected into the linac, 8.5 mA was accelerated to 20 MeV and injected into the Booster synchrotron[10]. 95 % normalized emittance of a 750 keV, 11 mA beam was 0.17 π cm•mrad at the entrance of the linac. The previous intensity record of the 500 MeV beam was 6.8 x 10^{11} ppp. A new record of 7.13 x 10^{11} ppp was achieved by 20 MeV H^- charge-exchange injection trial[11].

As the H^- ion source needs more power than the duoplasmatron, the high voltage terminal was modified. It was extended by 0.8 m in height and the 5 kW generator was replaced by a 10 kW one.

RF MODIFICATION

As shown in Fig. 1, the output of one TH516 amplifier is splitted by a power divider and fed to the 20 MeV tank through circulators. The other TH516 is replaced by TH116 and the output is divided and fed to the second tank by two-feed system as the first one. Necessary power for each tank is less than 2 MW for 30 mA H^- beam.

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