IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

THE MUNICH HEAVY ION POSTACCELERATOR

E. Nolte, G. Geschonke, K. Berdermann, M. Kress, W. Schollmeier, Y. Shida, H. Morinaga
Fachbereich Physik, E17, Techn. Universität München, Germany

Abstract

The heavy ion booster of the Munich MP-tandem is a linear RF accelerator of Interdigital H-type structure. It consists of a single cavity with many accelerating gaps. The chosen structure is extremely efficient. Its effective shunt impedance with the new types of drift tubes is as high as 18 $M\Omega/m \cdot \beta^{-0.83}$ in the velocity range $0.05 \leq \beta \leq 0.10$ ($\beta = v/c$, v mean particle velocity). For $\beta = 0.1$, a RF power input of 41 kW is sufficient for a total effective accelerating voltage of 5 MV. To increase the beam intensity a bunched beam is injected into the booster. The booster delivers ultrashort beam bunches, if it is synchronized with the existing low energy bunching system of the tandem. In first test experiments a ^{32}S tandem beam has been accelerating from 100 to 160 MeV and a ^{58}Ni beam from 130 to 230 MeV.

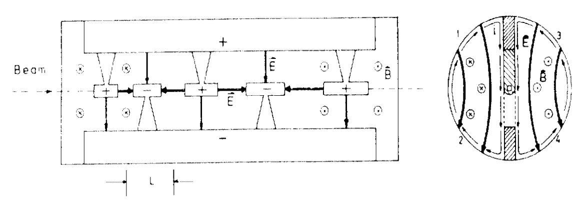

Fig.1: Interdigital H-type structure (electric field E, magnetic field H, current i)

The Interdigital H-Type Structure

An interdigital H-type structure has been chosen for the postacceleration of the heavy ion beams from the Munich MP tandem. Such structures have been studied by several authors: H. Morinaga[1], J.P. Blewett[2] P.M. Zeidlits et al.[3], V.A. Bomko et al.[4], J. Pottier[5], the Lyon[6] and the Munich group[7]. The ions pass through drift tubes on the axis of a cylindrical cavity (see figs. 1 and 2). Successive drift tubes are alternately connected by electrically conducting supports to the two opposite sides of the cavity. The cavity is excited in a mode similar to the H_{111}-mode of cylindrical cavities: the magnetic field H is essentially parallel to the axis of the cavity, the currents I flow azimuthally around the cylinder. Adjacent drift tubes are charged oppositely. A particle is synchronous with the RF field if the periodic length L (see fig.1) equals $1/2 \cdot \beta\lambda$ ($\lambda = c/f$, f resonator frequency).

Be
- l the resonator length
- D resonator diameter
- A half of the cross section of the cavity
- $\varkappa$ the electric conductivity of the walls
- δ the skin depth
- U,I,H effective values
- T the transit time factor

then the magnetic field is simply given by $H = I/l$.

The induced gap voltage is $U = 2\pi f \mu_0 HA$ and the power loss is given by $P = (\pi+2) D I^2 / (\varkappa \delta l)$. With n accelerating gaps the effective shunt impedance is $Z_{eff} = (n\sqrt{2}\,UT)^2/(Pl)$.

Combining the above equations one can find

$$Z_{eff} = \frac{2^5 \pi^{3/2} \mu_0^{3/2} \varkappa^{1/2}}{(\pi+2)c^2} \; \frac{A^2}{D} \; \frac{f^{7/2}}{\beta^2}$$

Clearly, f is a function of β.

Corrections have to be applied because of the surface roughness, the larger ohmic resistance in the drift tubes and the non-uniform current distribution along the cavity axis. In order to optimize the shunt impedance the resonator capacitance should be minimized.

Experimentally, for equal lengths of drift tubes and gaps, we have found $Z_{eff} = (18 \pm 1)\ M\Omega/m \cdot \beta^{-0.83}$. (This value includes also losses in the mounted frequency control).

Fig. 3 shows these measured values of Z_{eff} in comparison with other accelerating structures, such as Wideroe, Alvarez and Helix accelerators. In the considered velocity range the shunt impedance of the IH structure is more than three times larger than that of the other structures.

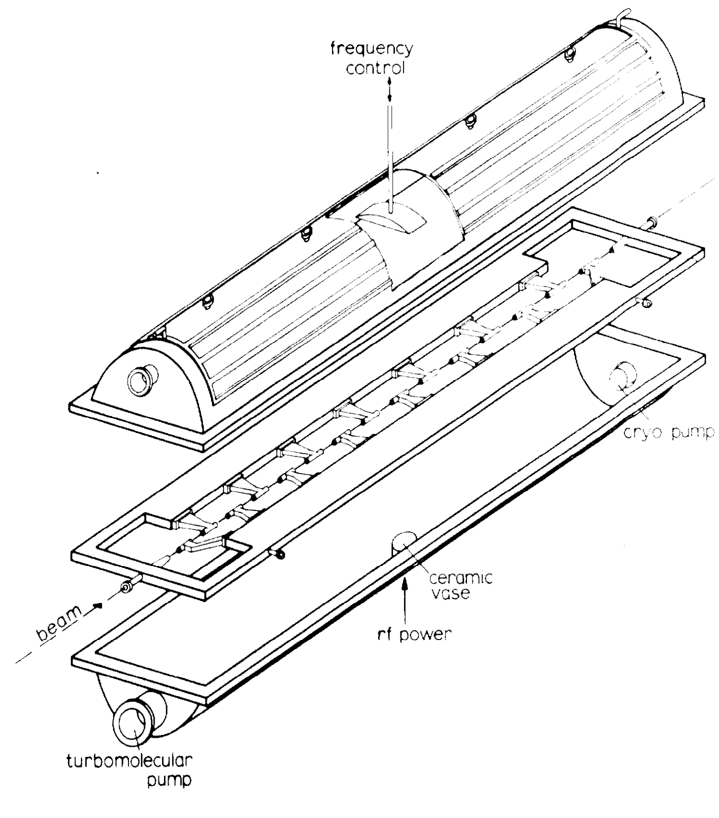

Fig. 2: The postaccelerator tank

0018-9499/79/0600-3724$00.75 © 1979 IEEE

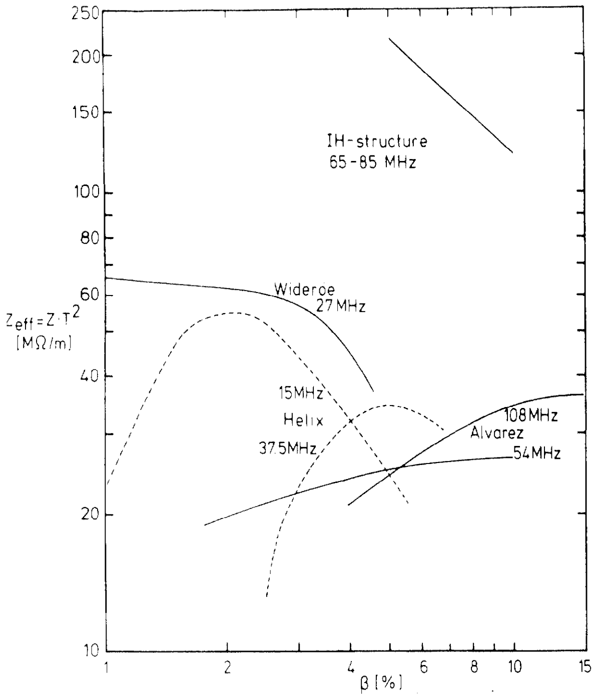

Fig.3: Effective shunt impedances of the IH structure and of other accelerating structures.

Construction of the Cavity

The cylindrical cavity is 5 m long and 1 m in diameter (fig.2). It consists of three electrolytically copper plated parts each of which is watercooled. The drift tubes are of solid copper and connected to the middle part by screws. In order to accelerate different ions or ions with different velocities the drift tube configuration has to be matched to the velocity profile of the beam. This can be done easily when the tank is opened. The resonator frequency is described by

$f=149\ \mathrm{MHz}\cdot\beta^{0.26}$. The vacuum is generated by a turbomolecular pump (2000 l/s) and a cryogenic pump (4000 l/s N_2). Vacuum and RF seal is a pure silver wire with 2 mm in diameter.

RF System

Fig. 4 shows the RF system for the booster, the high energy buncher and the low energy

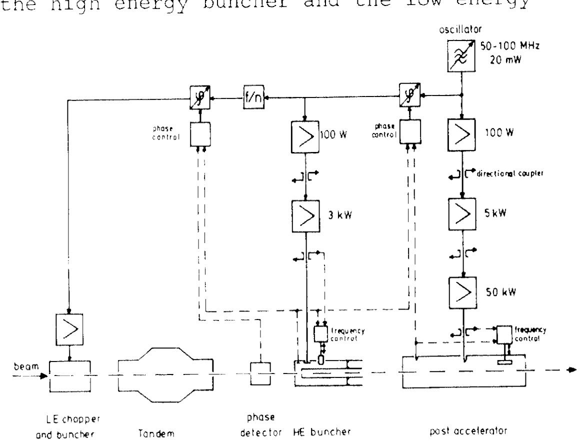

Fig.4: RF System

buncher. Since the resonance frequency of the booster depends on the drift tube configuration the RF power supply has been designed tunable from 50 to 100 MHz. For the velocity range of tandem beams a RF power input of less than 41 kW is sufficient for a total accelerating voltage of 5 MV. The RF power source for the booster is a transmitter amplifier in continuous operation. It consists of

- a crystal controlled frequency synthesizer
- a 100 W broad band amplifier
- a 5 kW driver stage
- a 50 kW power stage

The RF power is inductively coupled into the tank. The coupling loop is vacuum sealed by a ceramic cup. The resonance frequency of the cavity is controlled by means of a capacitive plunger, which can compensate a relative frequency drift of 1%.
The HE buncher is operated at the booster frequency. It is a tunable coaxial quarter-wave resonator with movable short circuit (fig.5). The RF voltage at the open end is used for the energy modulation of the beam.

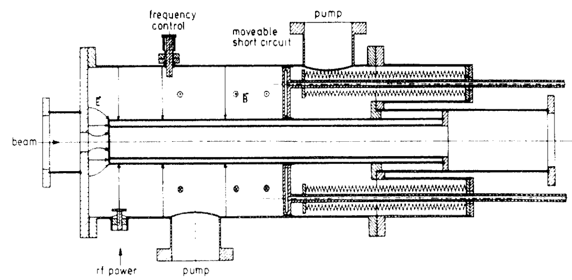

Fig. 5: HE buncher

The existing LE bunching system is driven at a frequency of approximately 5 MHz. This frequency is obtained by dividing the booster frequency through n($n \approx 15$). The phase between

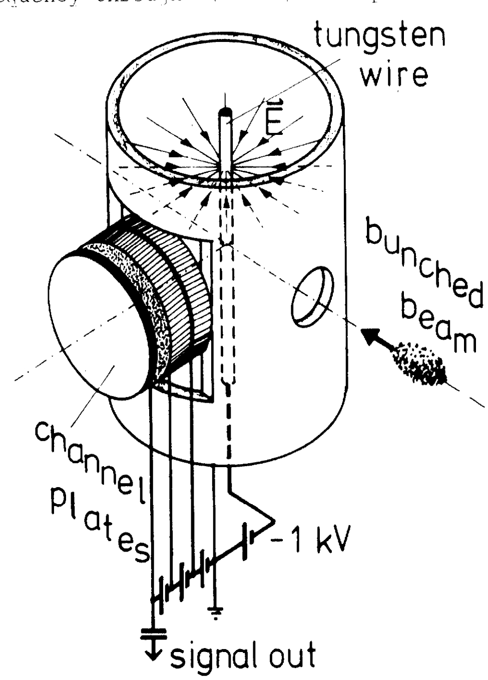

Fig.6: Phase detector for measuring the phase of the LE-bunched beam.

LE buncher and HE buncher is measured by means of a phase detector and controlled by a phase shifter. The detector consists of a thin tungsten wire with 10 µm in diameter and channel plates (fig.6).
The secondary electrons emitted from the wire, when it is hit by an ion, are accelerated towards the channel plates. The channel plate signal is used for the phase control.

Beam Line System

Fig. 7 shows the beam line system of the postaccelerator: LE buncher, tandem, post-stripper HE buncher and booster. Two target positions are provided, one immediately behind the booster and the other in the focal plane of an achromatic analysing system.

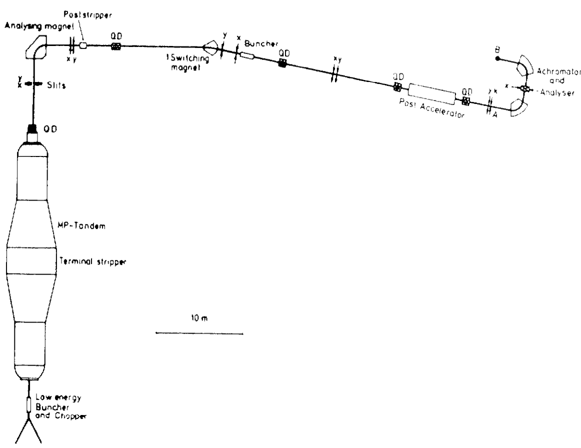

Fig. 7: Beam line system of the booster at the Munich MP tandem.

Beam Dynamics

In the first operation a synchronous phase of 0° was chosen for the booster. This is possible because the booster is a short accelerating structure and also non-captured ions can be used for experiments. If a HE bunched beam is injected into the booster the usable phase range is 46%. If the LE buncher is used and bunches of nsec width are injected into the HE buncher, the booster accepts 100% of the beam intensity. In this case beam bunches of 160 psec width are expected behind the booster. In the future, $SmCo_5$ quadrupole lenses will be installed in some of the drift tubes to compensate for the radial defocussing action of the accelerating gaps if synchronous phases $< 0^{\circ}$ are chosen.

Postacceleration of Tandem Beams

Initial nuclear physics experiments have been performed at the target position behind the achromator with postaccelerated ^{32}S and ^{58}Ni beams. For these tests tandem voltages between 10 and 11 MV and a RF power input below 40 kW were chosen. Drift tube configurations were installed for the postacceleration of $^{32}S^{14+}$ ions from 100 to 160 MeV and of $^{58}Ni^{21+}$ ions from 130 to 230 MeV at a synchronous phase of 0°. Currents of 3 pnA were measured for the postaccelerated ^{32}S beam and of 0.3 pnA for the ^{58}Ni beam.

References

1. H. Morinaga: Japan.Phys.Soc. Meeting, Osake 1949
2. J.P. Blewett: Proc.CERN Symp. on High energy accelerators (1956) p.159
3. P.M. Zeidlits and V.A. Yamnitskii: Plasma Phys. 4 (1962) 121
4. V.A. Bomko and E.I. Revutskii: Sov.Phys. Techn.Phys. 9 (1965) 973
5. J. Pottier: IEEE Trans.Nucl.Sci. NS-16, no. 3 (1968) 552
6. M. Bres, A. Chabert, F. Foret, D.T. Tran and G. Viosin: Part.Acc. 2 (1971) 17
7. E. Nolte, G. Geschonke, K. Berdermann, R. Oberschmid, R. Zierl, M. Feil, A.Jahnke, M. Kress and H. Morinaga: Nucl.Instr.Meth. 158 (1979) 311