LOW BETA STRUCTURE IN LINAC

S. Inagaki

National Laboratory for High Energy Physics

In LASL the studies of low beta structure ($\beta \leq 0.04$) of linac are triggered by PIGMI (Pion Generator for Medical Irradiation) and FMIT (Fusion Material Irradiation Test) project.

The focusing is the most serious problem in low beta region. D. Swenson[1] adopted the alternating phase focused linac for PIGMI. The idea goes back to M. Good[2] or Ia. Fainberg[3] in fifties, but was not payed much attention to because of the expected narrow stable region, though B. Murin reported the success to accelerate 2 mA protons from 50 keV to 575 keV. D. Swenson devided the PIGMI proto-type into four; APF, QUAD RAMP, PHASE RAMP and DTL sections (Fig.1). The APF structure has seven superperiod, each of which consists of FDDF radial rf focusing structure. The synchronous phase of the first gap decreases from - 78° to - 66° by 2° step in every superperiod. The author showed that the structure has a better space charge current limit campared to a simple FD structure if the designed electric field is attained.[4]

The idea to give up the axial symmetry dates back to the early sixties.[5] In 1969 Kapchinskii and Teplyakov proposed to generate an rf field by a configuration of four conducting wires. Soon various versions were proposed as a four-chamber resonator, a double-H resonator, a four-vane cavity (Fig.2) and a clover-leaf cavity. The papers by Kapchinskii[6] gave a comprehensive survey of the theory. In 1978 the vorkshop for RFQ structure were held for FMIT facility in LASL. In the case of RFQ the focusing is rather easily attained and the problem is how the four vanes should be scalloped to get the acceleration, how it should be manufactured and the four chamber should be excited etc. These studies indicate that the injection energy can be reduced to as low as 50 keV at 400 MHz for protons. The first cell length, which is defined by $\beta\lambda/2$, is 3.52 mm. This gives the byproduct that the beam has very low ingidity defined by

$$R = 2\pi\left(\frac{2\pi e\lambda E_0 T}{m_0 c^2 \gamma_s^3 \beta_s}\right)^{-\frac{1}{2}} \qquad (1)$$

Therefore the structure can be designed to have a good bunching effect. By a suitable combination of synchronous phase and electric field the capture efficiency over 98 % are easily obtained. Fig.3 shows an example of phase oscillation and energy and Fig.4 gives the capture efficiency-length charactristics.[7] The distance between vanes a and the modulation factor m can be inversely derived by the following relations.

$$E_{0r} = \frac{V}{2}\left[\frac{2r}{R_0}\cos 2\psi + \frac{(m^2-1)k_2 I_1(k_2 r)}{m^2 I_0(k_2 a) + I_0(k_2 m a)}\sin k_1 z\right], \qquad (2)$$

$$E_{0\psi} = -V\left(\frac{r}{R_0}\right)^2 \sin 2\psi, \qquad (3)$$

$$E_{0z} = \frac{V}{2}\cdot\frac{(m^2-1) I_0(k_2 r)}{m^2 I_0(k_2 a) + I_0(k_2 m a)} k_1 \cos k_1 z . \qquad (4)$$

The auther congratulates their success early in this year.

References

(1) D.A. Swenson, "Alternating Phase Focused Linacs", Part. Accel., 7, 61 (1975).

(2) M.L. Good, "Phase-Reversal Focusing in Linear Accelerators", Phy. Rev. 92, 538 (1953).

(3) Ia.B. Fainberg, "Alternating Phase Focusing", Proc. CERN Simposium on High

Energy Accelerators and Pion Physics, CERN, p.91 (1956).
(4) S. Inagaki, "Space-Charge Limit for an Alternating-Phase-Focusing Structure", LA-8287-MS (1980).
(5) G.M. Anisimov and V.A. Teplyakov, "Focusing by an Acceleraing Field", Pribory i Tekhnika Eksperimenta 1, 21 (1963).
(6) I.M. Kapchinskii, "Ion Linear Accelerator with Strong High-Frequency Focusing-Beam Dynamics in the Section with Spacially Uniform Focusing Part I", IHP-INZH-72-29 (1972).
(7) S. Inagaki, "Longitudinal Capture in the Radio-Frequency-Quadrupole Structure", LA-8290-MS.

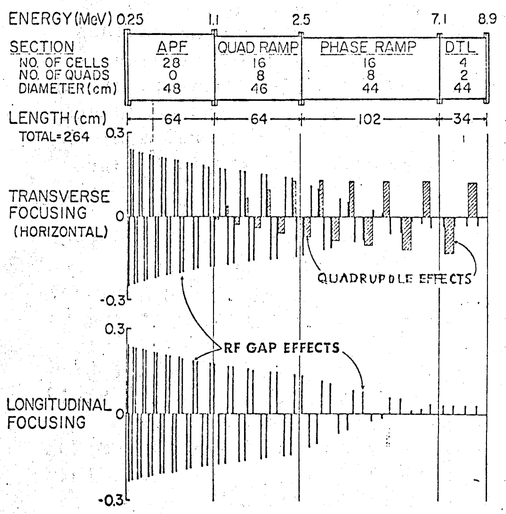

Fig.1 PIGMI prototype focusing effects.

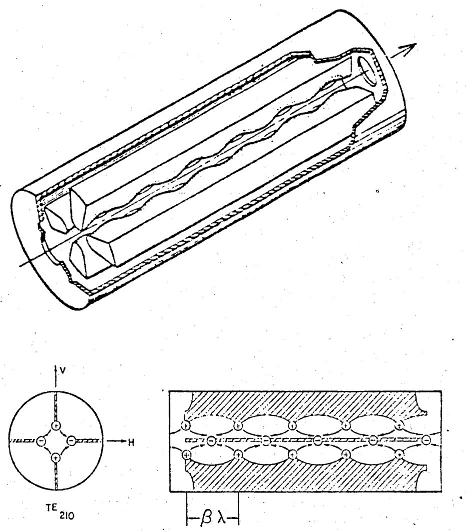

Fig.2 Four-vane cavity.

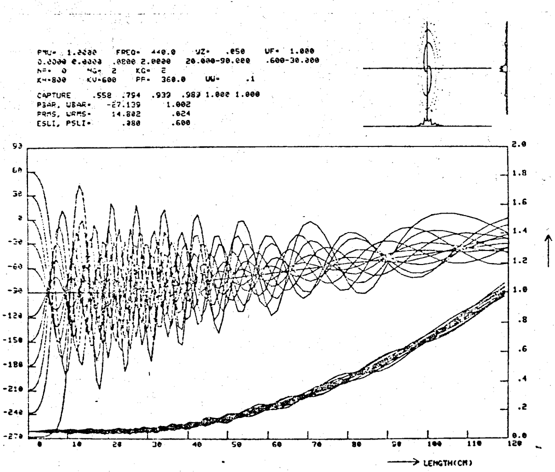

Fig.3 Phase oscillation and energy.

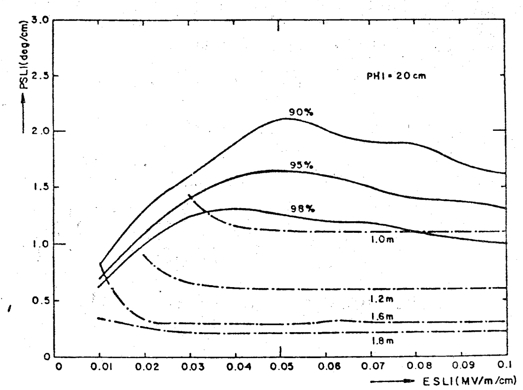

Fig.4 Capture efficiency vs. length characteristics for PHI = 20 cm.