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1 GeV リニアック検討資料

1 GeV LINAC DESIGN NOTE

題目 (TITLE) Proposal of RF Beam Chopper

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概要 (ABSTRACT)

新しいタイプの空洞 (RFD , 432 MHz) を RFQ と DTL の間に複数個置く事により、立ち上がり時間の速いチョッパーとして使用する。 設計は MAFIA を使用し、低電力モデルを製作して、応用可能な性能が得られる事を確認した。

KEY WORDS:
Ion source, RFQ, DTL, CCL, Magnet, Monitor, Beam Dynamics,
Transport, Vacuum, Cooling
Klystron, Low level rf, High power rf, Modulator
Control, Operation, Radiation, Others

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Proposal of RF Beam Chopper

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A 432 MHz rf beam chopper is proposed to decrease beam losses after an injection into a circular accelerator. Several numbers of RFD (radio frequency dipole) cavities between an RFQ cavity and a DTL deflect the beam from the center beam axis. Since RFQ beam is bunched, an rf field can be used to kick the beam. To increase the efficiency of the chopper system, fast rise time of an rf field in the cavity is important, which can be achieved with a low loaded Q- value of the cavity. Loaded Q-values of 15 for the test cavities are obtained, which correspond to the rise time of 13 nsec.

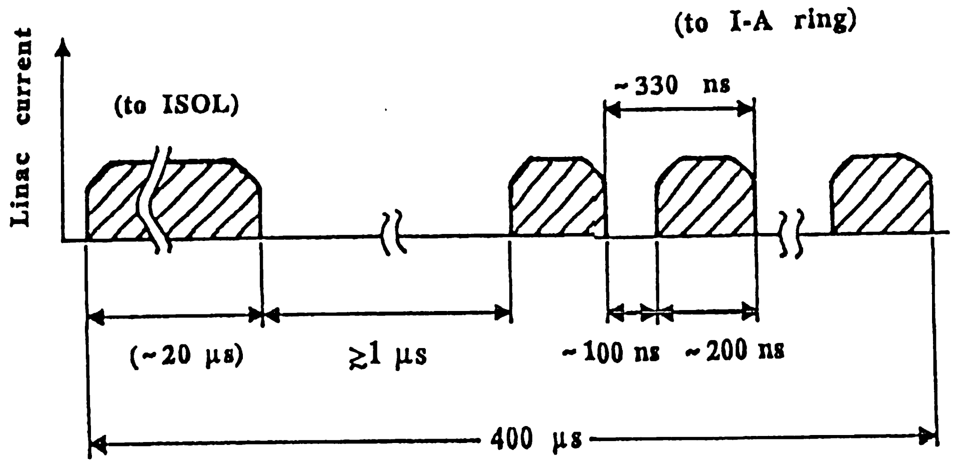

Fig.1 Required pulse structure for the linac beam.

ASSUMPTION

Figure 1 shows the expected structure of the linac beam. The required rf pulse length is 130 nsec with a 3 MHz repetition rate. A rather long beam line between the RFQ and the DTL is assumed to obtain both transverse and longitudinal matching. It consists of a 2 m long drift space, a bunching cavity and a 1.4 m drift space. Some transverse focusing elements are needed on the beam line, however, there are enough spaces to install several RFD cavities.

CAVITY TYPE

A 432 MHz rf dipole cavity (RFD) is an attractive candidate for producing a deflecting electric field. An RFD consists of two vanes and an outer wall. Figure 2 shows the RFD cavity shape. Program MAFIA can calculate rf properties for three-dimensional geometry. The cavity is excited with TE11 mode. The cavity length of 10 cm is short enough to install these cavities and focusing Q-magnets alternately. The width of the vane, that is, gap length, is 27 mm, which corresponds to the phase width of 180 degrees for a 3 MeV beam. Two pipes of 14 mm in diameter are inserted from the both end plates of the cavity to shield the beam from the magnetic fields. Calculated rf properties are shown in Figs. 3 and 4.

RF PROPERTIES

In order to give a deflecting angle of 10 mrad to the beam, it is necessary to achieve 3.4 MV/m with a 27 mm gap length, where a power consumption is 26 kW and an unloaded and a loaded Q-values are 10200 and 20, respectively. Since the deflecting angle is proportional to the amplitude of the electric field, it is advantageous to use several cavities to decrease the required rf peak power. If series of N cavity chain is used, the required electric field is reduced by $1/N$, then, an rf power is reduced by $1/N^2$.

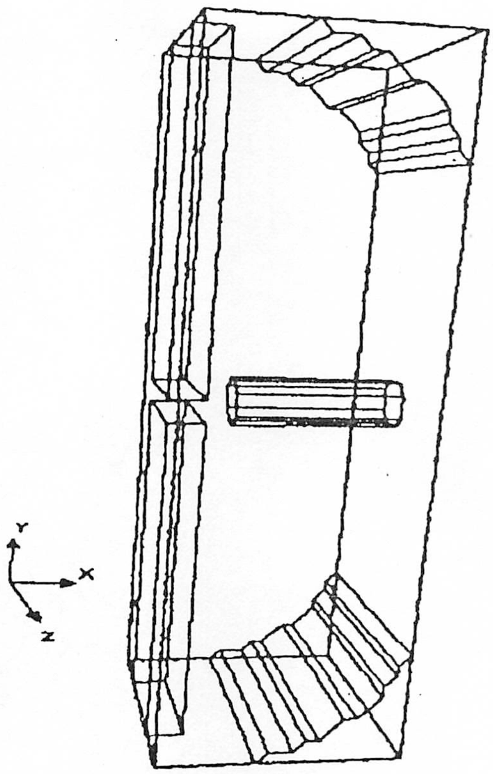

Fig. 2 RFD cavity shape (half cell).

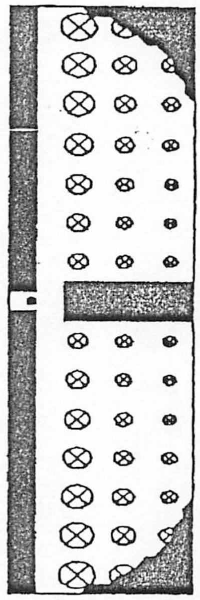

Fig.3 TE110 mode
magnetic field.

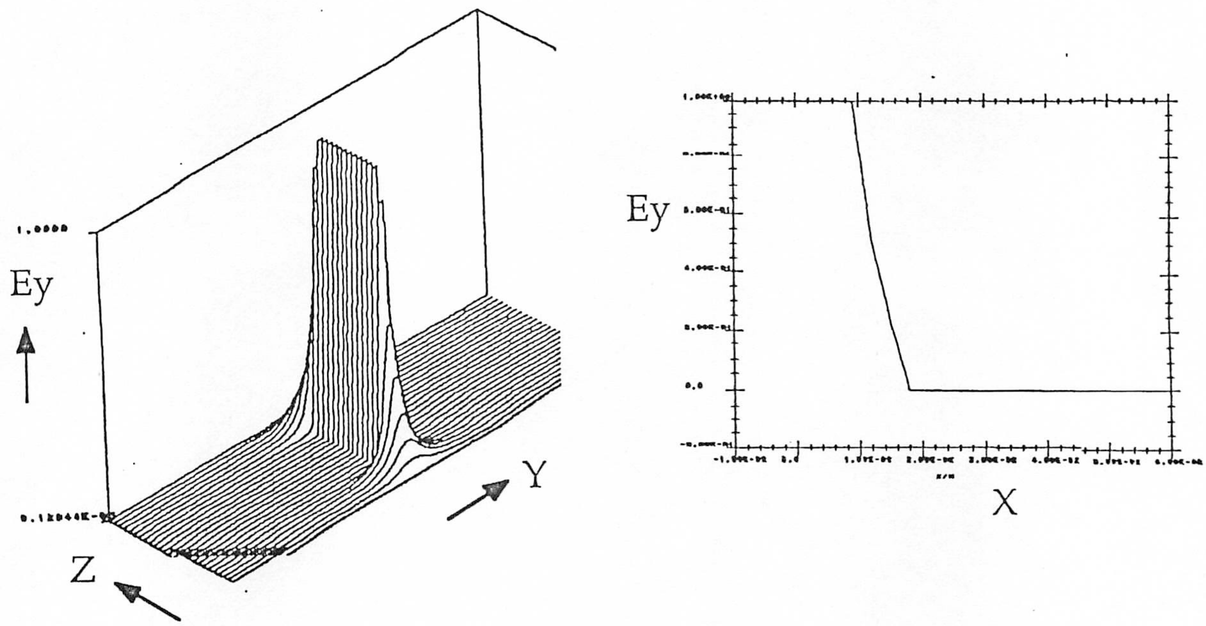

Fig. 4 Transverse electric field (Ey).

HOW TO GET FAST RISE TIME OF THE CAVITY?

The basic power relations of the two-ports cavity are listed in Table 1. We assume β_1 is equal to β_2 for simplicity, where β_1 and β_2 represent coupling coefficients of two rf ports. If the condition β_1 and β_2 are much larger than 1 and equal to β, then we have $P_{cav} = P_{in} / \beta$, where P_{cav} and P_{in} denote the rf power in the cavity and the incident power, respectively.

It is necessary to reduce the loaded Q-value by increasing the coupling coefficients β_1 and β_2 to achieve the fast rise time of the cavity. Then, the required rf power is increased by a factor of β compared with that of the matched one rf port cavity system. The RFD parameters are chosen as follows.

$\beta_1=\beta_2=255$, $Q_0=10200$, $Q_L=20$, $\tau=15$nsec,
Numbers of cavity =6,
Required electric field=0.88 MV/m,
Required rf power = 1.8 kW / cavity

Table 1 Rf power relation.

$$P_{cav}=\frac{4\beta_1}{(1+\beta_1+\beta_2)^2}P_{in}$$

$$P_{ref}=\frac{(1-\beta_1+\beta_2)^2}{(1+\beta_1+\beta_2)^2}P_{in}$$

$$P_{tr}=\frac{4\beta_1\beta_2}{(1+\beta_1+\beta_2)^2}P_{in}$$

$$Q_L=\frac{Q_0}{1+\beta_1+\beta_2}$$

$$\tau=\frac{2Q_L}{\omega_0}$$

HOW TO MAKE RF PULSE TRAIN?

There are fast rf switches whose rise time is less than 5 nsec. Then, it is easy to get rf pulse train with fast rise time in the low rf power level. However, when the rf pulse is amplified to reach the required power level, the rf power amplifier with the extreme characteristics is needed. If the rise time of an rf pulse is assumed to be 5 nsec, the required band width of the amplifier becomes 200 MHz. The power amplifier with such broad band width and a few kW output power becomes possible since an rf power amplifier of the solid state type has made progress in the last decade. It should be noted the slower rise time causes the transverse emittance growth during the rise time resulting in the extra beam losses in the high energy part of the linac and the following circular accelerator.

THE EXPERIMENTAL RESULTS

Two RFD cavities, one is made of Aluminum and the other steel, were fabricated(Fig.5). The measured unloaded and loaded Q-values as well as corresponding rise times were listed in Table 2.

Table 2 Measured Q-values of the RFD cavities.

	CAVITY-1	CAVITY-2
MATERIAL	Al	Fe
Q_0	4400	290
Q_L	16	14
τ (nsec)	13	12

The loaded Q-values could be easily chosen by varying the sizes of the input and output loop couplers. The minimum loaded Q-values obtained were listed in Table 2.

Transmitted rf power through the two ports cavity during an rf pulse is written as

$$P_{tr}=\left[1-\exp(-\omega t/2Q_L)\right]^2 P_{in}$$

The measured rf pulse with a loaded Q-value of 18 is shown in Fig.6.

Acknowledgement

The author would thank to Mr. Kubota for the mechanical design of the cavity.

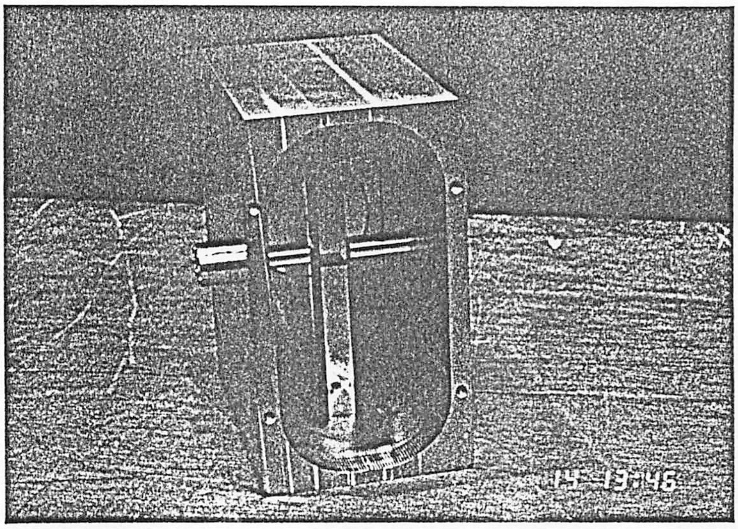

Fig.5 RFD test cavity.

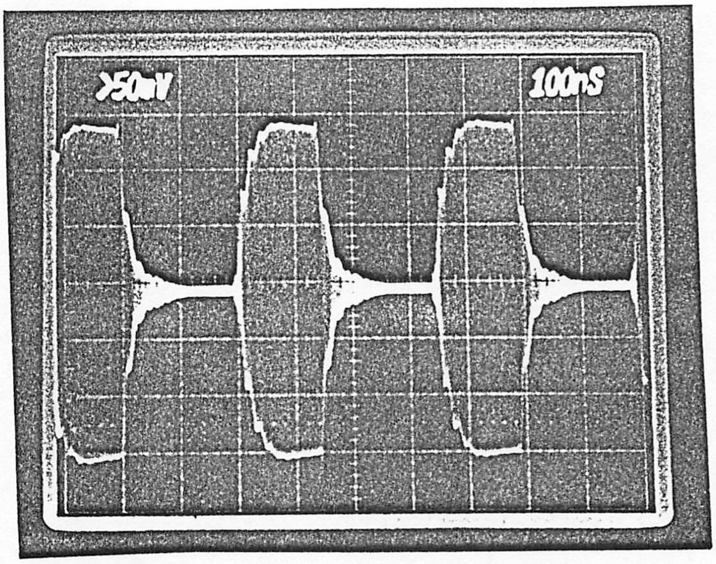

Fig.6 Transmitted rf field with loaded Q-value of 18.