# Accelerator Structure of PNC High Power Quasi-CW Electron Linac

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## Abstract

For PNC high power quasi-CW electron linac, one of the key points is how to enhance the threshold current of BBU. A short L-band accelerator section with a traveling wave resonant ring was adopted. Each accelerator section is a constant gradient structure under 100mA beam loading. And the progressive stop-band technique was adopted for all sections. In this paper, we put emphasis on the accelerator structure and measurement. A nonresonant bead perturbation method was used to measure the electric fields in the accelerator structure. The resonance frequencies of TM11-like mode were measured. The results of the measurement were in good agreement with the design values.

## 1. Introduction

The injector test of PNC high power electron linac [1] had been done in the last year. Now all accelerator sections have already been set in the accelerator room. The beam test will be started in the beginning of the next year. The scheme and main specifications of PNC high power electron linac[2] are shown in Fig.1 and Table 1 respectively. To design such kind of high power quasi-CW linac, a short accelerator section with a traveling wave resonant ring was adopted, a constant gradient structure under 100mA beam loading was used for each accelerator section, and a progressive stop-band technique was adopted to avoid the cumulative type of beam breakup as much as possible.
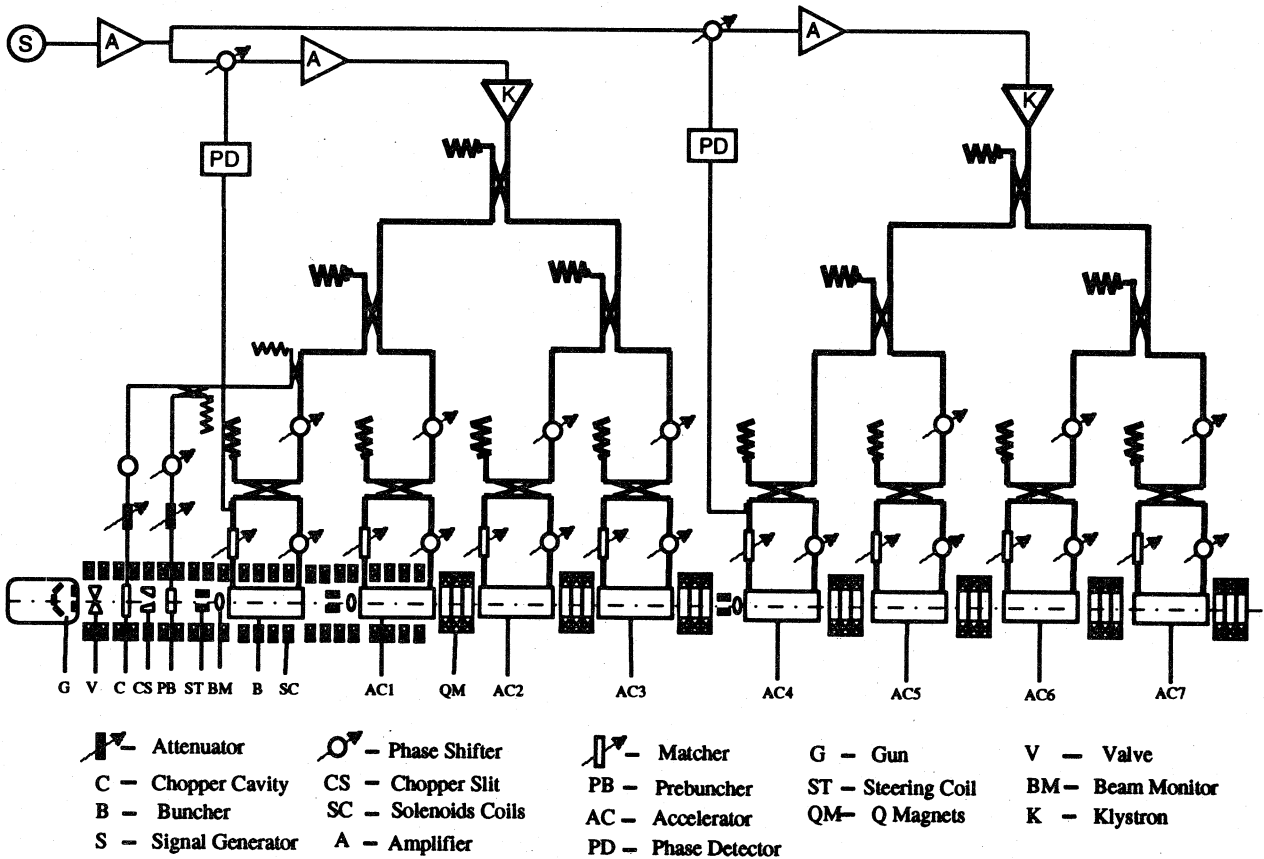


G  V  C CS PB ST BM  B  SC    AC1    QM   AC2        AC3           AC4        AC5        AC6        AC7

| | | | |
|---|---|---|---|
| ⟂ — Attenuator | ⟲ — Phase Shifter | ⟂ — Matcher | G — Gun | V — Valve |
| C — Chopper Cavity | CS — Chopper Slit | PB — Prebuncher | ST — Steering Coil | BM — Beam Monitor |
| B — Buncher | SC — Solenoids Coils | AC — Accelerator | QM — Q Magnets | K — Klystron |
| S — Signal Generator | A — Amplifier | PD — Phase Detector | | |

Fig.1 Scheme of PNC high power electron linac

Table 1. Specification of PNC high power linac

| | |
|---|---|
| Energy | 10 MeV |
| Current | 100 mA |
| Pulse duration | 4 ms |
| Pulse repetition | 50 Hz |
| Duty factor | 20 % |
| Frequency | 1249.135 MHz |
| Energy spectrum | < 0.5 % |
| Bunch width | <5° |
| Emittance | 10 π mm mrad |
| Efficiency | 70 % |
| Length of accelerator sections | 1.2 m |
| Number of accelerator sections | 8 |
| Klystron power | 1.0 MW |
| Number of klystrons | 2 |
| Gun voltage | 200 KV |
| Gun beam current | 300mA |

## 2. Accelerator Structure

In the usual case, an accelerator structure is designed at the constant gradient structure under zero current. It can enhance the threshold current of BBU, and keep dP/dz constant under zero current, but under beam loading dP/dz cannot be kept constant. For PNC high power linac, we designed the accelerator structure at the constant gradient structure under 100mA beam current. It means that each cavity in one section has greater difference, and can keep dP/dz constant under 100mA beam current. The former can enhance the threshold current of BBU, the latter can maintain the temperature constant over the entire accelerator structure easily.

The progressive stop-band technique is that for each accelerator section, the oscillation frequency of beam interaction with TM₁₁-like mode is located at a stop band of TM₁₁-like mode of all subsequent accelerator sections. This technique requires that the first iris diameters in the section be smaller than those in any preceding section but larger than those in subsequently located section.

According to above mention, the ranges of iris diameters of all accelerator sections are shown in Fig.2. One accelerator section has 15 cavities. The difference of the iris diameters between the neighboring cavities is 0.3 mm, which brings about the constant gradient structure under 100mA beam current. And the difference of the first iris diameters between the neighboring sections is 1.8 mm, which is required by the progressive stop-band technique.

## 3. Measurement

A nonresonant bead perturbation method was used to measure the electric field in the accelerator structure by measuring the reflection produced at the input port by a perturbation bead. In the accelerator along the z axis, there are no magnetic fields, one can get electric field z component $E_0$ as following:
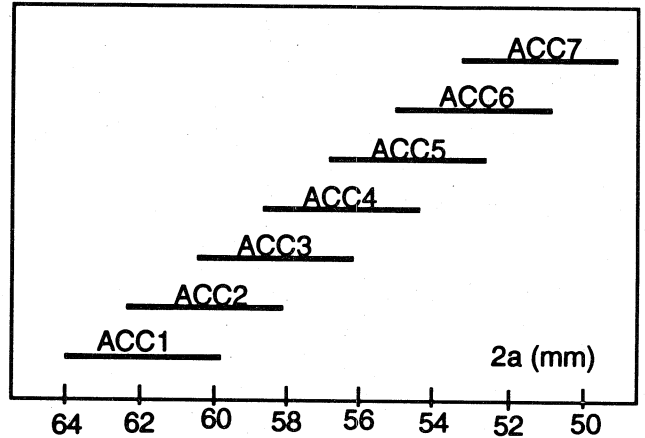


Fig.2, Ranges of iris diameters of all accelerator structure

$$E_0 = \sqrt{\frac{2P_{in}(\Gamma - \Gamma_0)}{4\pi r^3 \omega \varepsilon}}$$

where $\Gamma$ and $\Gamma_0$ are the reflection with bead and without bead. It should be possible to analyze them and to decompose $E_0$ into forward and backward wave components. After data processing by computer, the forward wave components of electric fields gave us values of the accelerating fields shown in Fig.3.
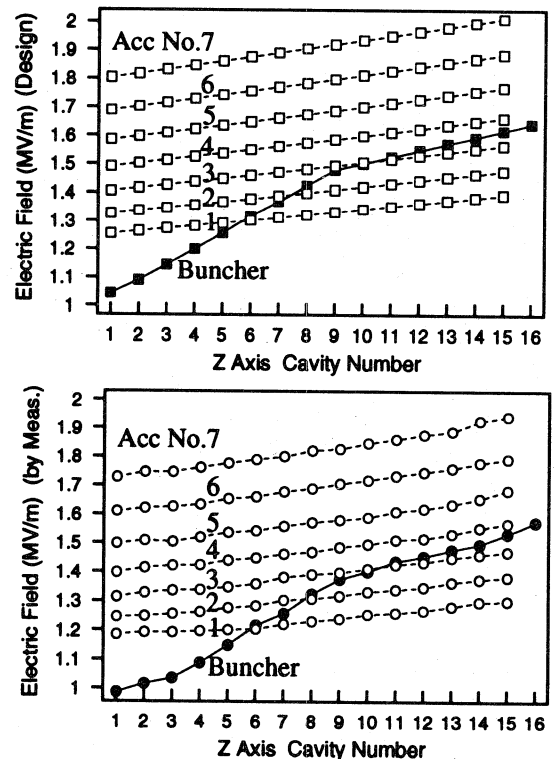


Fig.3, Electric fields in accelerator structures

The upper figure shows design data. The electric fields increase with z, because of no beam loading. The lower figure shows measurement data. They are in good agreement with design data.

The backward wave components of electric fields in each section showed us the information about the reflection of accelerator structure from where. This method was used to check the accelerator structure finally.

We used two loop couplers into the accelerator input and output couplers to measure frequency characteristics one section by one section by means of a network analyser. Fig.4 shows the frequency characteristic of one accelerator section. The left pass band is $TM_{01}$ accelerating mode and right one is $TM_{11}$-like mode.
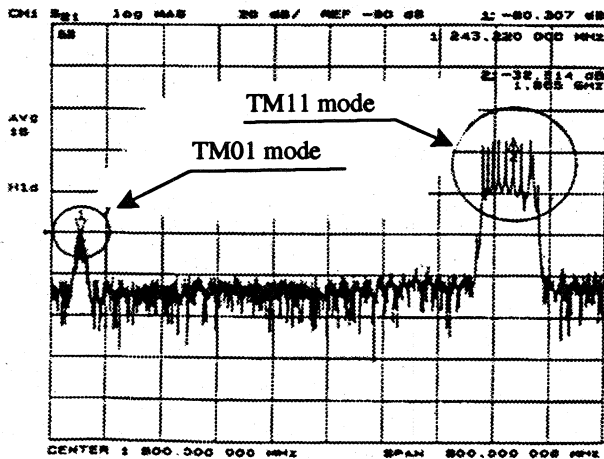


Fig.4, Frequency characteristic of one section



Fig.5, Brillouin ( $\omega$-$\beta$) diagrams
of all accelerator sections by measurement

We can detect the frequency of each mode (from 0 to $\pi$), then draw the Brillouin ($\omega$-$\beta$) diagrams of all accelerator sections which are shown on Fig.5. The results of measurements satisfied us. The upper part is $TM_{11}$-like mode dispersion characteristics' curves which intersect vp=c line at $A_1, A_2,...A_7$. They correspond to the request of the progressive stop-band technique. For the first accelerator section, the probable oscillation frequency of the beam interaction with $TM_{11}$-like mode is near the intersection $A_1$ point which is located at the lowest point and below the $TM_{11}$-like mode pass bands of all subsequently located accelerator sections. The following sections are the same situations. It is to avoid accumulation of the beam transverse $TM_{11}$-like mode oscillations one section by one section.

The lower part is $TM_{01}$ accelerating mode dispersion characteristics' curves, where only shows three curves (No.1, No.3 and No.7 section), and all of them intersect at $2\pi/3$ and fundamental frequency (1249.135MHz) point which is operation point.

This kind accelerator structure which we designed can operate at low gradient, high beam current 100mA and long pulse 4ms. During the last year injector test, we accelerated a 100mA beam with 3ms duration pulse to 3MeV successfully .[1]
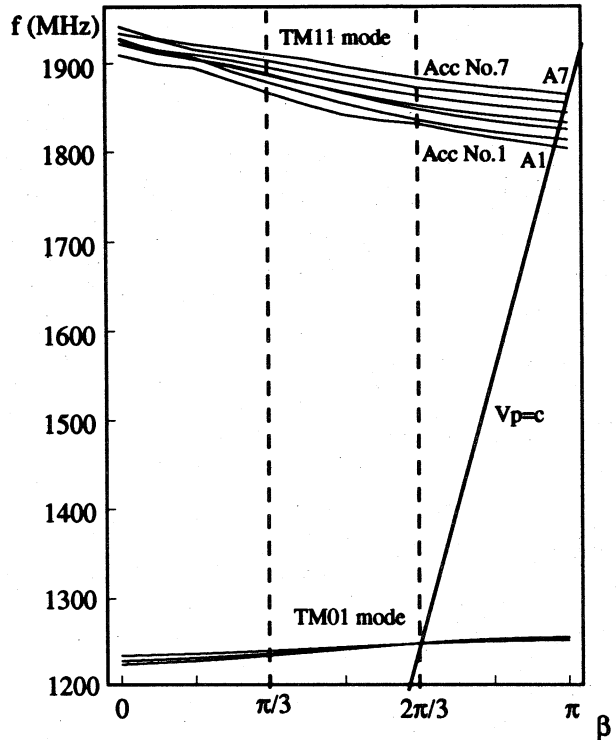
### References

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[2], Y.L. Wang,et al."Design of High Power Electron Linac at PNC". Journal of Nuclear Science and Technology, 30[12], Dec.1993. pp1261-1274.