R&D STATUS OF THE C-BAND RF-SYSTEM

H. Matsumoto, S. Takeda, KEK, Tsukuba
T. Shintake, RIKEN, Harima
M. Yoshida, Y. Takasu, University of Tokyo, Tokyo
J. S. Oh, PAL/POSTECH, Pohang, South Korea

Abstract

Hardware R&D on the C-band (5712-MHz) RF-system for the e^+e^- linear collider started in 1996 at KEK. We developed three conventional and a periodic permanent magnet (PPM) type 50-MW class C-band klystrons (TOSHIBA E3746 series and E3748 series), a smart modulator, a high power model of an rf-pulse compressor cavity is now under fabricating and the first HOM-free accelerator structure (Choke-mode type, full-scale high power model) [1], [2], [3].

As a upgrading program to 1 TeV c.m. energy scale, we developed a new PPM klystron in 1999. The first PPM klystron was generated 37 MW with 2.5-μsec pulse width and 50 pps repetition rate [4].

A very stable high voltage monitor using ceramic was successfully tested up to 230 kV of voltage and 4.5 μsec of pulse width. It was obtained very good agreement with expected a dividing ratio and the waveforms from the first high power

The first high power model of an rf compressor cavity was used a low thermal expansion material (super Invar) to make stable operation with 200k of Q-value [5], and its high power test will on a early 2002 in KEK.

The c-band linac rf-system will use for the SASE-FEL (SCSS) project in the SPring-8 [6], which is actually make strings test of the main linac rf system for the linear collider.

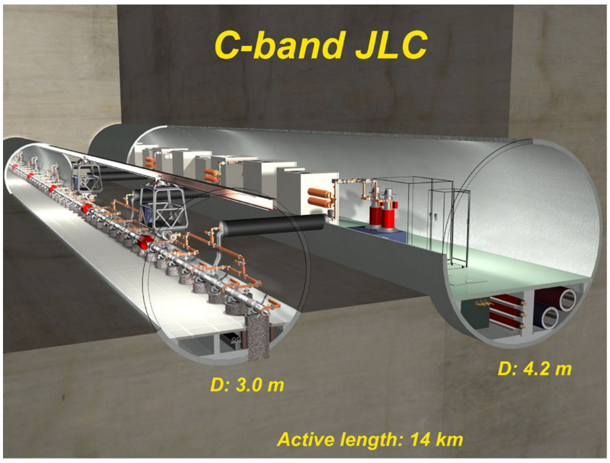


Fig.1: C-band main linac tunnels. It has diameter of 4.5-m for the klystron gallery and 3.0-m for the linac.

1 INTRODUCTION

An e^+e^- linear collider is a large-scale machine. In the main linac for two beams, we use more than 7000 accelerating structures, 3500 klystrons and their pulse modulators. Therefore, we have to develop the hardware as to meet the following demands:

(1) High reliability,
(2) Simplicity,
(3) Lower construction cost,
(4) Reasonable power efficiency and
(5) Operational ease.

The above list provides a guideline and boundary conditions to our design work. Among the system parameters, the choice of the drive rf frequency plays the most important role concerning the system performance as well as the hardware details. We proposed the C-band frequency as being the best choice to meet all of the demands listed above [2].

2 SYSTEM DESCRIPTION

Each unit in the main linac rf-system is composed of two 50-MW klystrons, their pulsed modulators, one rf-pulse compressor, four 1.8-m-long Choke-mode accelerating structures and associated wave-guide-system as shown in Figure 2.

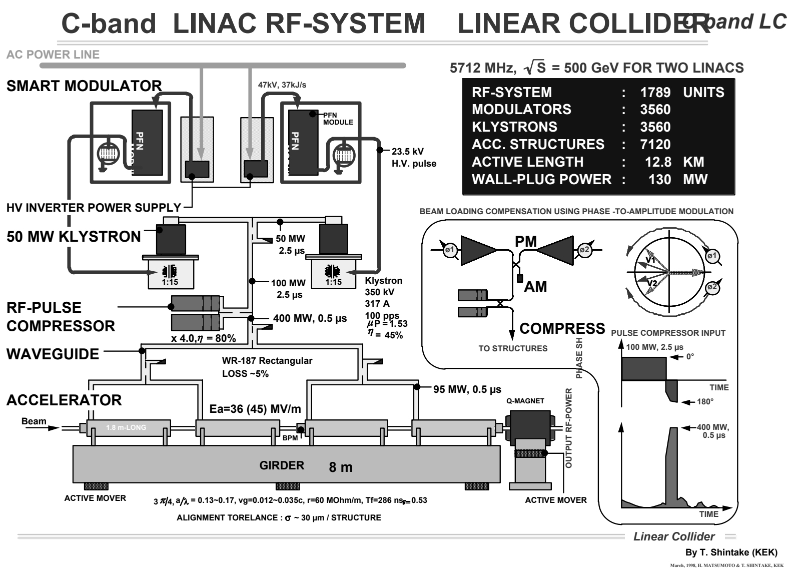


Fig. 2: One unit of the C-band main linac.

hiroshi.matsumoto@kek.jp
http://c-band.kek.jp

The accelerating gradient is 36-MV/m under the beam loading. The total number of the RF-system to achieve 500-GeV c.m. energy is 2000 units.

3 RESULTS OF HARDWARE R&D

In April 1996, we started hardware R&D, and up to now (June 2002) we have developed all of the hardware components and tested those performances, except the rf pulse compressor high-power model.

3.1 Klystron R&D

We have successfully developed the 50-MW class klystron, which meets specifications of the 500-GeV linear collider. In Phase-II R&D, we have to refine the design details to reduce cost before starting the mass-production. As a part of the R&D program toward 1 TeV c.m. energy scale linear collider, we developed the first PPM klystron in 1999 as shown in Figure 3 [4]. We chose the NdFeB magnet (Model N40A, Shin-Etsu Co. in Japan. Hot isostatic pressing (HIP) technique has been firstly applied to fabricate a magnetic circuit in a PPM klystron. An output power of 37 MW was generated with 2.5-µsec pulse width and 50 pps repetition rate.

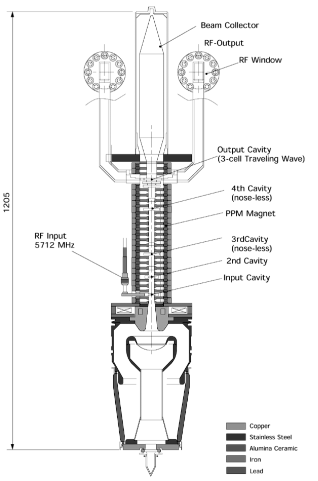


Fig. 3: Cut away view of the first C-band (5712-MHz) 50 MW-class PPM type klystrons (TOSHIBA-E3747).

3.2 Modulator Power Supply

Accordingly we focussed our R&D work on reducing the fabrication cost and improving the reliability. In 1993, the concept of the "Smart Modulator" was proposed by Prof. M. H. Cho and the author [7], [8]. As a first step, we developed a prototype modulator, whose features are:

(1) Direct HV charging from an inverter power supply,
(2) No de'Q-ing circuit,
(3) Much smaller size than the usual modulator,
(4) Use existing reliable circuit components.

To reduce the modulator size and allow removing the de'Q-ing circuit from PFN, we employed an inverter type DC-HV power supply: Model EMI-303L (Electric Measurement Inc. The smart modulator was installed in a metal cabinet of compact size 160 (w) x 200 (H) x 120 (D) cm. It is now in daily use for driving the 50-MW klystron. The total run time has exceeded 10,000 hours. The fluctuation of the measured output voltage was lower than ±0.17% (at 3σ), which meets the energy stability requirement for the linear collider. The timing variation (jitter and drift) of the pulse output is around 2-nsec (at 3σ) for 4 hour run at 50 pps [8], [9].

The second step of the smart modulator will install into the insulation oil filled one box metal cabinet with very compact size 150 (Width) x 100 (Height) x 100 (Deep) cm as shown in Figure 4 [9]. A prototype is now under construction by NICHIKON Co. in Japan, and it will begin testing by the end of this year (2002).

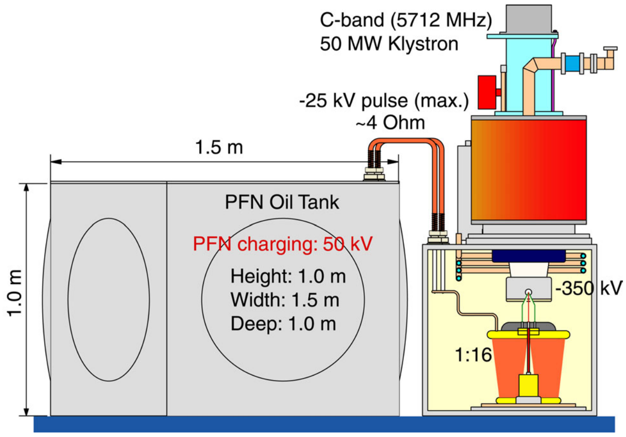
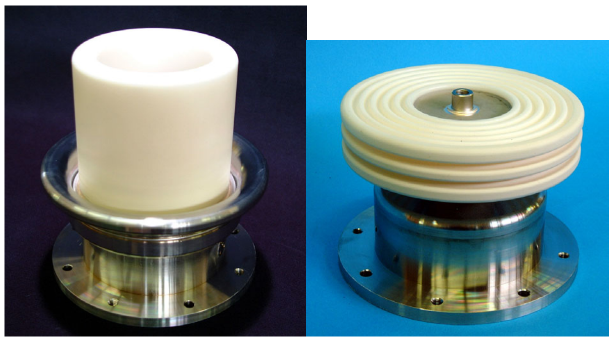


Fig 4: Closed type compact modulator.

3.3 Pulsed High-Voltage Monitor

We have been developing a very stable and accurate high-voltage monitor use for a monitoring the klystron pulsed beam voltage. Since it uses a ceramic material as the capacitive type divider, the monitoring capacitance becomes quite stable against temperature change, or change in set-up configuration, or mechanical stress applied to the monitor port through the input read. We made two different types of high-voltage dividers using ceramic as shown in Figure 5 [10].



5-a : Cup type   5-b: Disk type

Fig 5: Pulsed high-voltage monitor using ceramic material. Up: Cup type. Bottom: Disk type.

3.4 RF Pulse Compressor

A new scheme was proposed as a flat-pulse rf-pulse compressor by T. Shintake in 1996, and the demonstrated generation of a flat-pulse, which have obtained the 3.25 of power gain with 65% of efficiency. The first high power model is using an invar metal as the rf cavity with copper plating, the temperature control system to the rf compressor will be simplified and contributes to reduce cost of the total system. The high power model is now under fabricating, and it will be tested end of this year (2002) in KEK. A set up is shown in Figure 6.

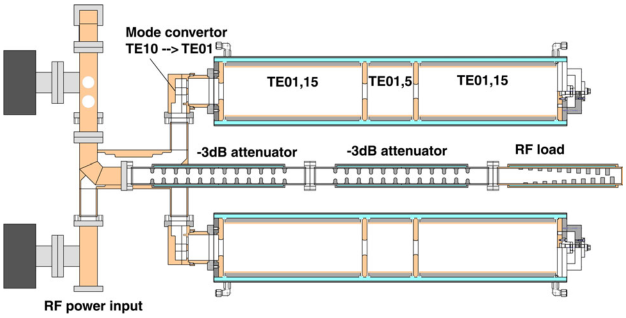


Fig 6: High power test stand for RF pulse compressor cavity.

3.3 The C-band accelerating structure

The C-band Choke-Mode type damped structure was developed in 1998, its performance was tested with ASSET at SLAC as shown in Figure 7. The powerful HOM damping performance was proven. We found parasitic resonance at very high frequency around 23 GHz, which is caused by EM field trapping inside the cavity. It can be solved by changing the cavity dimensions by small amount. For the beam alignment, the cavity type RF-BPM was developed and its performance was tested with ASSET beam [12]. The position accuracy of 10-µm and the resolution of 1-µm were confirmed. High power test of the structure will start in middle of 2002 in SPring-8.

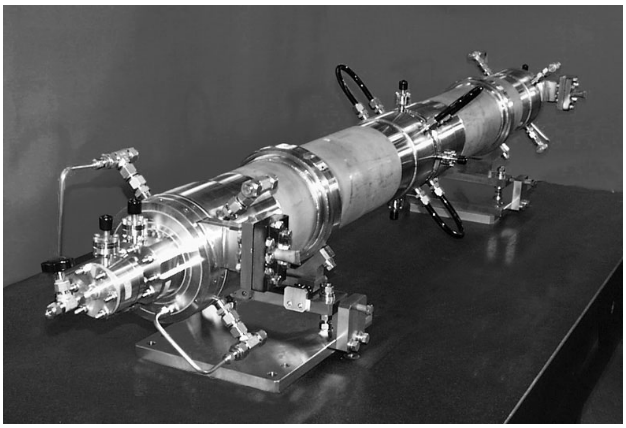


Fig 7: C-band HOM free accelerating structure (high power model).

4 FUTURE R&D

The first stage of the C-band R&D between 1996 and 1998 was successfully completed. For 1999, the first priority is to develop a 50-MW class PPM type klystron with power efficiency of higher than 50%.

For the next step, in order to examine the system performance in a realistic situation, one unit of the C-band system has to be installed and tested with beam in an existing machine.

The c-band linac rf system now under fabricating for 1-GeV electron injector linac for the SCSS project (SASE-FEL) in SPring-8 [13]. Its comprises of 1-GeV injector include the buncher system and 20-m long vacuum type undulator can be applied the water-window with range of 1- and 10-nm of the light wavelength. The first operation of the c-band linac at beam energy of 500-MeV will start on a early 2004, second step will accelerates the beam energy of 1-GeV in a early 2007.

5 REFERENCES

[1] T. Shintake et al., “C-band Main Linac RF System for Linear Collider ”, KEK preprint 96-122, September. 1996.
[2] H. Matsumoto et al, “Fabrication of the C-band (5712 MHz) Choke-Mode Type Damped Accelerator Structure”, KEK preprint 98-143, September 1998.
[3] T. Shintake et al., “The first Wakefield Test on the C-band Choke-Mode Accelerating Structure”, KEK preprint 99-11, May 1999.
[4] H. Matsumoto et al., "DEVELOPMENT OF THE C-BAND (5712 MHz) 50 MW CLASS PPM Klystron(II)", 26th Linear Accelerator Meeting in Japan, Aug.01~03,2001, Tsukuba, Japan
[5] M. Yoshida et al., "RF Pulse Compressor using Low Thermal Expansion Invar Material", 26th Linear Accelerator Meeting in Japan, Aug.1~3, 2001,
[6] T. Shintake et al., "The SPring-8 Compact SASE Source (SCSS)", SPIE2001, 29 July – 3 August 2001, San Diego, California, USA
[7] J-S. Oh et al, “Efficiency Analysis of the First 111-MW C-band Klystron–Modulator System for Linear Collider”, KEK Preprint 98-32, March 1998.
[8] H. Baba et al., “Pulsed Modulator for C-band Klystron”, 1st APAC98, March 23-27, 1998, KEK
[9] H. Baba et al., “Closed type Compact Modulator for 50 MW C-band Klystron”, Power Modulator Conference & High Voltage Workshop, June 30 – July 3, 2002, Hollywood, CA.
[10] Y. Takasu et al., “Pulsed High Voltage Monitor Using Ceramic”, 27th Linac meeting August 7-9, 2002, Kyoto.
[11] M. Yoshida et al., “RF Pulse Compressor System”, 27th Linac meeting August 7-9, 2002, Kyoto.
[12] T. Shintake, "Development of Nanometer Resolution RF-BPMs", HEAC99.
[13] T. Shintake et al., “Status of SCSS Project at SPring-8”, 27th Linac meeting August 7-9, 2002, Kyoto.