NEXTEF : 100MW X-BAND TEST FACILITY IN KEK

S. Matsumoto*, M. Akemoto, S. Fukuda, T. Higo, N. Kudoh, H. Matsushita, H. Nakajima, T. Shidara, K. Yokoyama, M. Yoshida, Accelerator Lab, KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

Nextef is the 100MW-class X-band (11.424GHz) RF test facility in KEK. By combining the power from two klystrons, 100MW RF power is produced. It is planned to conduct fundamental research programs such as the RF breakdown experiment with specially designed waveguides as well as the high power testing of accelerator structures as a research on future normal conducting high gradient linear accelerators. The construction work was completed and the commissioning of the whole facility was started in November 2007. The operation for accelerator structure testing will start soon.

INTRODUCTION: WHAT IS NEXTEF?

We had conducted the high power test of X-band accelerator structures in XTF (X-band Test Facility; It had run during 2003-2007) as the R&D program for the normal conducting linear collider (LC) project. A series of prototype accelerator structures have been tested and the latest model (named KX03, 60cm-long structure) achieved the unloaded accelerating gradient of 65MV/*m* with the breakdown rate of ~10^{-6} per pulse [1].

We terminated our R&D program of normal conducting LC in 2004 and XTF was eventually evacuated in May 2007. Most of the key equipments and essential components of XTF were selected and moved into the "new place", KEKB Injector test area, to be reassembled as Nextef (stands for New X-band Test Facility). Its construction work was mostly finished in August 2007 and the commissioning of the whole facility started in November 2007.

It was originally planned to use Nextef for the fundamental research program of normal conducting high gradient issues. On the other hand, in December 2006, a decision was made on the parameters of Compact Linear Collider (CLIC). They optimized the operating frequency of the main linac from 30GHz to 12 GHz and relaxed the accelerating gradient from 150MV/m to 100MV/m [2]. In order to establish the feasibility of this parameter choice, we started a new research collaboration program with CERN and SLAC on the X-band accelerator structures [3].

In order to test a high gradient (~100MV/*m*), accelerator structure, at least several tens MW RF power is necessary. Nextef meets this requirement. KEK has agreed to run Nextef for the research program to demonstrate 100MV/m accelerating gradient by testing a series of X-band structures newly developed and prepared in collaboration among KEK, CERN and SLAC.

The configuration of Nextef is shown in Fig.1. By combining the power from two klystrons, the maximum RF power of 100MW for 400ns can be produced. The structures to be tested are installed in the bunker. The generated power is transmitted into the bunker through a long circular waveguide to make the power loss minimized. The specification of the facility is given in Table.1.

Table 1: Nextef nominal specifications

Frequency	11.424GHz
Max power production	100MW / 120MW#
Max power for test*	75MW / 90MW#
Pulse width	400ns / 300ns#
Repetition rate	50pps

* 25% power loss in the waveguide.
\# Special operation for the CLIC structures.

FACILITY

Modulator

The modulator that we use in Nextef is the one originally made for XTF [4]. It is a modulator with two conventional line-type PFNs and thyratrons in parallel driven by inverter charging. It drives two klystrons simultaneously. The inverter makes the PFN charging system compact. The usage of PFN and thyratrons makes the system reliable.

Nextef operation is moderate compared to the original specification of the modulator (Table2). For example, the flat-top pulse width is required 0.4μs in Nextef. Therefore, the original PFNs are truncated into half. This helps not only to suppress the gun arcing of the klystrons but to save wall-plug power, which is not so much available for Nextef. So far the modulator runs fairly well.

Table 2: Modulator specifications

Peak output power	283 MW
Primary output voltage	21 kV
Primary output cur rent	13.6 kA
Pulse width	4.5 μs
Flat-top width	>1.6 μs
Flatness	±0.5%
Repetition rate	150 pps

*shuji.matsumoto@kek.jp

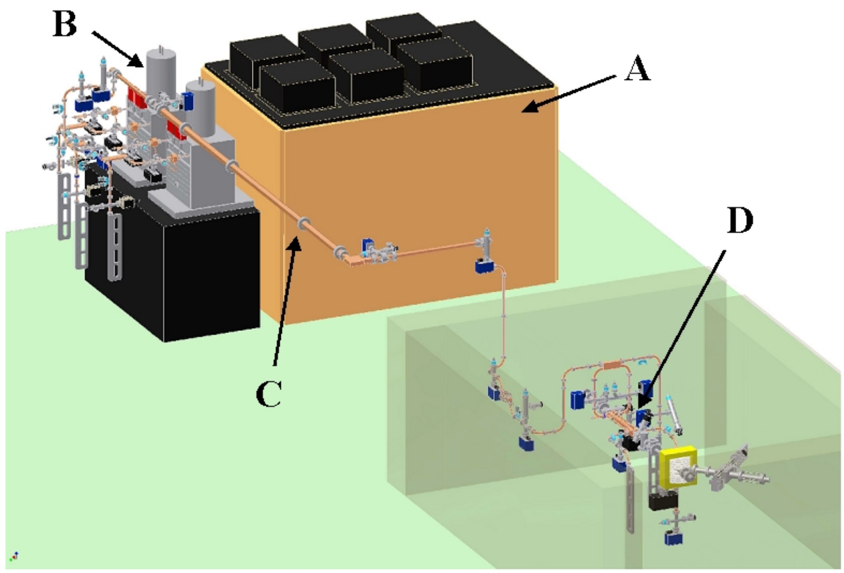

Figure 1: Configuration of Nextef. A: Modulator B: Klystrons C: Circular Waveguide D: Accelerator Structure in the Bunker. The control hut is not shown but present in the same room.

Klystrons

We employed twin PPM (Periodic Permanent Magnet) klystrons for Nextef, which used to run in XTF. Use of a PPM klystron has an advantage to save the electric power and cooling water since it does not have the focussing solenoid magnet. The PPM klystron has been developed as the prototype for the normal conducting linear collider project [5]. It was originally designed as a 75MW klystron.

The stability on the operation of PPM klystron depends both on the peak power and pulse width. We are confident from our previous klystron test result that the single PPM klystron can produce 50MW, 0.4μs RF with the fault rate being low enough. Also 60MW, 0.3μs RF is possible for the test of CLIC structures.

Table3: PPM klystron operation in Nextef

Operating Frequency	11.424 GHz
RF Pulse Width	0.4 μs
Peak Output Power	50 MW
Beam Voltage	460 kV
Repetition Rate	50 pps
Efficiency	43 %

Waveguide

The distance from the klystrons to the structure is about 16*m*. Over about half of the distance, a circular waveguide is used to reduce the power loss. Two SLAC mode converters are used at both ends of the circular waveguide as the interface between rectangular WR90 TE10 mode and circular TE01 mode. From the power measurement done in recent operations, the transmission loss is found to be about 25%.

Beam-line setup

The beam-line setup in the bunker is shown in Figure 2. The propagating RF pulses into and from the accelerator structure are monitored by crystal detectors. Once the breakdown event occurs, the disturbed RF pulse is detected and the interlock system cuts off the trigger signal for the next pulse. In order to identify the location of breakdown in the structure, we use X-ray detectors, consisting of scintillators and photomultipliers, as well as the SLAC-made acoustic sensors.

The dark current is detected and monitored by the profile monitors and the Faraday cups placed along the beam line. The energy spectrum of the dark current can be measured with the analyser magnet.

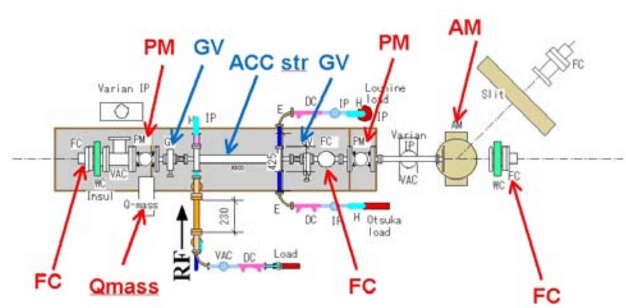

Figure 2: Nextef Beam-line setup. FC: Faraday Cup, PM: Profile Monitor, AM: Analyser magnet, GV: Gate Valve.

Control system

The modulator PLC plays the central role in Nextef operation. First of all, it controls the modulator. The PLC monitors the status of klystrons, waveguide and other devices: Interlock signals from these devices are sent to the PLC treated as the external interlocks of the modulator control. Remote access to Nextef operation is also through the modulator PLC.

The data such as the charging voltage or RF power as well as those of vacuum and temperature are logged in the storage area linked to those of KEKB Injector. High voltage and RF pulse waveforms are primarily monitored by oscilloscopes. These waveforms are regularly collected and stored by a PC. A fast pulse-to-pulse RF waveform analysis is being prepared by Tektronix 7054.

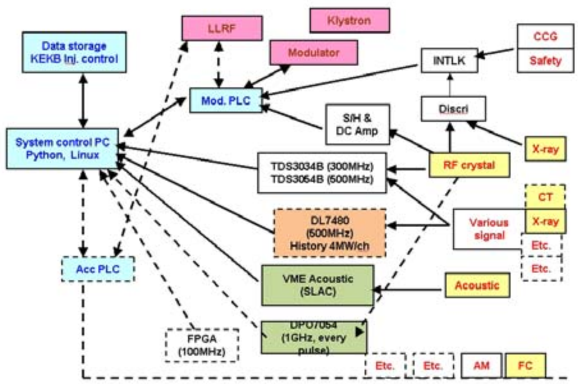

Figure 3: Diagram of Nextef operation and data acquisition system.

OPERATION STATUS AND PLAN

Nextef is jointly operated with KEKB Injector. This enables 6,000 hrs of annual operation of this facility. After the construction work was finished, we began the commissioning of Nextef, starting with the diode operations of the klystrons. From November 2007, we started the operation with RF to commission the whole system. The waveguide was terminated with RF loads to condition the waveguide before the accelerator structure being installed.

Nextef has run well so far. The power rating has been gradually increasing. In the last run from May 23 to June 4, we have achieved 90MW RF production with 210ns pulse width (65MW feed to the structure if it is installed). The facility currently runs with KX03 structure for the commission of the breakdown detection system.

The first accelerator structure to be tested in Nextef will be T18_vg2.4_Disk, a disk loaded 18-cell structure without HOM damping slots, developed in 2007-2008 in collaboration with CERN and SLAC. It was planned that four identical structures were made based on the same design and fabrication process. The high power test of structure #1 is ongoing at SLAC [6]. The second structure shown in Figure 4 is now waiting for the test in Nextef. The test results will be compared to check the reproducibility of the structure.

Since the minimum power needed for the test of T18_vg2.4_Disk is estimated about 60MW with 300ns, Nextef is already established to start the test. Nextef will be busy for this collaboration program at least in next two years. A near future plan is shown below. Other program such as the fundamental research of high gradient breakdown in narrow waveguides [7] are being done at KT-1 (Klystron Test station #1), the 50MW station driven by a single klystron, located adjacent to Nextef.

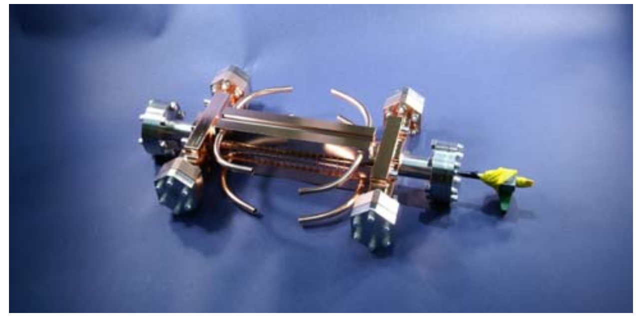

Figure 4: Test structure T18_vg2.4_Disk #2.

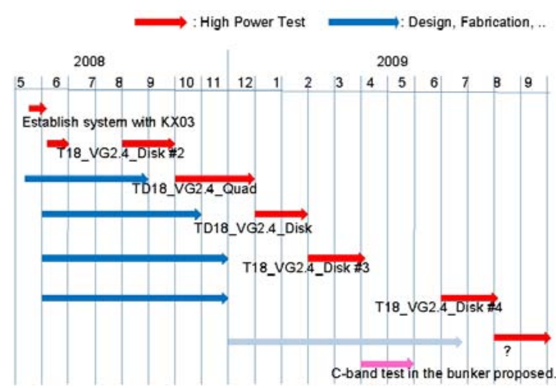

Figure 5: Planned schedule of the test structures in Nextef.

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