THE STATUS OF NEXTEF: THE X-BAND TEST FACILITY IN KEK

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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. While the facility was originally planned to conduct fundamental research programs of RF breakdown issues, it will be used as the one of the high power station for new international research collaboration on the study of future high gradient linear accelerators. A series of high gradient test structures are being tested at the facility. The gradient is as high as 100MV/m.

INTRODUCTION

XTF (X-band Test Facility) was the test facility for X-band accelerator structures in KEK which had run during 2003~2007. It was eventually evacuated in May 2007 due to the termination of R&D program of normal conducting linear collider (LC) project. 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 them as Nextef (stands for NEw X-band TEst Facility), based on the plan originally proposed to use this new facility for small size fundamental research programs for the development of high gradient normal conducting linear accelerator and its applications. The new place for Nextef is chosen since the facility can be jointly operated with KEKB Injector. This enables 6,000 hrs of annual operation of this facility.

In December 2006, a decision was made on 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 [1]. In order to establish the feasibility of this parameter choice, we organized new international research collaboration with CERN and SLAC on the X-band accelerator structures in June 2007 [2].

To demonstrate such a high gradient (~100MV/*m*) accelerator structure, at least several tens MW RF power is necessary and Nextef meets this requirement. Although the construction of Nextef was still ongoing when the collaboration started, KEK has agreed to run this new facility for testing a series of X-band structures (T18 series) newly developed and prepared in this collaboration. There have been some active X-band test facilities at SLAC and Nextef plays a role of their new counterpart in this collaboration research.

The commissioning of Nextef has been done and the facility currently runs for its first testing of the structure, named T18_vg2.4_Disk #2 shown in Fig.1. As we will see below, we will conduct the tests of T18 structures at this facility for next two years. Our fundamental research program originally supposed to be done here, such as the study of high gradient RF breakdowns in narrow waveguides [3], is now being done at another X-band test station (Klystron Test stand). It is an individual 50MW RF station driven by a single klystron, located adjacent to Nextef, originally prepared for the X-band klystron tests. Although the available power is half to that of Nextef, this station is usable for small size experiment.

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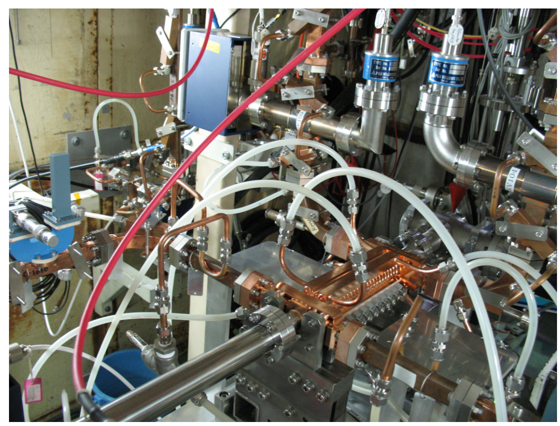

Figure 1: T18_vg2.4_Disk installed in Nextef.

FACILITY

The configuration of Nextef is shown in Fig.2. The modulator drives two klystrons simultaneously. By combining the power from two klystrons, the maximum RF power of 100MW for 400ns can be produced. We employ twin PPM (Periodic Permanent Magnet) klystrons. The structures to be tested are installed in the bunker. The distance from the klystrons to the test area is about 16*m* [4]. About half of the distance, a circular waveguide is used to reduce the power loss. Two SLAC mode converters are mounted at both ends of the circular waveguide to transform rectangular WR90 TE10 mode ↔ circular TE01 mode. Measurement shows there is about 25% power loss in the power transmission. The specification of the facility is given in Table.1. For the details of each component, refer to [5].

Table 1: Nextef Nominal Specifications

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

* 25% power loss in the waveguide.

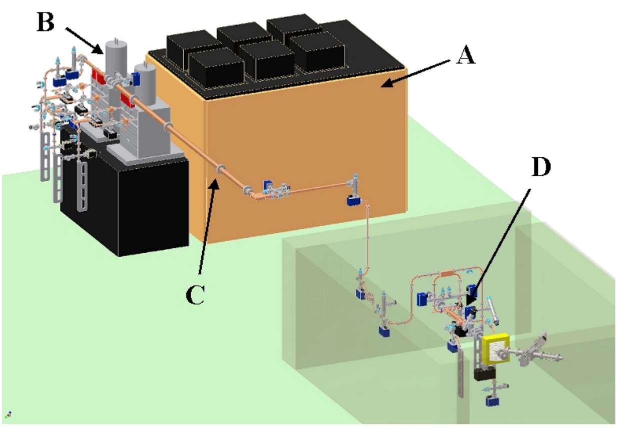

Figure 2: Configuration of Nextef. A: Modulator B: Klystrons C: Circular Waveguide D: Accelerator Structure in the Bunker. The control hut is not shown explicitly in the figure.

The PLC mounted on the modulator, which primarily controls the modulator, plays the central role in the control of whole facility. It monitors the status of the modulator as well as that of other devices such as the klystrons and waveguide. Remote access is also through this PLC. The data such as the charging voltage or RF power vacuum and temperature are logged in the storage area linked to those of KEKB Injector. Some oscilloscopes are used to monitor high voltage and RF pulse waveforms and a local PC collects and stores these waveforms regularly.

The beam-line (although we have no beam here) setup in the bunker is shown in Fig. 3. Several crystal detectors monitor the RF pulses propagating into or from the test structure. In order to identify the location of breakdown, we use X-ray detectors, consisting of scintillators and photomultipliers, as well as the acoustic sensors on the structure. 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.

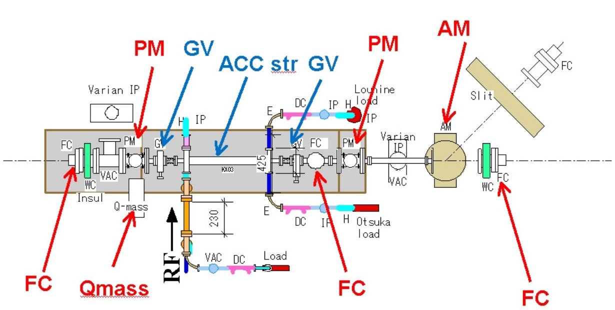

Figure 3: Plan view of Nextef beam-line setup. ACC: Space for Accelerator Structure to be tested. FC: Faraday Cup, PM: Profile Monitor, AM: Analyser magnet, GV: Gate Valve.

COMMISSIONING

After the construction work being finished, we begun to run Nextef, starting with the diode operations of the klystrons. From November 2007, we started the operation with RF. We conditioned the waveguide terminated with RF load before the accelerator structure being installed. In the run from May 23 to June 4 2008, we have achieved 90MW RF production (equivalent to 65MW feed to the structure) with 210ns pulse width and 25pps repetition rate. Though this power is smaller than the specification of the facility, it suffices for T18 series structure tests.

Before we install the structure to be tested, we installed an old structure KX03 instead in June 2008. (KX03 is a 60cm-long X-band structure which is the latest model of the series of prototype LC accelerator structures, achieved the unloaded accelerating gradient of 65MV/*m* with the breakdown rate of $\sim 10^{-6}$ per pulse at XTF [6].)

From June 11 we started the run with KX03 to commission the detectors and data acquisition system for the breakdowns and to confirm the way to identify the breakdown event, which is crucial for the structure tests. A typical example of the RF waveforms recorded at a structure breakdown event is shown in Fig. 4.

The video signal from the crystal detector monitoring the reflected power can be used for the breakdown identification. Also do the signals from the Faraday cups. Actually those signals are used for the system interlock to inhibit the next RF trigger once the breakdown is detected. Disappearance of transmitted power through the structure also looks usable but is not included in the interlock.

We will prepare fast pulse-to-pulse RF waveform analysis, which is important for the breakdown study, by Tektronix 7054. It can store the waveforms consecutively over several pulses inside and put them out when the breakdown occurs. We have the data of waveforms not only the pulse with breakdown but those of previous pulses.

The power needed to produce 100mV/m gradient in T18_vg2.4_Disk structure is about 60MW with 300ns pulse width. This power was established in this run as shown in Fig. 5.

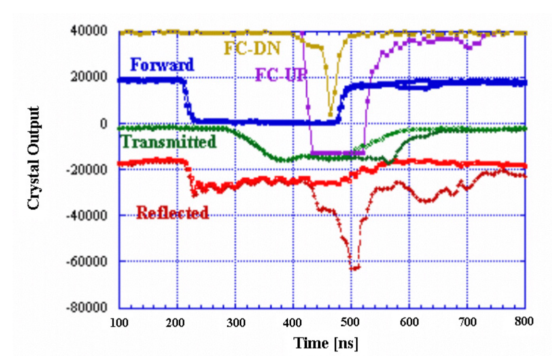

Figure 4: RF waveforms at a breakdown event. Crystal detectors monitor the power of forward to, transmitted through and reflected from KX03 structure. Faraday cups (FC) of both DN (downstream) and UP (upstream) detect anomalous current.

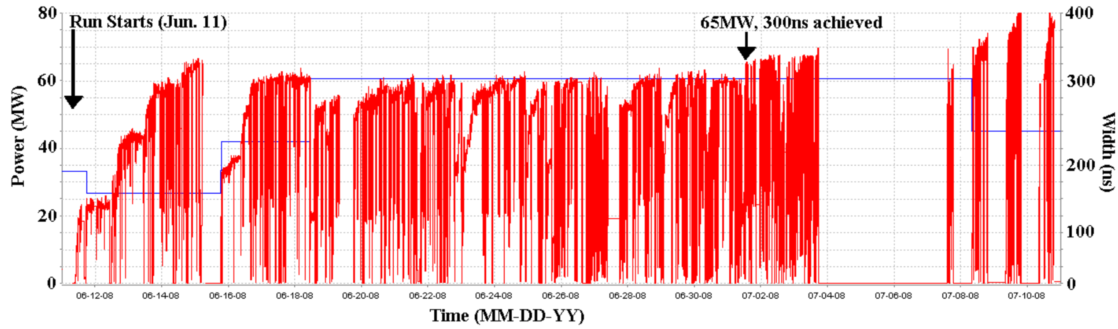

Figure 5: The RF input power to KX03 accelerator structure (red line) and pulse width (blue). One-month history plots of these values in commissioning run starting Jun. 11 2008 with KX03 structure installed. The power of 65MW with 300ns was achieved on Jul.1. Note that Nextef operation was done on daytime after July 4, since KEKB Injector was in scheduled long-term shutdown from this date.

STRUCTURE TEST & FUTURE PLAN

T18_vg2.4_Disk is the first accelerator structure to be tested at Nextef. This is a disk loaded 18-cell structure without HOM damping slots, designed vg /c varies from 2.6 to 1.0. Its design and fabrication was done during 2007-2008 in the collaboration among KEK, CERN and SLAC. It was planned to make four identical T18_vg2.4_Disk structures (#1-#4) under the same fabrication process. This enables us to check whether the same fabrication process can reproduce the same structure. The high power test of structure #2 has just started at Nextef while that of #1 has already been done at SLAC NLCTA[7]. Both test results of #1 and #2 will be compared.

As shown in Fig. 6, we are going to test a series of structures at least in next two years. Some structures are currently under fabrication process and already on the list to be tested at Nextef. TD18_vg2.4_Quad is a CLIC type structure consists of four quadrants and TD18_vg2.4_Disk is a disk-loaded structure with damping slots.

Here are a few comments on our other future plans.

1) C-band: We have a C-band accelerator program for KEKB Injector and we need to test a few C-band structures in next a few years. The bunker of Nextef will be used for these tests. X-band structure test may be stopped during the C-band tests since C-band test is not compatible with that of X-band (Nextef). The extension of the bunker is now under examination to find a way to do both tests individually.

2) Pulse compression: The maximum power available in Nextef for the structure is currently 75MW (50MW * 2 * 75%). This may not enough for the future structures to be tested at Nextef. A plan to install a pulse compression system is now under examination. The goal of the power is 150MW with 300ns by the compression rate is about 3. Design works for this project has just started. The installation of the system may be in the end of next year.

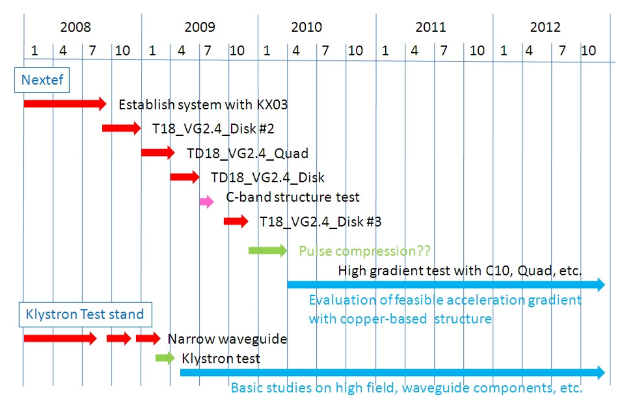

Figure 6: Planned schedule of the testing of structures in Nextef.

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