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# DEVELOPMENT OF TSINGHUA X-BAND HIGH POWER TEST FACILITY

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*Abstract*

An X band high power test facility at a frequency of 11.424 GHz is under constructing in Tsinghua University. The system consists of a CPI klystron with maximum output power up to 50 MW and a ScandiNova solid-state pulse modulator which provides the pulsed high voltage with the maximum flat top of 1.5 µs. Ion pumps keep super high vacuum of the inside of the klystron and the high power waveguides. RF breakdown interlock system has installed to protect the RF window on the klystron and the RF system. A pulse compressor [1] is under development and it is expected to boost the power up to about 250 MW at 200ns pulse width. Different RF load are tested and plans are under processing.

## INTRODUCTION

X-band normal-conducting RF accelerating structure is becoming a trend in both collider prototypes and FEL (Free Electron Laser) light sources for its high accelerating gradient and compact size. The accelerating structures need high power tests to verify the accelerate gradient and to study the RF breakdown inside the structures. Most high-power test data is reported from three X-band high power test facilities at SLAC [2], CERN [3], and KEK [4]. For the exploring of new accelerate structure and RF breakdown theorem, an X band high power test facility is under constructing at Tsinghua. The T24-11G-THU-No.1 accelerator will be tested first to confirm that the test facility function well. Then a half-cell accelerator and a photo cathode RF gun will be installed and tested.

The test facility produces high power RF pulse with variable pulse width and power level controlled by the signal source and pulse modulator.

## SYSTEM DIAGRAM

The system diagram is as shown in Figure 1. The high power test facility comprises the hardware system and the software system, including the low-level RF system, high power RF system, interlock system and RF breakdown system. The target parameters are shown in Table 1. The maximum output power of the klystron is 50 MW with the pulse width of 1.5 µs without pulse compressor. The power will be five times of the klystron's output after pulse compressing. All the power levels are measured by crystal detectors that has been calibrated by the signal source.

Table 1: Target Parameters

| **Parameters** | **Value** | **Unit** |
|---|---|---|
| Frequency | 11.424 | GHz |
| Pulse width | 1.5 | Ms |
| RF power | 50 | MW |
| Power with PC | 250 | MW |
| Repetition frequency | 10 | Hz |
| Vacuum pressure | $1 \times 10^{-7}$ | Pa |

## *Hardware*

There is a signal generator as the source of 11.424 GHz RF which power level is about -30 to -20 dBm depends on the target output power. The SSA (Solid State Amplifier) then amplifies the RF signals to several hundred or a thousand watts, and transits them to the klystron by the medium power waveguide system. There are two isolators in the medium power waveguide system to eliminate the reflect RF power back to the SSA and the input port of the klystron. Three cross directional couplers are also included for the need of power and waveform envelope measuring of RF.

The trigger generates pulses with variable delay to timing the signal source, SSA, the modulator and control the pulse width of output RF. The maximum repetition frequency of the pulse modulator is 10 Hz at the moment.

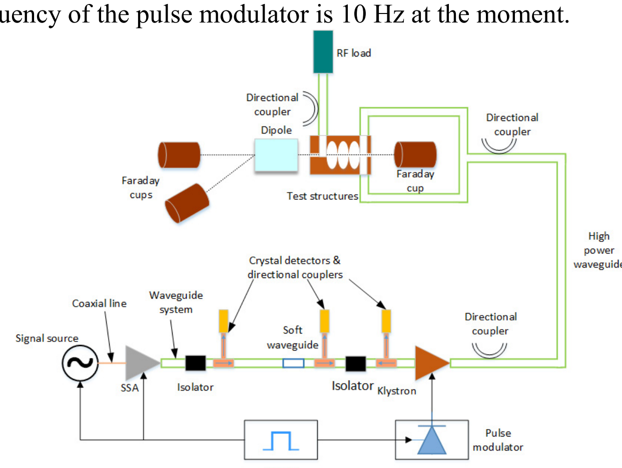


Figure 1: System diagram of the test facility.

The highest voltage of the pulse modulator is 410 kV. A pulse compressor is in the schedule, which is expected to compress the RF pulse to 200 ns length and 250 MW power. The high power part of the test facility keeps an ultra-high vacuum by ion pumps.

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Three faraday cups installed in the upstream and downstream of the accelerator to be tested and the terminal of the dipole magnet to measure the dark current of the tested structure. The dipole magnet gives the energy spectrum of the dark current electrons.

Considering the X-ray produced by the dark current and RF breakdown, the tested structures are installed in a bunker shielded with 2.4m-thick walls.

### *Software*

The software system ensures the safety of operators and the well function of the devices.

The control system enables the remote control and data acquisition of the test facility. A rack beside the pulse modulator contains all the low-level systems and control devices, including a trigger, a Pico oscilloscope, an arc detector and other communication devices. The optical fibres are the only access to operating room, making it more precise for the measurement of analog signals. It is possible for the operators to alter the pulse width, output power and on/off status of the RF output.

An auto conditioning system is also under development. The criteria of RF breakdown is the abnormal reflecingt waveform and high stand wave ratio of the tested structure. The trigger will be stopped when an RF break down happens or the vacuum pressure is higher than the set value.

## STATUS

The pulse modulator, klystron and the low-level RF system have already installed, as shown in Figure 2. The klystron has been installed on the pulse modulator and the RF load is in position.

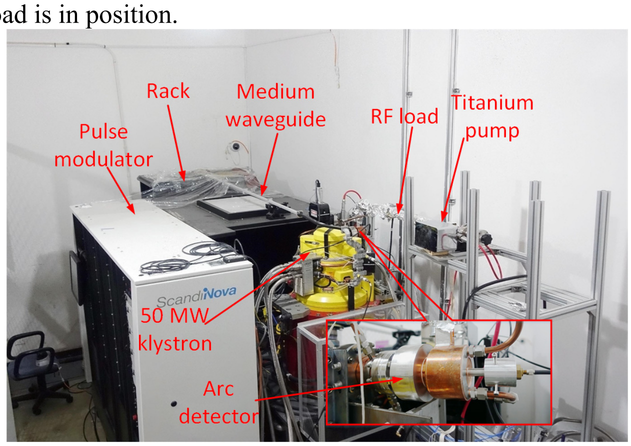


Figure 2: Photo of the high power source.

The output power after RF conditioning depends on the pulse width and the type of RF load. The first RF load under test is a stainless steel RF load from CERN. The maximum output power 50 MW at the pulse width 200 µs and no frequent RF breakdown observed. The maximum power this RF load can bear at 400 ns pulse width is 40 MW. With the pulse width of one µs, the RF load can only manage 10 MW power. The stainless steel RF load designed by Tsinghua has no continuous RF breakdown at 31 MW with the pulse width of 400 ns. New RF load will be tested in the near future. We find that there is an obvious relationship between the vacuum pressure and breakdown rate.

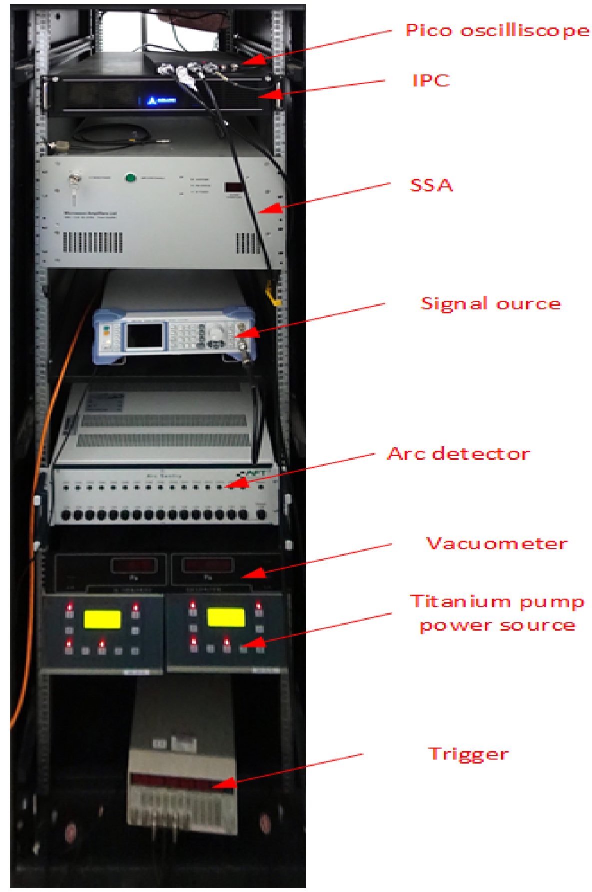


Figure 3: Devices on the rack.

Figure 3 shows the low-level RF and other control devices in the rack besides the modulator, including the oscilloscope, whose data transited to the operating room by an optical fibre and shown the an software. The IPC runs the database, which contains the vacuum pressure versus time. The trigger generates TTL pulses with different delays for the timing of signal source, SSA and the pulse modulator. The pulse width of the trigger decides the pulse width of output RF pulse width. The arc detector protects the RF window of the klystron from too much RF breakdowns. It stop the trigger when gets the spark of RF breakdown arcs at the RF window.

## PLANS

The high power RF pulse will be transited into the shield room by a long waveguide. There will be a power splitter at the end of the waveguide for the RF feed-in of tested structures. An auto conditioning system is under development, which allow unattended conditioning. The system increases the output power of klystron automatically and gradually when there is no RF breakdown happened and stop the trigger when a breakdown confirmed. The breakdown status will be reset after few minute and the output power reduced. The criterial of RF breakdown is the surge of the reflect power back from the tested structure and the stand wave ratio. The signal source will be replaced by the LLRF system of S band and an X-adapter, which up converts the S band RF to X band [5].

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The faraday cups and dipole magnetic is in preparation and the installation will be completed soon. The first structure under test is the T24-11G-THU-No.1 accelerator, for the verification of robustness and conditioning data for the auto conditioning system. More structures like half-cell accelerator, RF gun are in the schedule.

## CONCLUSION

The X band high power test facility of Tsinghua University is under construction as planned. The installation will be finished in a month and the test of T24 will be start at the beginning of June. The 11.424 GHz, 50 MW RF pulse will be used in the test of accelerators and the research of RF breakdown mechanisms.

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