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Design and High-Power Test of the High Efficiency RF Power Source Test Stand

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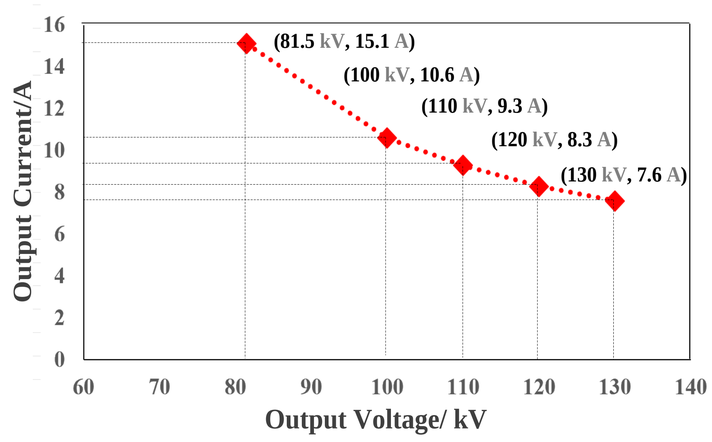
INTRODUCTION

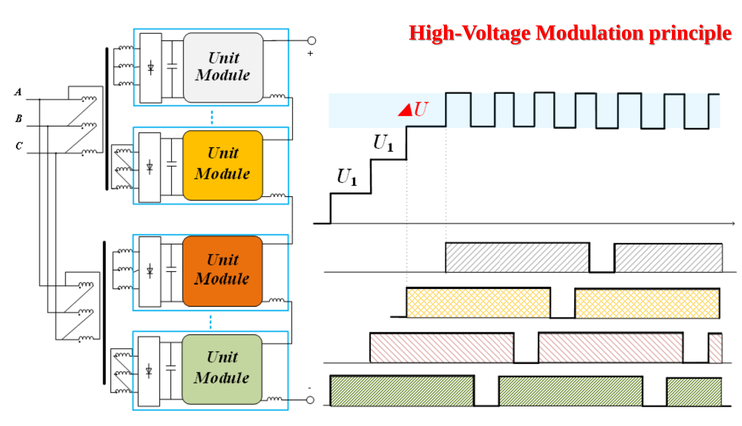
The high-power RF power source system is the energy acquisition of particle acceleration, and is the key devices. The CEPC project planned in China, the total power requirement of the RF power system is about 110 MW, which is a huge energy consumption. Therefore, it is important to explore the ways to maximize the energy conversion efficiency of RF power systems for future advanced projects. The Institute of High Energy Physics (IHEP) has developed a high power test stand (HPTS) for high-power RF power source systems, which is used for explore topics in high-efficiency klystrons, multi-beam klystrons, multi-stage depressed collection (MSDC), energy recovery, and high-power reliability research and high power conditioning tasks. And it is also a prototype validation of the CEPC megawatt PSM high-voltage power supply.

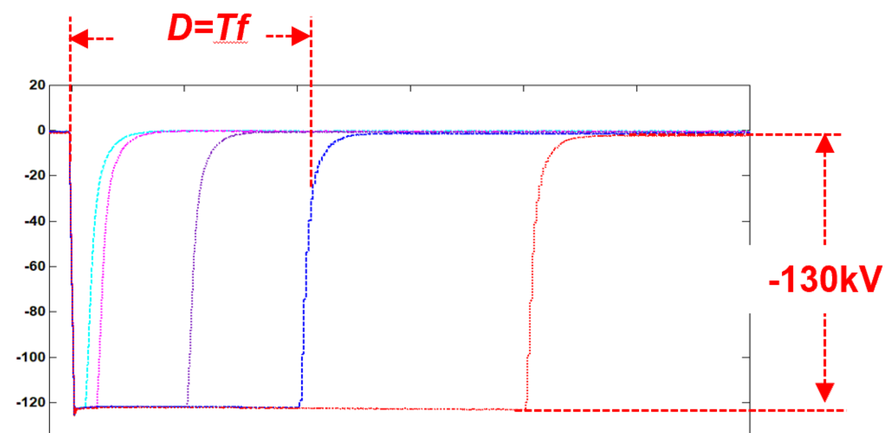
This article provides a detailed introduction to the design and implementation of the platform. The highlight of this HPTS is that it achieves full output range of high-voltage duty cycle from pulse to DC. In continuous wave DC applications, the high voltage ripple/stability is improved from the traditional PSM power supply's 1% level to the 0.1% level, achieving an order of magnitude improvement. Compatible with pulse mode applications, the pulse width can be adjusted from 0.5ms to DC, with leading edge, flat top, and repetition stability indexes reach the level of specially designed long pulse modulators. As a result, the newly developed power supply can provide a flexible high-power test environment for the research and development of CEPC high-efficiency klystron tubes. Not only effectively reducing the probability arcing events in newly processed klystron, but also synchronizing the entire RF conditioning process, reducing consumption, and improving energy utilization efficiency. The prototype was completed in 2021 and passed a 200kW resistive load test. In 2024, full-scale power experiments were completed for CEPC high-efficiency 800kW/650MHZ klystron loads. Its RF power reaches up to 800kW, which also verifies the effectiveness of the proposed hybrid modulation high-voltage power supply and lays an excellent foundation for the subsequent high-efficiency program of RF power source.

In 2024, full-scale power experiments were completed for CEPC high-efficiency 800kW/650MHZ klystron loads.



The power requirements of the operating point for the high-efficiency klystron load

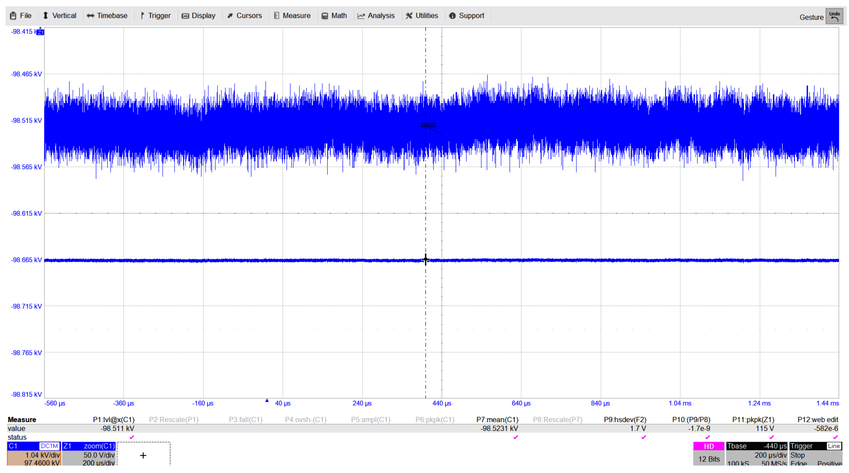




High voltage power supply system and High-Voltage output simulation（from pulse to DC）

From Resistive Loads (kW level) to Klystron Loads (MW level)

Pulse high voltage output (100kV/16A. max 200Hz)



Continuous-wave DC operation mode

2021年11月
- Pulse Mode 130kV/16A
- CW 130kV/100kW

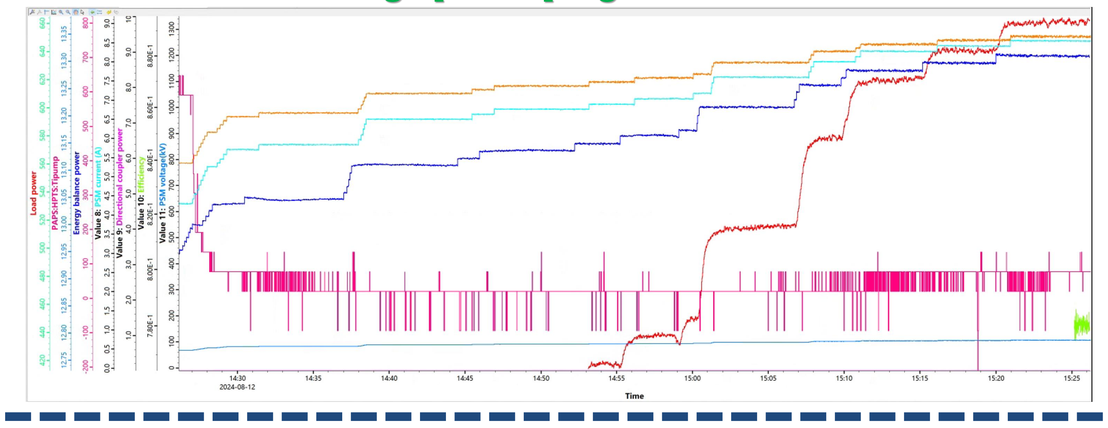
2022年1月~5月
- High-power test of the first klystron load
- PAPS High Voltage Long Cable Layout Klystron Load Short Circuit (arcing) Experiment

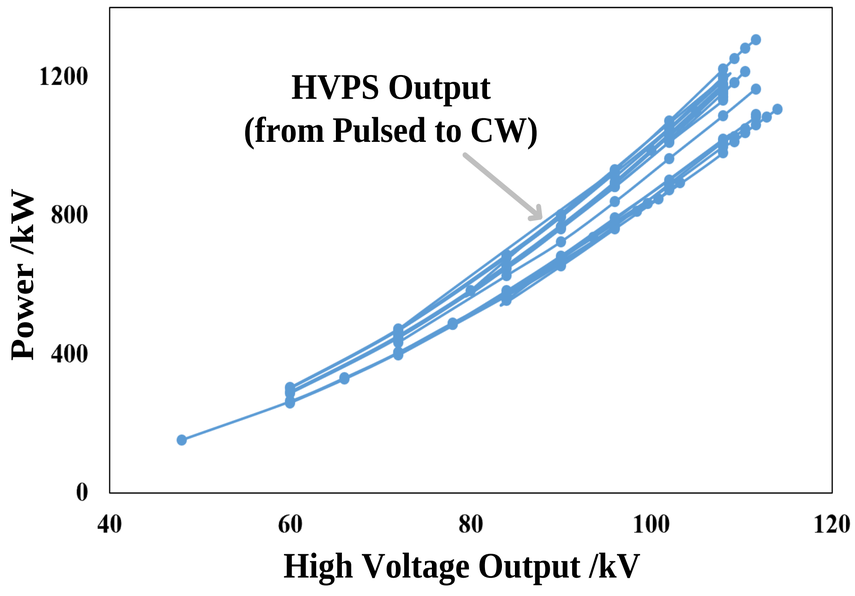
2023年12月~2月
- Power experiment of high-efficiency klystron (pulse mode)

1ms/110kV 800kW RF Power

2024年4月~8月
- 1‰ High voltage and RF power Duty cycle
- CW 800kW，Eff. 78%

High-power progress of HPTS





Megawatt power test data statistics

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