Fig. 2 (color online) Liquid nitrogen testing for HIAF cryomodule prototype.

HIAF linac cryomodules are divided into two types, QWR007 and HWR015 which contains total 97 superconducting resonators. The liquid nitrogen testing for two kinds of cryomodule prototype has been completed at the factory now and a lot of new technical issues need to be demonstrated through cryogenic testing, as shown in Fig. 2.

In additional, the cryogenic system for cryomodule horizontal testing at Dongjiang Laboratory is under simultaneous construction and is expected to be ready for testing in 2023, it is expected that all cryomodules of the superconducting linear accelerator will be installed by 2024 for HIAF project.

8 - 10 New Developments Based on SSPA Standardization for CiADS at IMP

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Institute of Modern Physics, Chinese Academy of Sciences is the first domestic institute that widely applied solid-state power source to linear accelerator project since 2011 in China. Up to now, the same design has already been considered for the large-scale scientific facilities in Guangdong Province of southeast China, China initiative Accelerator Driven System (CiADS). Furthermore, following the successful development of the IMP SSPA, a new "standardization" design concept was put forward after many times of modifications and improvements, which means all designs meet the stringent system requirements: high performance, low cost, high scalability, high reliability, and ease of maintenance need. Last year, some new designs and technologies have been developed for new requirements, such as the high-performance power combiner and special DC supply, which are all new solutions for special design on-site. This paper will detail the new development of "standardization" and its technical characteristics.

A new combiner based on the empty resonator was developed for the SSPA rack, whose prototype has already been measured carefully with a four-port vector network analyzer. The rotation of one coupling loop could isolate the corresponding port from the whole system with the worsening S parameter of the left ports. Especially for a 12-in-1 or 16-in-1 combiner system, the mismatch was slight to be compensated by adjusting the left loops. The specific structure is shown in Fig. 1.

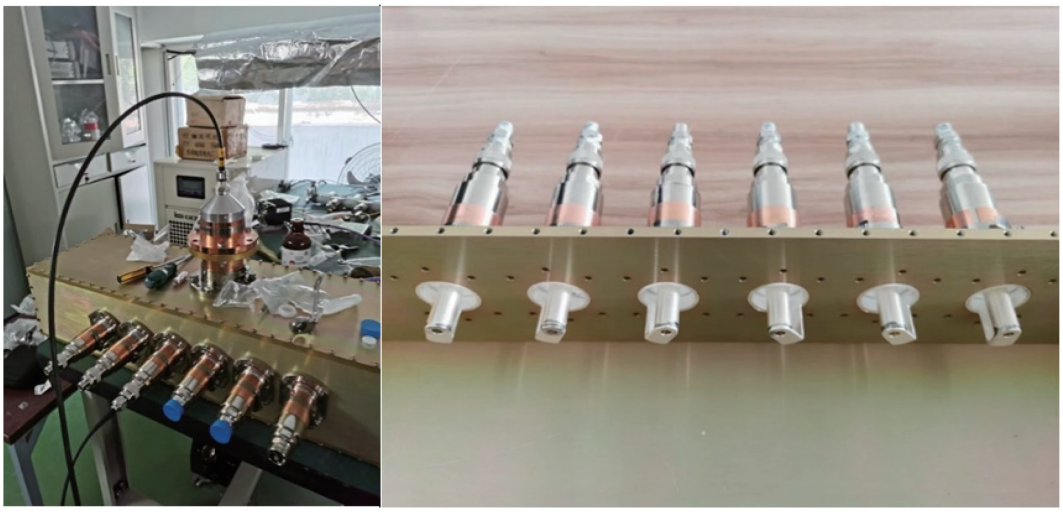

Fig. 1 (color online) The resonator combiner prototype and its coupling loops.

It has good isolation between the ports through loop coupler without extra influence[1], which is a perfect hot-swap combiner.

On the other hand, the new design is a DC supply module to be placed centrally away from PA modules for better redundancy. In this way, DC supply with current-sharing control is relatively independent, considering some failure modules will not affect the rated output power, which has obvious advantages in high-power operation and long-term stability. Every module can be replaced during the operation in case of failure.

The DC supply module was designed for 5 kW output at 50 V with a dimension of 185 mm×60mm×520 mm(width × height × depth), shown in Fig. 2.

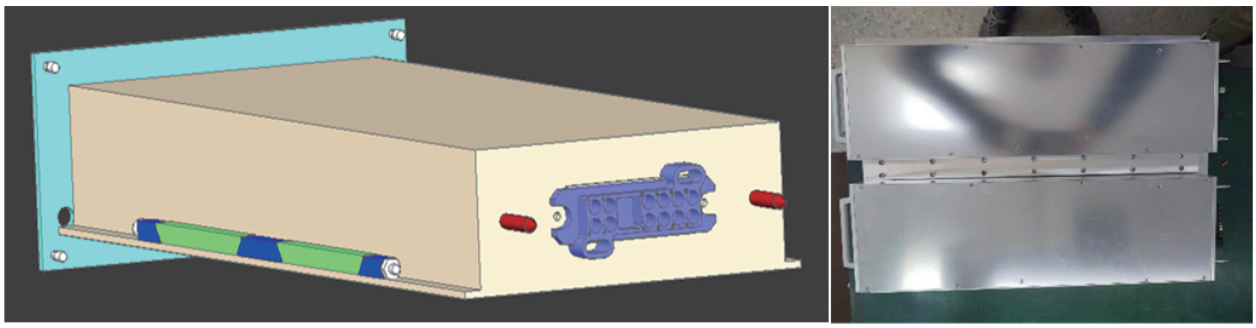

Fig. 2 (color online) The structure of DC module with two fastening strips.

Due to the requirement of pulsed operation and EMC compatibility, some specifications were paid particular attention to, such as the power factor, THD, and three-phase equilibrium, which were shown in Table 1. Some special methods for contact cooling are under test.

Table 1 The specifications of DC supply module.

Input	AC 380±15% VAC, TN-S
AC Frequency	50 Hz
Max output Current	⩽100 A
Power Factor	>0.95 at full power
Outputs	DC 48∼65 V
Output Power	5 kW Maximum
Efficiency	>93%
Ripple/Noise	⩽300 mVpk-pk with 20 MHz bandwidth
Line Regulation/Load Regulation	⩽1% of output voltage
THD	⩽10% of harmonic voltage and current
three-phase equilibrium	⩽1% of rated power
Operating Temp.	+5 to +50 ℃
Storage Temp.	-40 to +85 ℃
Humidity	0 % to 95 % non-condensing
Cooling	Liquid Cooling

Finally, the new development about the power combiner and DC power supply was considered for hot swap to realize ultra-high maintenanceability in CiADS[2]. Some failure parts during the operation were replaced or repaired on time without obvious influence to the whole accelerator.

References

[1] Alexei V Smirnov, Nucl. Instrum. Meth. A, 931(2019)207.
[2] S. Liepeng, Y. Zhenyu, Z. Cheng, et al., High Power Laser and Particle Beams, 31(2019)065103-1.