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Design, fabrication and performance of taper cavity cryomodule for ADS Injector II

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ABSTRACT

A $\beta = 0.15$ taper cavity cryomodule was designed for the China Accelerator Driven Sub-critical System Injector II(ADS) at the Institute of Modern Physics (IMP) of the Chinese Academy of Science (CAS). This cryomodule is the third cryomodule of the ADS Linac and contains five $\beta = 0.15$ taper cavities and five 5.5 T solenoids that operate at 4.2 K and 1.05 Bar. Manufacturing of the cryomodule and construction of the cold mass was finished at the beginning of 2017. The cryomodule assembly was completed at the end of March, 2017. The ADS Injector II linac accelerated a 10 mA proton beam to 25 MeV in June of 2017. This paper reports the design, fabrication and performance of this taper cavity cryomodule.

1. Introduction

The ADS project is designed to accelerate a proton beam in the superconducting linac, strike a tungsten target and produce neutrons via a spallation process. The resulting neutrons travel out to instrument stations for use in various types of research. The Institute of Modern Physics has undertaken the construction of Injector II, which includes twenty-three cavities and solenoids. [1–4] These cavities will be grouped into 4 independent cryomodules with the taper cavity cryomodule in the third position. This taper cryomodule will accelerate the proton beam from 10 MeV to 18 MeV. The schematic layout of the ADS project is shown in Fig. 1.

Made of pure niobium, the taper cavity is one type of half-wave superconducting cavity developed by IMP. [5–7] Fig. 2 shows the subassembly of the taper cavity. Table 1 lists the main parameters of the taper cavity. Our goal is to design a top-loading cryomodule with a lower heat load and higher operational stability while still adhering to the basic function specifications for cryomodules. According to previous experience, the existence of dead space in the mechanical structure can influence the helium pressure stability because gas is periodically vented. As shown in Fig. 3, if cavities are horizontally installed in the cryomodule, the liquid helium at the upper part of the ring will vaporize gradually because of the heat load, and periodically, when the vaporizing gas pressure reaches a certain value, they will be vented in an instant. Considering structural limitation of the taper cavities, they are vertically installed in the cryomodule to avoid pressure fluctuation. In addition, double-window couplers are adopted instead of the previous single-window couplers. Additionally, structure optimization is employed, including a support system and a cooling circuit. This paper reports the design and fabrication of a taper cavity cryomodule, in addition to some challenges that we faced in the process. We analyze these challenges carefully and provide valuable information for improving future designs. We then present the performance of this cryomodule in terms of cool down, static heat load and helium pressure stability.

2. Cold mass

The cold mass subsystem consists of 5 taper cavities (including their ancillary components, frequency tuners and fundamental couplers), 5 solenoids, 4 cold beam position monitors (BPMs) and 2 end flanges. Because of the length limitations of the linac tunnel, the length of the cold mass subsystem must satisfy specific physical and mechanical size requirements. It is necessary to compromise when designing an accelerator. The cold mass subsystem is assembled in a class 100 clean room to minimize the particulate contamination, as seen in Fig. 4. The cavities are vertically positioned in the cryomodule and immersed in a liquid helium vessel made of titanium, which has a thermal contraction that is similar to that of the niobium cavity. The coupler consists of two

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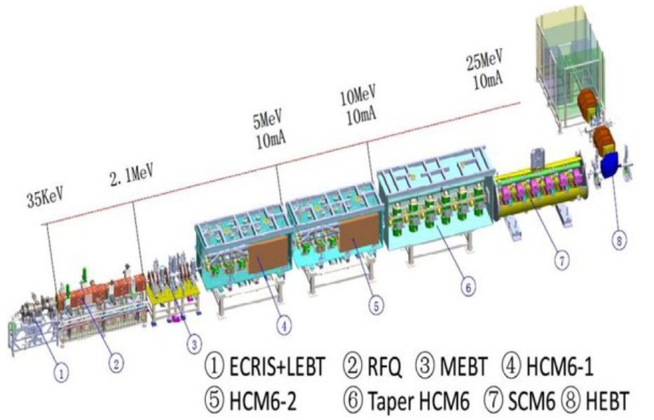

Fig. 1. Layout of ADS project. (1. Electron cyclotron resonance ion source + low energy beam transport line, 2. radio frequency quadrupole, 3. medium energy beam transport line, 4. 1# HWR010 cavity cryomodule, 5. 2# HWR010 cavity cryomodule, 6. taper cavity cryomodule, 7. spoke cavity cryomodule, 8. high energy beam transport line.).

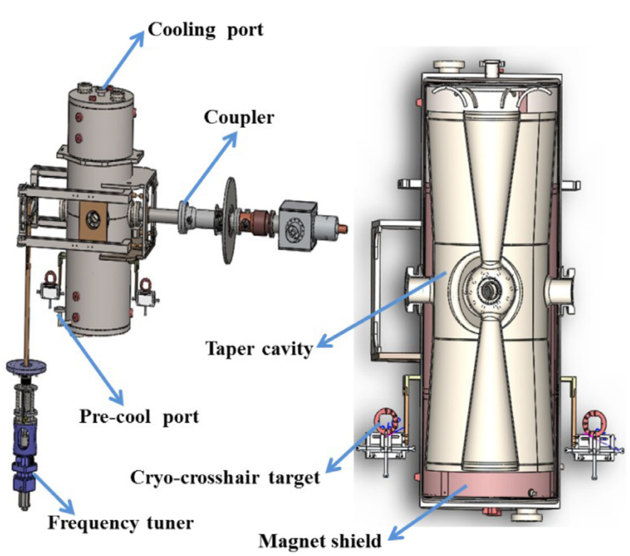

Fig. 2. Taper cavity subassembly.

coaxial parts that are horizontally positioned and are cooled by thermal conduction. The cold part is attached to the cavity beam tube and has a common vacuum with the cavity, preserved by a ceramic cylindrical window. The warm part is assembled with the vacuum chamber once the cavity is inserted into the cryostat. Through the bottom side of the vacuum chamber, the cavity tuner operates a cavity frequency via a stepper motor. The magnet is composed of three solenoids, one main coil operated at a current of 200 A and two correctors at 80 A, such that the center magnetic field can reach 5.5T.

3. Cryostat

The taper cavity cryostat consists of a support system, cooling circuit, HTS current leads for the solenoids, thermal shielding, vacuum chamber, instruments and safety devices, as shown in Fig. 5. Availability and stability are very important features for the ADS that facilitate its use. The arrangement of the above components leads to several cryogenic system specifications, including minimum heat load and the ability to warm up or cool down while keeping the other cryomodules at their operating temperatures. Thus, the cryomodule is upgraded to

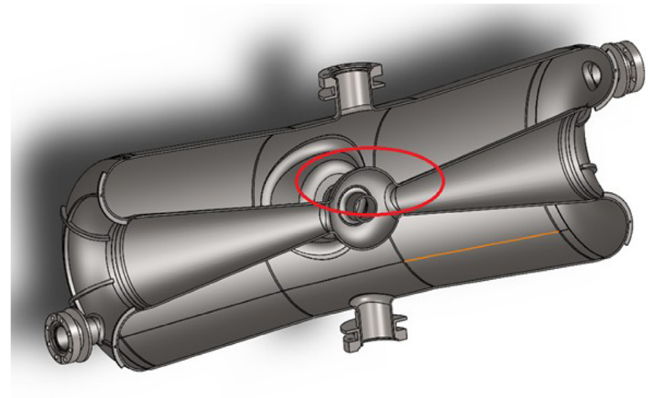

Fig. 3. Dead space of the taper cavity.

Fig. 4. Cold mass assembly in a clean room.

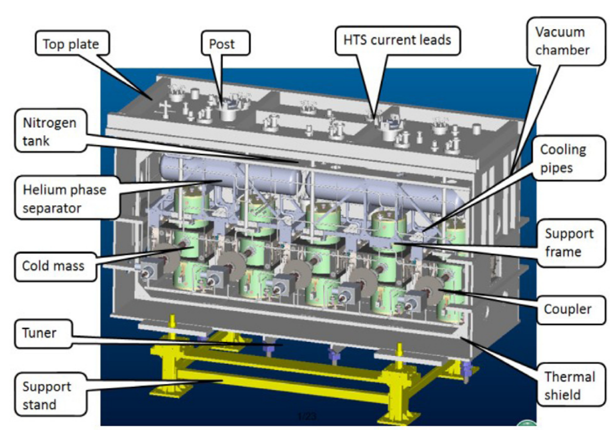

Fig. 5. Cross section of the taper cryomodule.

connect with the multi-channel cryogenic distribution line instead of the previously used bayonet connection mode to meet these operation requirements.

3.1. Support system

A top-loading structure is used in this cryomodule. Cold mass string and thermal shielding are suspended from the top plate of the vacuum