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Construction and experiment of quasi-axisymmetric stellarator CFQS-T

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A stellarator embedded with magnetic symmetry of tokamak, often called quasi-axisymmetric stellarator (QAS), was proposed in 1990s [1,2]. Since the QAS provides rotational transform in vacuum in addition to tokamak-like low toroidal viscosity and magnetic well in entire domain of plasma, good plasma performance realized in tokamaks can be expected in QAS with steady-state operation capability and without suffering from major disruption. The CFQS quasi-axisymmetric stellarator project has been undertaken since 2017 as an international joint project between National Institute for Fusion Science (NIFS), Japan and Southwest Jiaotong University (SWJTU), the People's Republic of China [3].

A primary purpose of CFQS is in a proof-of-principle of quasi-axisymmetry (QA) to prove favorable influence of QA on plasma confinement and/or formation of plasma flow structure. Because the CFQS is characterized by tight space and strong electromagnetic (EM) force, in particular, at the inboard side of the machine due to its low-aspect-ratio, there has been many challenging issues in the design of supporting structure. We have carefully investigated the supporting structure withstandable against 1 T operation by using ANSYS Maxwell and Mechanical. As a result, we have reached the cage-like supporting structure of which maximum stress is about 100 MPa tolerable to withstand strong EM force during 1 T operation in balance with port arrangement [4].

The CFQS project is divided into the two phases, i.e., the first phase: CFQS-TEST, hereafter called CFQS-T for 0.1 T operation, and the second phase: CFQS for 1 T operation. Construction of CFQS-T was successfully completed in July, 2024. Engineering design and manufacturing of the modular coil system for CFQS-T is available in Ref. 5. The whole view of CFQS-T together with the team members is shown in Fig. 1. At the beginning, based on mapping experiment strategy carefully drawn up for CFQS [6], we performed magnetic field mapping experiment and obtained good magnetic surfaces with sufficient accuracy as expected [7]. Subsequently we achieved the first plasma with the help of electron cyclotron resonance wave of which frequency is 2.45 GHz. Many valuable phenomena were observed in the CFQS-T, e.g., an indication of zonal flow, MHD instabilities which seem to be most likely global Alfvén eigenmodes associated with suprathermal electrons etc. Also, CFQS-T played an important role as a platform to develop the heavy ion beam probe in the future [8]. Having fulfilled CFQS-T's intended role, we have stepped into the modification of CFQS-T to realize CFQS capable of 1 T operation.

References

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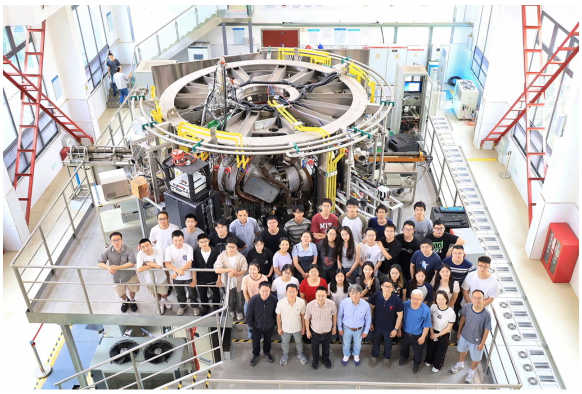

Figure 1. A bird's eye view of CFQS-T together with the team members of NIFS and SWJTU.