RECENT PROGRESS ON THE SUNIST-2 SPHERICAL TOKAMAK

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1. INTRODUCTION

SUNIST-2 is a spherical tokamak aimed to study the confinement at higher magnetic field, ion heating by magnetic reconnections, and repetitive pulsed operations. Its major parameters are: R_0, 0.53 m; a, 0.33 m; B_{T0}, 1.0 T; I_P, 500 kA. The first plasma of SUNIST-2 was obtained in 2023. Since then, plasma startup by merging and plasma gun was tried on SUNIST-2 to save the flux of central solenoids. With the help of those methods, plasma current of SUNIST-2 has reached 480 kA. Dual pulses operation was succeeded by programming the power supplies. An initial plasma control system was also applied to SUNIST-2 enabling both diverted plasmas with triangularities up to 0.6 and spherical tokamak plasmas with negative triangularities up to -0.6. Plasma heating scaling by magnetic reconnection during merging was also studied and showed a proportion to the square of the plasma current before reconnections. Lithium coating was also tried on SUNIST-2 and greatly reduced the carbon and oxygen impurities from the wall of the vacuum vessel.

2. MAJOR PARAMETERS OF SUNIST-2

Major parameters of SUNIST-2 are: major radius (R_0), 0.53 m; minor radius (a), 0.33 m; maximum on-axis toroidal field (B_{T0}), 1.0 T; nominal plasma current (I_P), 500 kA; maximum elongation (κ), 2.0; triangularities (δ), -0.6 – 0.6. The vacuum vessel of SUNIST-2 consists of a central cylindrical shell made by Inconel 625 with 1 mm thickness, an outer spindle-shaped cylindrical shell made by stainless steel with 7 mm thickness, as well as the bottom / top plates. The toroidal magnets of SUNIST-2 contains a central column segmented into 24 wedges, and eight "C"-shaped limbs of three turns each, carrying 2.64 MA in total.

To enable in-depth studies of reconnection heating physics, the SUNIST-2 coil design incorporates adjustable internal coils inside the vacuum vessel (*Fig. 1*). While also serving as standard flux source for plasma initiation, these coils are mounted on movable supports with 200 mm of vertical adjustments. By varying their position and spacing, flexible experiments can be conducted to optimize the reconnection process for heating. The internal coils can also be fully retracted outside the main plasma region, enabling highly elongated ST configurations. This unique design provides unmatched flexibility to research fusion plasma heating via magnetic reconnection on SUNIST-2. Another unique feature of SUNIST-2 is its segmented central column divided into six independently powered sections, contributing 0.6 Wb flux. This enables precision current profile control to optimize reconnection heating during the merging process.

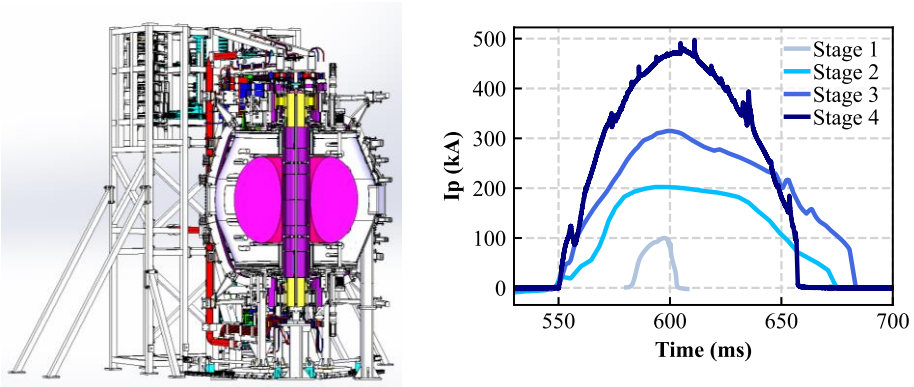

Fig. 1 The SUNIST-2 spherical tokamak (left), plasma current waveforms (right)

Multiple non-central-solenoid startup methods have been successfully applied to SUNIST-2. The movable internal coils (the MC coils) can breakdown the working gas without the need of zero-field configurations. Two plasma rings were generated from the bottom and the top, and then were pushed to be merged together forming a single but larger plasma torus (*Fig. 2* left). Two washer guns were installed inside the vacuum vessel of SUNIST-2. These two guns could initiate two plasma rings, which were then coupled by mering, without any loop voltages (*Fig. 2* right).

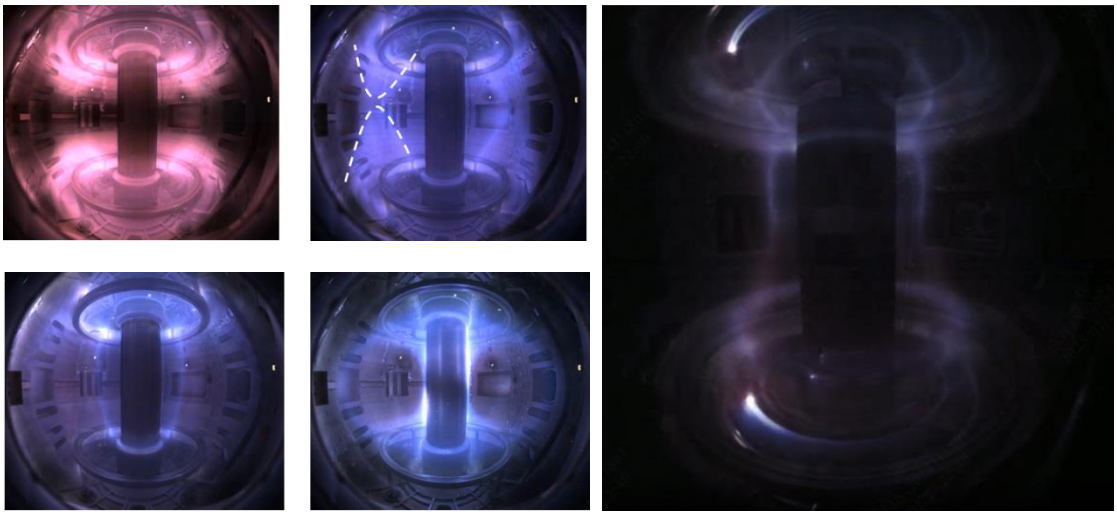

Fig. 2 The mering startup of SUNIST-2 (left 4 sub-images), plasma initiation by dual washer guns (right)

3. PLASMA CONTROL

An initial plasma control system (PCS) was developed for SUNIST-2. High performance divertor plasmas was formed with it (*Fig. 3* left). With the help of multiple poloidal field coils of SUNIST-2, negative triangularity low aspect ratio plasmas were successfully formed in SUNIST-2 (*Fig. 3* right). The properties of both configurations are under investigated.

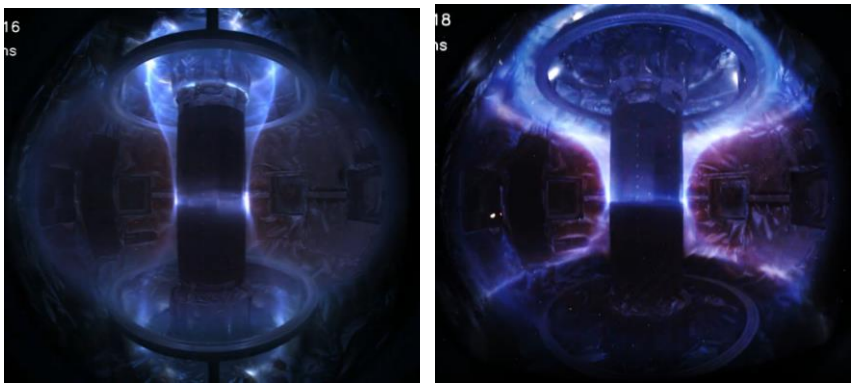

Fig. 3 The diverted plasma of SUNIST-2 (left, R_0: 0.61 m, a: 0.38 m, κ: 1.51, δ: 0.6), the negative triangularity plasma (right, R_0: 0.57 m, a: 0.33 m, κ: 1.42, δ: -0.65)

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