SUNIST United Laboratory and Improvement of Operation on SUNIST Spherical Tokamak


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SUNIST United Laboratory

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OUTLINE

SUNIST United Laboratory
SUNIST spherical tokamak
Progress of discharge
Problems and research program
SUNIST United Laboratory

founded in 2004, consists of Department of Engineering Physics, Tsinghua University (DEP); Institute of Physics, Chinese Academy of Science (IOP) and keeping very close collaboration with Southwestern Institute of Physics (SWIP) and Institute of Plasma Physics, Chinese Academy of Science (IPPAS).

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SUNIST- Sino UNIted Spherical Tokamak

(1999-2002) building a spherical tokamak device;
theory study and experiment preparation of ST

sponsored by:
National Nature Science Fund of China (theory and experiment research) (IOP, DEP, SWIP)
Improving Tsinghua to Top-ranking University Fund (facility and laboratory)
Innovation fund of Institute of Physics, CAS (facility)

(2003-) non-inductive plasma current startup (preparation);
equilibrium control of low aspect ratio plasma;
instability, fluctuation, transport in ST;
edge plasma on SUNIST

sponsored by:
National Nature Science Fund of China
and etc.
SUNIST spherical tokamak

SUNIST main parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major radius</td>
<td>$R$ 0.3 m</td>
</tr>
<tr>
<td>Minor radius</td>
<td>$a$ 0.23 m</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>$A$ $\sim$ 1.3</td>
</tr>
<tr>
<td>Elongation</td>
<td>$\kappa$ $\sim$ 1.6</td>
</tr>
<tr>
<td>Toroidal field $B_T$</td>
<td>$B_T$ 0.15 T</td>
</tr>
<tr>
<td>Plasma current</td>
<td>$I_P$ 0.05 MA</td>
</tr>
<tr>
<td>Central rod current of $B_T$</td>
<td>$I_{ROD}$ 0.225 MA</td>
</tr>
<tr>
<td>Flux (double swing)</td>
<td>$\Delta \Phi$ 0.06 V·s</td>
</tr>
</tbody>
</table>
SUNIST spherical tokamak magnets and power supply

<table>
<thead>
<tr>
<th>coil</th>
<th>turn</th>
<th>$L(\mu\text{H})$</th>
<th>$R(\text{m}\Omega)$</th>
<th>$I_p(\text{kA})$</th>
<th>$V_C(\text{V})$</th>
<th>$\text{Capacitor}(\text{mF})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF</td>
<td>24</td>
<td>508</td>
<td>4.72</td>
<td>9.4</td>
<td>200</td>
<td>2560(1280)</td>
</tr>
<tr>
<td>HF</td>
<td>236</td>
<td>519</td>
<td>17.8</td>
<td>13</td>
<td>3000</td>
<td>13.3/1280</td>
</tr>
<tr>
<td>EF</td>
<td>26</td>
<td>684</td>
<td>15</td>
<td>1.5</td>
<td>1200/120</td>
<td>1(2)/476(18.8)</td>
</tr>
</tbody>
</table>
SUNIST spherical tokamak

**vacuum and vacuum vessel**

**main parameters – vacuum vessel:**

- **Outer diameter:** 1.2 m
- **Inner diameter:** 0.13 m
- **Height:** 1.2 m
- **Volume:** ~ 1 m³
- **Surface area:** ~ 2.3 m²

**vacuum pumps:**
- Main pump: TMP (1000l/s)
- Maintenance: Ti ion pump (200l/s)

**wall conditioning:**
- Baking: PTC Curie point 160 °C
- Glowing discharge,
- Siliconization

**background pressure:** ~ 6×10⁻⁵ Pa

**leaking rate on cross seal:** ≥ 2×10⁻⁷ Pa·m³/s
SUNIST spherical tokamak diagnostics and data acquisition

**Diagnostics**

**electromagnetic probes:**
- 2 Rogowski probes, 9 flux loops (4 inside vessel)
- 15 2-D minor probes (13 in one poloidal cross section)

**electrostatic probes:**
- Sets of movable 4 probes for $I_{si}$, $\Phi$, and $V_{toridal}$

**Data acquisition**
- 48 channel ADC: 32 ch new, 16 ch used in CT-6B
Progress of discharge
typical discharge in early 2003

Discharge condition:
- $I_T \sim 5.1\text{kA} \ (B_T \sim 800 \text{ Gauss})$
- $I_{OHM} \sim 7\text{kA}$
- $I_{Bv} \sim 1.5\text{kA} \ (1100/80\text{V})$
- $P_{He} \sim 9 \times 10^{-3} \text{ Pa}$
- Pre-ionization with filament

Results:
- $I_p \sim 53 \text{kA}$, $\tau_{pulse} \sim 2.5 \text{ ms}$
- $\bullet$ High ramp rate ($dl_p/dt \approx 50 \text{ MA/s}$)
- $\bullet$ High normalized current ($I_p/aB_T \approx 2.8$)
- $\bullet$ High produce efficiency ($I_p/I_{ROD} \approx 0.4$)
- $\bullet$ No major disruption

$\bullet$ Too short of pulse duration
- No flattop on $I'$ to hold plasma position
After rearrangement of capacity banks for vertical field:

from 1mF/2000V, 476mF/200V to 2mF/1000V, 18.8mF/450V (or 4.7mF/900V)

Progress of discharge typical at the end of 2003
Progress of discharge typical at the end of 2003

$B_T (185V \sim 6.5kA): 1kG \quad I_{OHM}: \sim 10kA$;

**Scanning $I_V$:**

$V_E$  
$250/160 V$  
$300/216 V$  
$400/240V$
Siliconization has been tried on Jan. 2004, and effected discharge quality obviously. But after 10 more shuts, plasma became very hard to control and easy to disrupt that just observed after siliconization.

**Siliconization**

\[ H_e + S_i H_4 \text{ (8/2)} \]

1 hour

\[ P_{T^+} > 0.5 \text{ Pa} \]

\[ I_{GDC} = 0.8 \text{ A} \]
Progress of discharge
discharge after siliconization

1. Plasma current extended to flux loop signal down to zero.
2. Fueling by pressure feedback may influenced recycle with Si film, then discharge quality.
plasma current ramp rate is high to 50MA/s, no physics factor to limit ramp rate observed.

no hard disruption of plasma current before siliconization, IRE concerned plasma current ramp up/down.

glowing discharge improves discharge reproducibility obviously.

holding $B_T$ and $I_{\text{OHM}}$, plasma current increase with charge voltage of vertical field. With $V_V$ increase, observed two current ramp up rate (fast at beginning, then slow). And plasma current could sustain to $I_{\text{OHM MAX}}$ (no volt second available from ohmic field).

generally, no obvious effects on discharge observed to change $B_T$. 
Problems and research program

Difficult to control discharge without any feedback with strong coupling between $B_V$ & $B_{\text{OHM}}$

Too small Volt second in single swing discharge for keeping current flattop

Continue discharge will influence discharge quality, specially after siliconization

Lacks of diagnostics for plasma experiment
### Problems and research program

#### 1 upgrade system
* modification of ohmic field power supply, from single swing to double swing mode
* upgrade diagnostics: H\(\alpha\), SX array, visible and UV spectroscopy, \(\mu\)W interferometer…
* connection of microwave power system
* device upgrade for CHI
* gas puffing and control
* vertical field discharge control

#### 2 SUNIST discharge performance
* operation regime with \(B_t\), \(n_e\), \(I_p\) scanning and MHD behavior
* vertical field volt second contribution to plasma current
* vacuum vessel conditioning effects to discharge
* magnetic surface evolution from signals of magnetic probes, outside & inside plasma
3 plasma current startup without ohmic field
   * ECR current startup with or without electrode assistance
   * CHI current startup
   * possibility transit to typical discharge from non induced start plasma current
4 turbulence and instabilities
   * edge plasma performance research by Langmuir probes
   * theory research of transport properties in spherical tokamak, especially including
effects of small aspect ratio and noncircular geometry on microinstabilities and
micro-turbulence, sheared flow generation and effects in small aspect ratio
plasmas
Conclusion

SUNIST device has been completed in November 2002.

Test discharge of SUNIST completed at the end of 2002

modified $B_V$ power supply to overcome the coupling effect between $B_V$ & $B_{OHM}$

A series of experiments has been taken for edge plasma and MHD performance

After siliconization, plasma current flat top extended and observed disruption

improve experimental conditions will be an important issue

Noninductive current startup will be a new subject in 2004
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Thank you