SUNIST United Laboratory and Improvement of Operation on SUNIST Spherical Tokamak

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OUTLINE

SUNIST United Laboratory

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SUNIST United Laboratory

SUNIST United Laboratory

founded in 2004, consists of Department of Engineering Physics, Tsinghus 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 United Laboratory research program

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

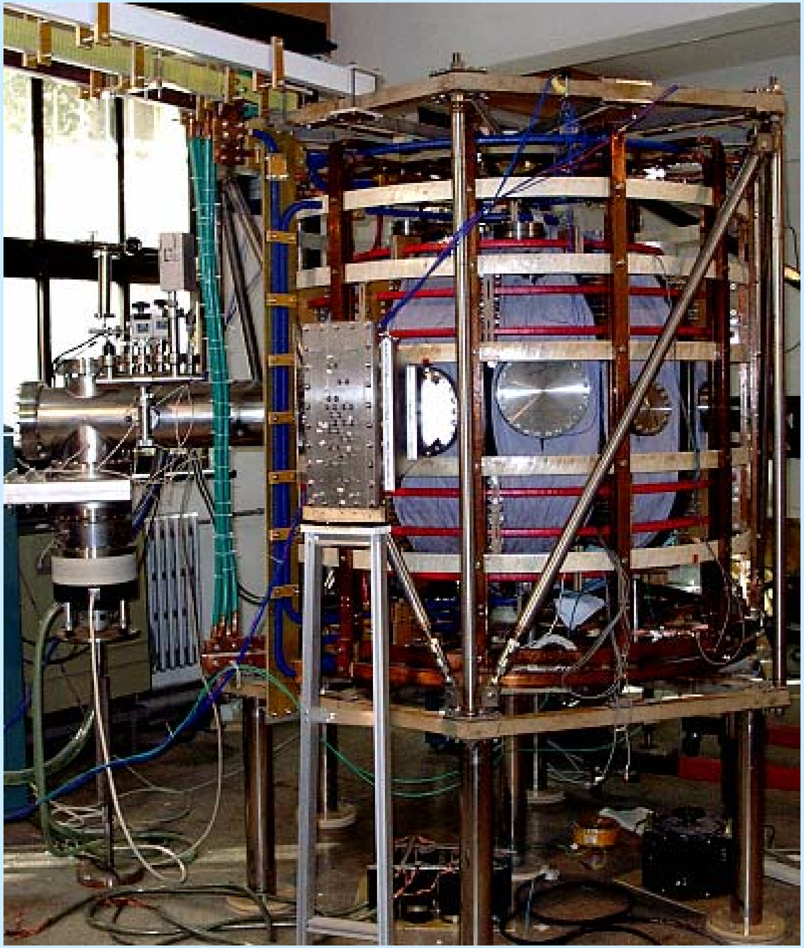
sponsored by:

National Nature Science Fund of China
and *etc.*

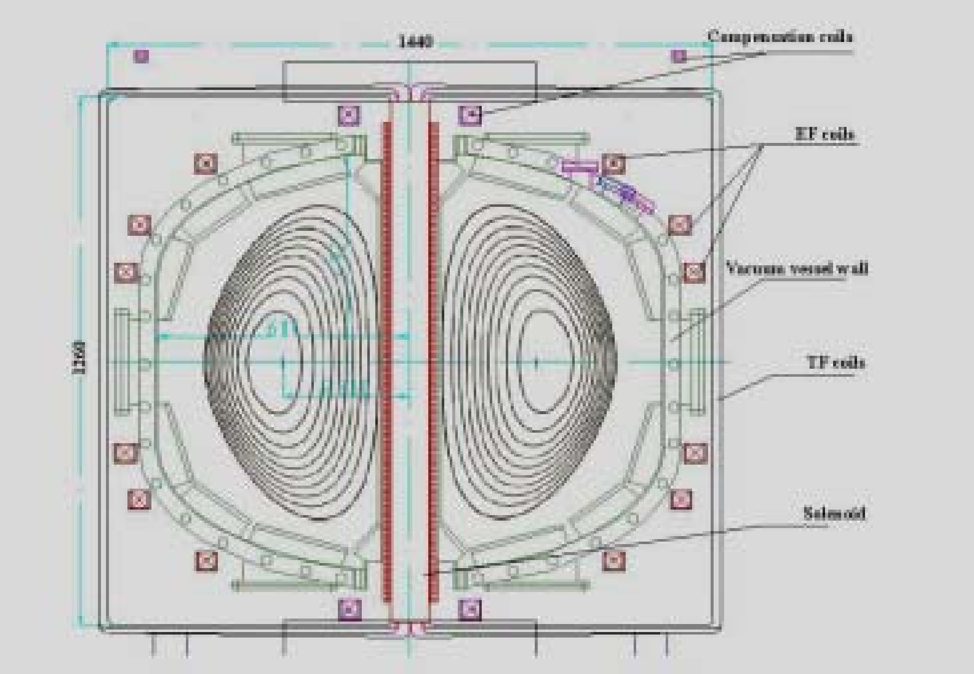
SUNIST spherical tokamak

SUNIST main parameters:

major radius	R	0.3m
minor radius	a	0.23m
Aspect ratio	A	~1.3
elongation	κ	~1.6
toroidal field (R_0)	B_T	0.15T
plasma current	I_P	0.05MA
central rod current of B_T	I_{ROD}	0.225MA
flux (double swing)	$\Delta\Phi$	0.06Vs



SUNIST spherical tokamak magnets and power supply



coil	turn	L(μH)	R(mΩ)	I_D(kA)	V_C(V)	Capacitor(mF)
TF	24	508	4.72	9.4	200	2560(1280)
HF	236	519	17.8	13	3000	13.3/1280
EF	26	684	15	1.5	1200/120	1(2)/476(18.8)

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	m^3
surface area	~ 2.3	m^2

vacuum pumps: main pump: TMP (1000l//s)

maintenance: Ti ion pump (200l/s)

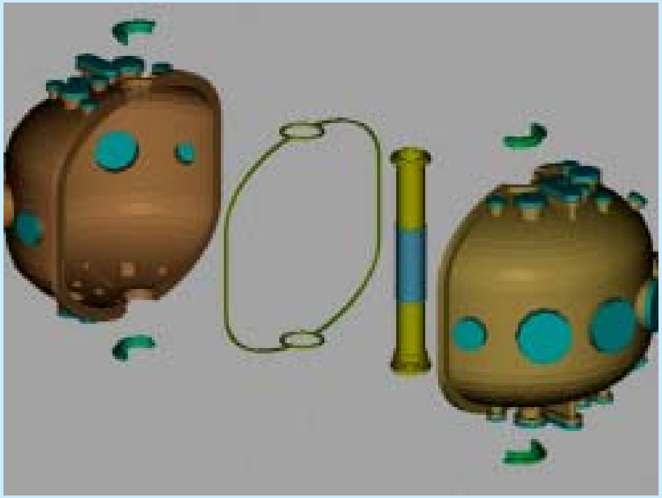
wall conditioning: baking: PTC (Curie point 160 ^{0}C)

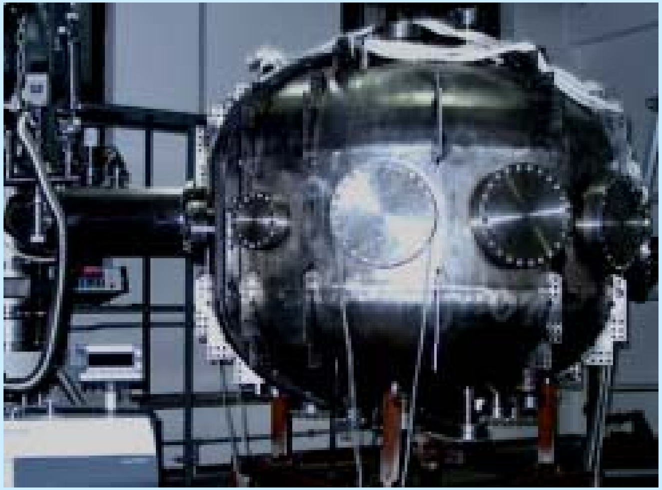
glowing discharge,

siliconization

background pressure: $\sim 6\times10^{-5}\ P_a$

leaking rate on cross seal: $\ngtr 2\times10^{-7}\ P_a m^3/s$





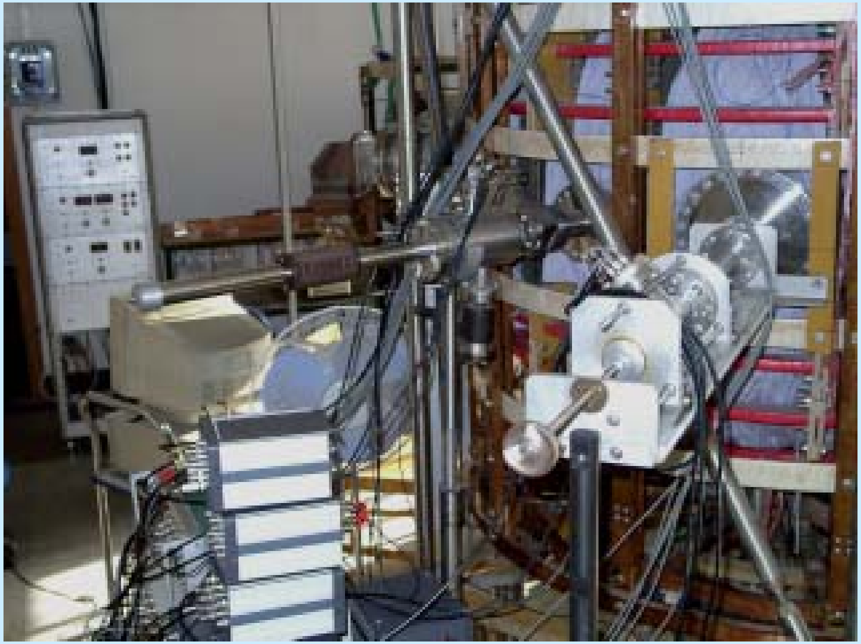
SUNIST spherical tokamak diagnostics and data acquisition

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}, Φ, and $V_{toridal}$

Data acquisition 48 channel ADC: 32ch new, 16ch used in CT-6B



Progress of discharge

typical discharge in early 2003

Dischage condition:

$I_T \sim 5.1$kA ($B_T \sim 800$ Gauss)

$I_{OHM} \sim 7$kA

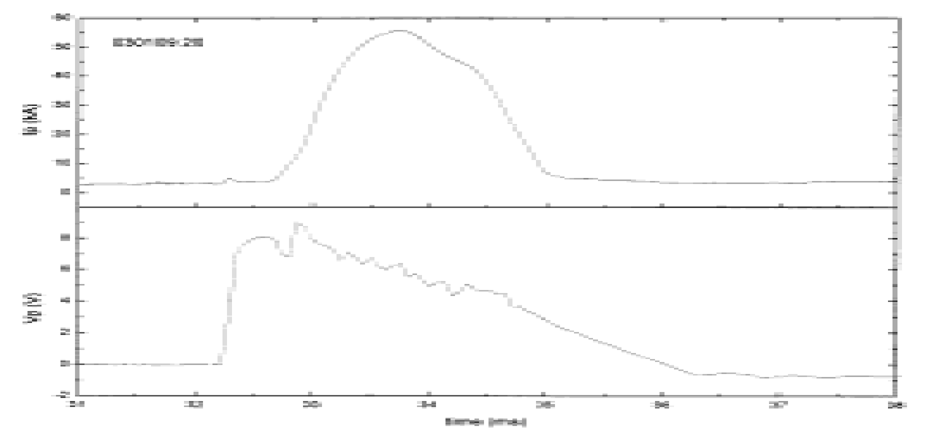
$I_{Bv} \sim 1.5$k A (1100/80V)

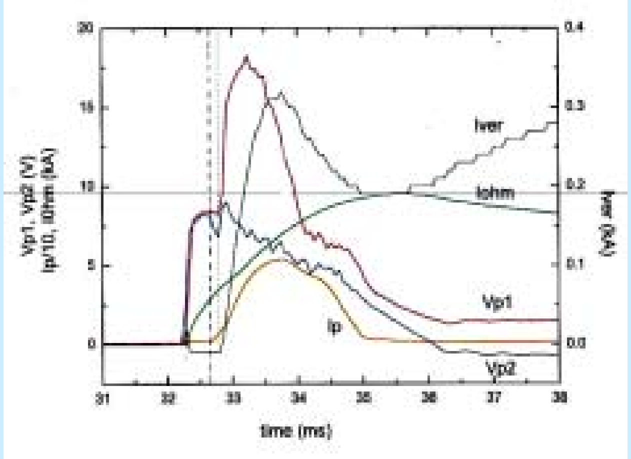
$P_{He} \sim 9 \times 10^{-3}$ Pa

pre-ionization with filament

Results:

$I_P \sim 53$ kA, **$\tau_{pulse} \sim 2.5$ ms**





☺ **high ramp rate ($dI_P/dt \approx 50$ MA/s)**
high normalized current ($I_P/aB_T \approx 2.8$)
high produce efficiency ($I_P/I_{ROD} \approx 0.4$)
no major disruption

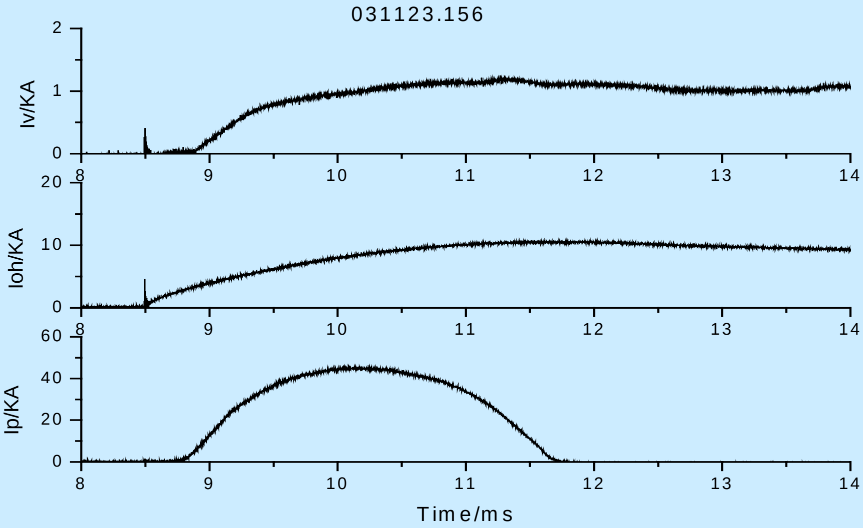
? **too short of pulse duration**
no flattop on I_V to hold plasma position

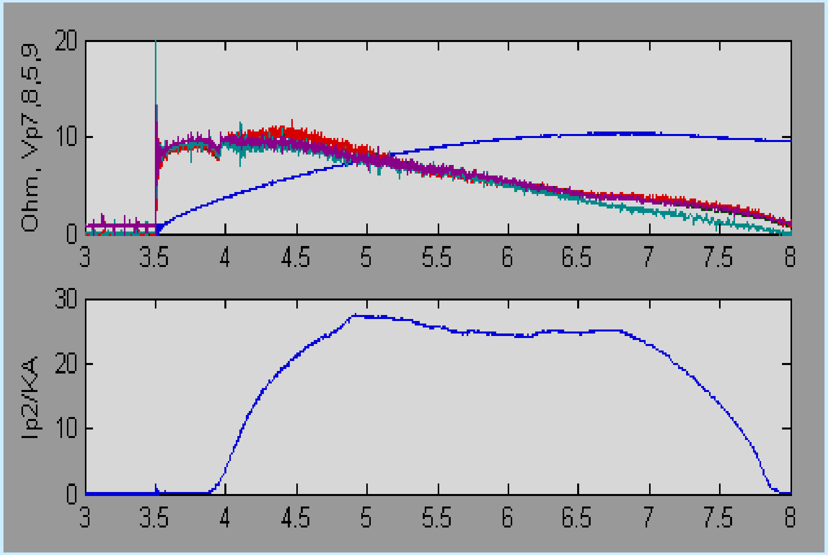
Progress of discharge

typical at the end of 2003

After rearrangement of capacity banks for vertical field:

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



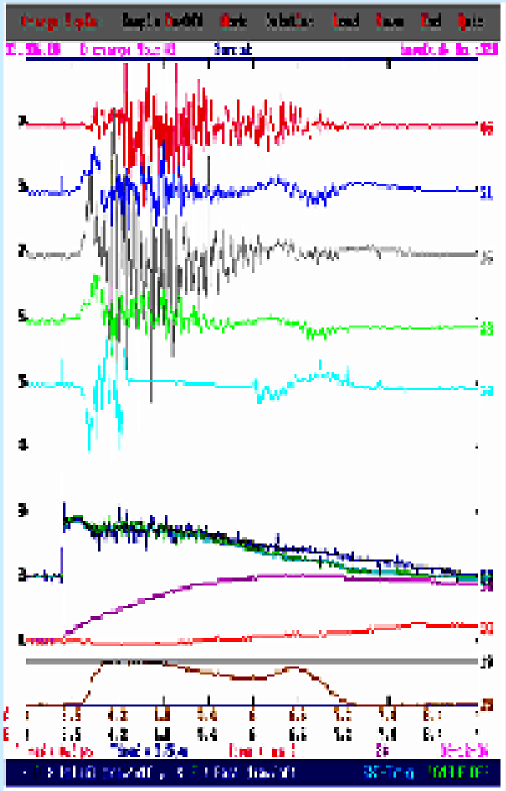


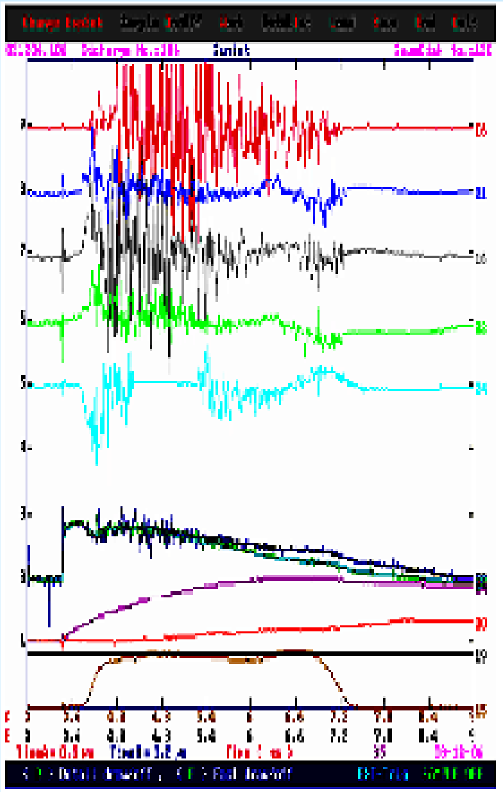
Progress of discharge typical at the end of 2003

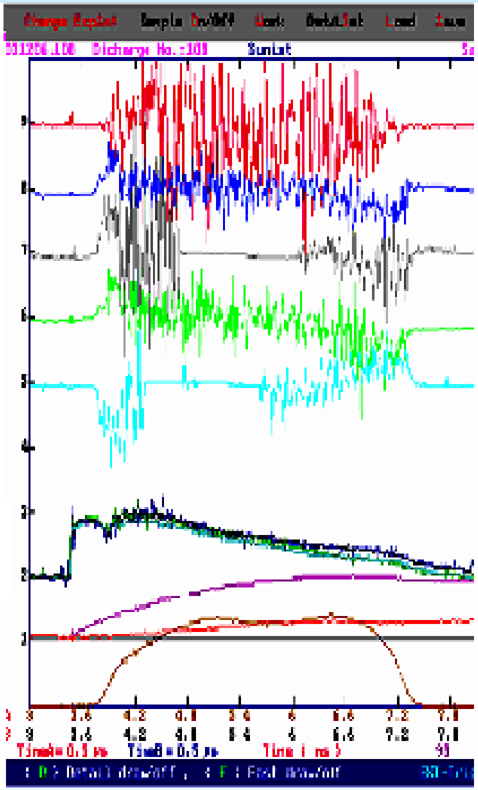
B_T (185V、~6.5kA): 1kG，I_{OHM}: ~10kA;

Scanning I_V:

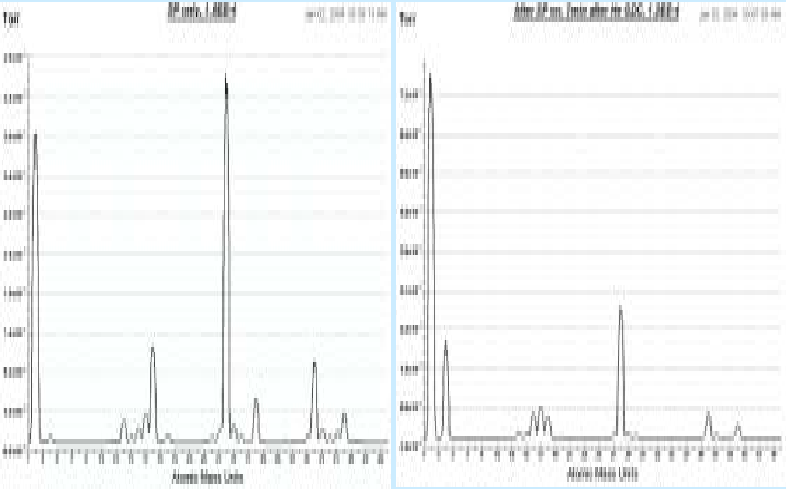
V_E 250/160 V 300/216 V 400/240V







Progress of discharge glowing discharge and siliconization



right: H_e GDC

(P: $5\times10^{-2} – 1\ P_a$

I_{GDC}: < 1 A

left: MS before

after

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

$H_e + S_iH_4$ (8/2)

1 hour

P_T: > 0.5 Pa

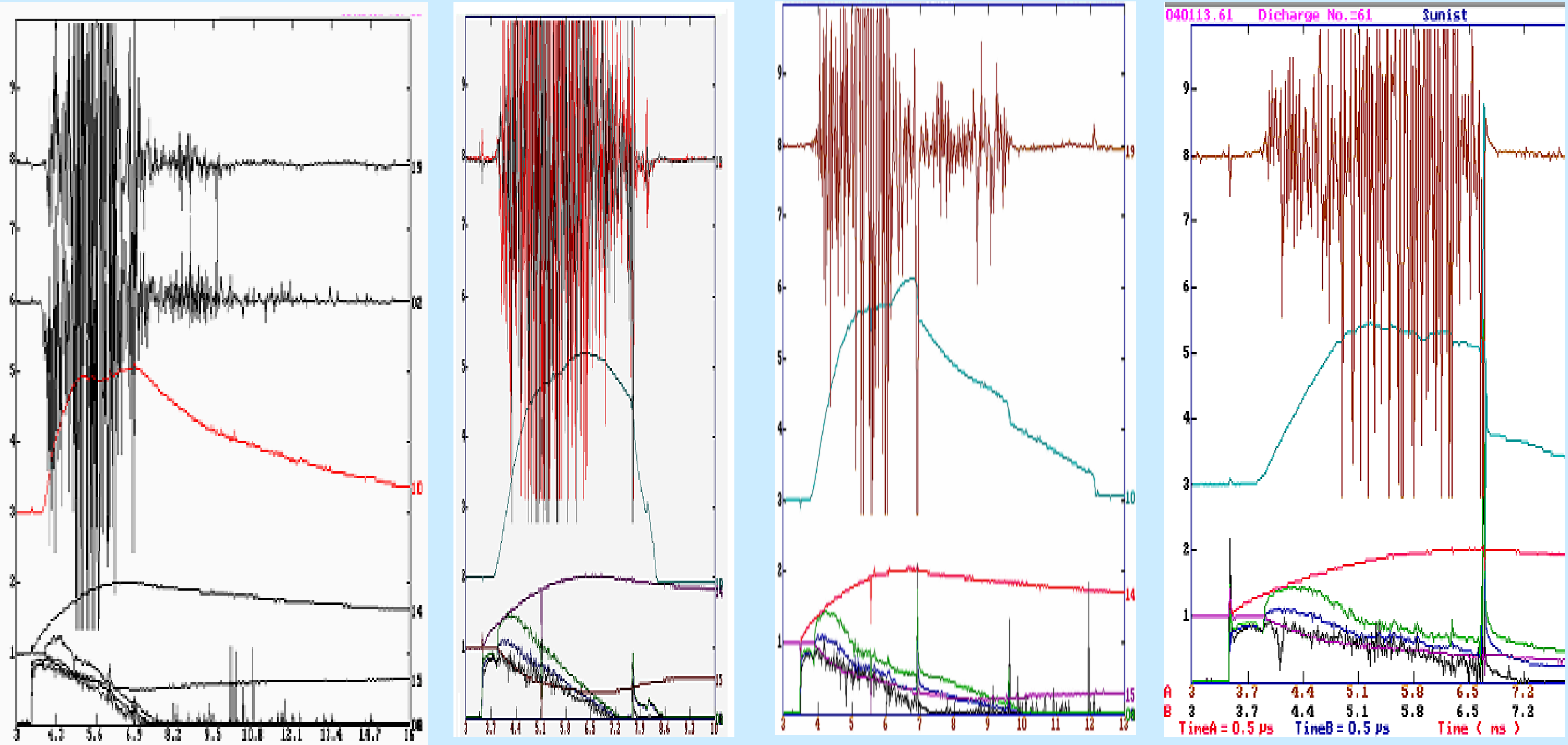
I_{GDC}: 0.8 A

Progress of discharge

discharge after siliconization

! **plasma current extended to flux loop signal down to zero.**

? **fueling by pressure feedback may influenced recycle with S_i film, then discharge quality.**



Progress of discharge

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_{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 $I_{OHM\ MAX}$ (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_{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

research program (1)

1 upgrade system

*modification of ohmic field power supply, from single swing to double swing mode

*upgrade diagnostics: Hα, SX array, visible and UV spectroscopy, μW 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

Problems and research program

research program (2)

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 a important issue

Noninductive current startup will be a new subject in 2004

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Thank you