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Recent status of SUNIST and future plans*

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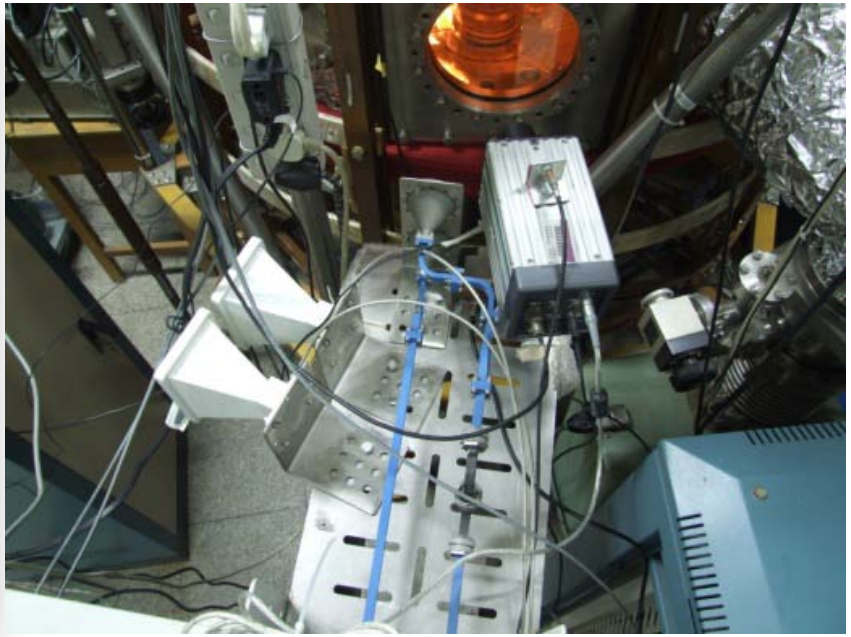
OUTLINES

- **Progress of device upgrade**
- **Experimental results of Ohm discharge**
- **Preliminary results of Alfven wave injection**

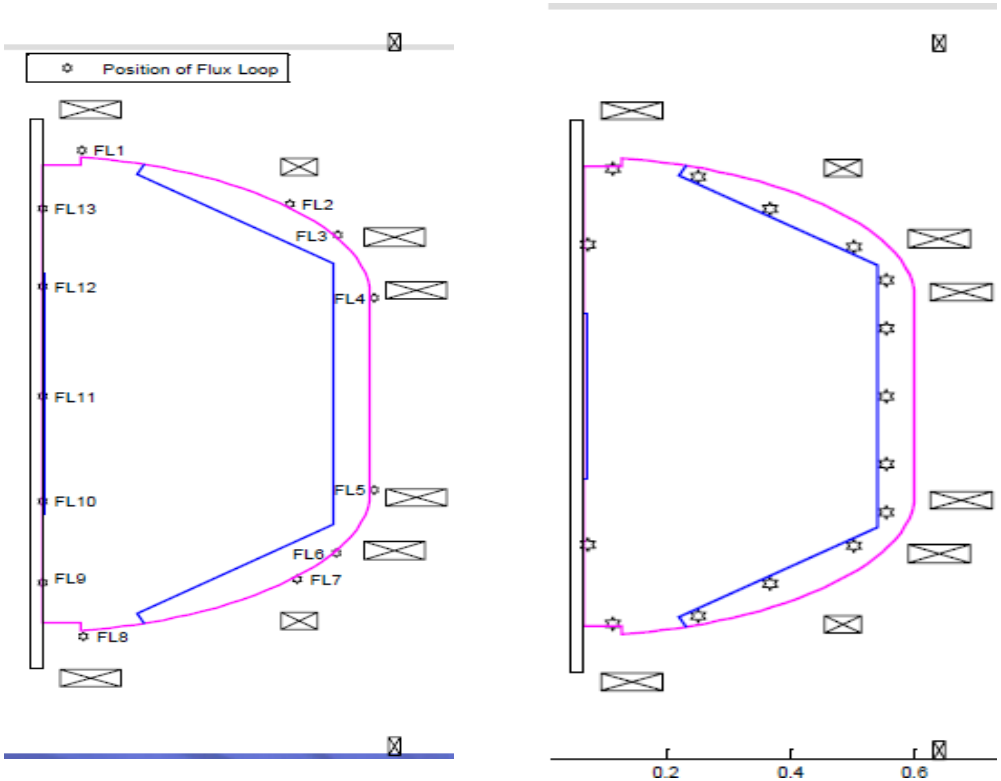
Device upgrade: vacuum chamber

- **A manhole window opened for convenience of in-vessel components installing and servicing and as an optical /radiant diagnostic window(CCD camera, reflectometer, spectrometer)**
- **Supporting blanket/point installation for magnetic diagnostic system and Alfven wave antenna system**



Device upgrade: magnetic diagnostic system

- **New magnetic diagnostic system (including 13 flux loops, 15 poloidal magnetic coils and 6 toroidal magnetic coils)**

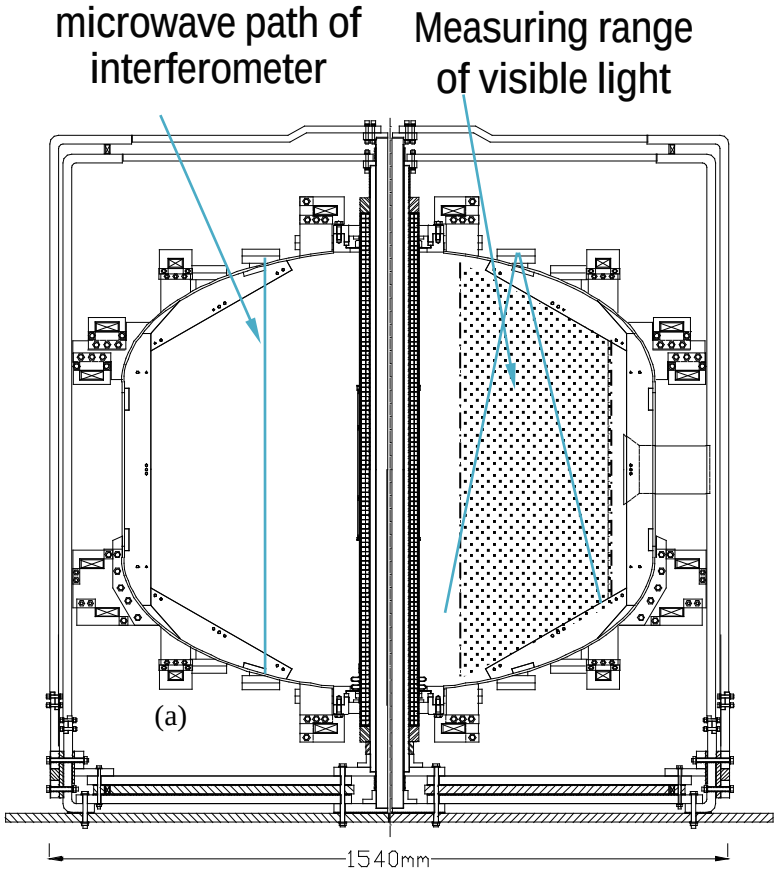


Profile of flux loops and poloidal magnetic coils

Zeng, et al *Plasma Sci. Tech.* 2008

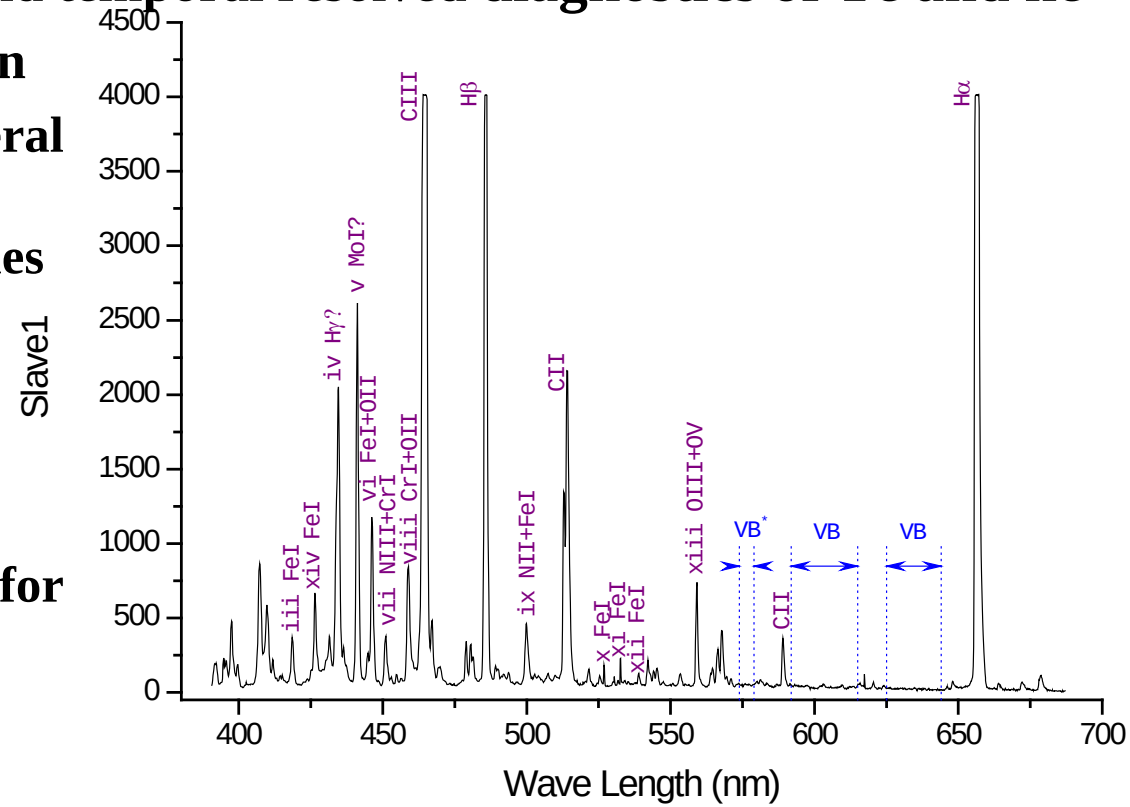
Device upgrade: microwave reflectometer and interferometer

- **reflectometer : 2~13 GHz, 26~40 GHz**
- **3mm Interferometer**
- **Density information of the SUNIST is obtained for the first time**
  - **$n_e > 1 \times 10^{19} m^{-3}$ from the reflectometer**
  - **$\int n_e dl \sim 0.5\text{-}2.5 \times 10^{19} m^{-2}$ from the Interferometer**
  - **strong oscillation in reflectometer signal : relative large density fluctuation (20%~60%) with comparable wavelength (5~20mm) observed in SUNIST previously by Wang et al *PPCF* 2005**



Device upgrade: spectrometer diagnostics

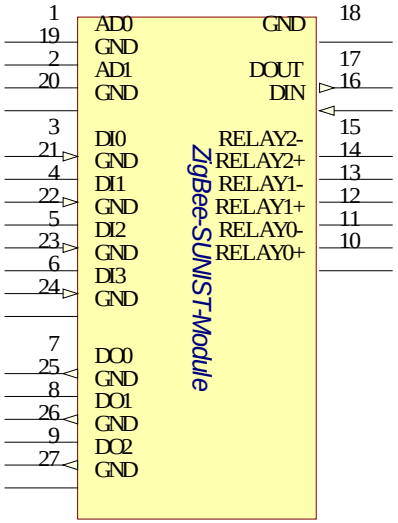
- **An Ocean S2000 four-channel visible spectrometer installed**
- **A 46-channel Hamamatsu S4114-46N photodiode array to be installed**
- **A spectrometer with multi-chord detector and higher spectrum resolution planned for higher spatial and temporal resolved diagnostics of Te and ne**
- **Spectroscopic diagnostic plan**
  - **Use three peaks with several Carbon spectral lines to measure Te and Ne profiles**
  - **three region of visible bremsstrahlung available for Zeff diagnostics**
  - **Spectral line emission broaden effects is planed for ions' temperature measurements**



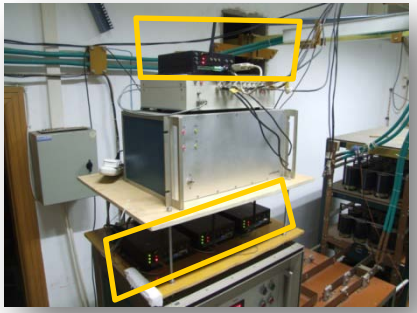
*VB: Visible Bremsstrahlung

Device upgrade: control and data acquisition

- **The SUNIST tokamak is now wirelessly controlled and monitored**
  - **ZigBee technology utilized**
  - **Robust and flexible for distributed applications of danger (high voltages, radiations)**
- **The experimental data is now stored, managed and accessed by MDSplus**

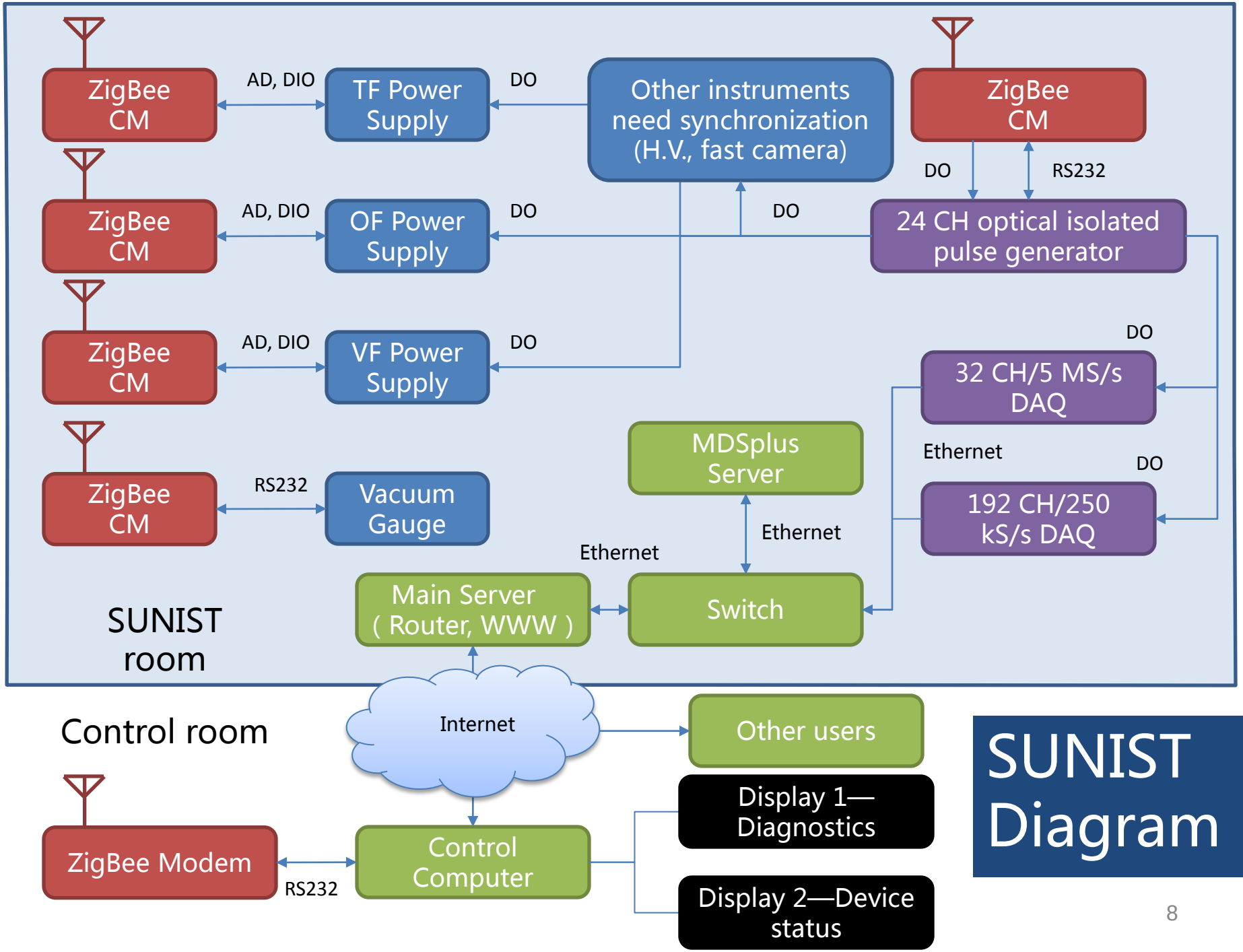


ZigBee controller and monitor



4 ZigBee CMs controlling the capacitor banks

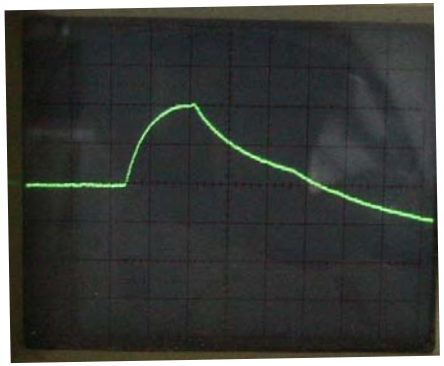
A ZigBee modem is installed on the control computer to communicate with CMs



SUNIST Diagram

Device upgrade: **power supply**

- **OF power supply**
  - **Present 4 ms rising edge (30 mV.s flux) can produce >8 ms plasma current (2 ms flattop).**
  - **New double swing power supply is being manufactured (60 mV.s flux). Expect to produce >20 ms plasmas (10 ms flattop).**
- **VF power supply**
  - **Break up to 3 discrete programmable power supplies**
  - **Better equilibrium control (with present power supply, the plasma column was always pushed inward by the VF)**



Double swing current in a small scale experimental coil.

Device upgrade: status

- **Disassembled on April 17, 2008**
- **Vessel reassembled on Sep. 25, 2008**
- **Field coil/power supply reassembled on Dec. 18, 2008**
- **in-vessel components (except for the antenna) installed on Jan 6, 2009**
- **First ohmic plasmas after reassembly, Jan. 15, 2009**
- **Alfven antenna installed on Sep. 25, 2009**
- **Ohm discharge resumed on Sep. 29, 2009**
- **Power supply upgrade scheduled in 2010**

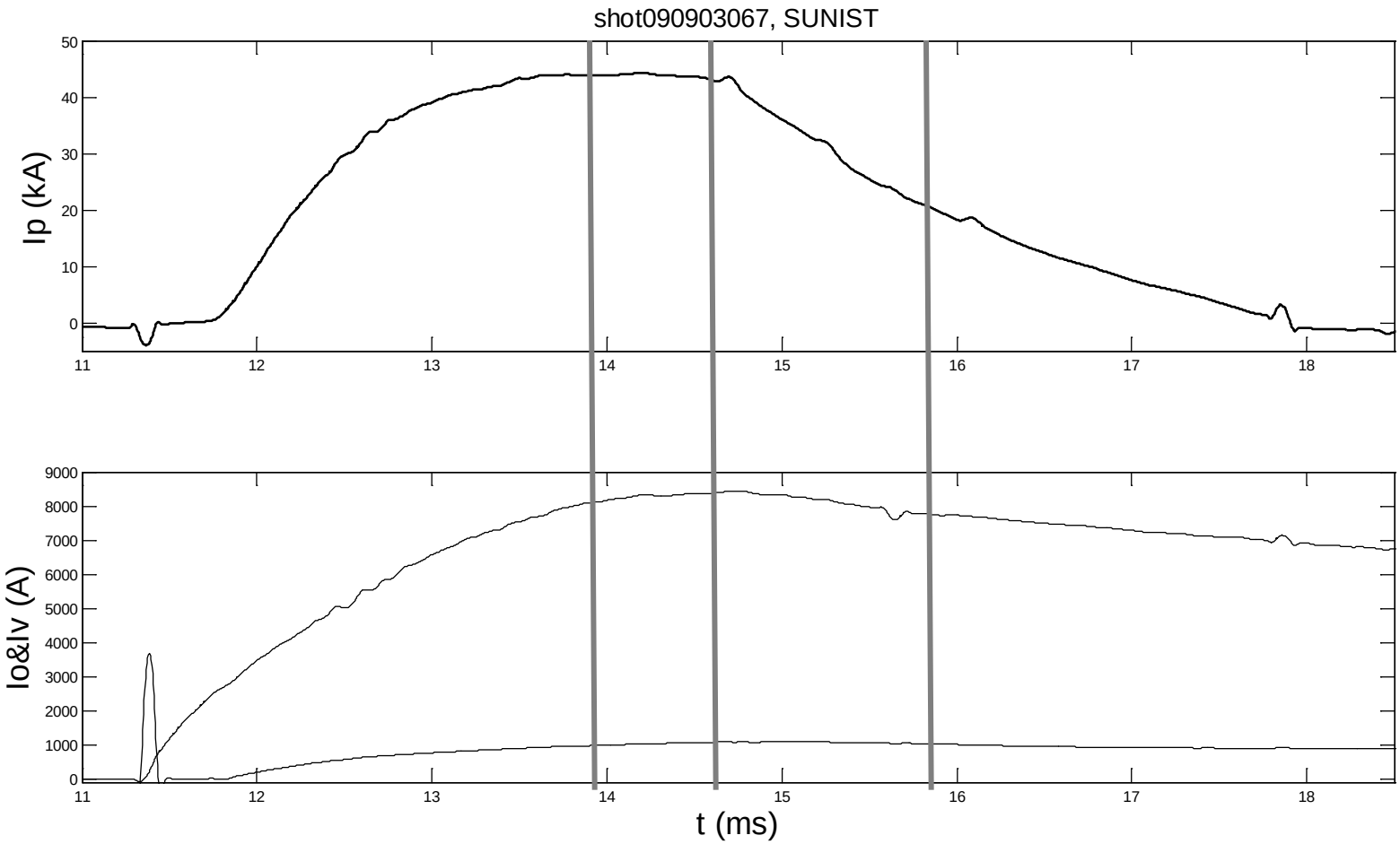
OUTLINES

- **Progress of device upgrade**
- **Experimental results of Ohm discharge**

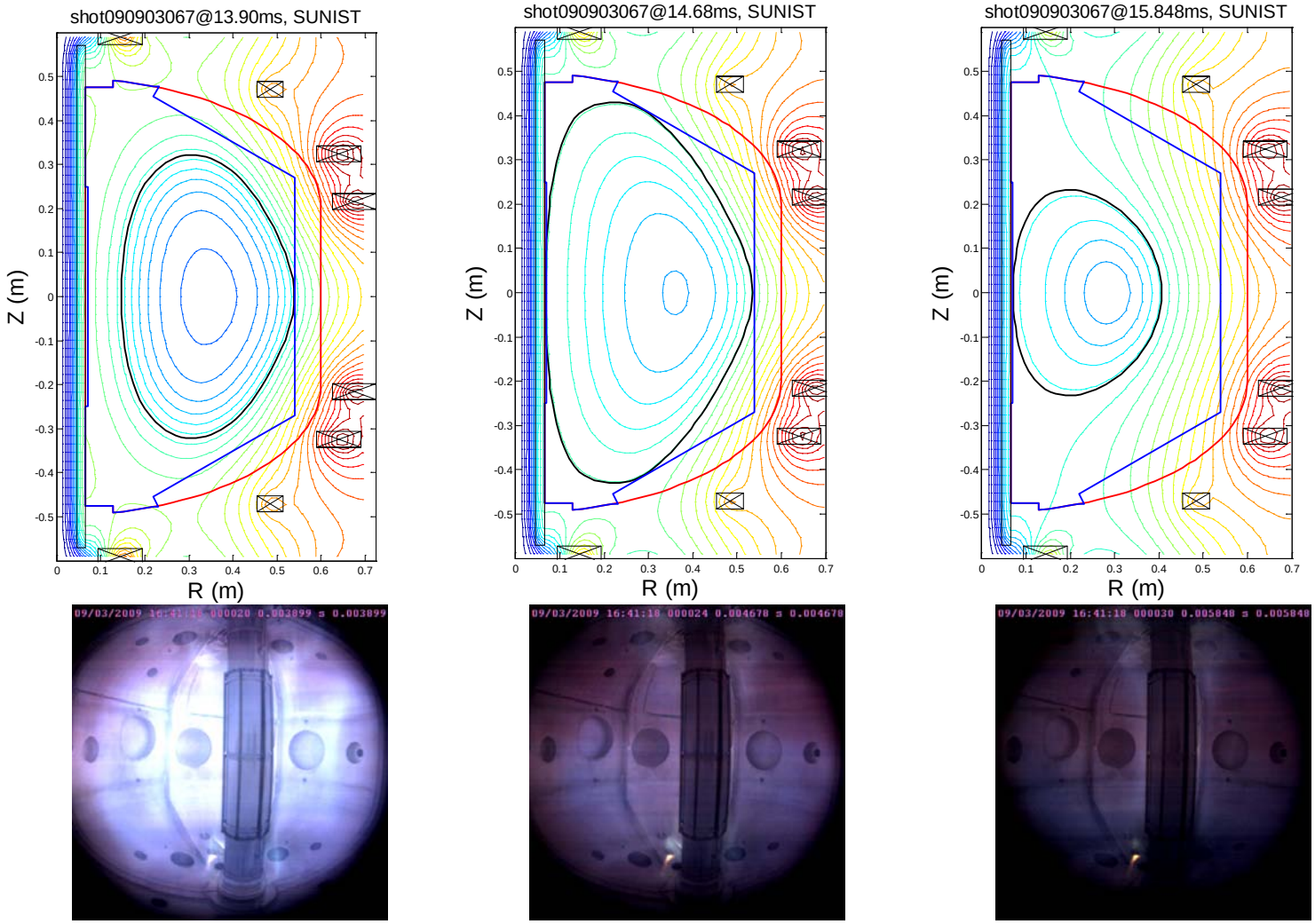
  Mission: test of device and diagnostics after the upgrade
- **Preliminary results of Alfven wave injection**

Ohm discharge recuperated easily

- **Typical discharge of SUNIST after the upgrade**



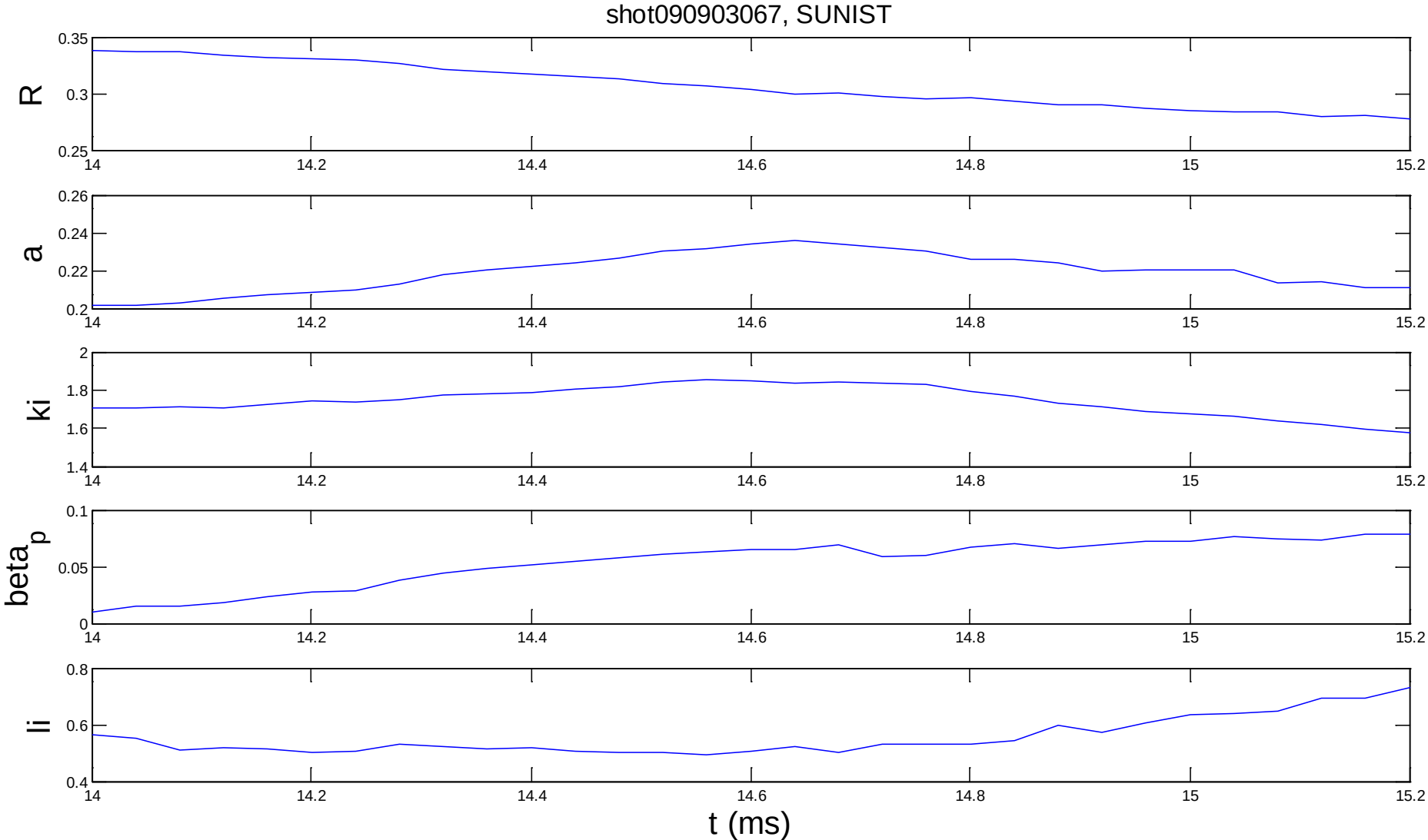
Equilibrium Reconstruction



- outside-limiter plasma → inside-limiter plasma
- urgent requirement of vertical field modification

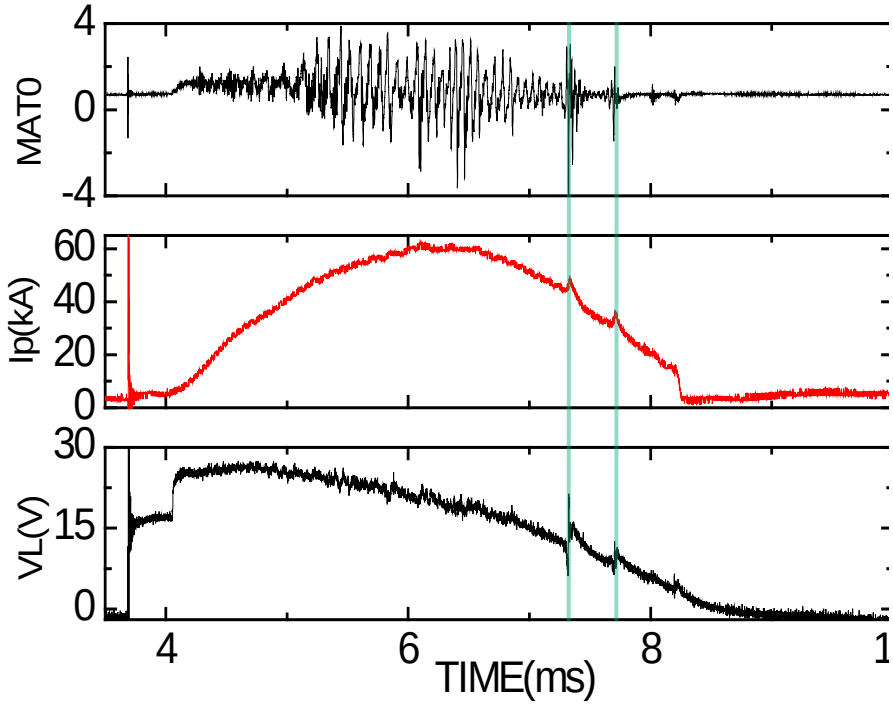
Evolution of plasma parameters

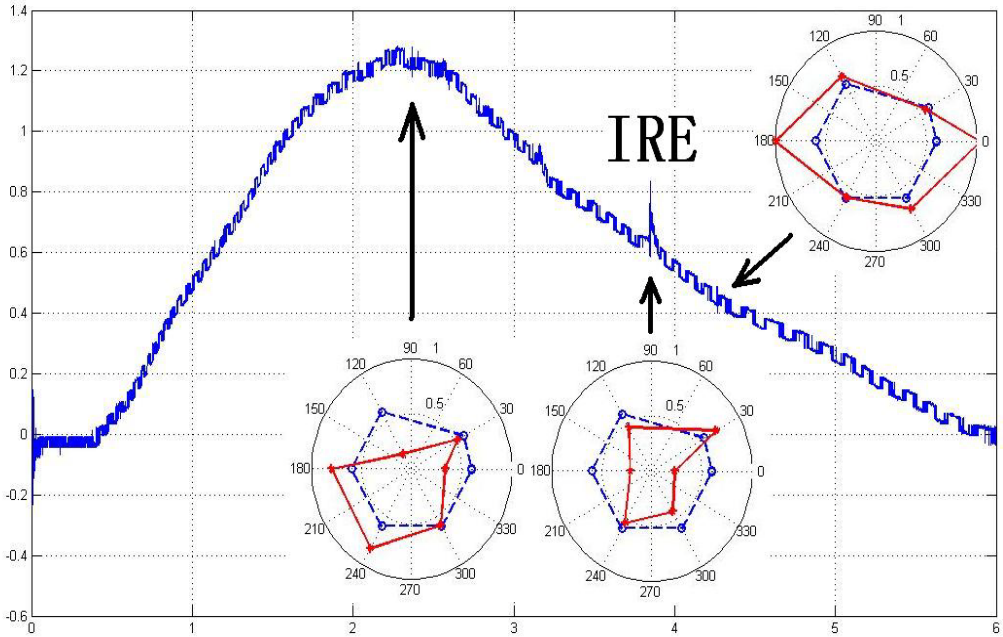
- **major/minor radius, elongation, poloidal beta, internal inductance**



Internal Reconnection Events

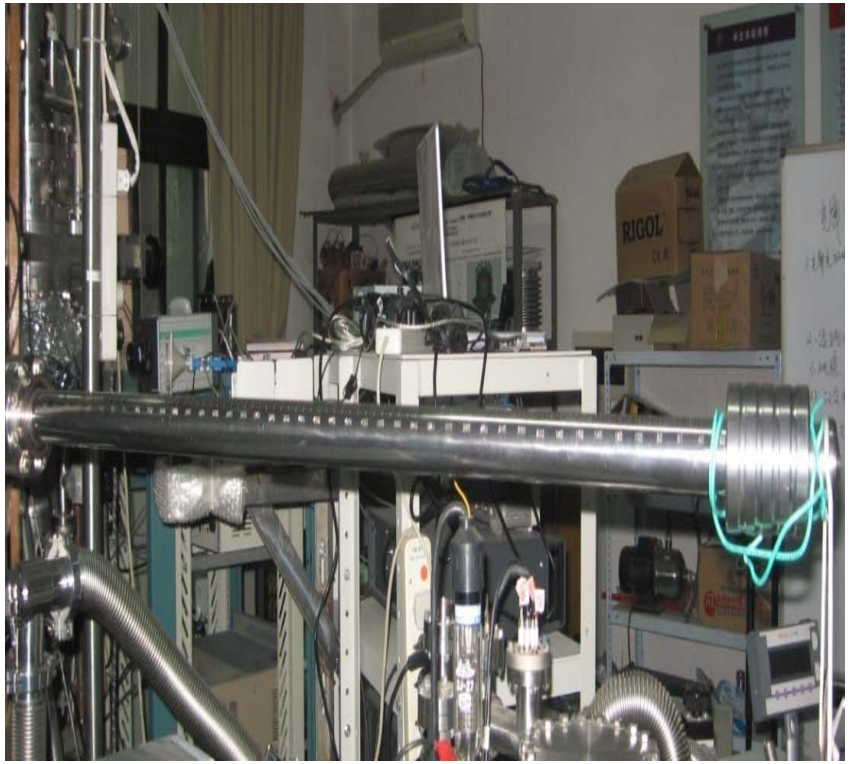
- **Shot090415.21**

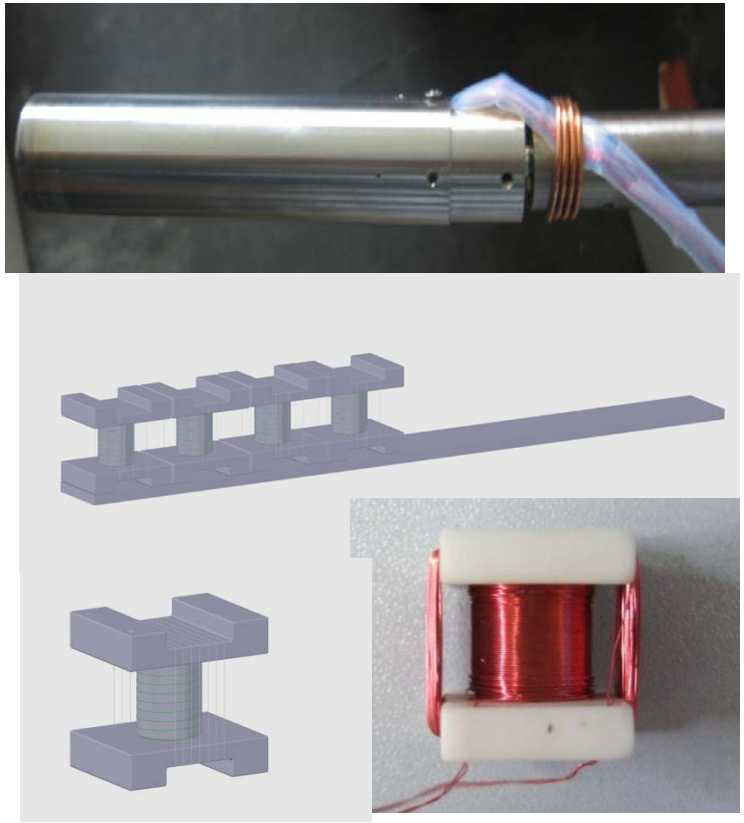




Details in Dr. Zeng's talk

Magnetic field profile and its fluctuation





Magnetic probe

Discharge conditions

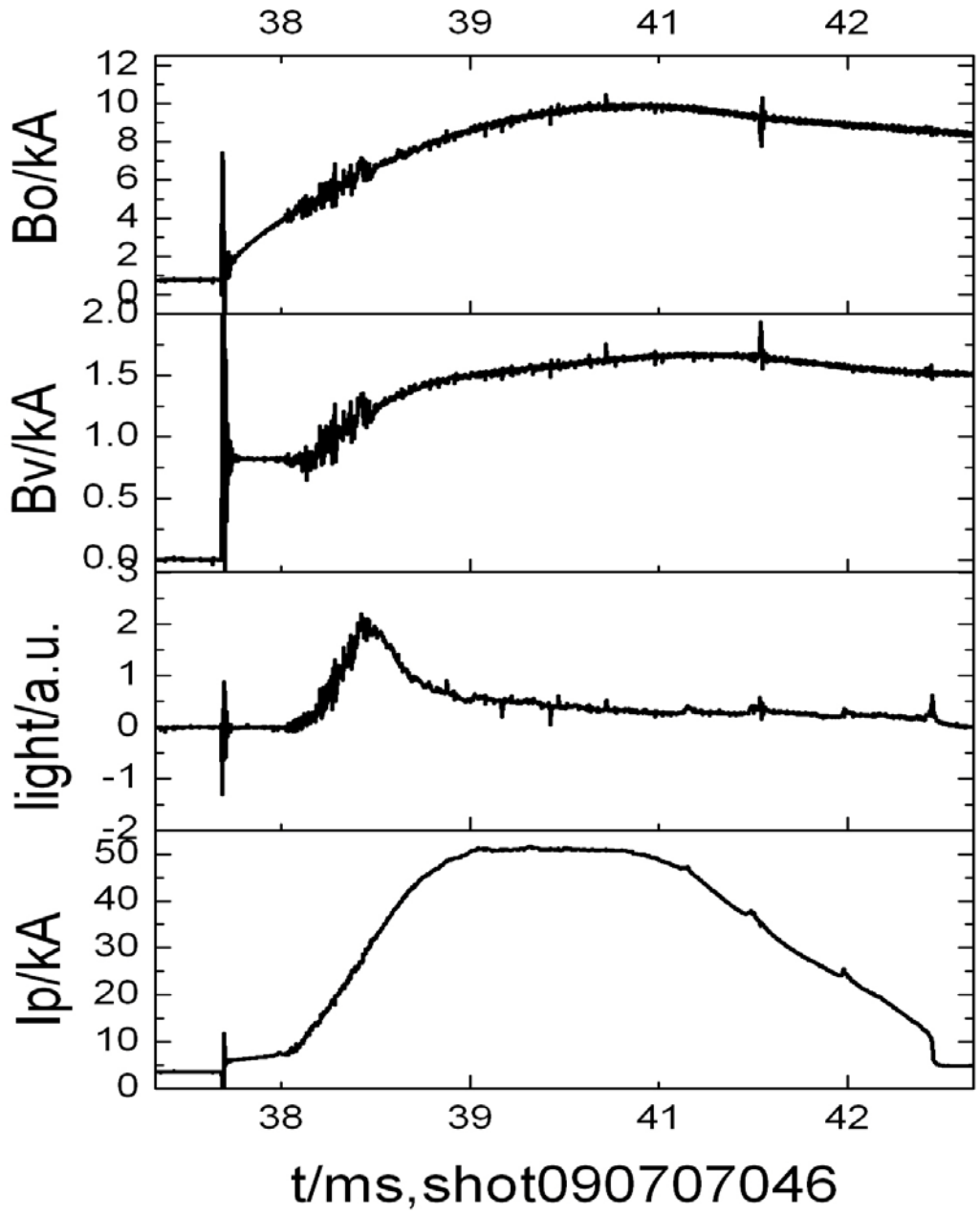
Hydrogen Ohm discharge

Background pressure：

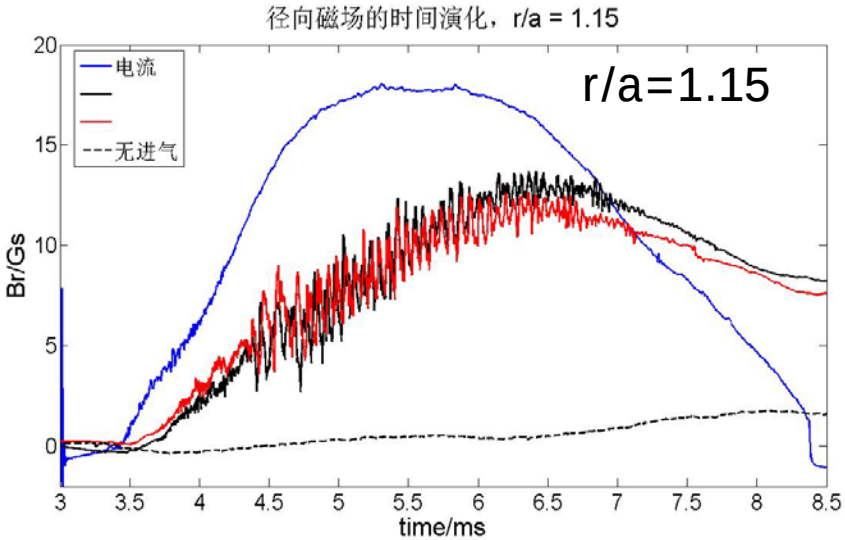
$1.0\times10^{-4}\sim1.3\times10^{-4}$ Pa

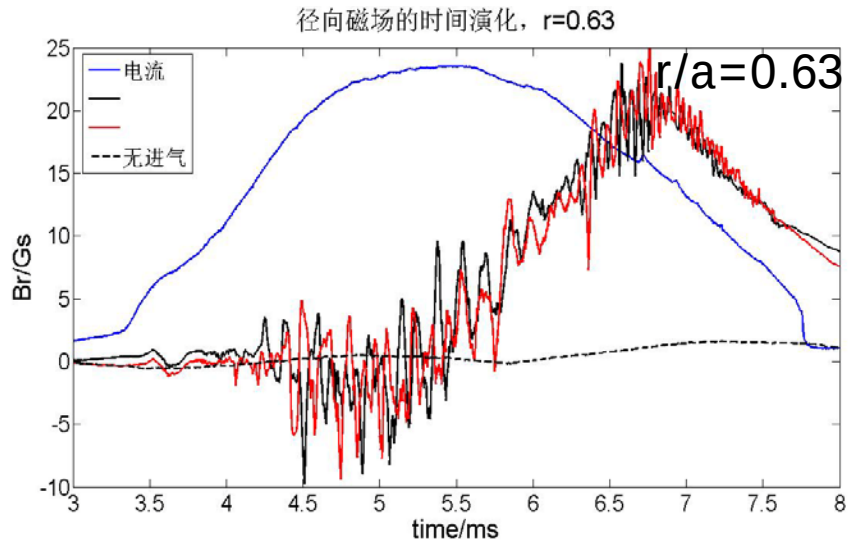
Discharge pressure：

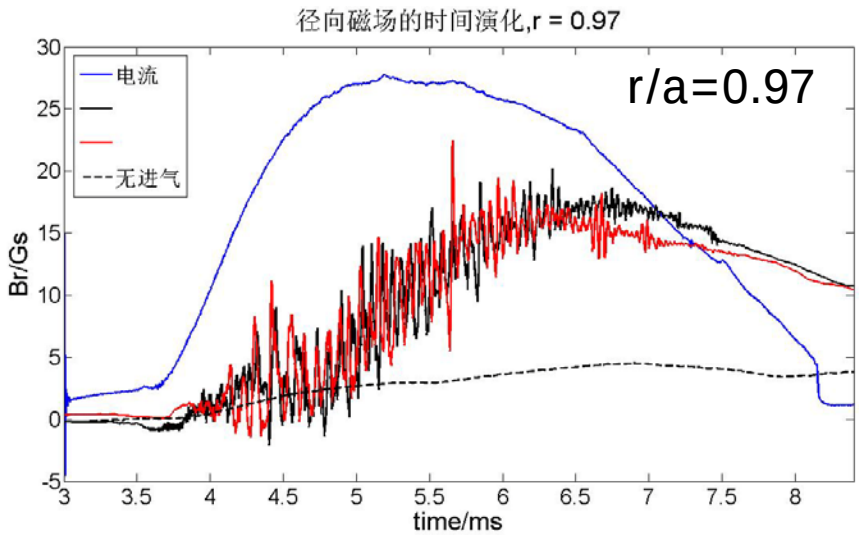
$1.0\times10^{-3}\sim3.0\times10^{-3}$ Pa



Radial magnetic field: temporal evolution

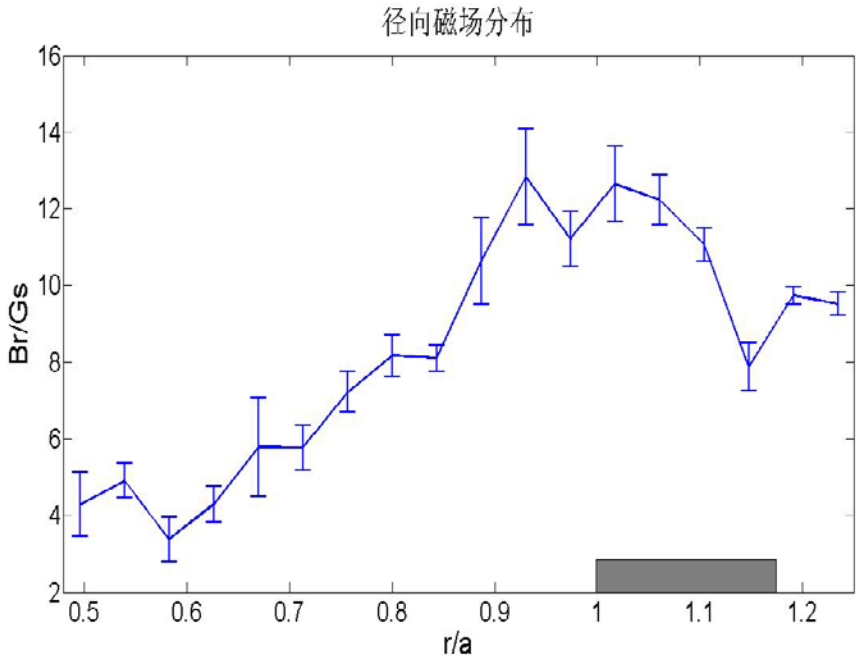


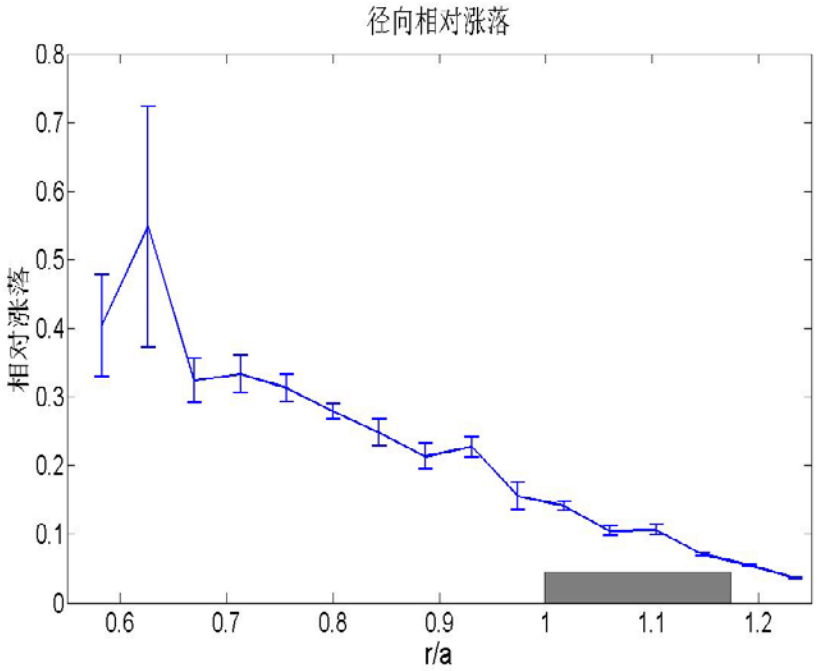




At edge, the radial component increase with plasma current ;

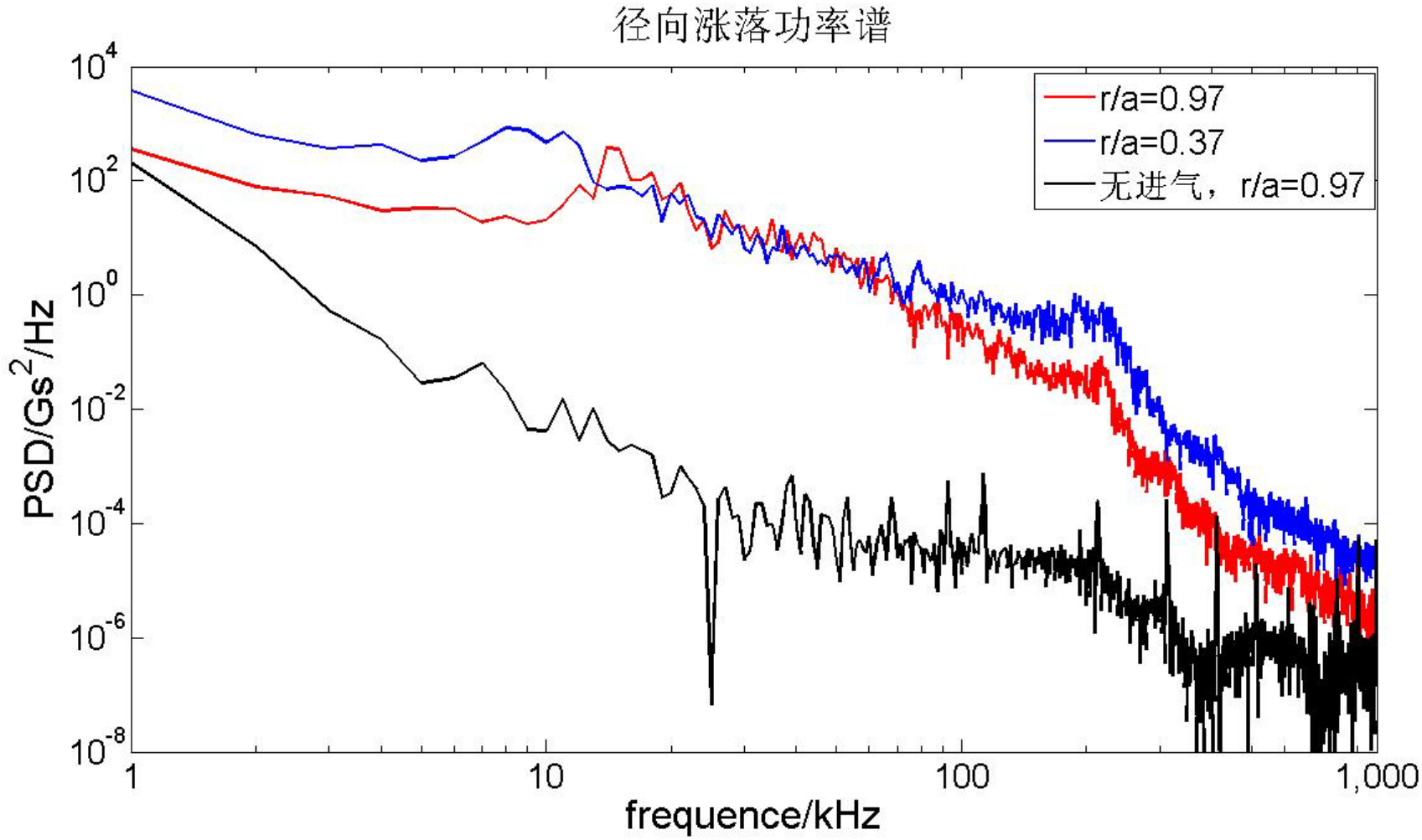
At core, the radial component develop till the current drops



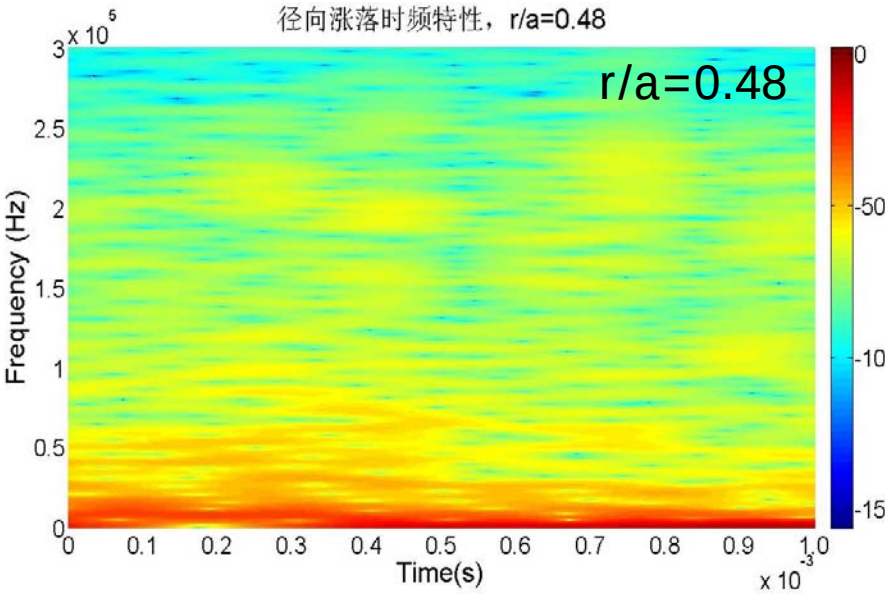


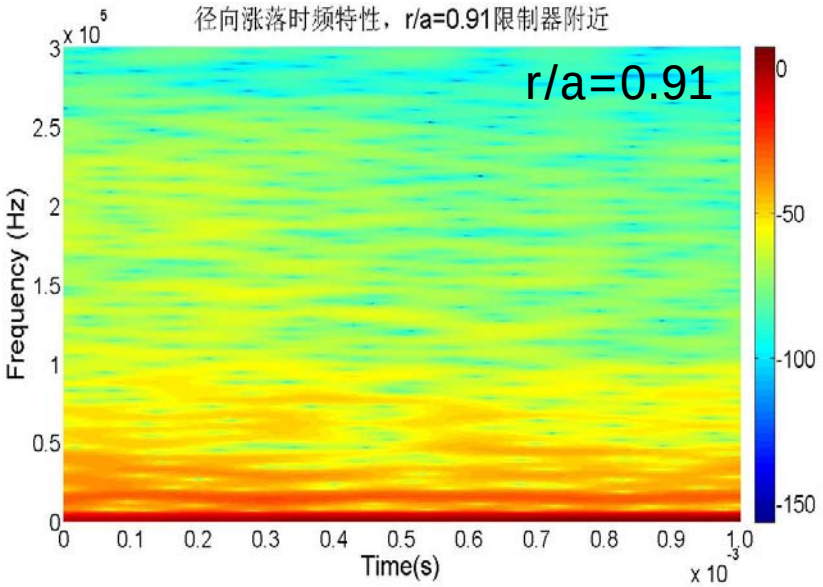
Obvious radial magnetic field in the equatorial plane

Br <15 Gauss (Bp ~100 Gauss)


径向涨落功率谱
r/a=0.97
r/a=0.37
无进气，r/a=0.97
PSD/Gs²/Hz
frequence/kHz
10⁴
10²
10⁰
10⁻²
10⁻⁴
10⁻⁶
10⁻⁸
1
10
100
1,000

T-F domain analysis





- fluctuation energy distributed in 0-300kHz
- major in low frequency regime (<10KHz)
- at edge, a peak about 15KHz appears, consitent with power spectrum
- Intermittery in temporal evolution in high frequency regime

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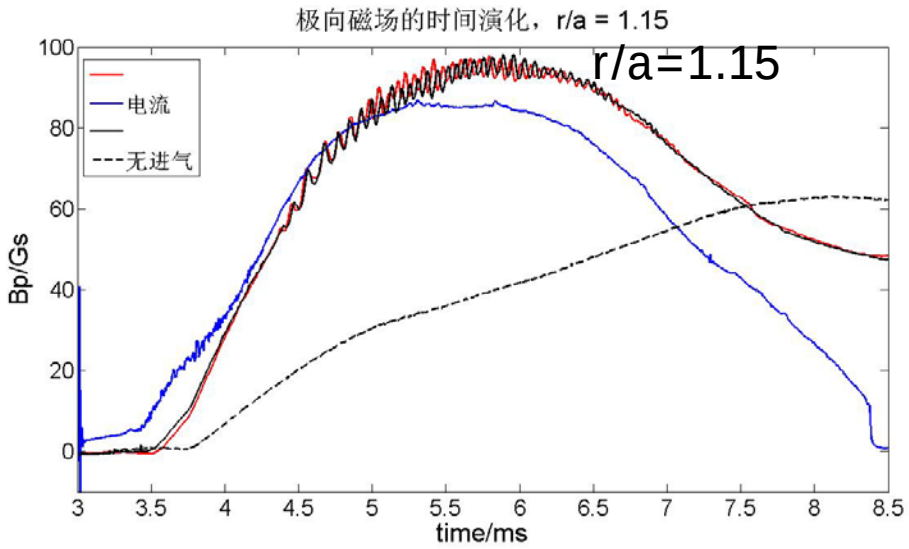
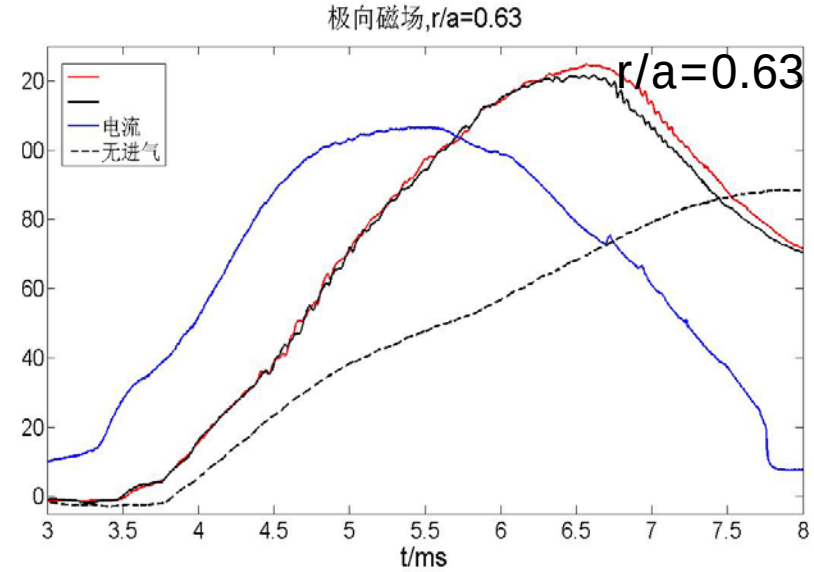
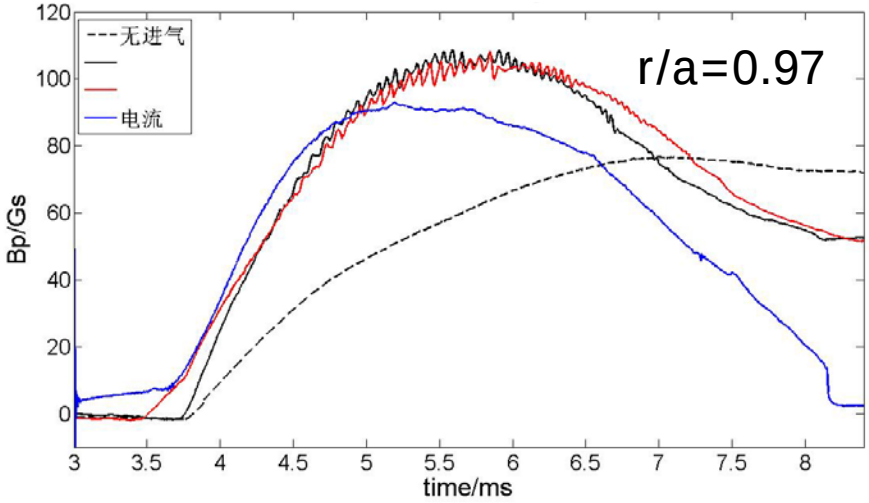
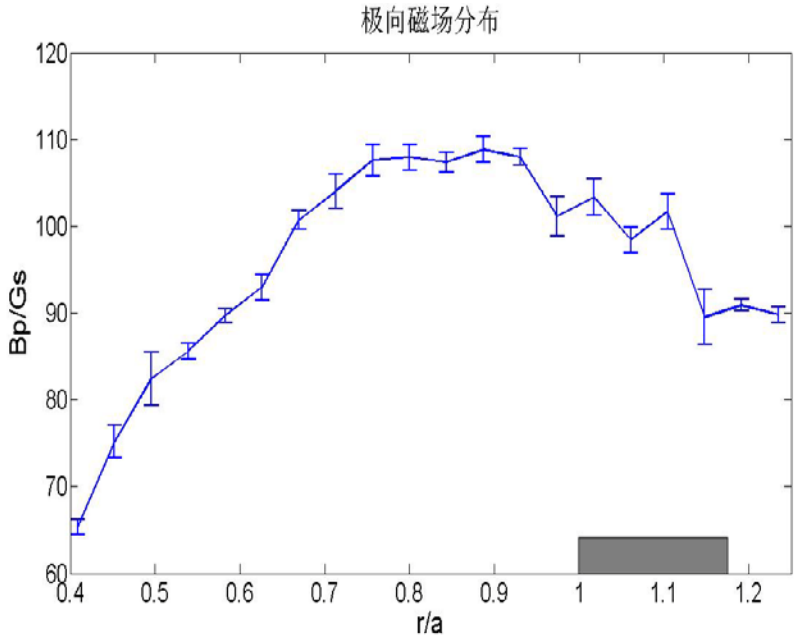
Poloidal magnetic field: temporal evolution

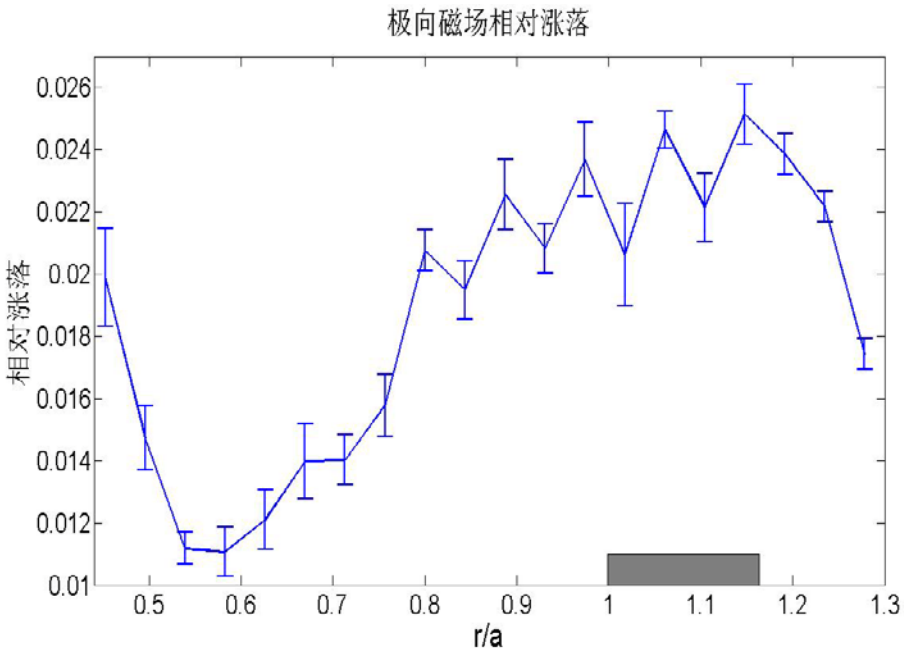




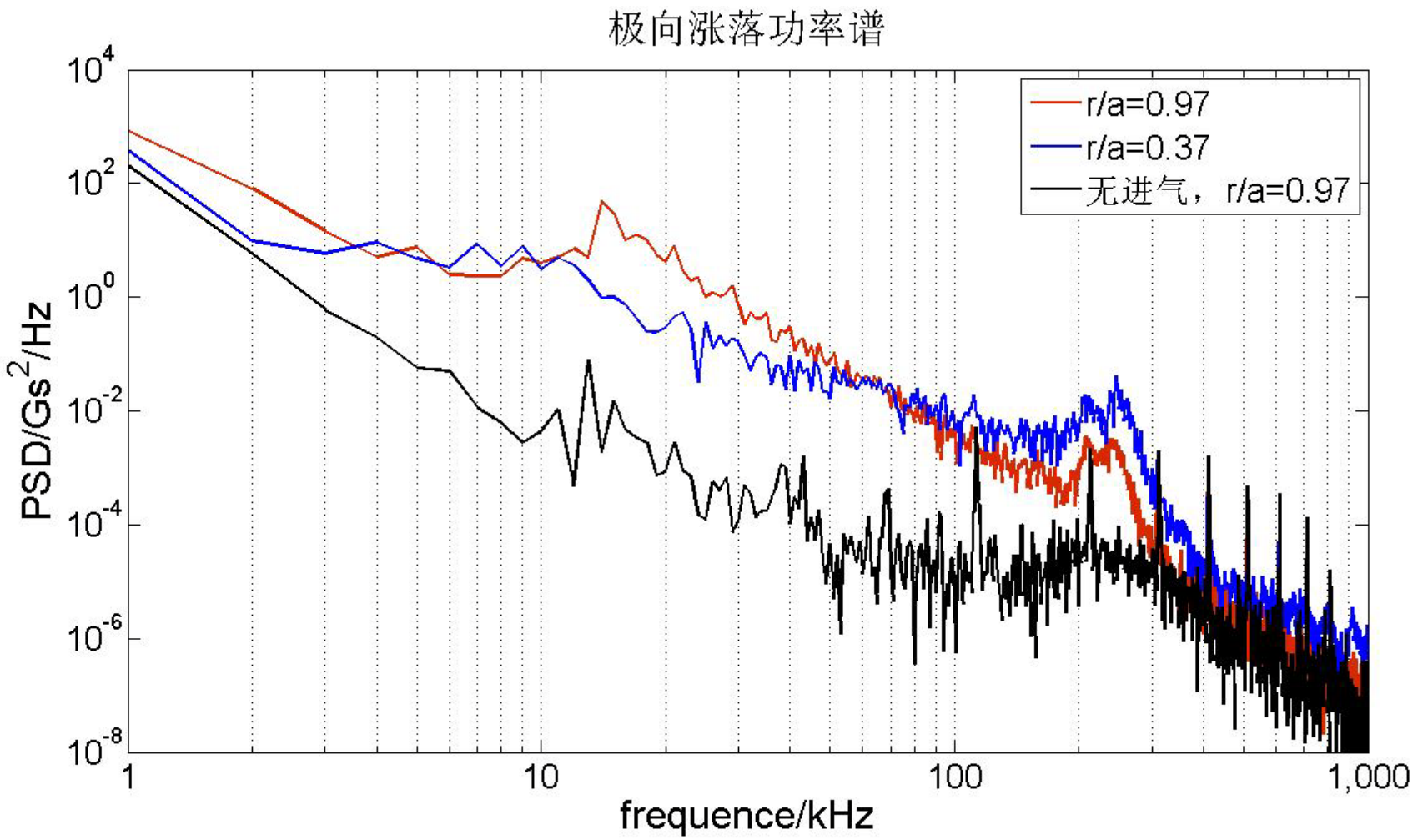


It is natural that the poloidal field increase with plasma current





Relative small poloidal fluctuation


极向涨落功率谱
r/a=0.97
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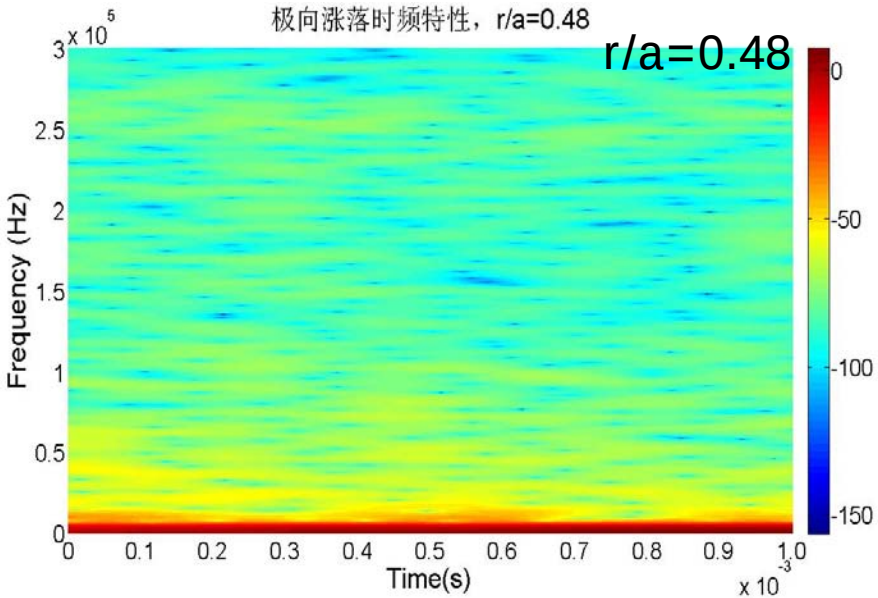
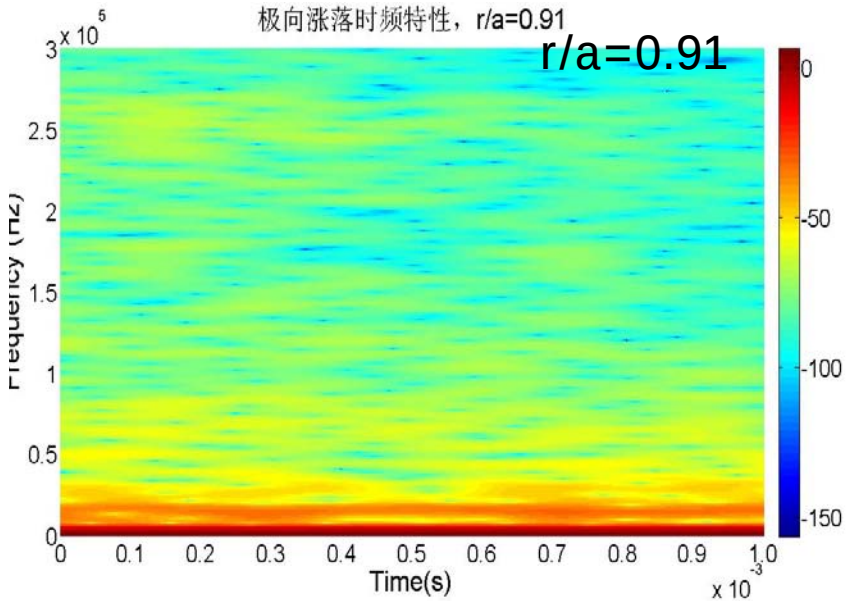
PSD/Gs^2/Hz
10^4
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
1
10
100
1,000
frequence/kHz

T-F domain analysis





- Comparing to the radial component, the poloidal fluctuation more concentrating in low frequency regime
- Only at edge, a few high frequency fluctuation appears

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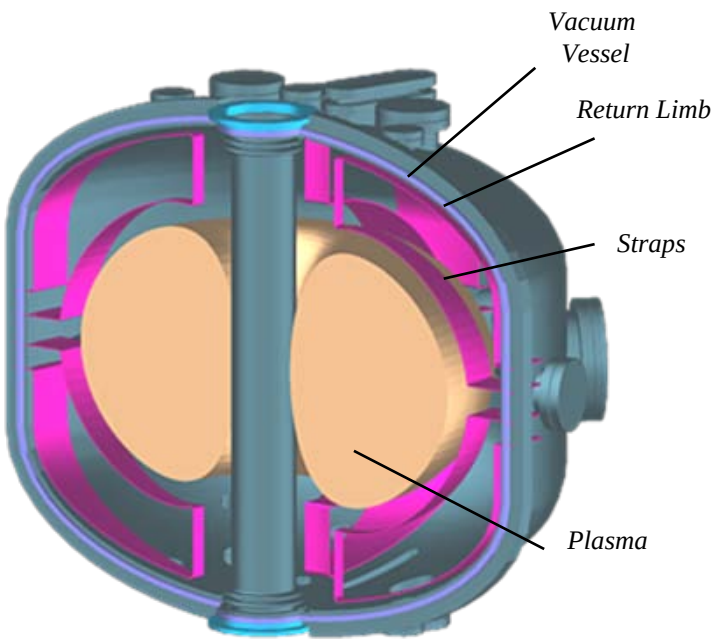
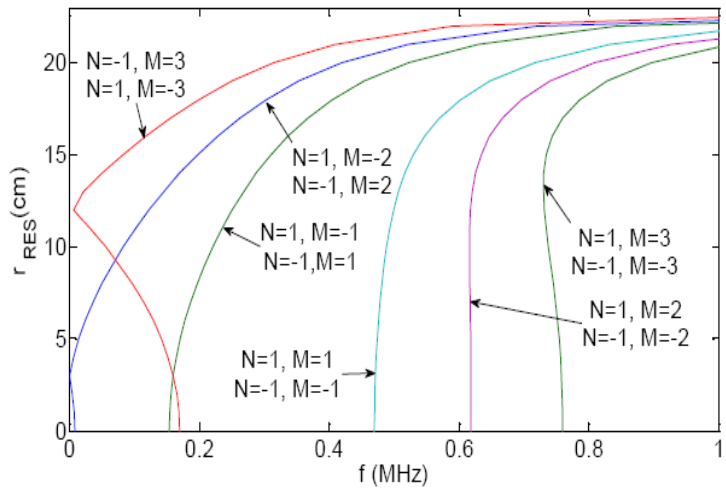
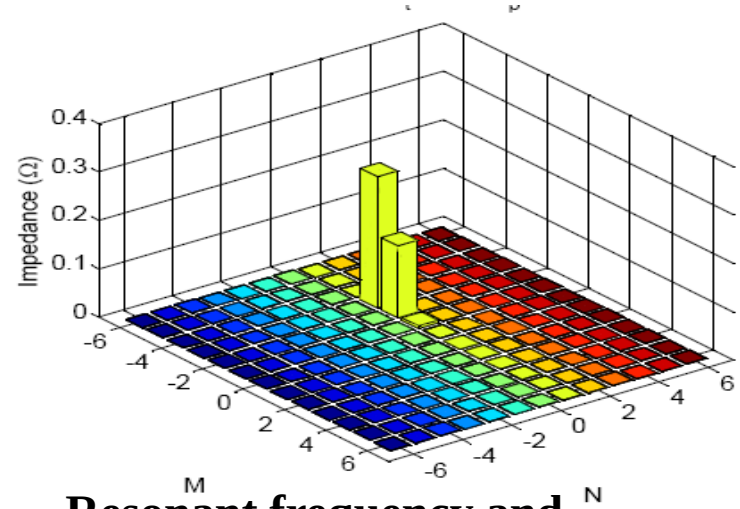
OUTLINES

- Progress of device upgrade
- Experimental results of Ohm discharge
- **Preliminary results of Alfven wave injection**
  - **System design and built**
  - **Preliminary results of test**

Concept design of antenna system



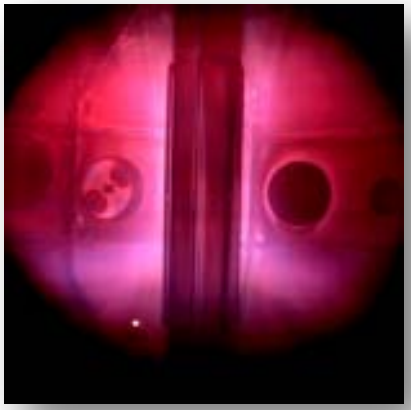




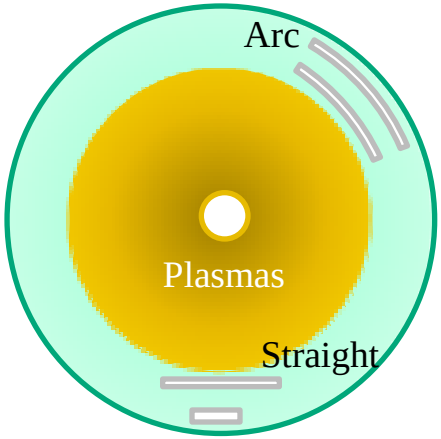
- **four modules in toroidal direction and two antenna straps in poloidal direction for each module**
- **referenced to the design for the ETE in Ruchko 2004**

- **Resonant frequency and impedance calculation**

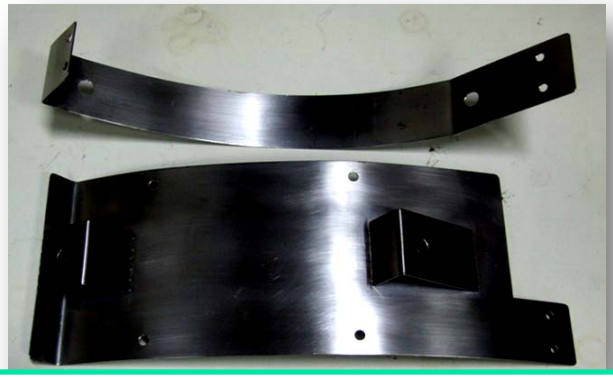
Engineering design of antenna system



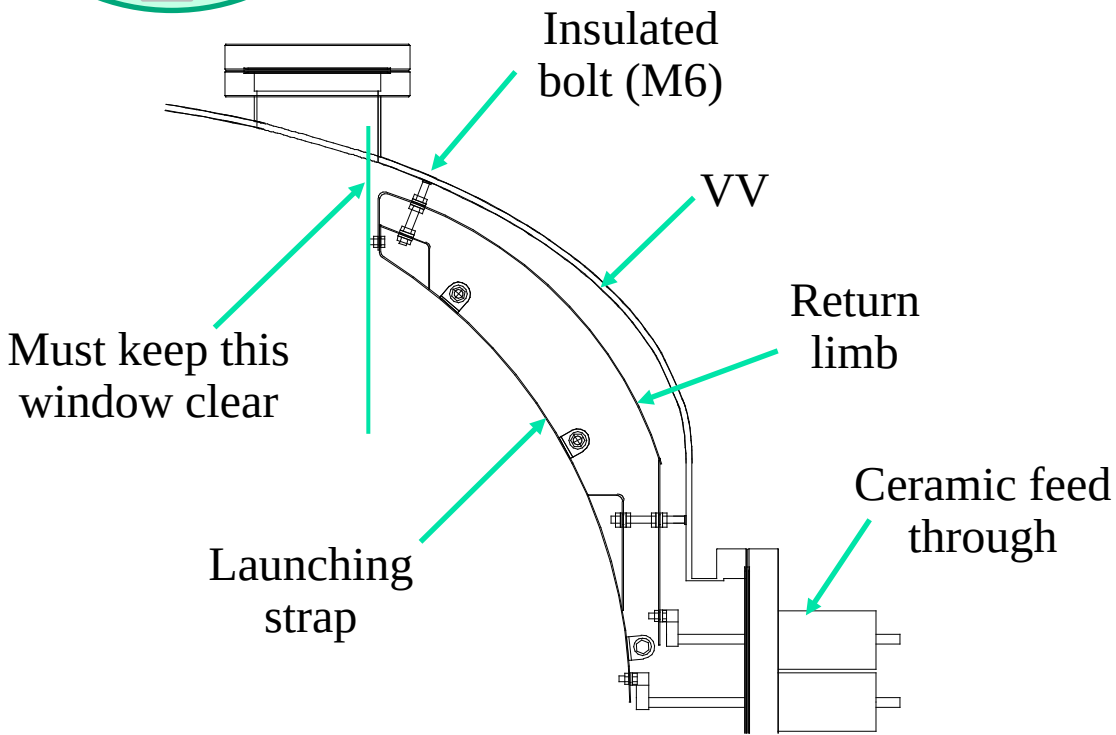
Few spare space available for antennas



- To simplify manufacture
  →Arc to straight
- To keep electrical insulation
  →The width of return limb is limited



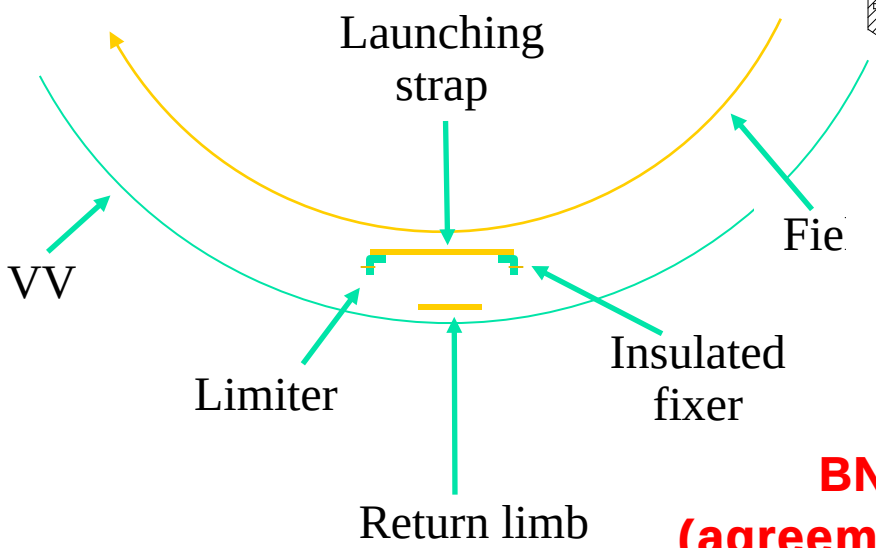
Launching strap: 1 mm x 150 mm
Return limb: 1 mm x 50 mm
Stainless Steel

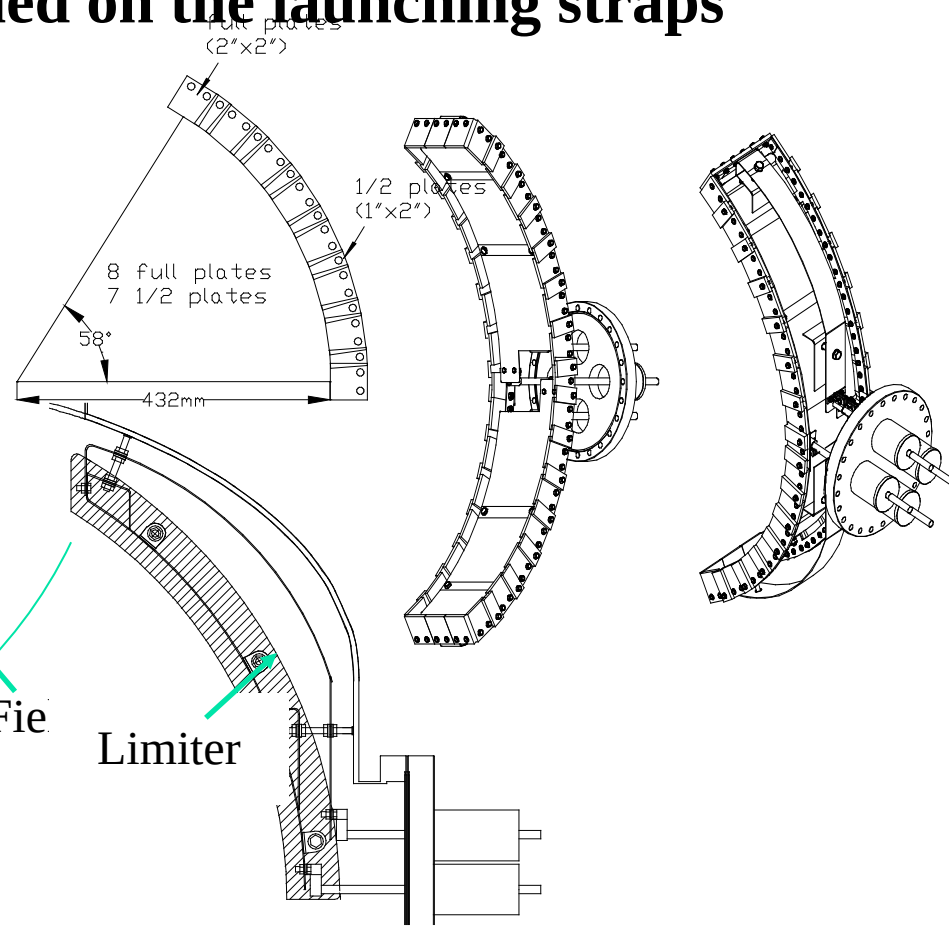


Shielding design of antenna system

- **Limiters will be directly attached on the launching straps**
- **Made by 5cmX5cm BN plates**
- **Uncertainties remained**

Much simpler than FS, and seems effective in Phaedrus-T (Sorensen 1996), but useless in Alcator C-mod

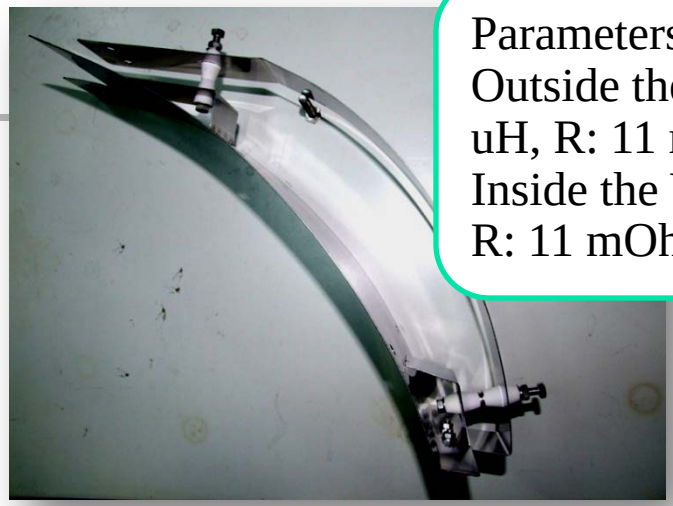




BN plates borrowed from PPPL
(agreement assigned, but not received yet)
Thanks to Dr. Majeski and PPPL

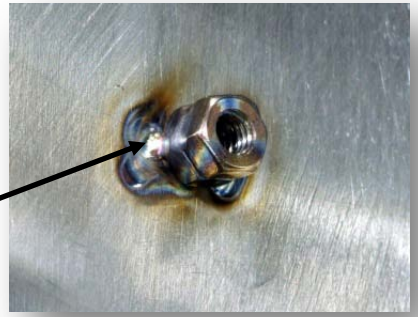
Pre-installation and test

Ceramic washer, the most uncertain point. 2.5 kV test passed @ 1 atm. But how it will be in vacuum with some plasmas?



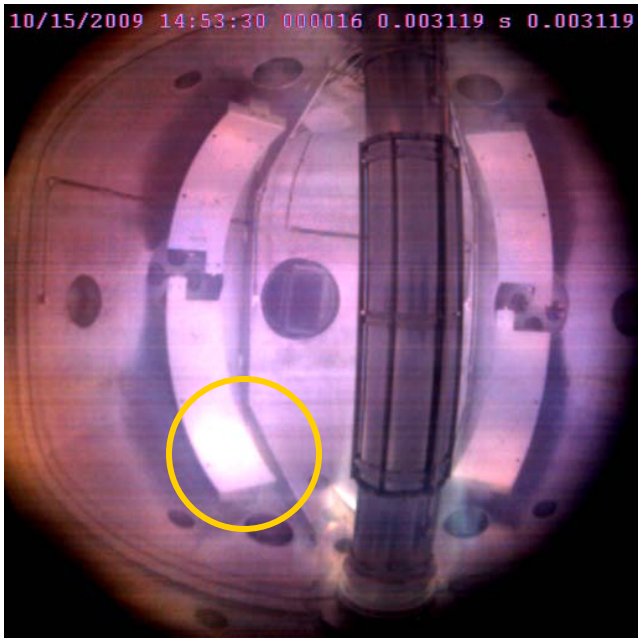
Parameters:
Outside the VV, L: 0.3 uH, R: 11 mOhm
Inside the VV, L: 0.8 uH, R: 11 mOhm

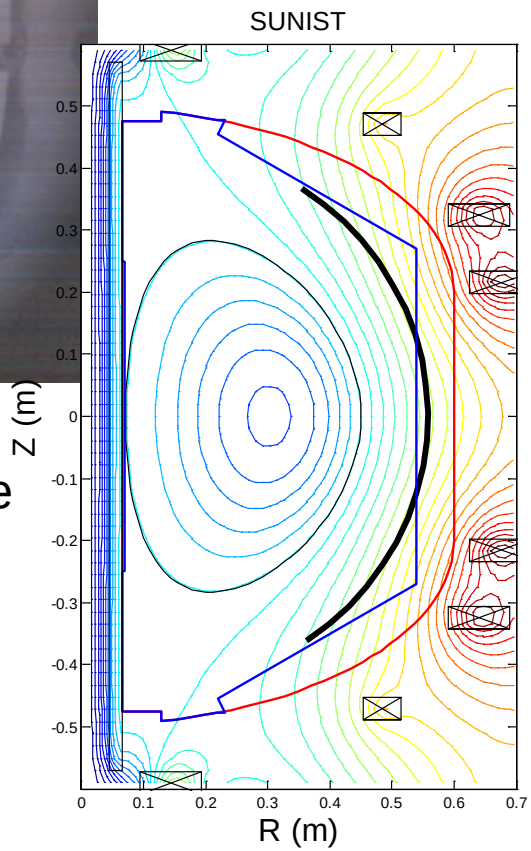
Double M6 nuts, TIG welded on the wall of VV. Minimum residual effects when antenna is not installed.



Totally 8 modules have been installed in the VV.

Antenna straps as limiters at the breakdown stage

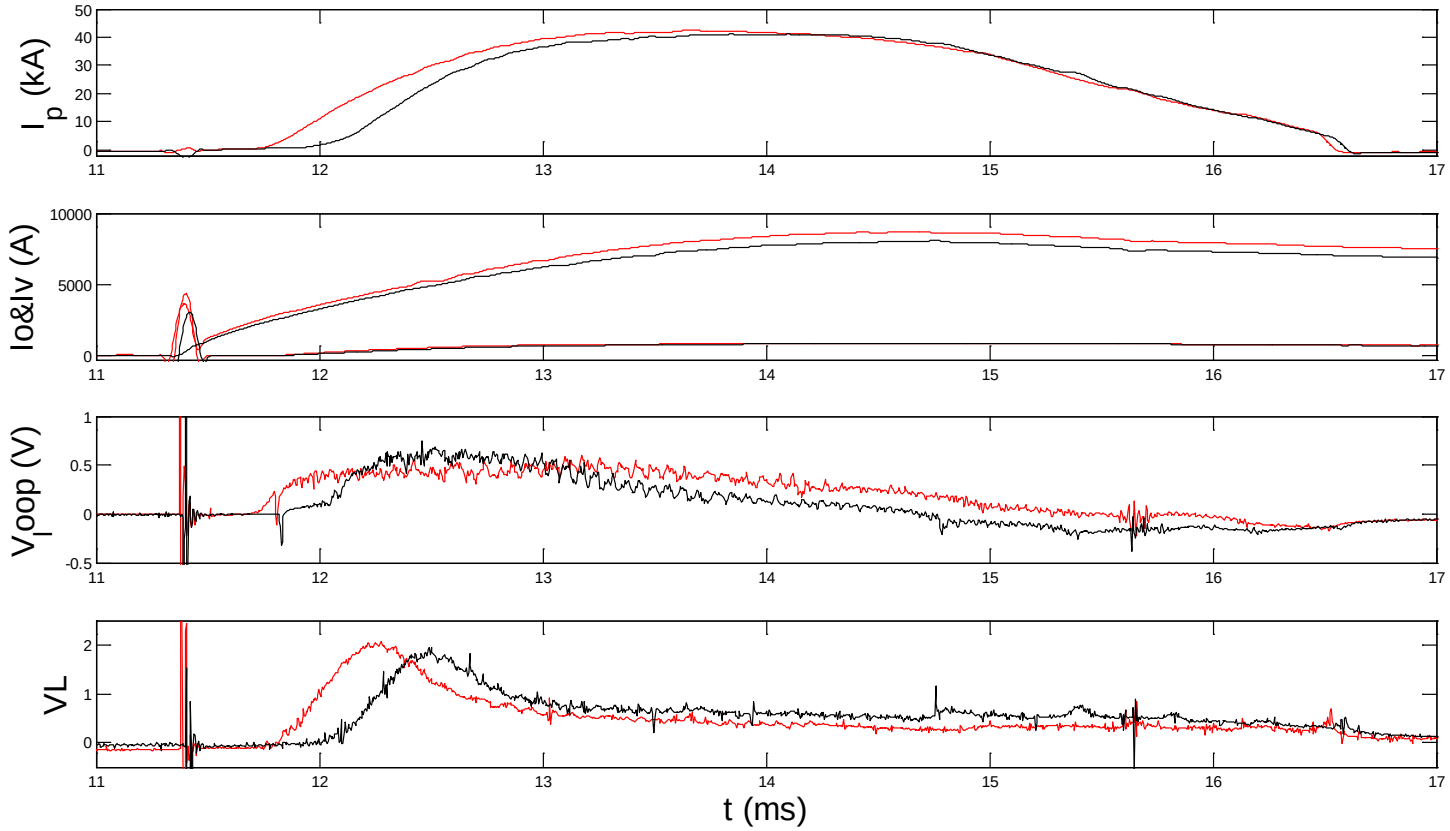




At the breakdown stage, plasmas occupy a large volume of the vacuum vessel. Antenna straps directly interact with plasmas as limiters. See the bright area on the strap.

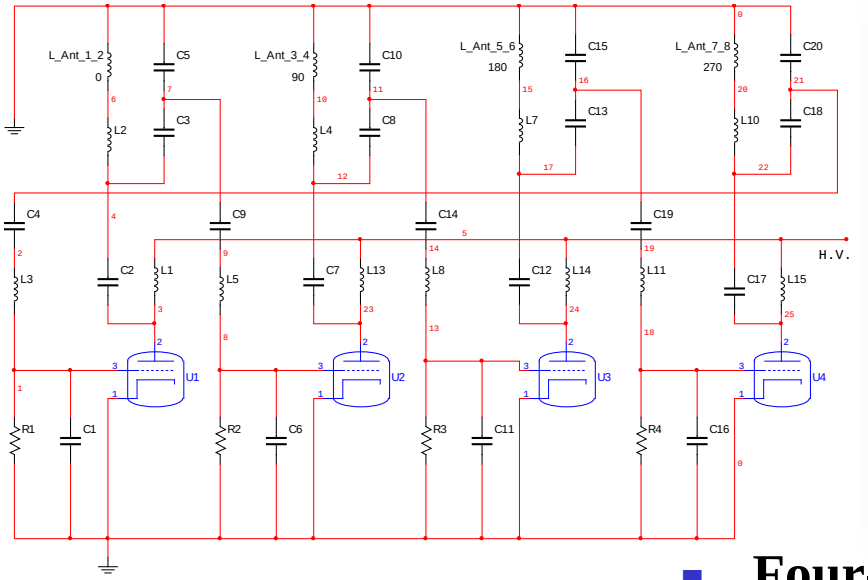
When closed flux surface was formed, plasmas were detached from the straps.

Slight influence of the antenna installation on the property of Ohm discharge



Red line represents discharge before the installation of Antenna, and the black lines represents discharge after the installation

rf generator



referenced to

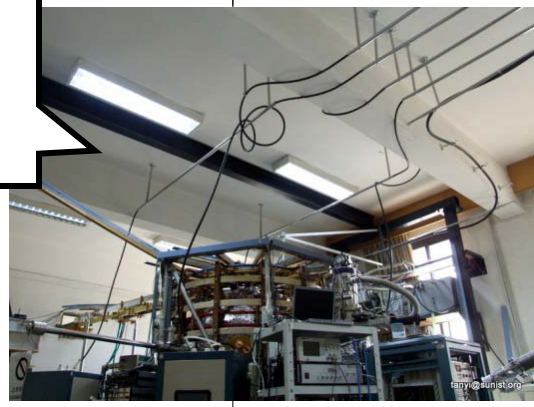
Ruchko 2004 at TCABR

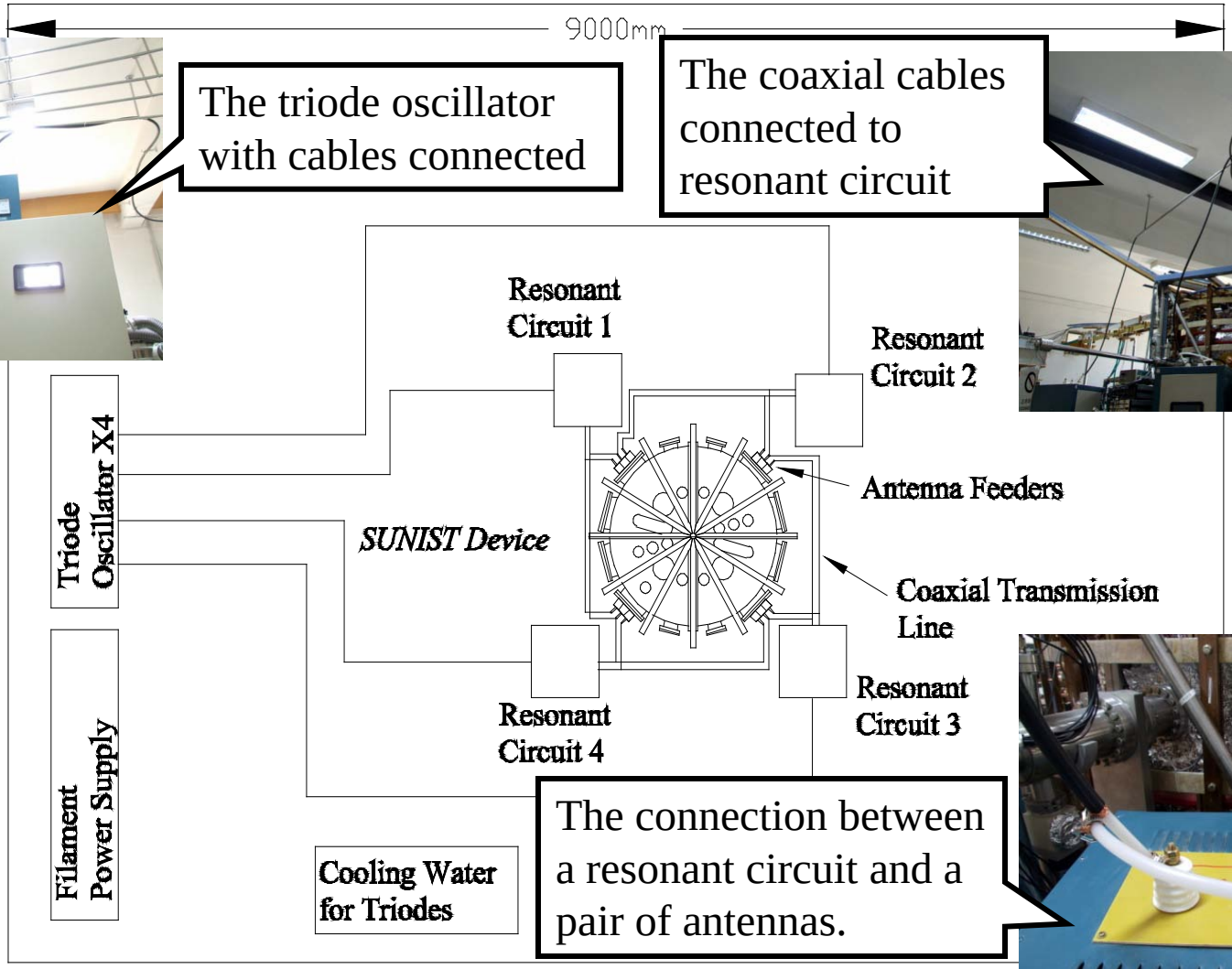
- **Four-phase oscillator (the phase shift between outputs does not depend on the variation of the antenna impedance)**
- **4x100kW / 0.4~1MHz**
- **Currently, the phase shift between two triodes is random, can be 0, 90, 180, 270 degree. Modification is on the way.**

Layout of AWCD experiment

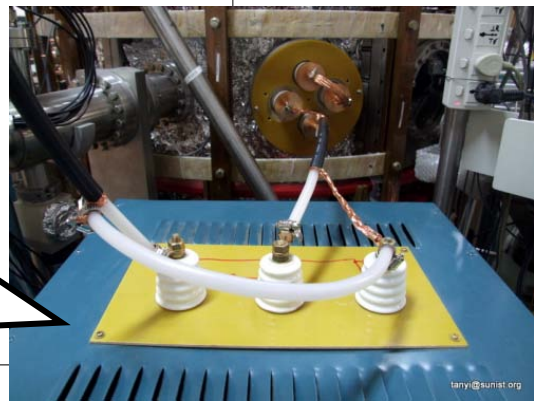
The triode oscillator with cables connected

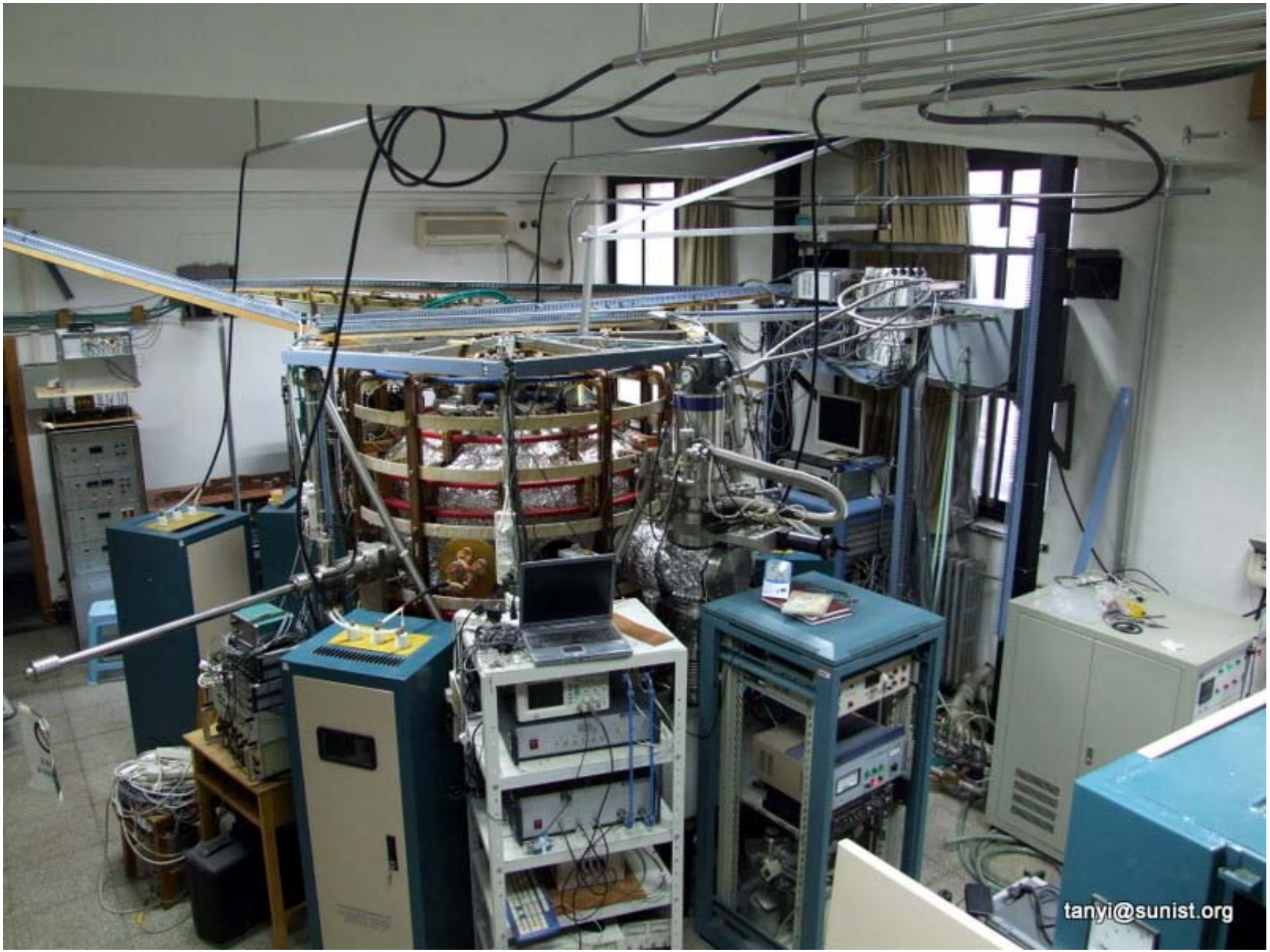
The coaxial cables connected to resonant circuit





The connection between a resonant circuit and a pair of antennas.

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Preliminary test undergoing

- Ohm discharges w/o and w/ antenna
  - **slight influence even the antenna straps occupied as limiters at the breakdown stage**
- low power Alfven wave injection w/o plasma
  - **mode analysis from magnetic signal?**
- low power Alfven wave injection to Ohmic plasma (antenna w/o and w/ shielding)
  - **coupling analysis(edge behaviors: impurity, hot spot, arcing; bulk plasma response)**
- full power Alfven wave injection to Ohmic plasma expected before the new year

Summary

- **SUNIST upgrade is partially completed. Now it is well controlled, convenient for in-vessel components installing and servicing, equipped with basic necessary diagnostics for Ohmic discharge and Alfven wave experiment. Power supply upgrade is planned in next year.**
- **To identify the status of the upgraded device, Ohmic discharge experiments are performed and some fundamental plasma behaviors are studied as well**
- **Alfven wave experiment is undergoing now. Design, assembling and offline-test of components of the system are finished.**

If you have any comment and suggestion, please contact gaozhe@tsinghua.edu.cn or tanyi@sunist.org.

Your comments and suggestions are greatly acknowledged.