Remote Steering Antenna System and Its Application to ECH/ECCD Experiments on the TRIAM-1M tokamak

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3. Tests of Antenna System
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Introduction

---- *TRIAM-1M tokamak* ----

---- *ECH System on the TRIAM tokamak* ----

Introduction to TRIAM-1M

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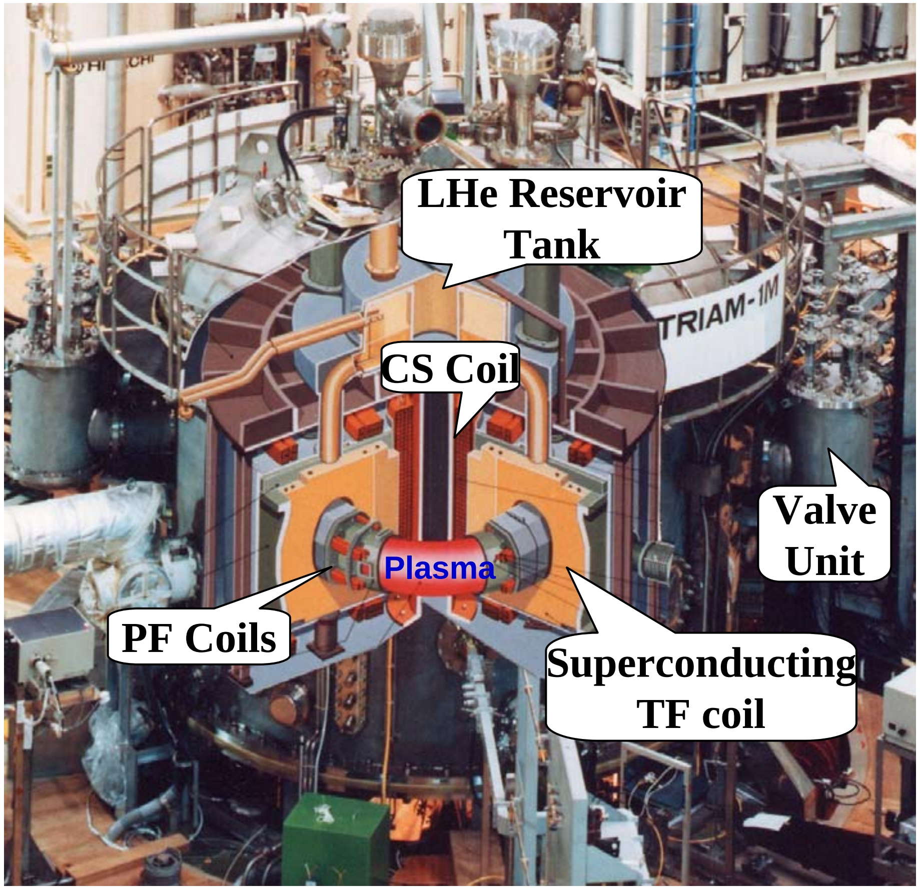

Major radius	**0.84m**
Minor radius	**0.12m x 0.18m**
Toroidal Field	**8T (Steady State)**
Plasma current (OH)	**<430kA**
(LHCD)	**<70kA**
Additional power	**450kW (LHCD)** **200kW 8.2GHz x2** **50kW 2.45GHz x1** **200kW(ECH)** **170GHz x 1**

16 Nb_3Sn TF coils
PF coils : Cu (normal conductor)

Specification of Gyrotron

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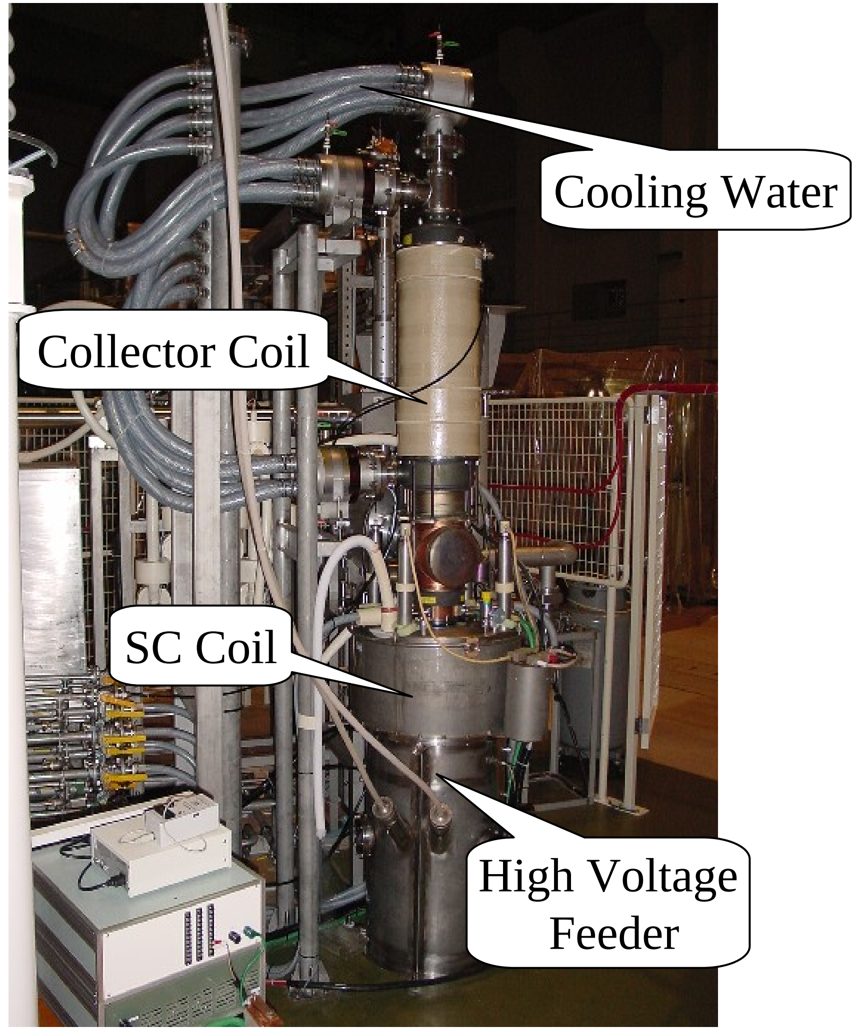
Gyrotron Specification

Output Power	
at Gyrotron Window	260k
at output of MOU	200k
Frequency	169.9G
Pulse Length	5se
Beam Voltage	65k
Beam Current	17
SC Coil Current	68.5
Magnetic Field of SC Coil	7T



ECH System in TRIAM-1M tokamak

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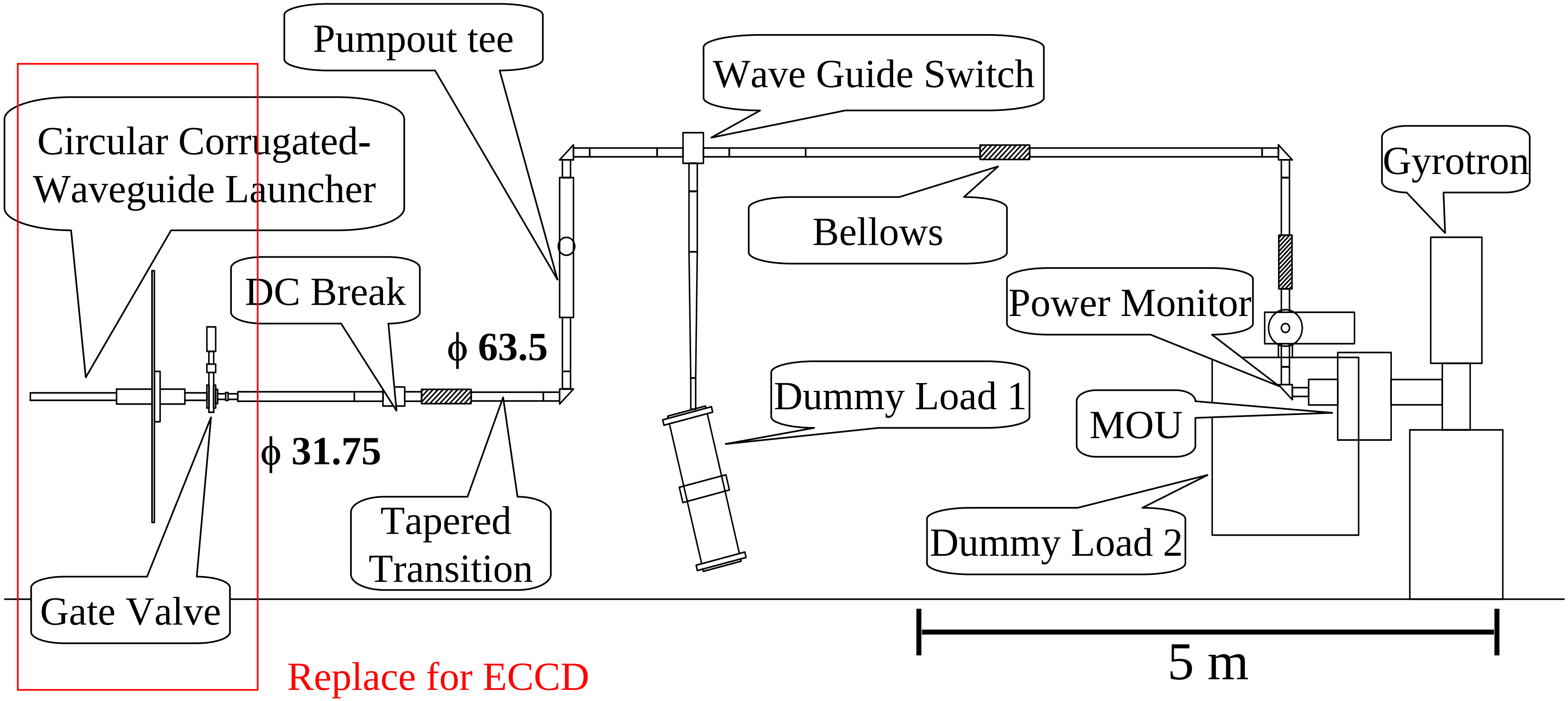

- **A new launcher system should be installed to carry out the ECCD experiments.**

Antenna System for the TRIAM-1M tokamak (I)

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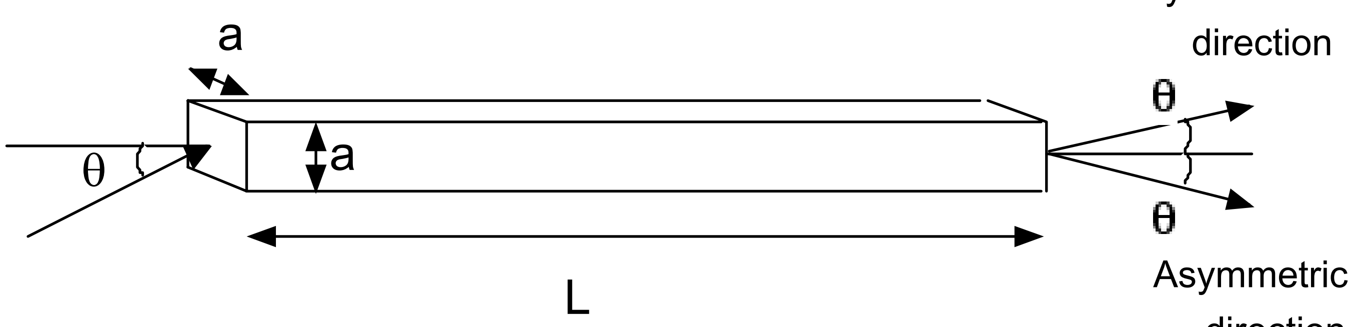
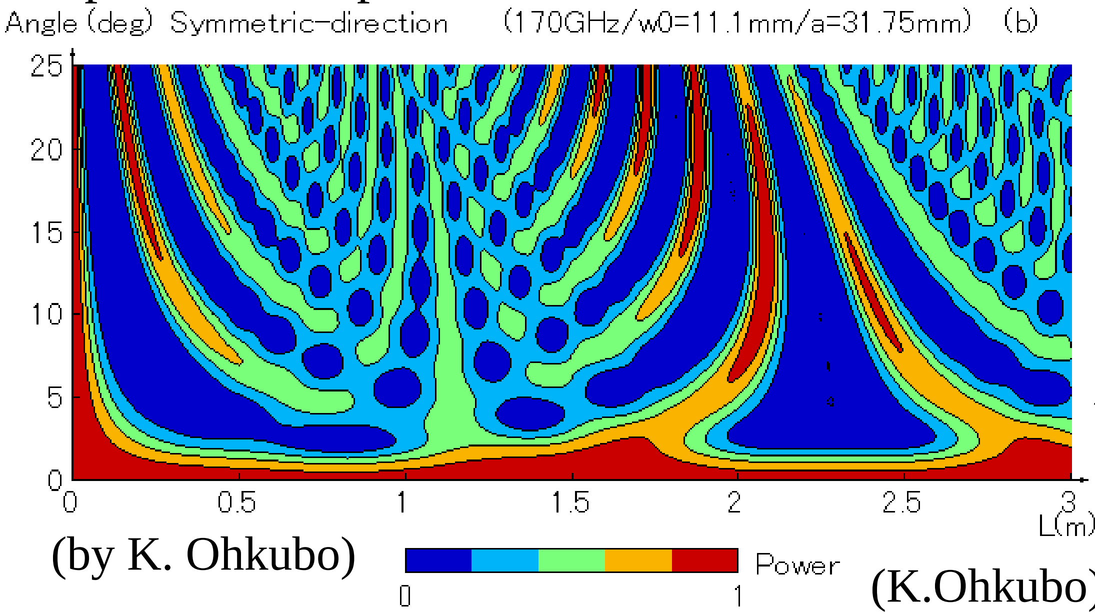


Dependence of power fraction on *θ* and *L* :



(by K. Ohkubo) (K.Ohkubo)

Symmetric direction antenna
Frequency : 170GHz
a : 31.75mm

$E_\perp$: perpendicular field to steering plane

Power fraction
$= P_{out} / P_{in}$

Antenna System for the TRIAM-1M tokamak (II)

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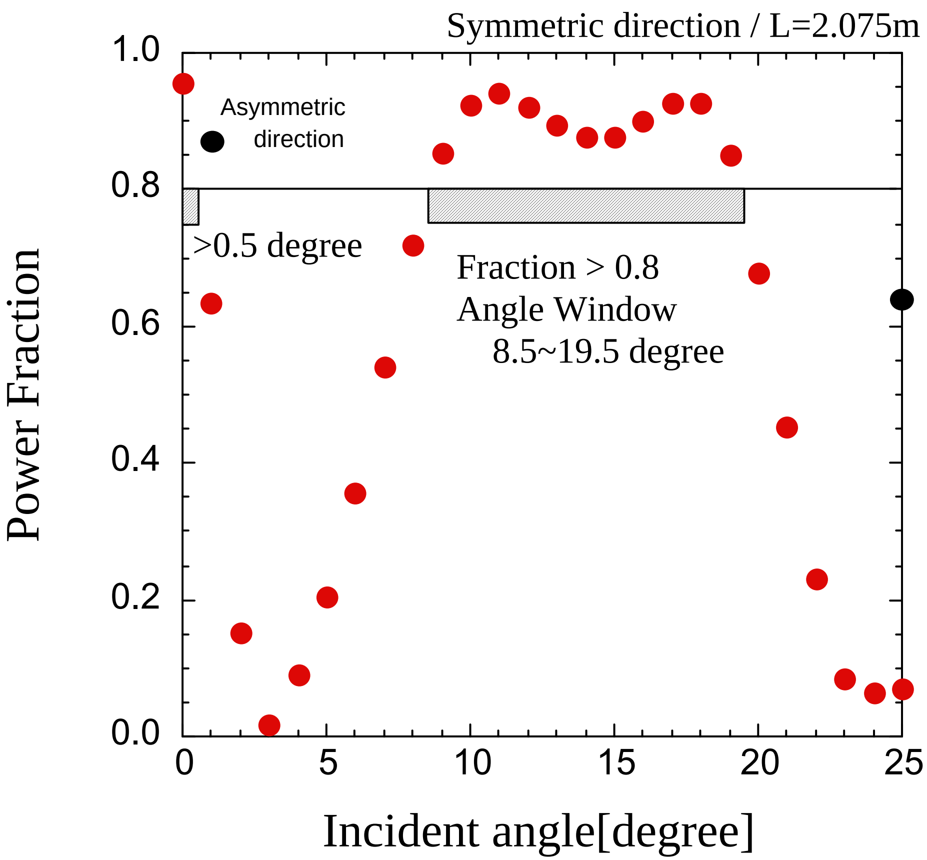
$E_\perp$: perpendicular field to steering plane



For the ECCD experiments, it will be operated as a symmetric direction antenna with a steering capability of 9-19 degrees.

It is also designed to work for the ECH experiments with the perpendicular injection to the magnetic field.

Antenna System for the TRIAM-1M tokamak (III)

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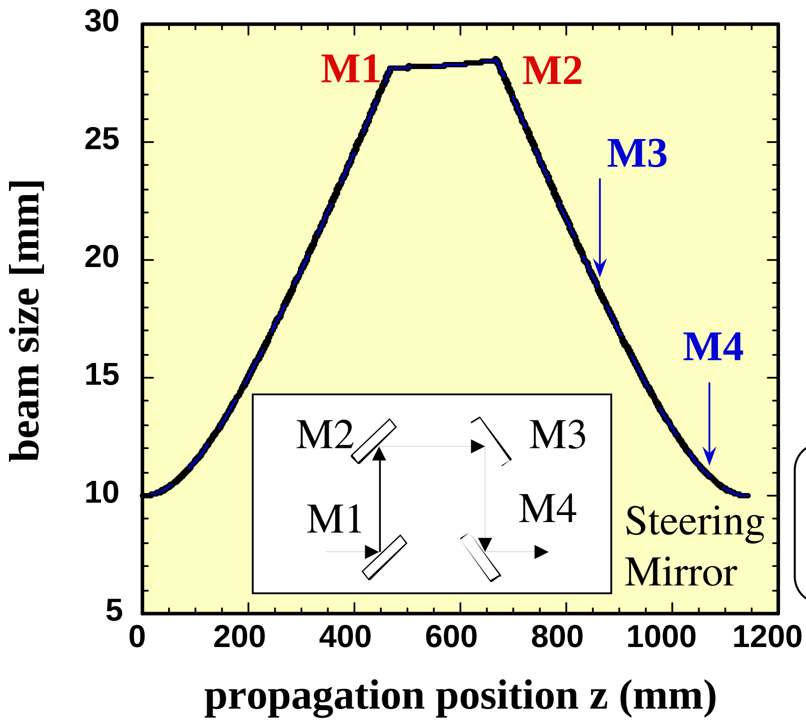
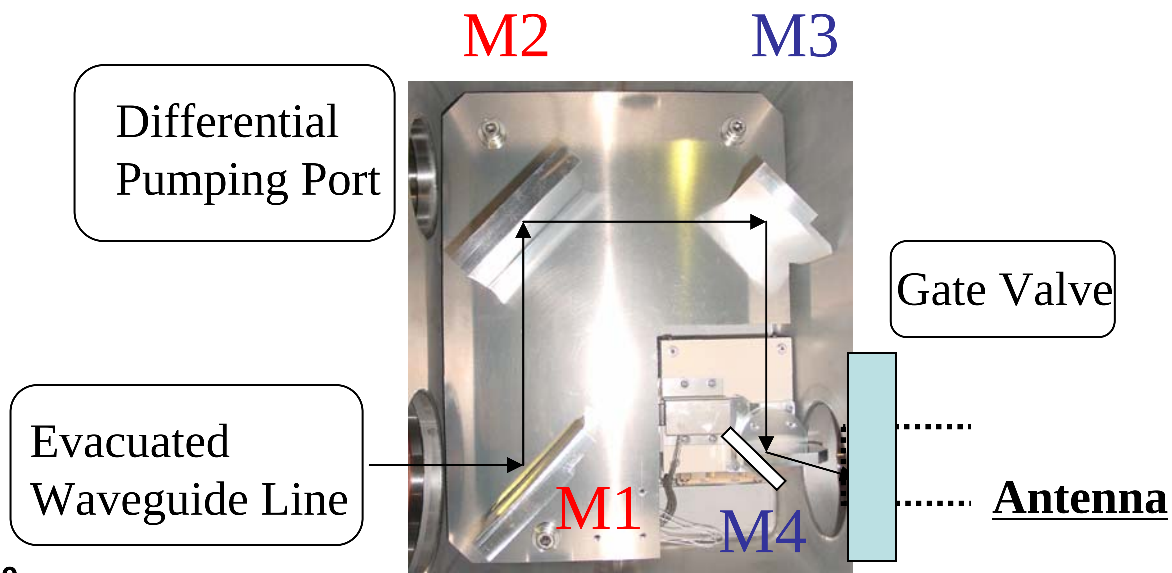
Matching Optics Unit for Antenna





In order to locate this MOU section in the existing transmission line with small modification, a mirror array system composed of four mirrors is adopted.

Antenna System for the TRIAM-1M tokamak (IV)

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Circular Corrugated Waveguide Antenna

Square Corrugated Waveguide Antenna (Remote Steering Antenna)

The new antenna is made of Aluminum, and the aluminum welding technique is used to evacuate the antenna and to make a water-cooling channels.

The power loss at the antenna is evaluated from increased temperature of the cooling water.

Tests of Antenna System

---- *Low power level* ----

---- *High power level* ----

Low power test stand

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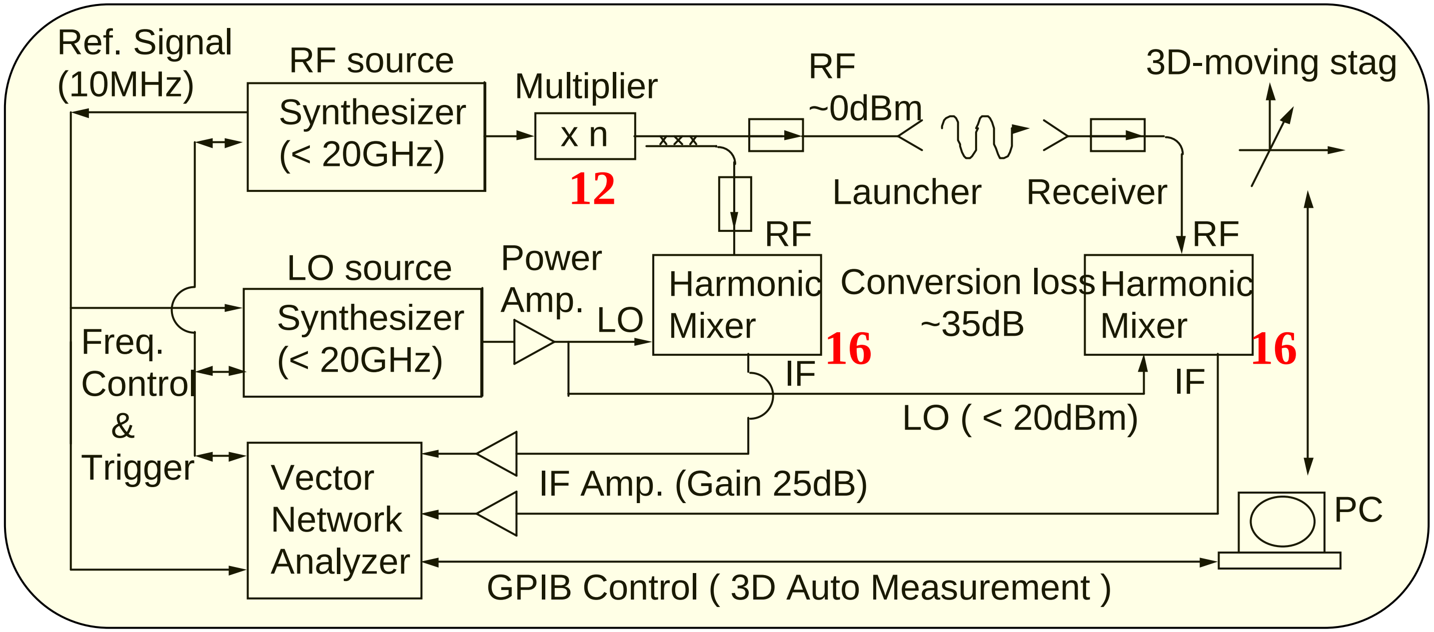

High spatial resolution <== three dimensional moving stage at the receiving part .
(~ λ/100 at 100GHz)
High frequency stability <== two synthesizers for RF and LO sources.

The intensity ratio and the phase difference at both of the launcher and the receiving sides are detected at the vector network analyzer.

Low power test for MOU

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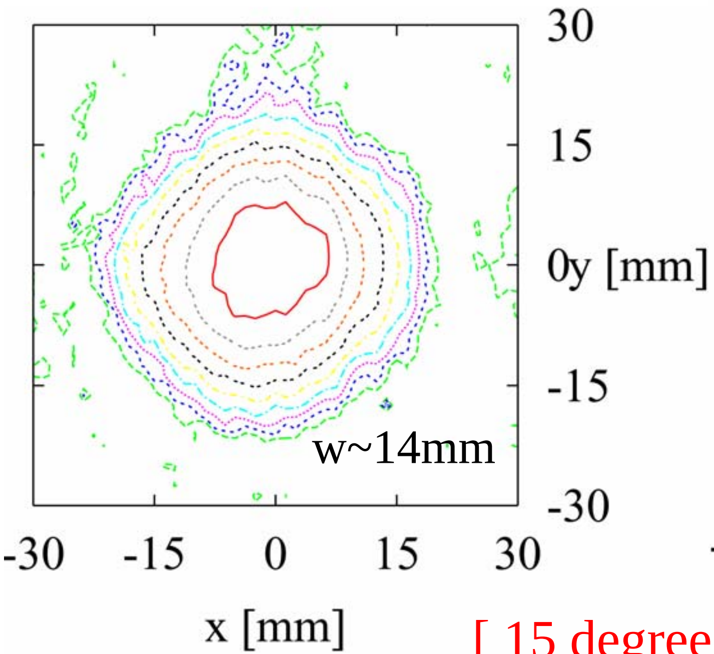
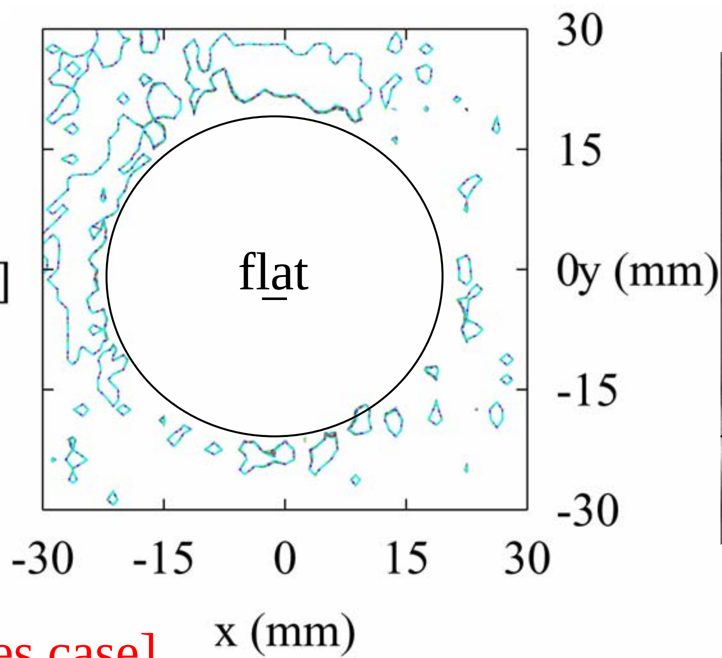
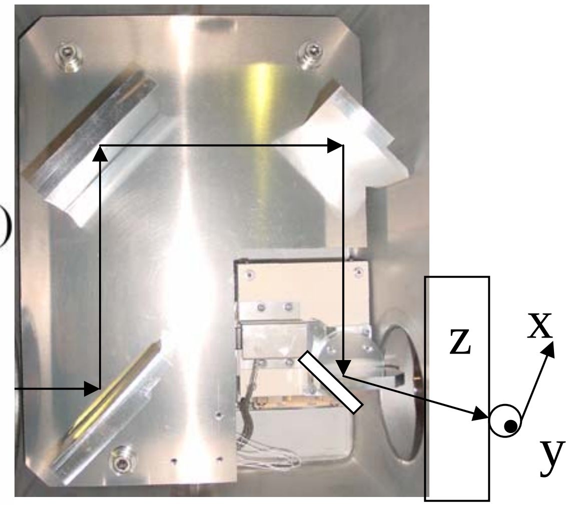
Intensity [by 3dB step]



Phase [by 0.5 rad. step]



[15 degrees case]



Detector stage was rotated according to the steering angle.

It was confirmed that the incident beam is preferable even in 17.5 degrees case, as designed.

Low power test for Antenna [Output Intensity Pattern]

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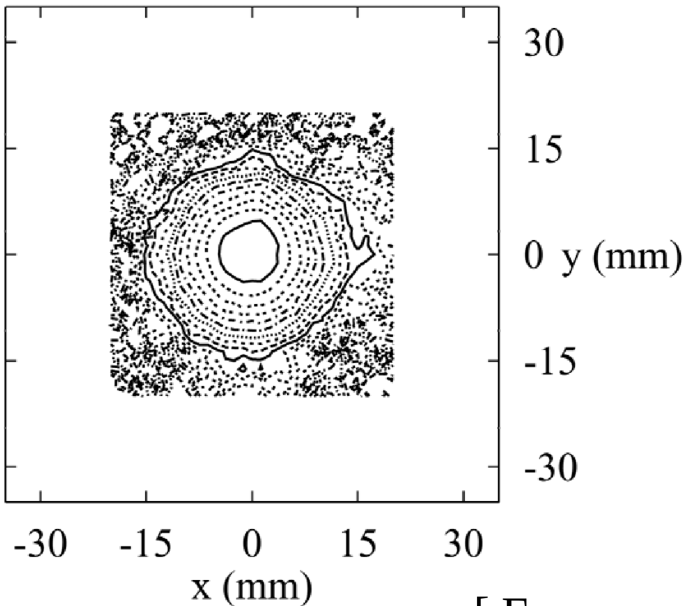
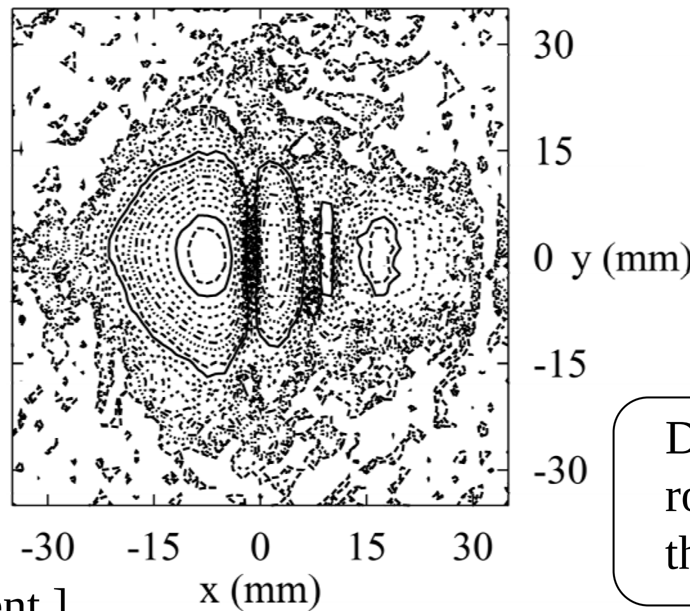
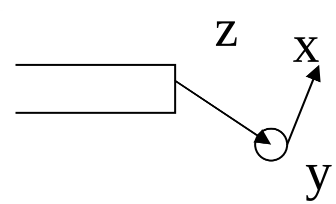
0 degrees [by 2dB step] 5 degrees





[Ex component]



at z=50mm

Detector stage was rotated according to the steering angle.

<u>The pattern in the 0 degrees case shows circular Gaussian beam, but that in the 5 degrees is deformed, and has beam center offsets and side lobes.</u>

Low power test for Antenna [Radiated Angle]

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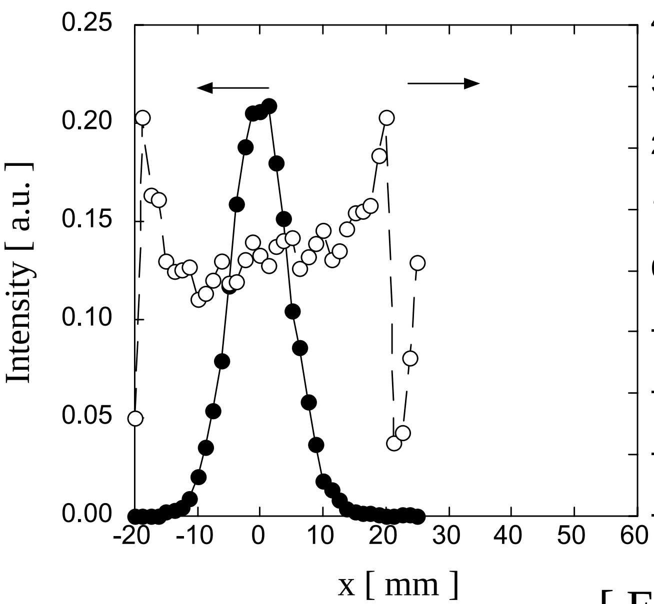
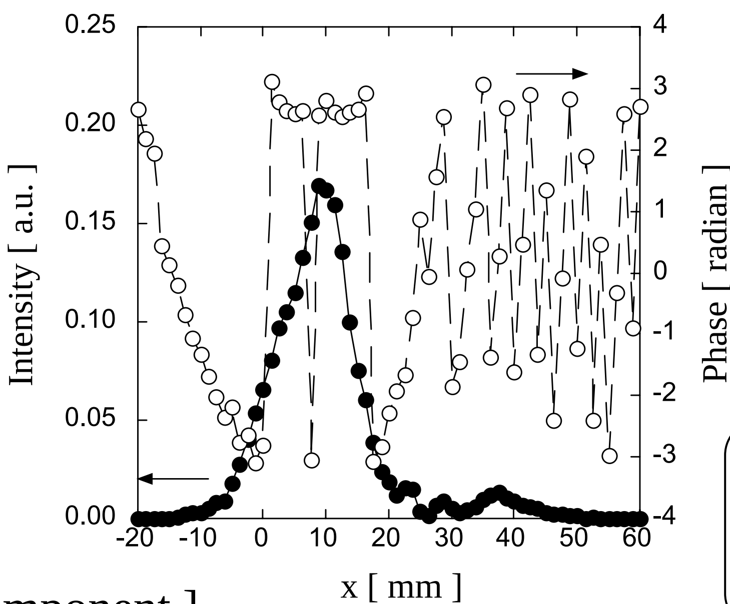
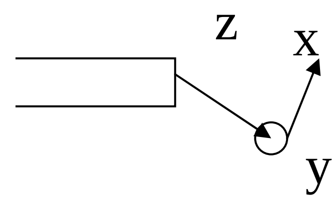
0 degrees



15 degrees



[Ey component]



at z=50mm

Detector stage was rotated according to the steering angle.

The phase profiles are flat near the beam centers in both cases.
That means the beam propagates along the *z*-axis.
The output direction of the beam corresponds to the incident steering angle.

Power Fraction *Pout/Pin* at Low and High power tests

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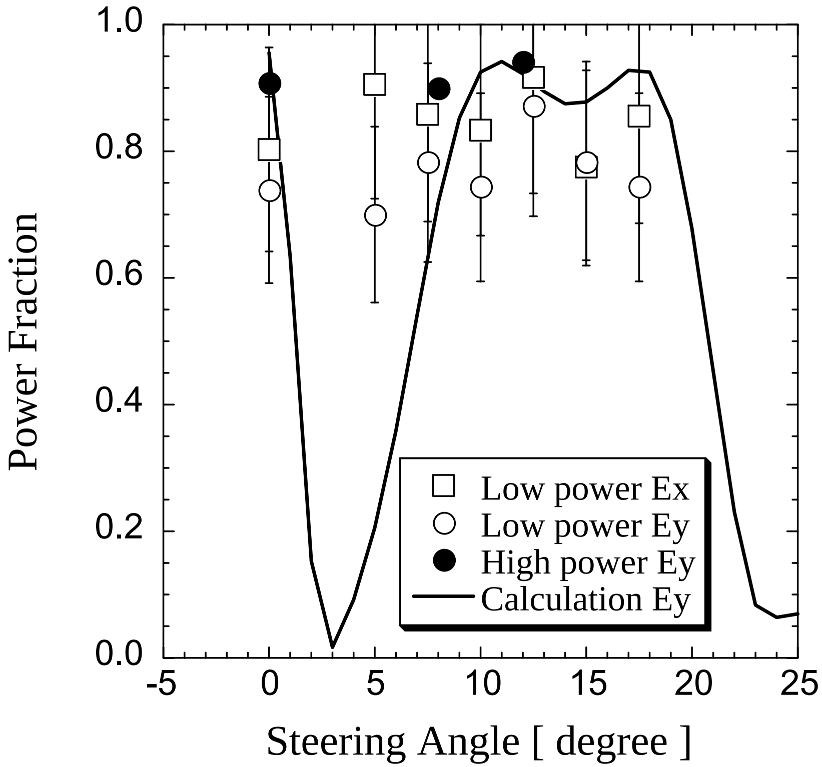
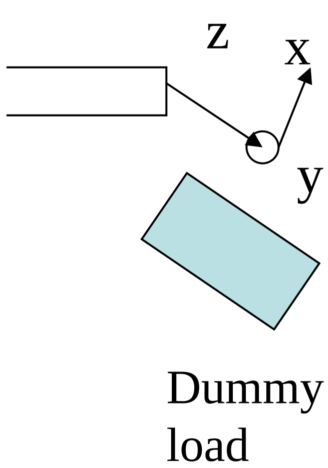


To evaluate the fraction, the intensity patterns are integrated in the *x-y* plane at the low power test.

Since the 2 D measurements of the intensity patterns took a long time, there was a thermal drift in an IF amplifier with +/- 0.5dB.

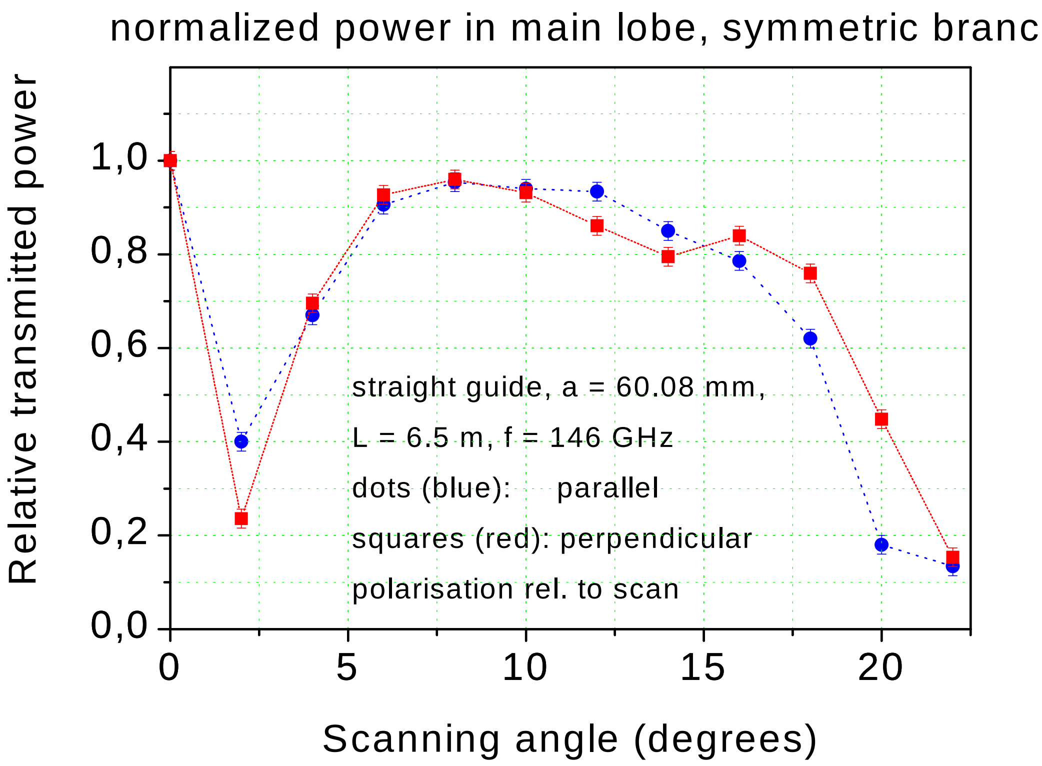
A dummy load was connected befere or after the antenna to evaluate the fraction at the high power test.



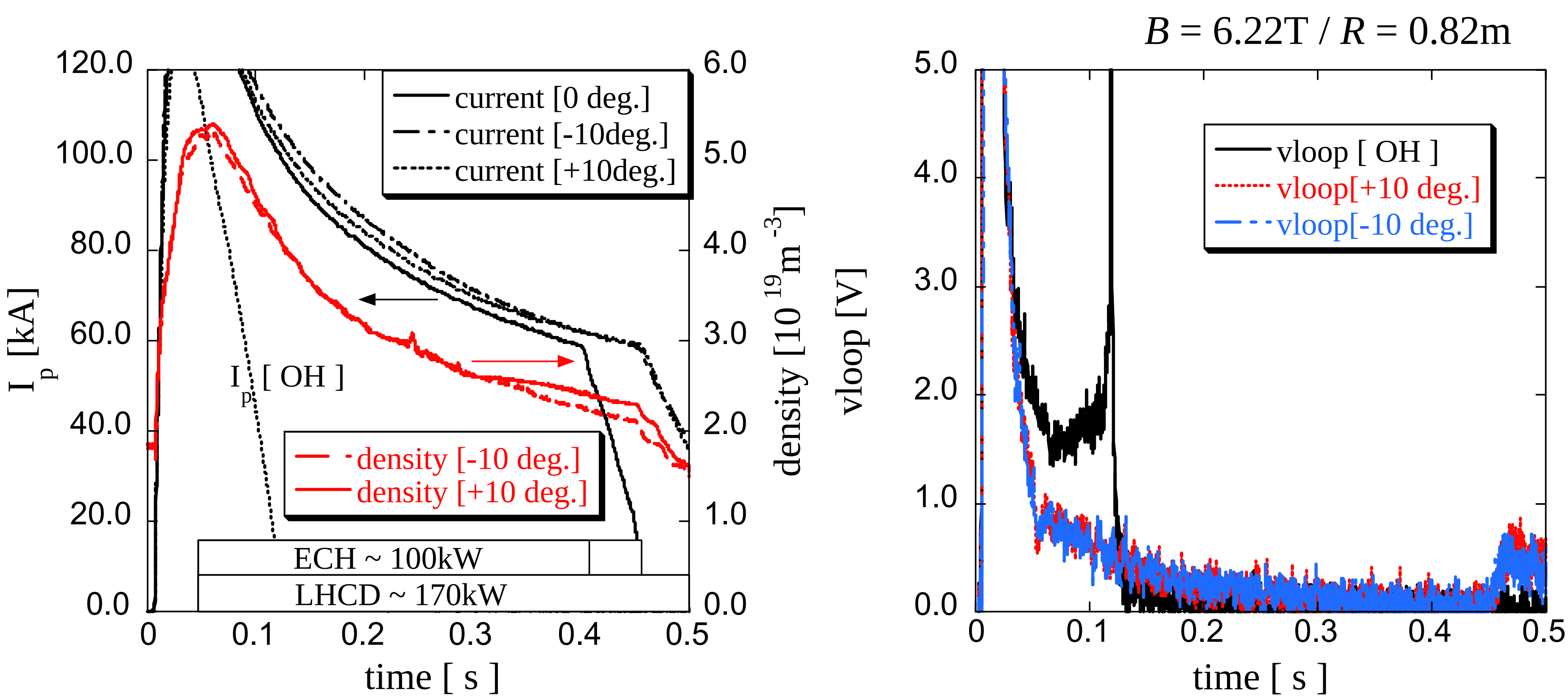
It is noted that the fractions of output to input powers at the antenna near 5 degrees are calculated as low, provided that the TEM00 mode is only taken into account.

Low Power Test Results at Stuttgart University (W. Kasparek et al.)

[Far Field Measurement]



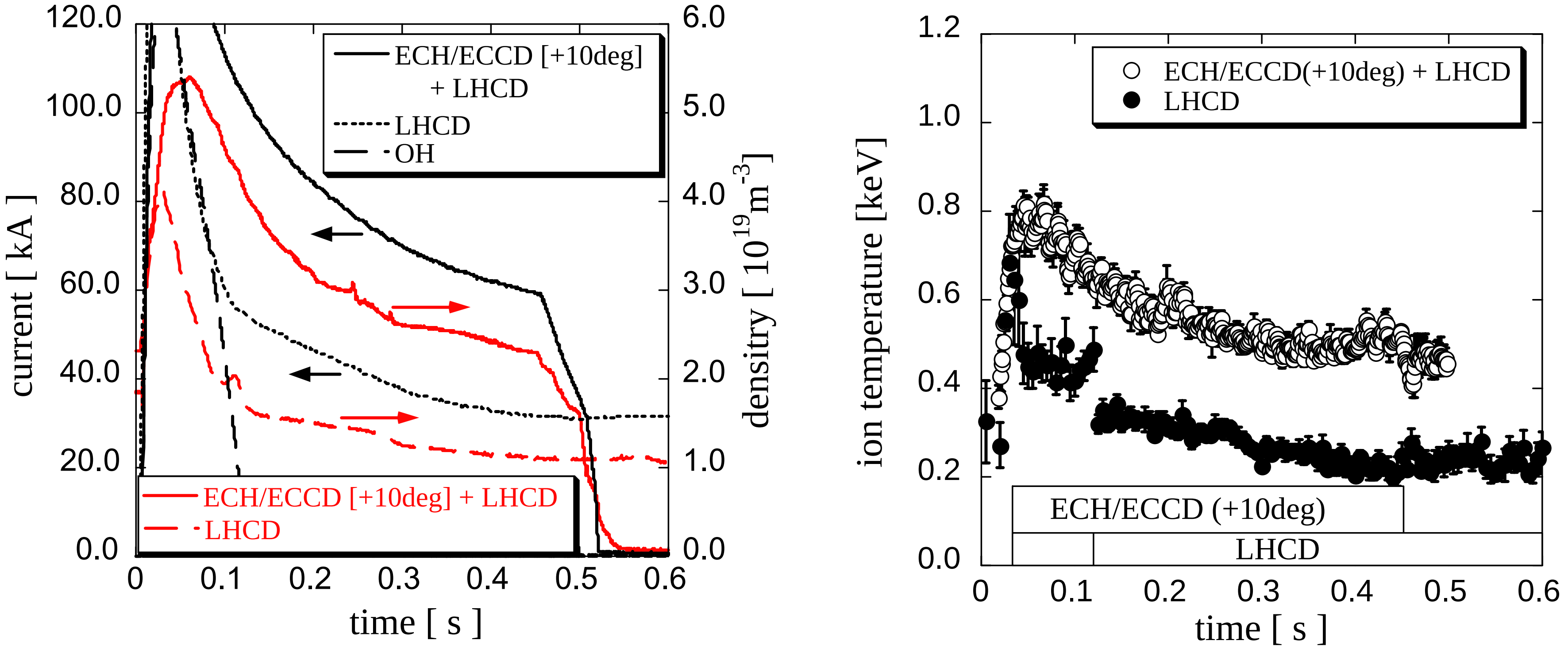
Preliminary Results of ECH/ECCD Experiments



With the EC wave, the loop voltage decreases and the current was sustained.

There is not clear dependence of the current on the incident direction, that is, the sign (+/-) of the steering angles.

The Lower Hybrid wave also is injected, but it can not sustain the plasma current without the EC wave in this case.



The density and ion temperature with ECH were two times higher than those without ECH. They with ECH are comparable to those observed in an improved mode on the current drive efficiency at the LH current drive experiment.

Summary

A remote steering antenna was designed and fabricated for the ECH/ECCD experiments on the TRIAM-1M tokamak.

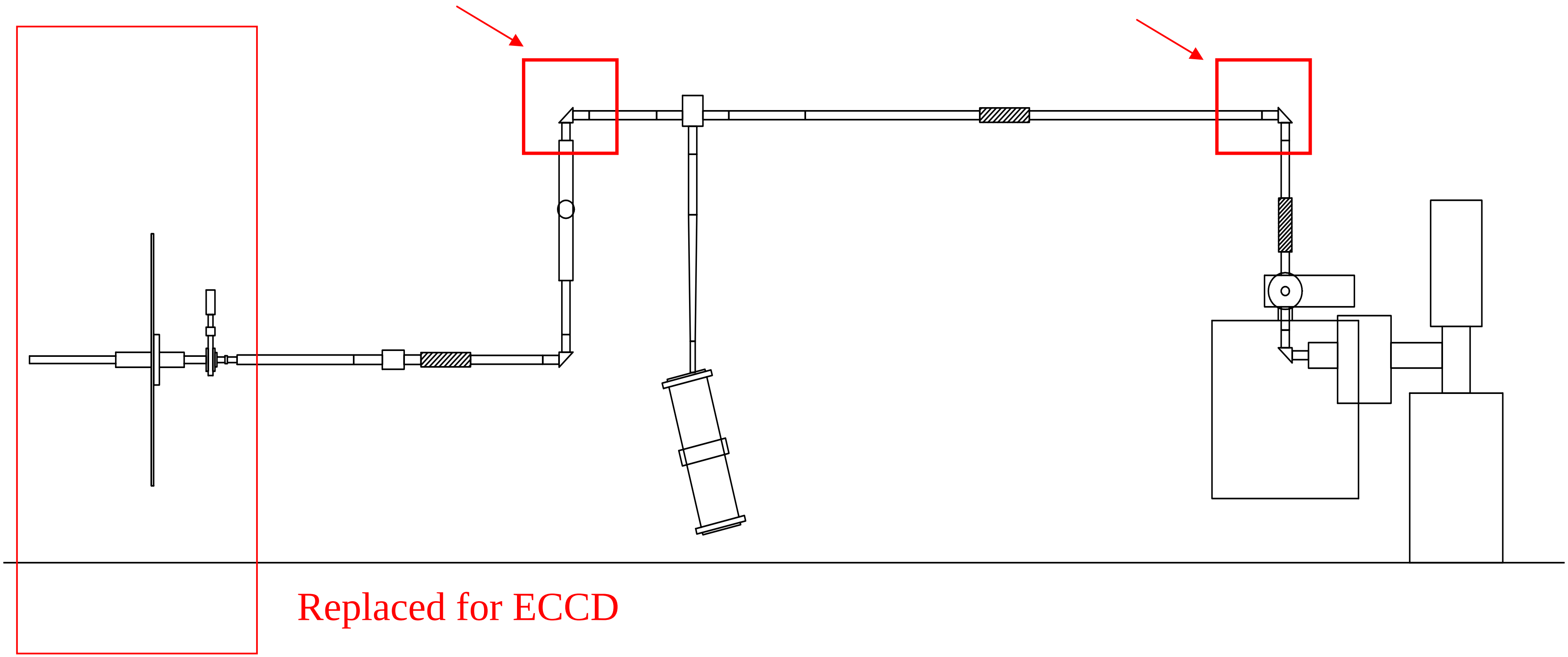
The antenna was designed as a symmetric direction antenna in the extended operating region.

The output angle was checked from the intensity and phase measurements in the low power test.

The fraction was measured in both of the low and high power tests.

The antenna was evaluated to work correctly.

The ECH/ECCD was effective to sustain the high plasma current, density and ion temperature, but there is no clear dependence on the incident direction.



Detailed experiments to confirm the effect of ECCD are planed after installation of polarizers to optimize of incident polarization.