QUESTにおける28 GHz 入射によるプラズマ電流立ち上げ・維持実験の現状と展望

出射　浩

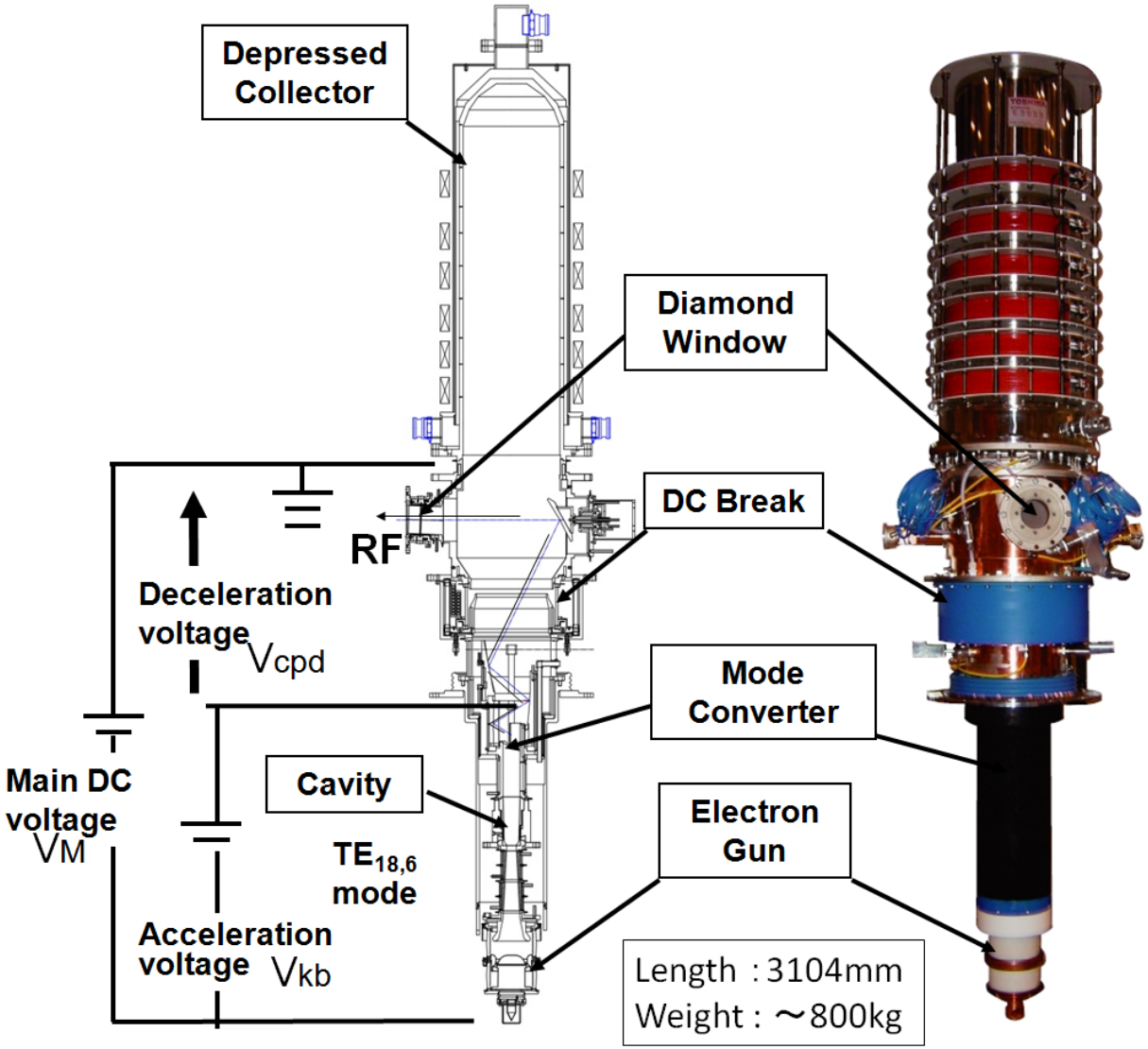
2011-2016:　ジャイロトロン管運転に向けた周辺機器の整備と初期実験（66 kA 電流の達成）

2015-2016　局所加熱・電流駆動システム整備と実験（70kA を 140 kW 入射で実現）

2017-:　大電力ジャイロトロン管CW発振に向けた整備
【1MW 入射を目指して】
【CW入射を目指して】

Gyotron Development at University of Tsukuba [28GHz]
【High Power mm-Wave Source】

QUEST Advanced Fusion Research Center



28 GHz gyrotron has been developed for Gamma-PDX projects at Tsukuba University by themselves.

Bi-directional collaboration among National Institute for Fusion Science (NIFS), Univ. of Tsukuba and Kyushu Univ. has been begun since 2011.

28 GHz　ジャイロトロン管システム

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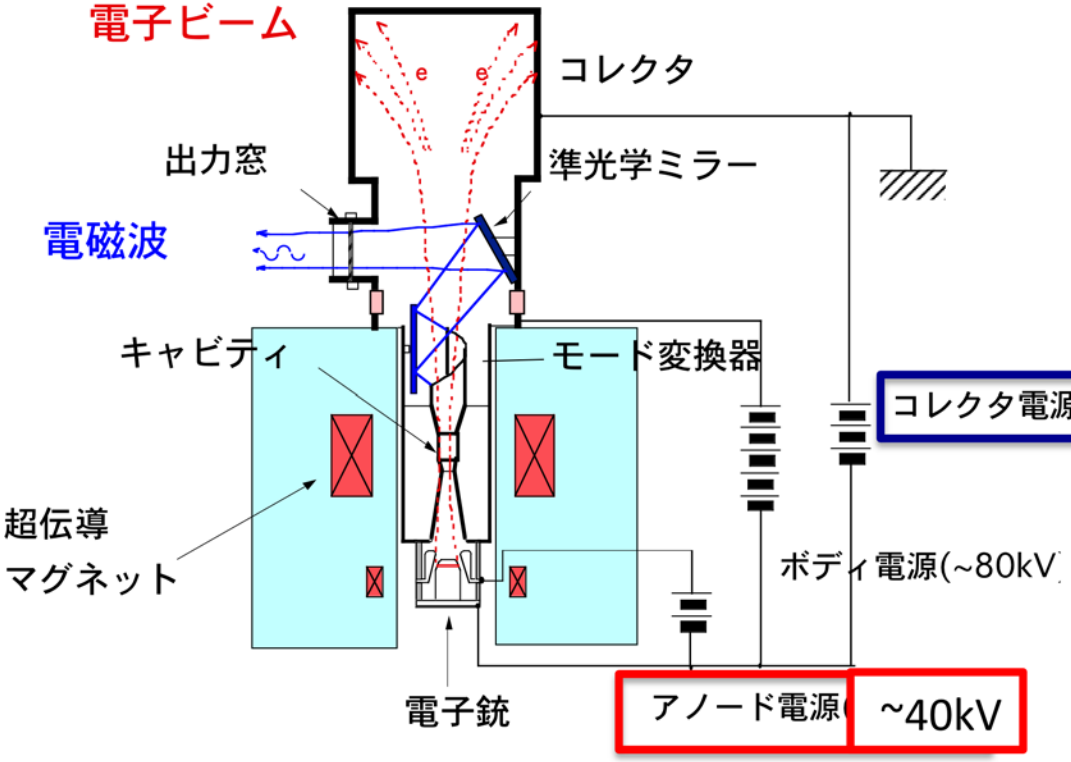


50 kV商用電源と
高電圧・高速
スイッチを準備

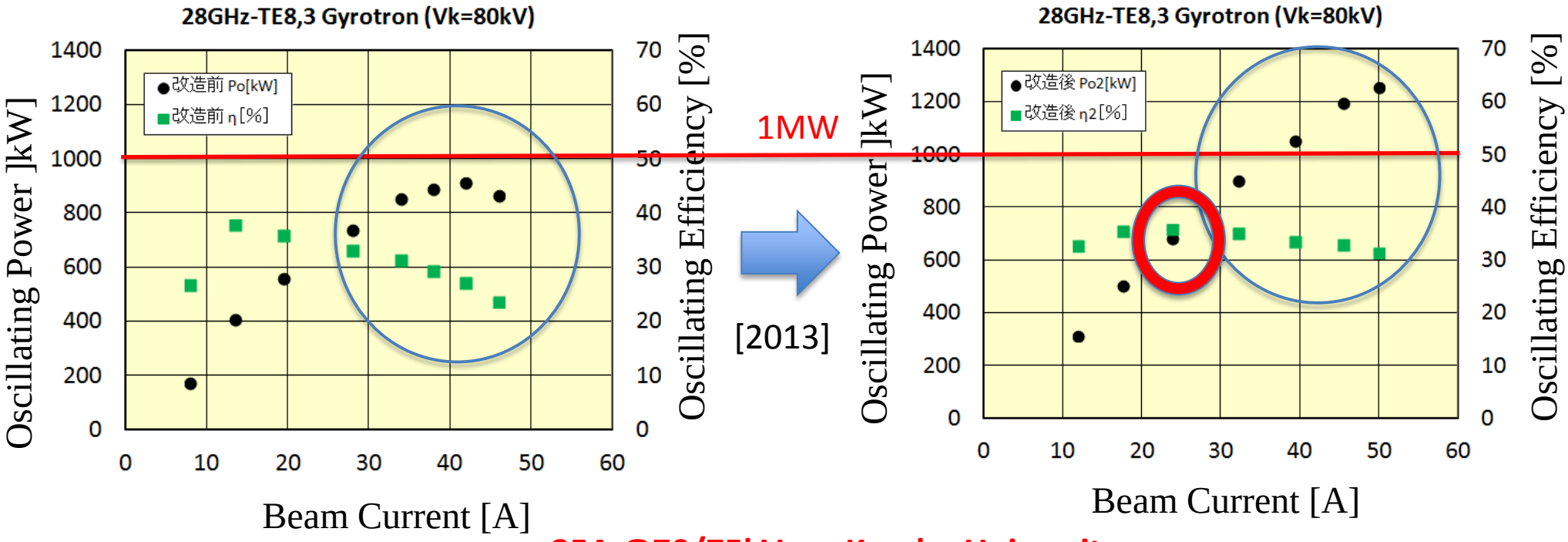
<u>九大で筑波大学 28GHz ジャイロトロン
を運転するために必要な要素</u>

- コレクタ電圧・電流の制限
- ジャイロトロンタンク
- アノード電源部（電源、スイッチング、
  インターロック）の整備

Gyotron Development at Tsukuba University [28GHz]

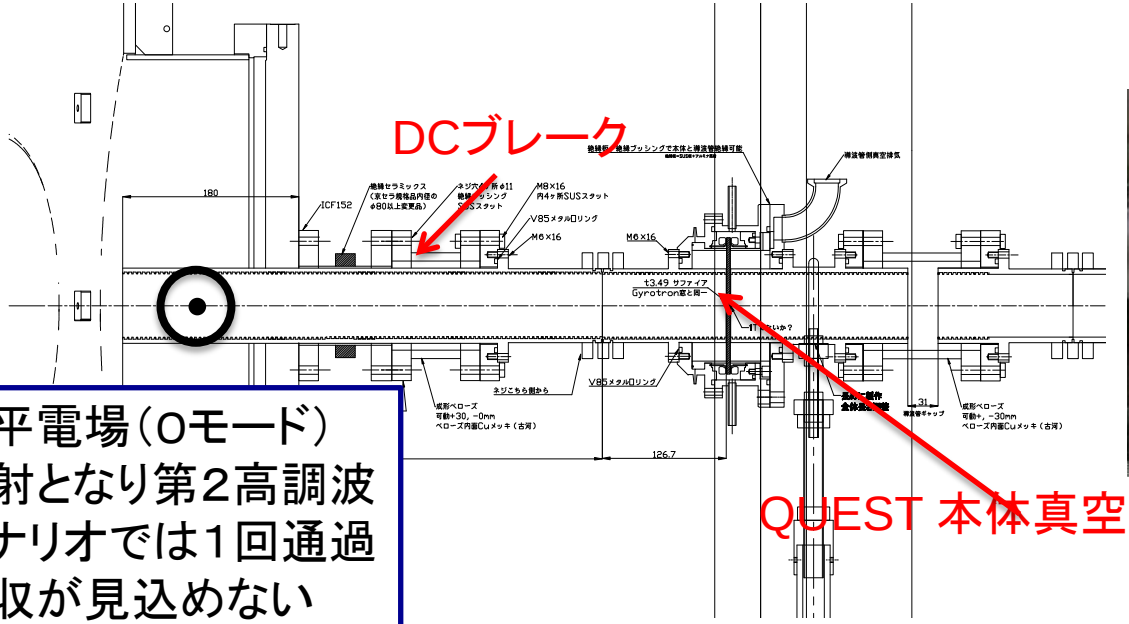
【High Power mm-Wave Source】

QUEST Advanced Fusion Research Center

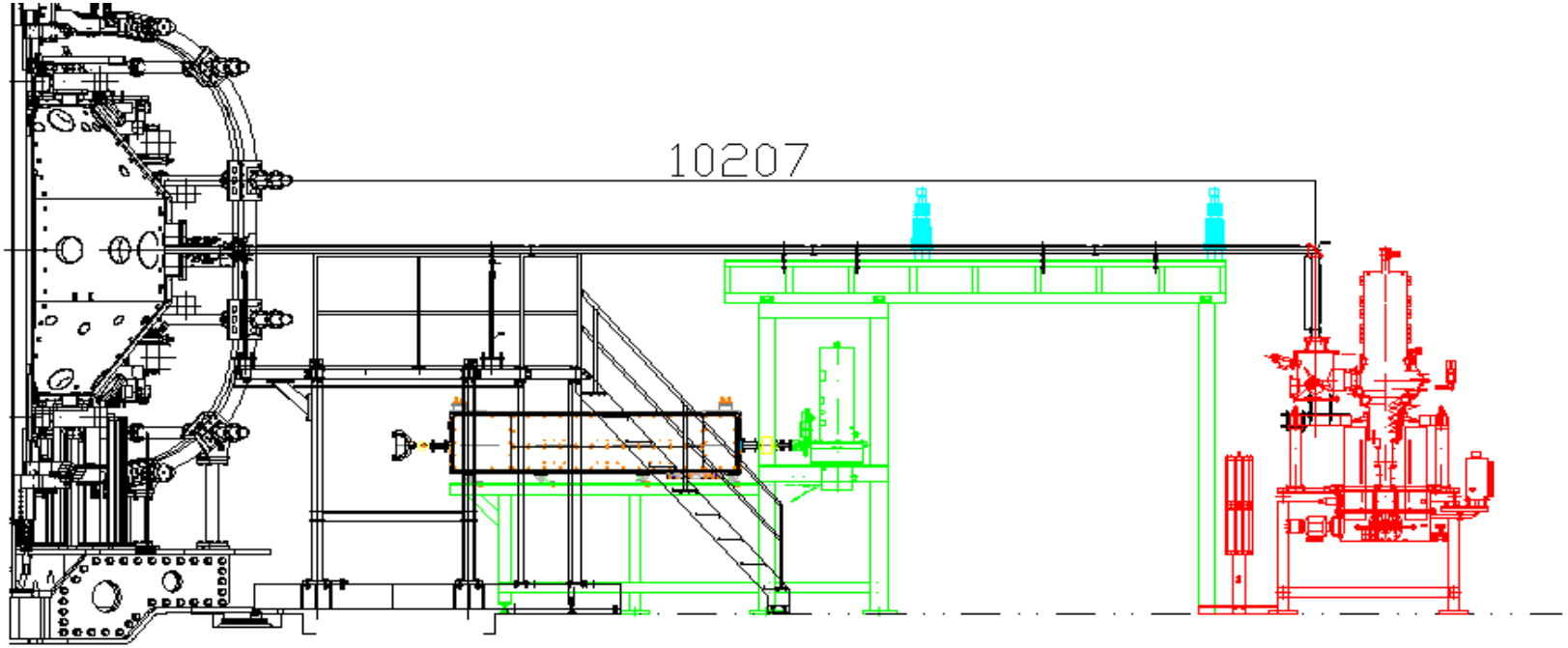


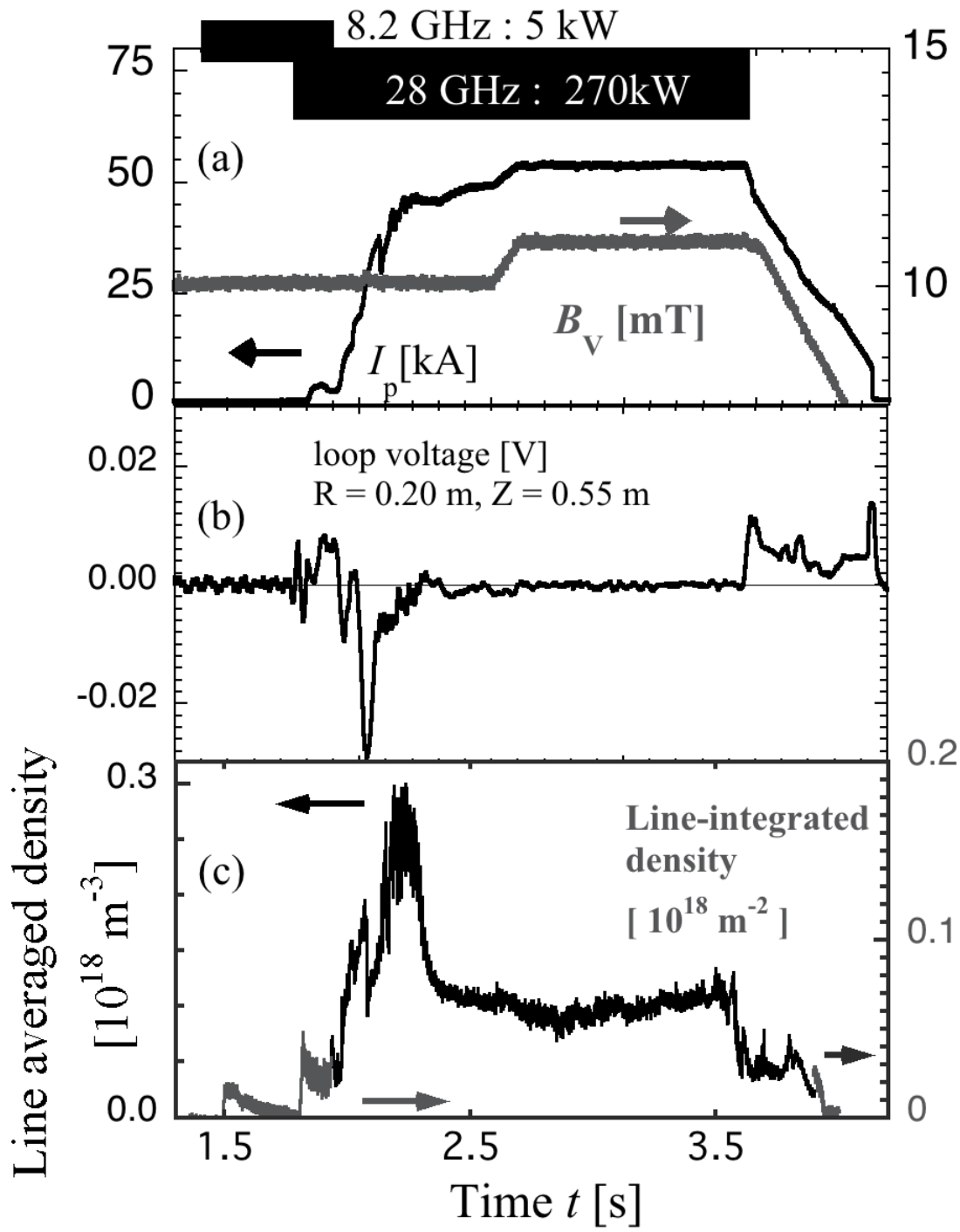
25A @70/75kV ---- Kyushu University

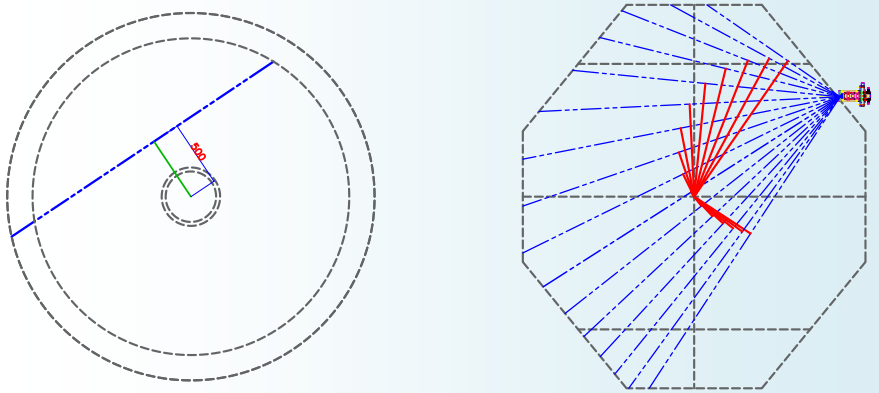
600 kW power level is available for 2s injection.
The oscillating efficiency is improved to attain more than 1MW output.

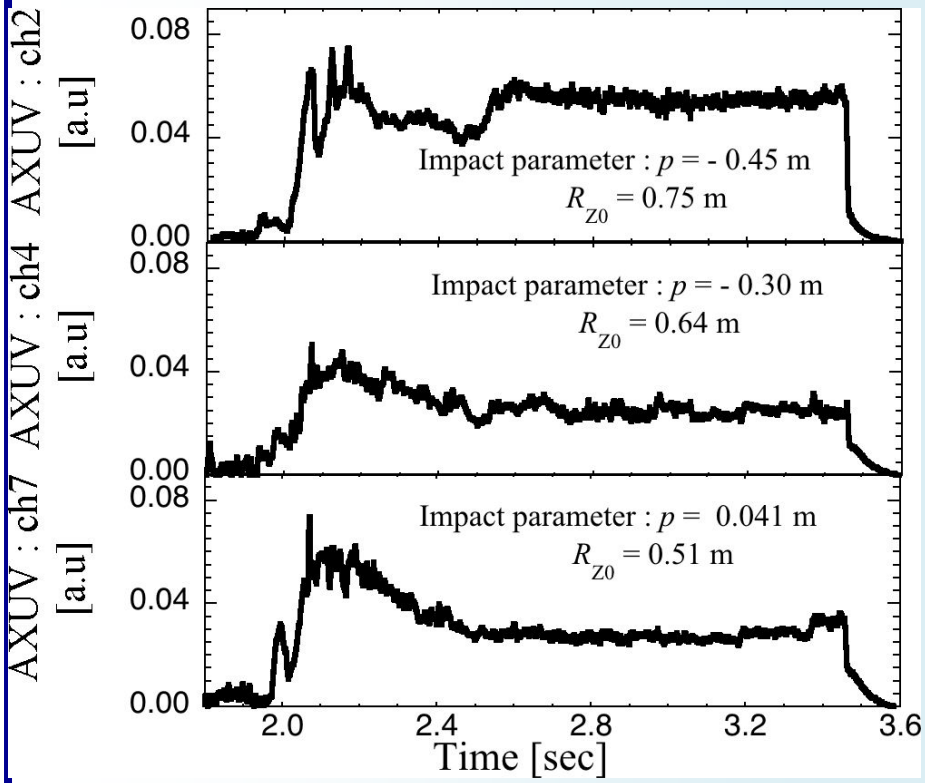


水平電場（0モード）
入射となり第2高調波
シナリオでは1回通過
吸収が見込めない

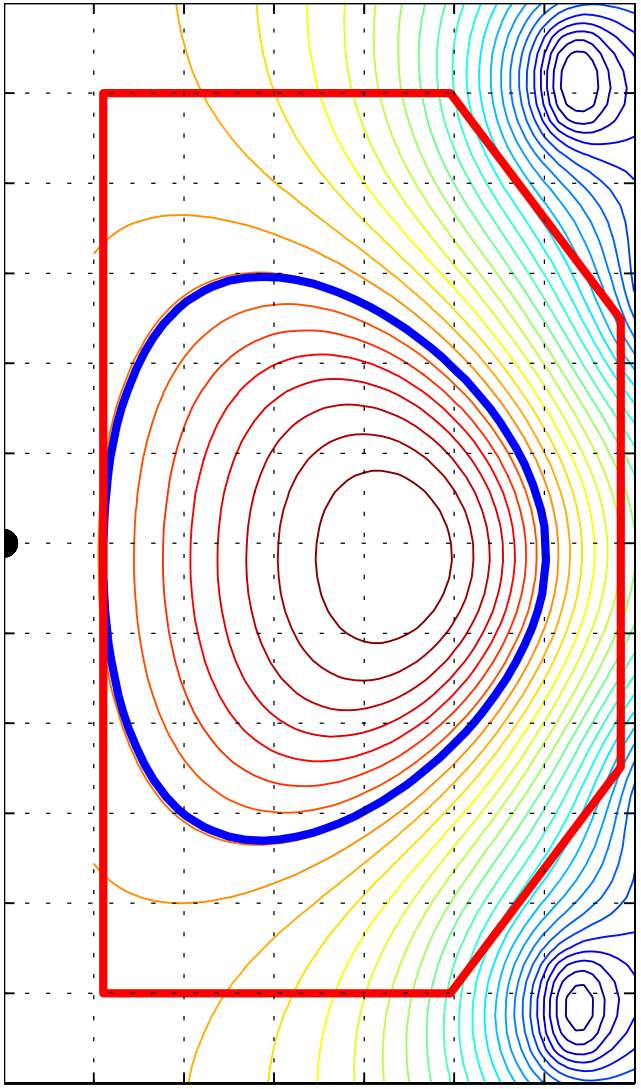


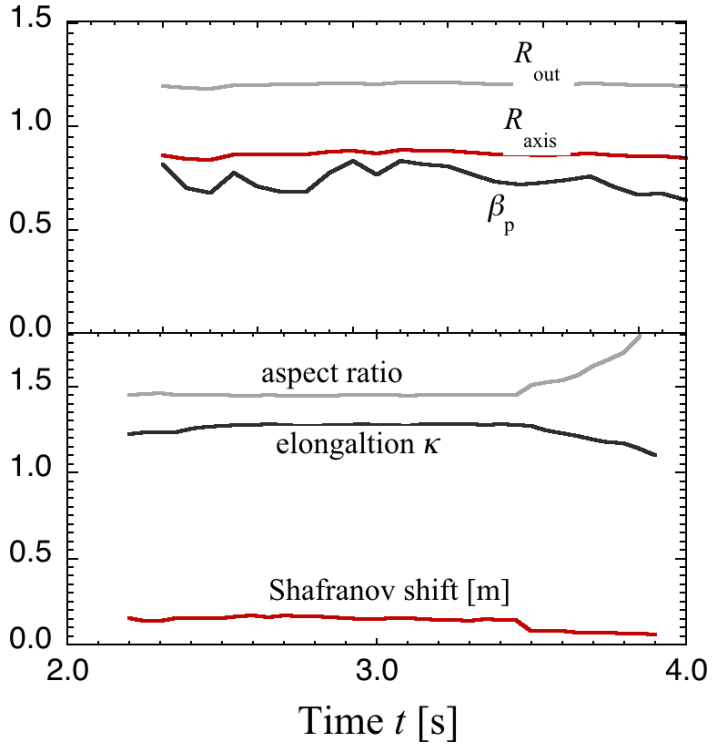

8.2 GHz : 5 kW
28 GHz : 270kW
(a)
B_V [mT]
I_p[kA]
loop voltage [V]
R = 0.20 m, Z = 0.55 m
(b)
(c)
Line-integrated density
[10^{18} m^{-2}]
Line averaged density
[10^{18} m^{-3}]
Time t [s]

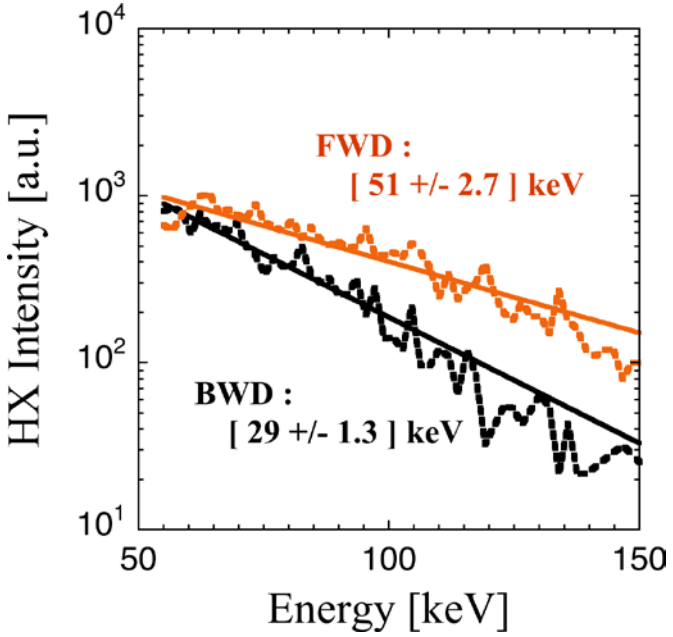



AXUV : ch2
AXUV : ch4
AXUV : ch7
[a.u]
Impact parameter : p = - 0.45 m
R_{Z0} = 0.75 m
Impact parameter : p = - 0.30 m
R_{Z0} = 0.64 m
Impact parameter : p = 0.041 m
R_{Z0} = 0.51 m
Time [sec]

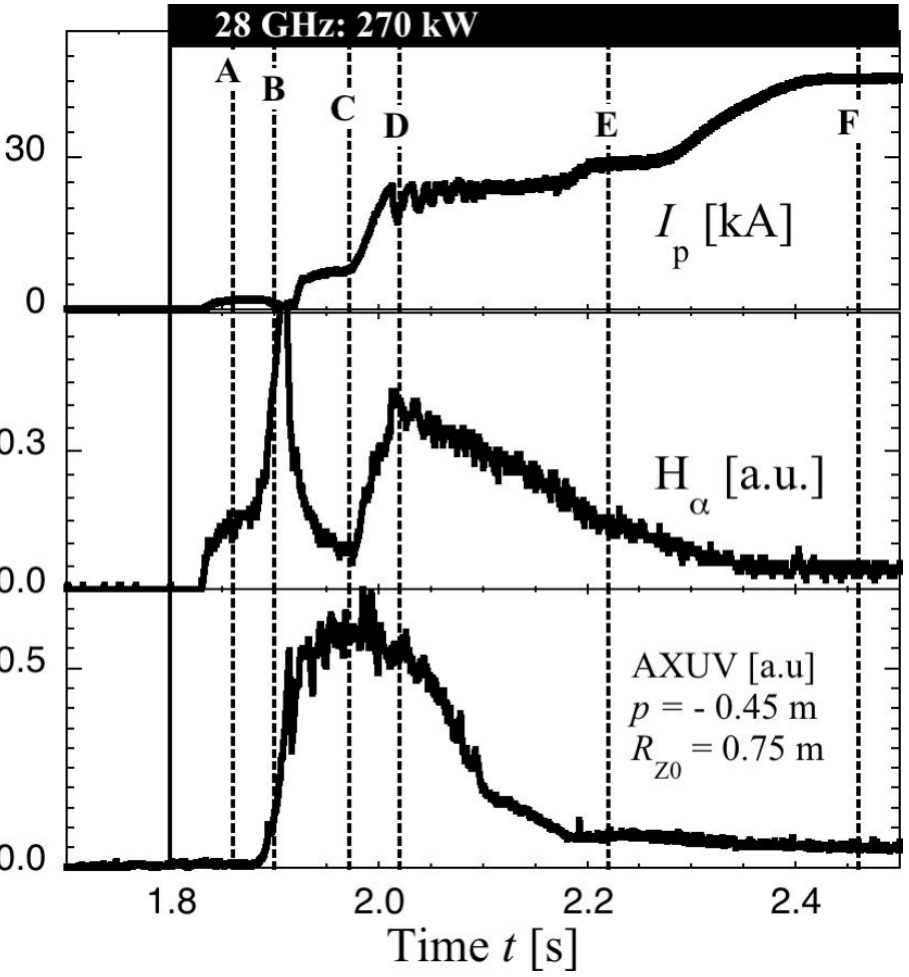
EFIT 解析

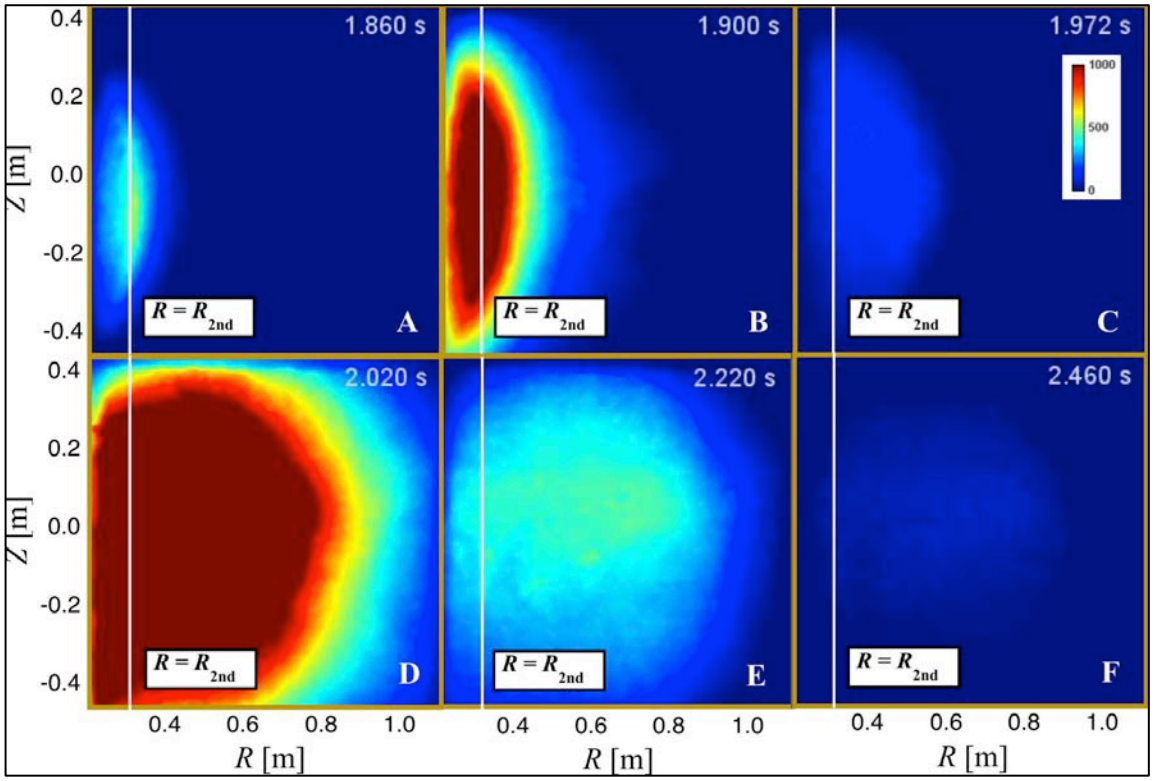


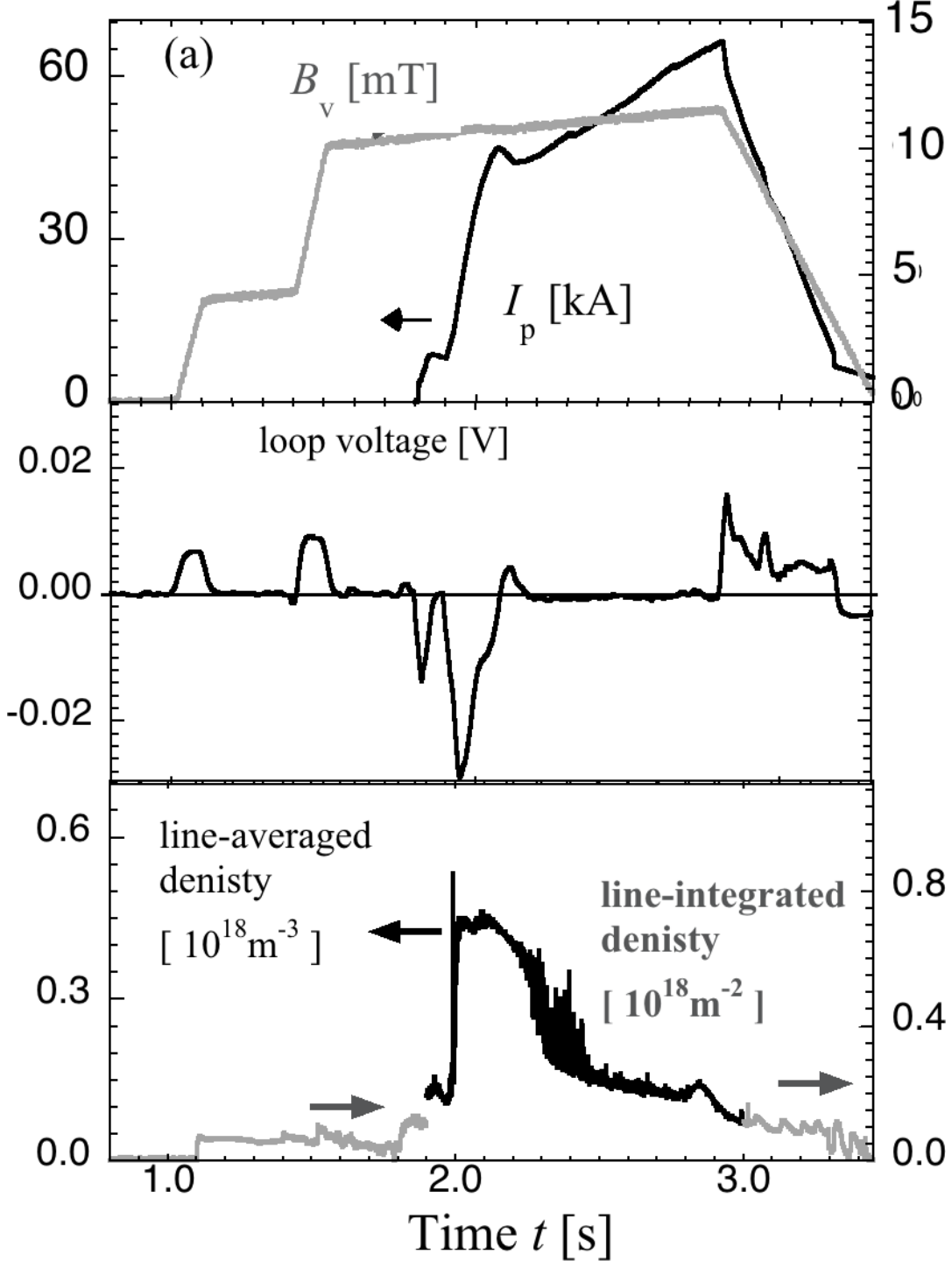

1.5
1.0
0.5
0.0
R_{out}
R_{axis}
β_p
aspect ratio
elongaltion κ
Shafranov shift [m]
2.0
3.0
4.0
Time t [s]


10^4
10^3
10^2
10^1
HX Intensity [a.u.]
FWD :
[51 +/- 2.7] keV
BWD :
[29 +/- 1.3] keV
50
100
150
Energy [keV]

28 GHz off-axis　第2高調波単独入射でも プラズマ電流立ち上げが可能

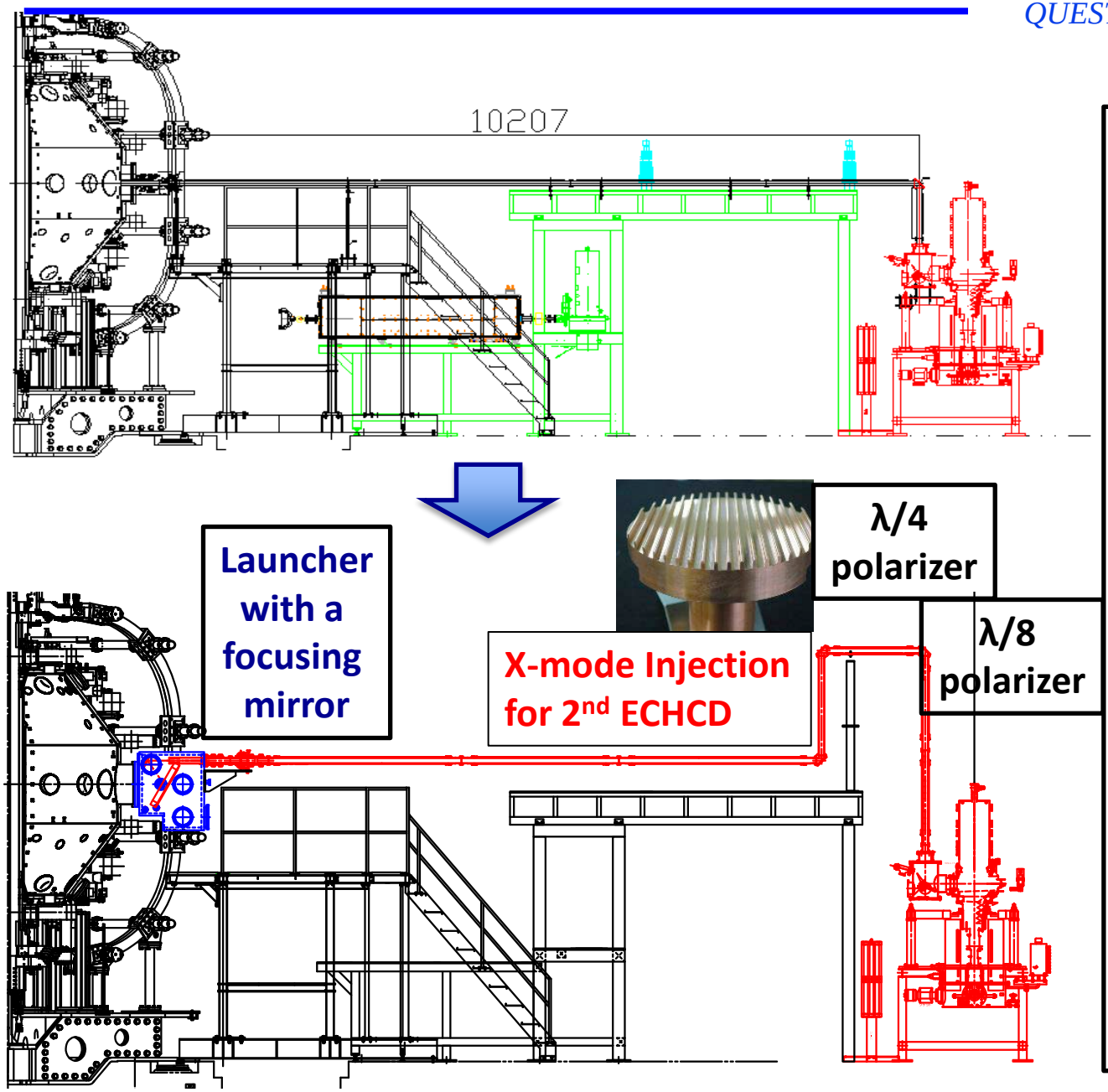






270 kW 入射：垂直磁場のランプアップで　非誘導プラズマ電流立ち上げに成功

Local ECHCD Non-inductive Plasma Startup



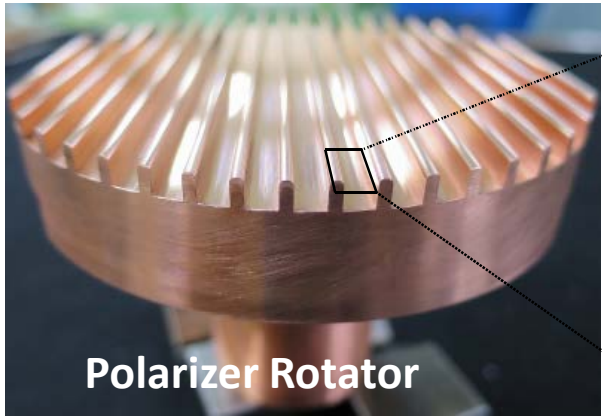
To realize the local 28 GHz ECHCD, there were two aspects.

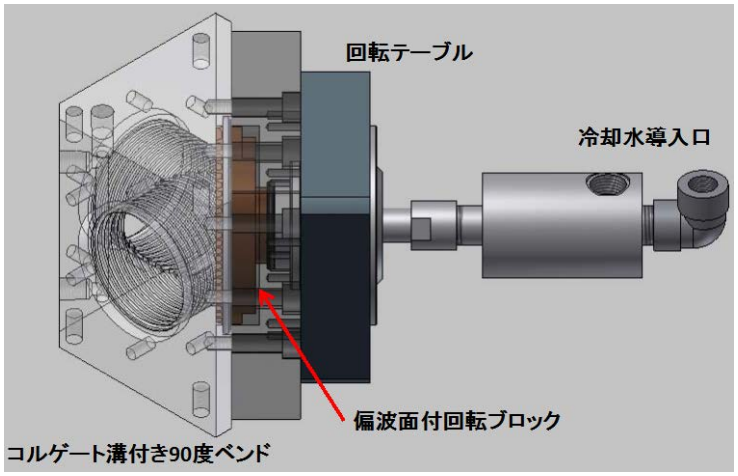
One is polarization control into a desired X-mode to obtain good single pass absorption, and the other is focusing of the launched field to obtain a narrow beam.

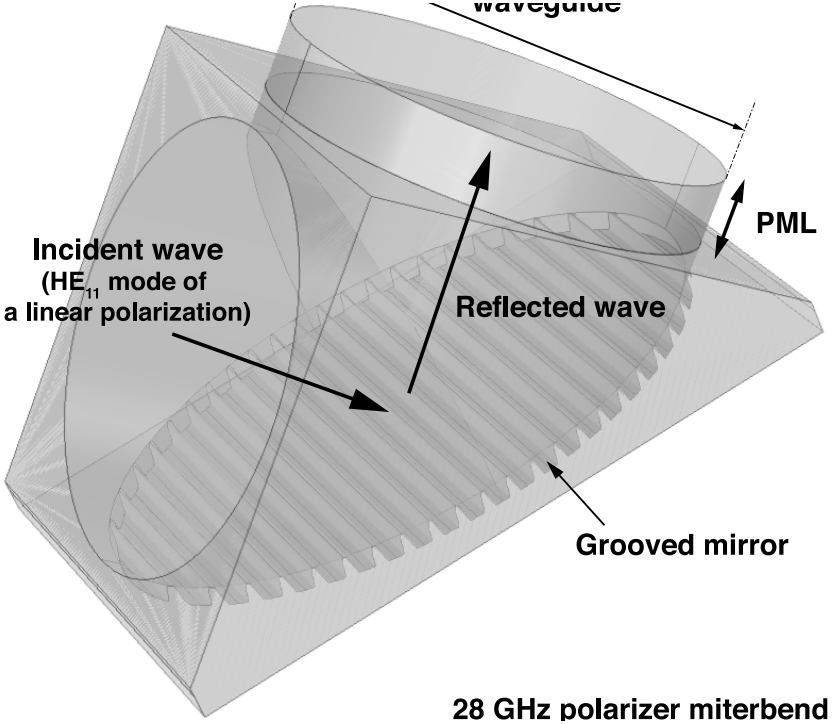
The elliptical polarization control was required for the X-mode oblique injections.

A new 28 GHz transmission line with polarizer / launcher systems has been designed and fabricated for local ECH/ECCD experiments.

Polarizer Development (NIFS)

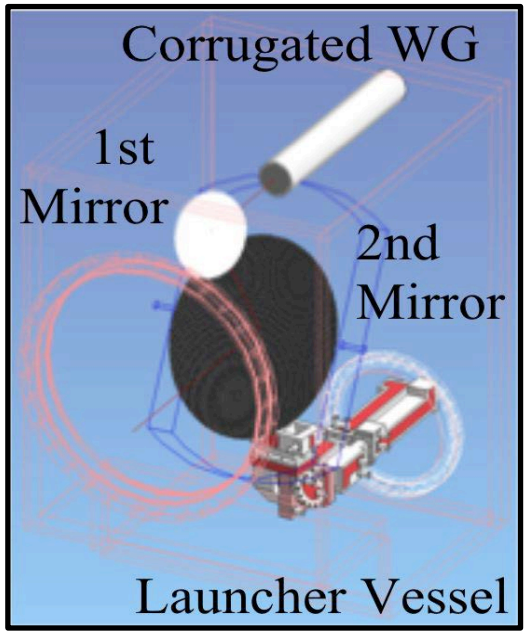




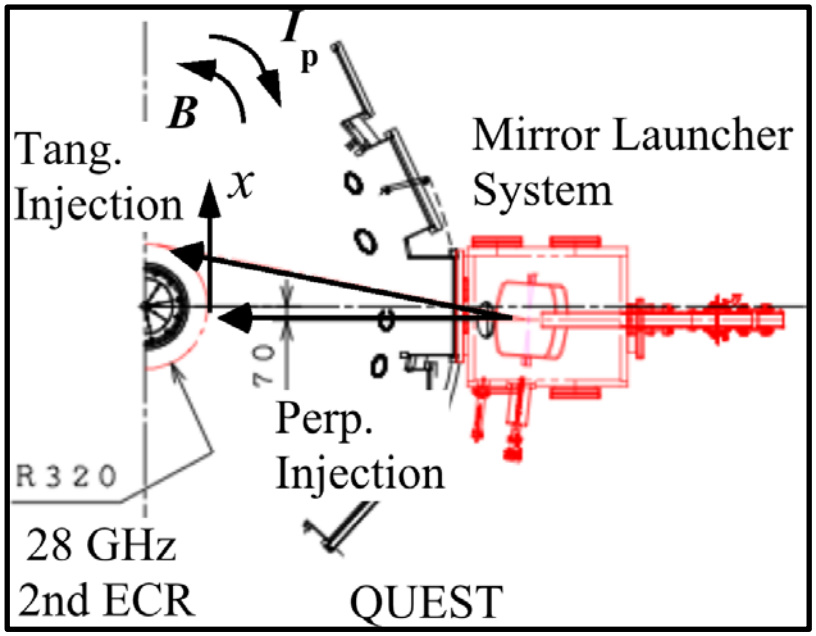


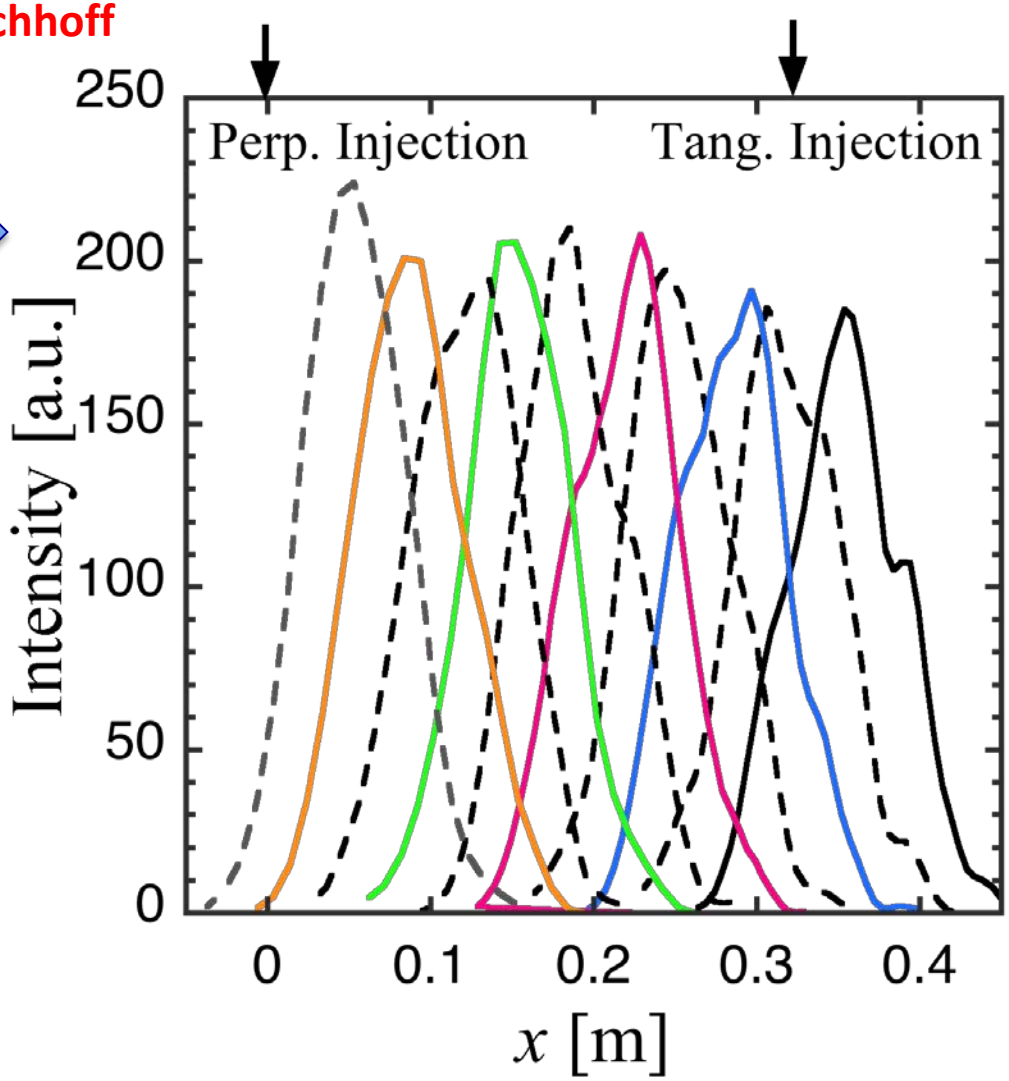
28 GHz polarizer miterbend

Launcher System and Beam Steering



Mirrors were designed by a developed Kirchhoff Integral code.





Beam Focusing

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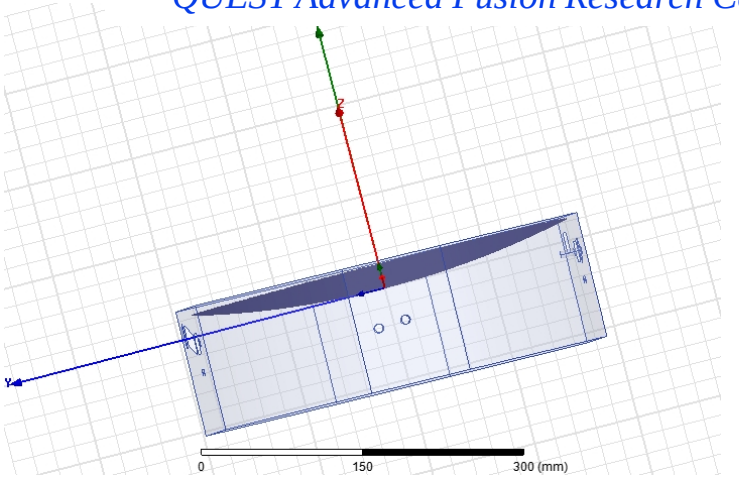

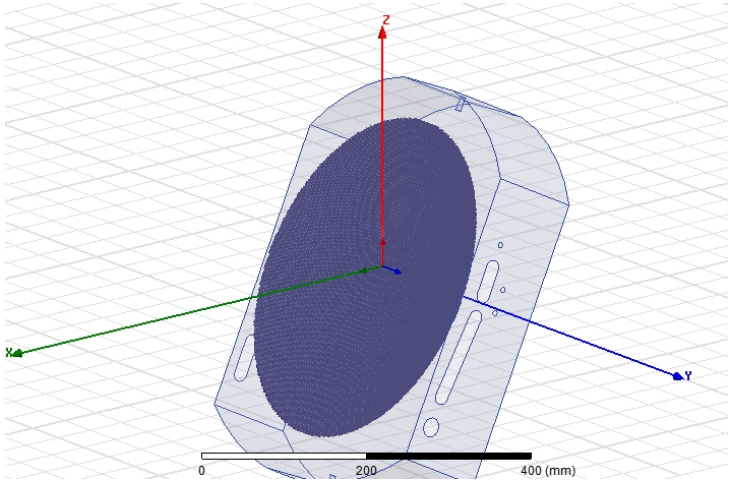

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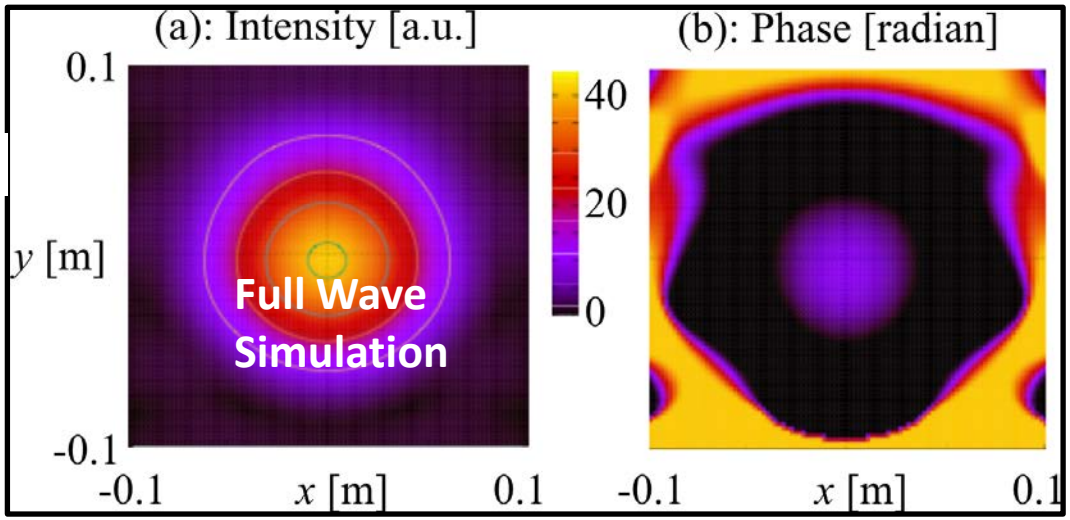
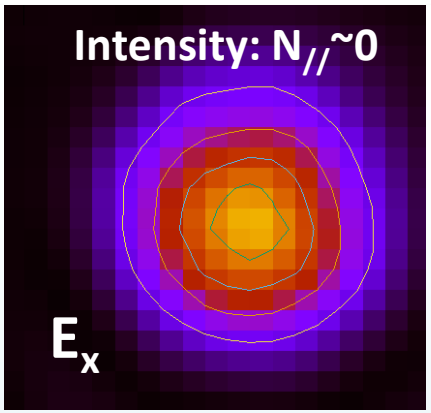
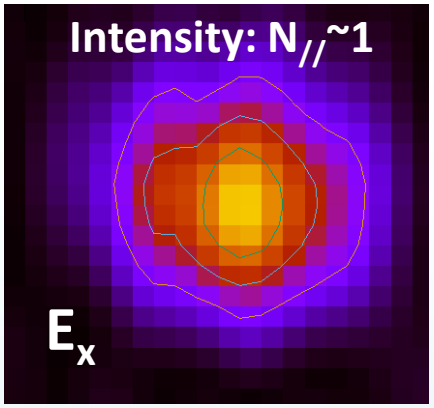
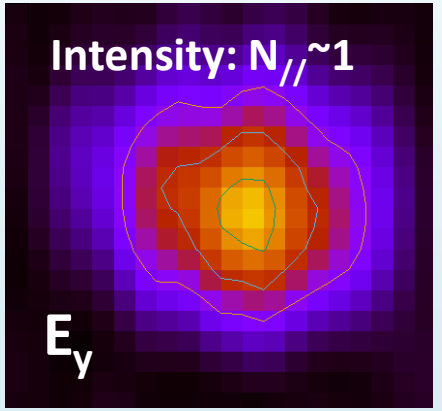






Low Power Test



28 GHz Plasma Start-up Experiments with New Launcher System

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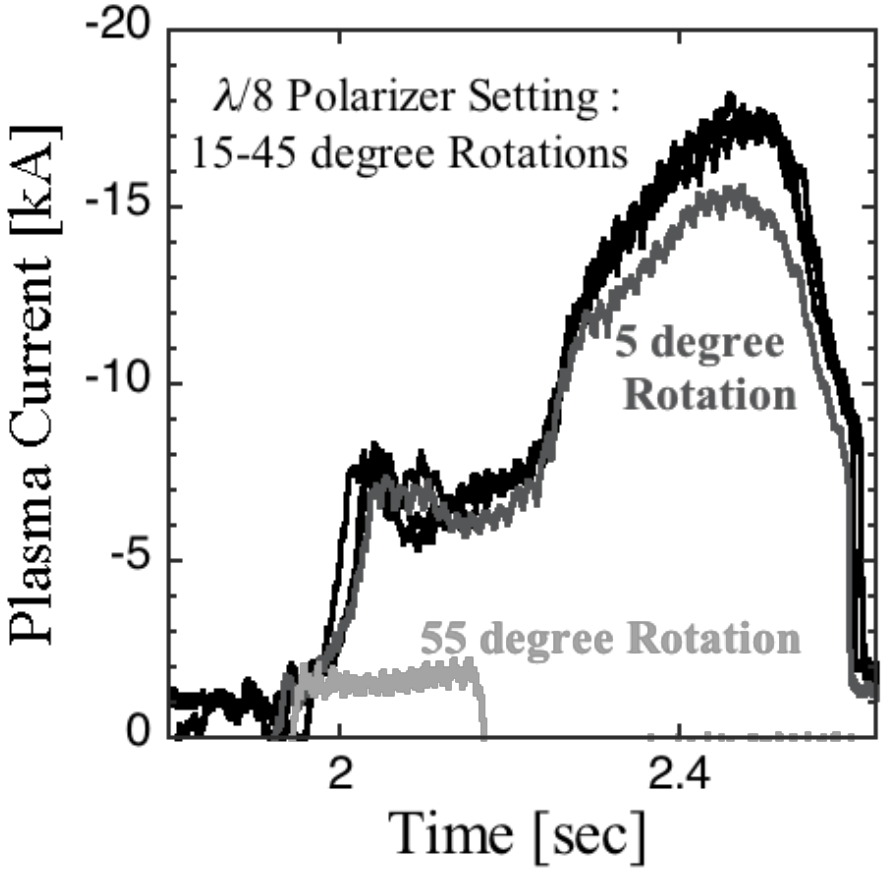
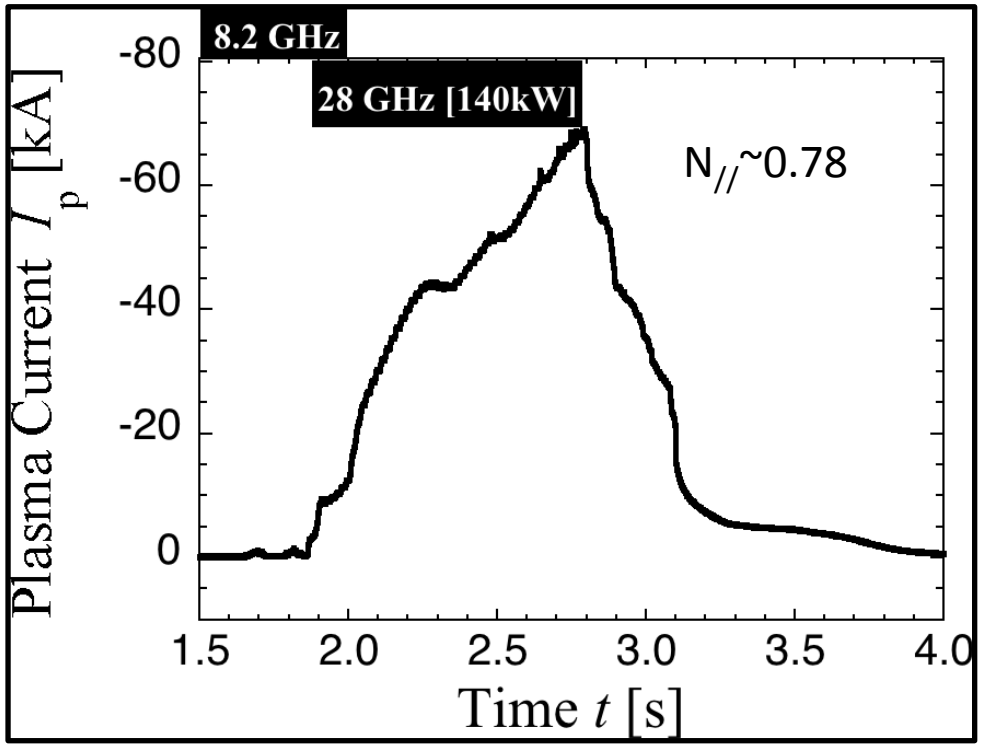
Incident Polarization Scanning

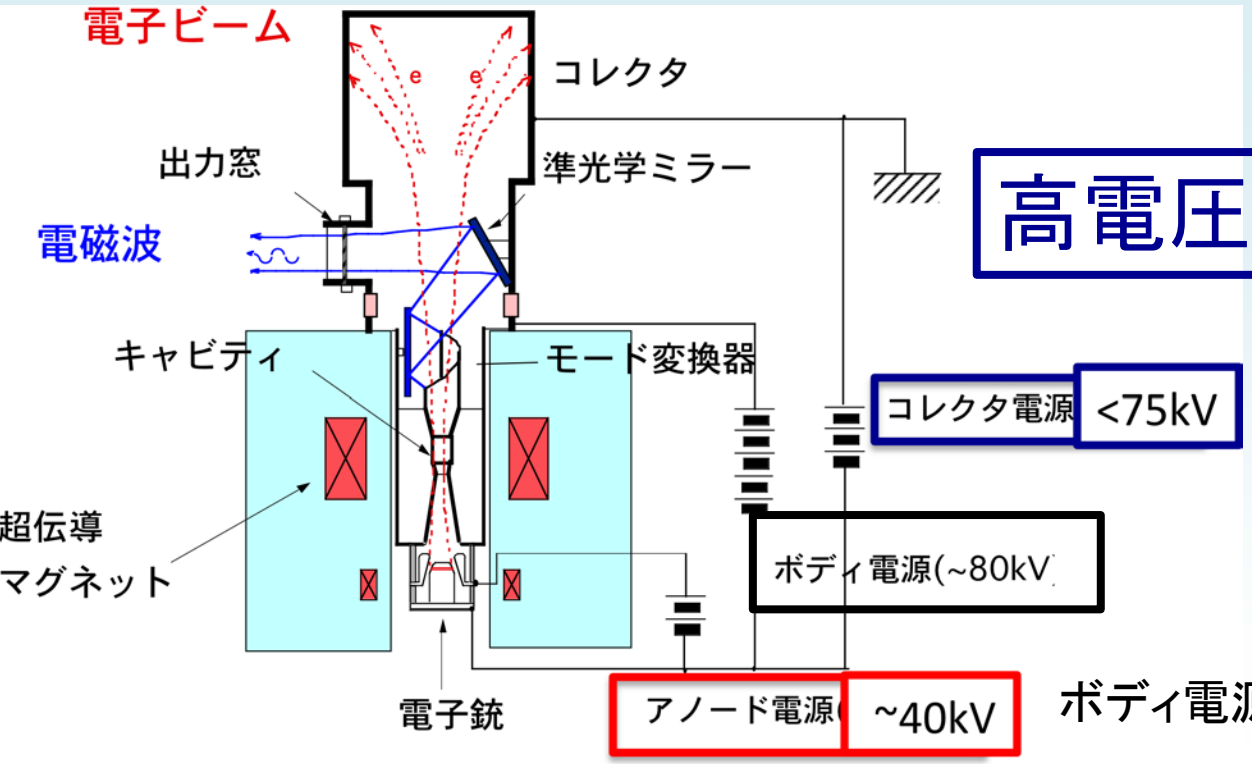


The incident polarization, mainly the ellipticity, could be controlled by the λ/8 polarizer.

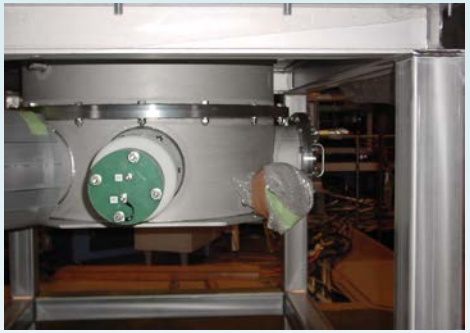
70 kA plasma build-up



High non-inductive *I*p of 70 kA has been achieved using a new 28 GHz polarizer or launcher.



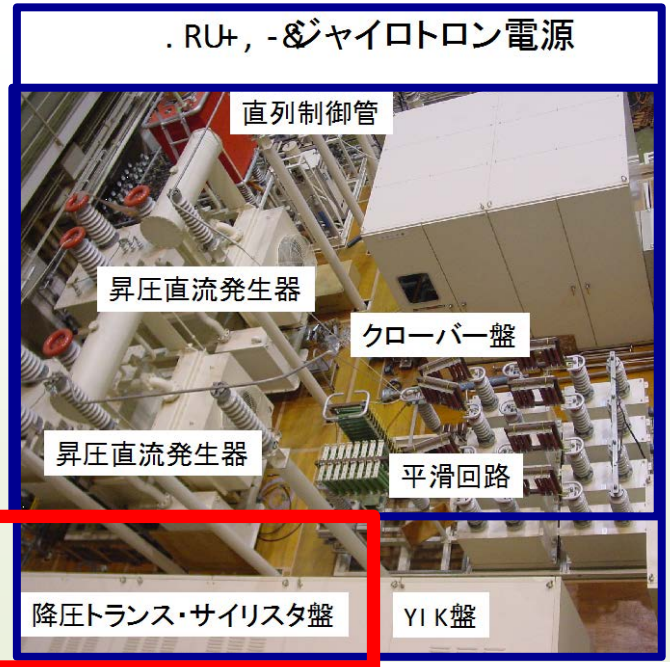
高電圧化



ジャイロトロン管タンクでは、
既に対地 20kVの電極が
設けられている。

ボディ電源部開発

カソード基準で80-90 kV
コレクタ基準（対地）で~20kV

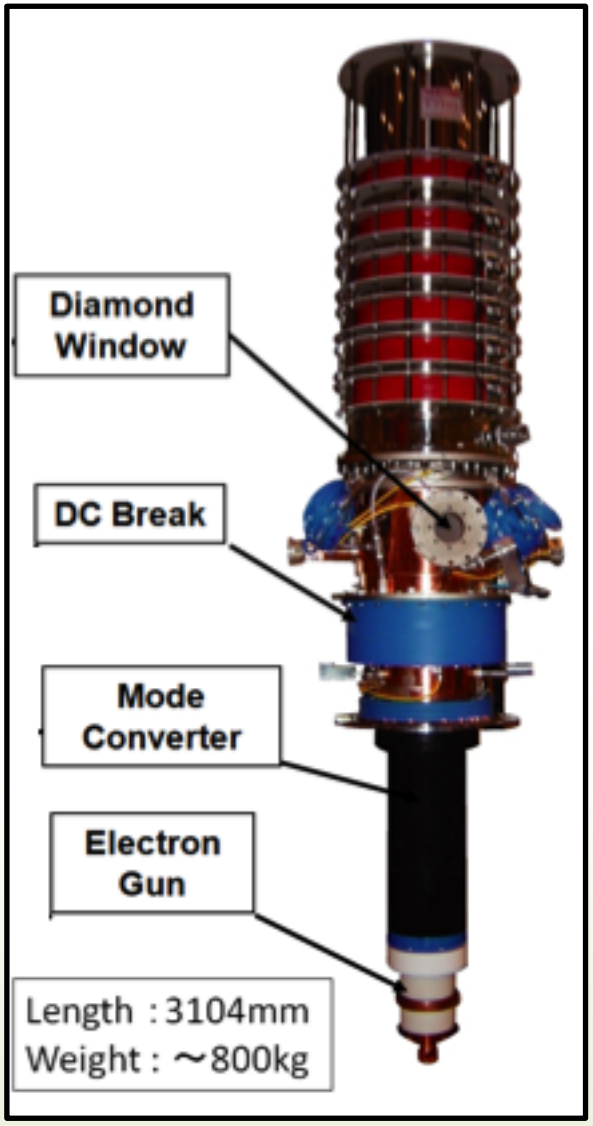


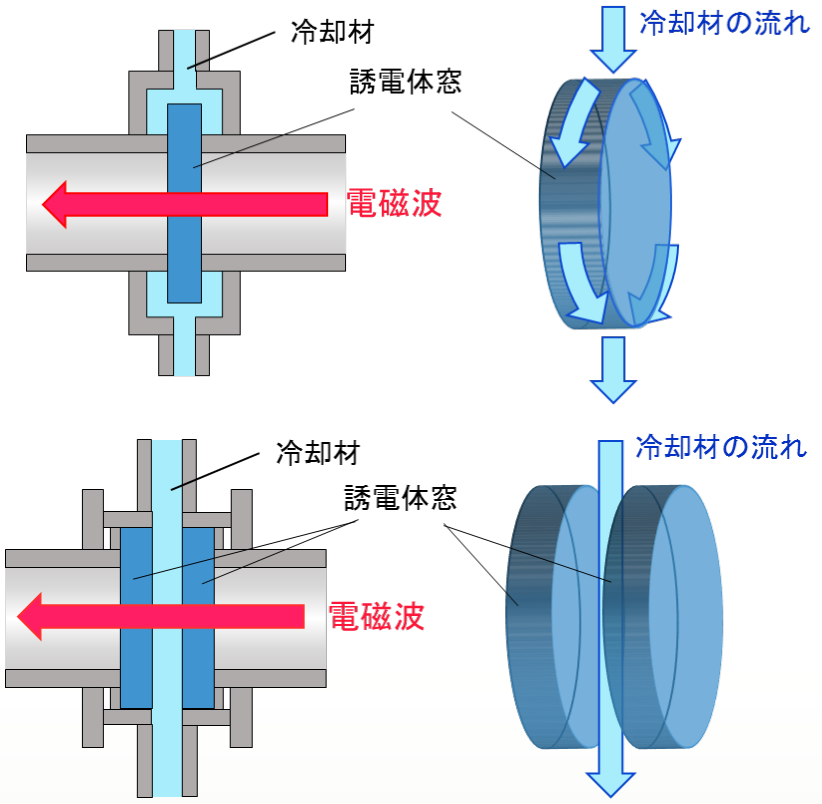
昇圧直流発生器は、25A 定常、**35A 30 秒運転に対応**
直列制御管は 50A 定常に対応

大電流化

1MW 出力に向けて、**サイリスタ盤　の改造が必要**

CW 運転には、ジャイロトロン管内の電磁波処理が必要





筑波大学　岡田麻希　2016年度卒業論文より

高価なダイヤモンド窓でなく、低周波数（28GHz）で対応できるサファイヤダブルディスク窓を開発

CW 運転には、サファイヤダブルディスク窓の開発が必要