Polarization control of incident microwave for non-inductive formation of spherical tokamak by electron Bernstein wave heating and current drive in LATE

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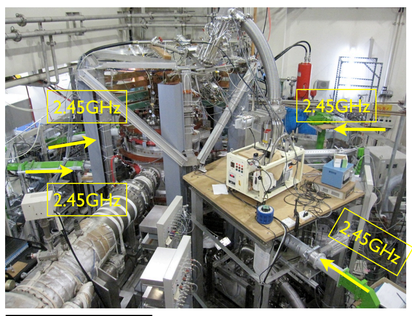
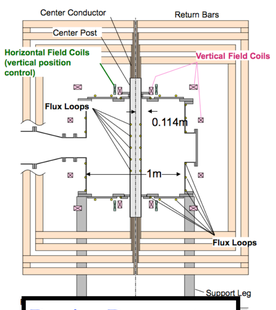
LATE (Low Aspect ratio Torus Experiment) is exploring non-solenoidal start-up by ECH/ECCD.



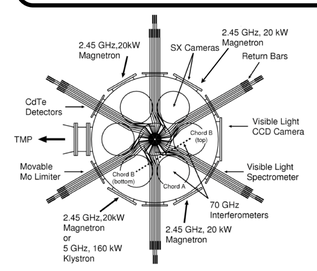


Microwaves

2.45GHz 20kWmagnetron x 4 , 2s
5GHz 200kWklystron x 1 , ~0.10s

Device Parameters

Vacuum Vessel:
diameter = 1m
hight = 1m
center post diameter = 11.4cm



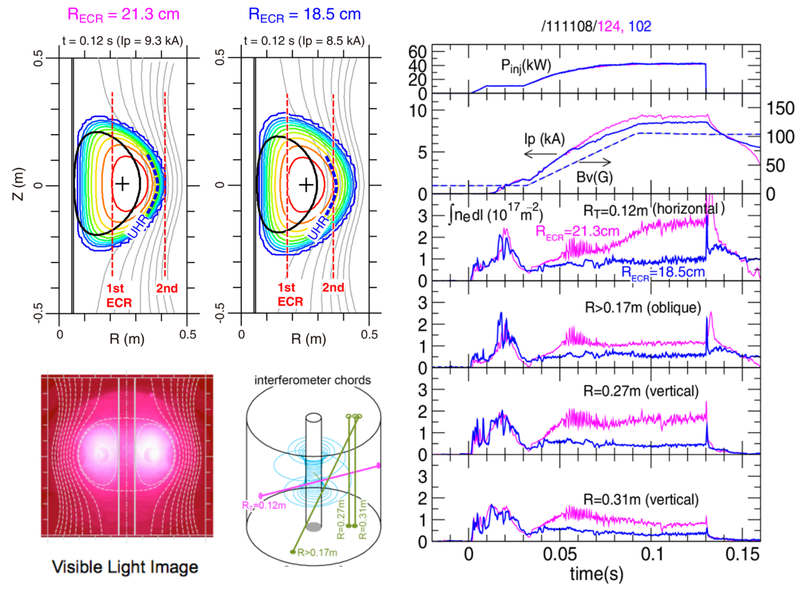
Diagnostics

Magnetics (17 Flux loops)
70GHz interferometer (7 chords)
AXUV cameras
Fast visible camera(CCD camera)
Spectrometer
High Xray Pulse Height Analyzer

Start-up by ECH/ECCD using Electron Bernstein Wave

→ Obliquely injection to the toroidal field in the form of O-mode from the lower field side (OXB Scheme)

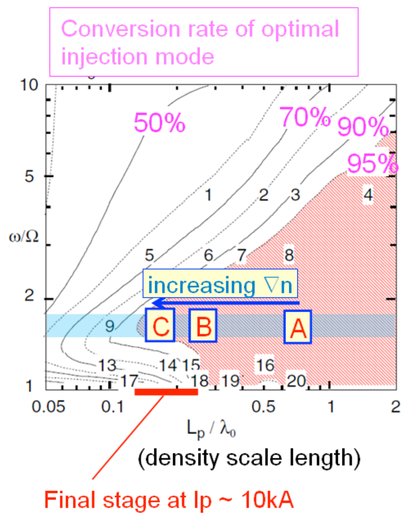
Electron density strongly depends on the ECR location

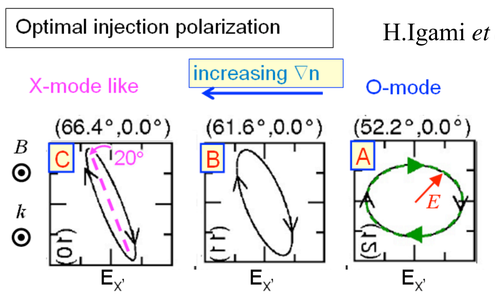


EB Wave is an electrostatic wave so that can propagate in over-dense plasma. The plasma increase up 7 times the plasma cutoff density. This suggests that EB waves heat the plasma.

When R_{ECR}=18.5cm, UHR layer shifts to outside of the 2nd ECR layer. Then a large portion of the incident EM wave may be mode-converted to EB waves and absorbed before the 2nd ECR layer. Therefore we locate 2nd ECR layer outside UHR layer for high-density and high-current plasma.

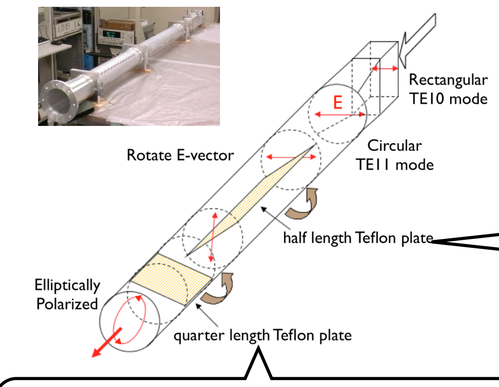
Mode-conversion rate to EBW depends on density gradient(∇n) near UHR layer

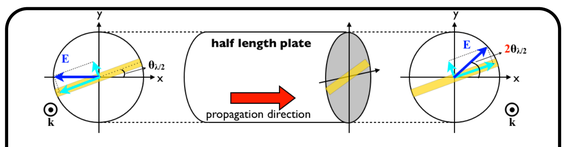




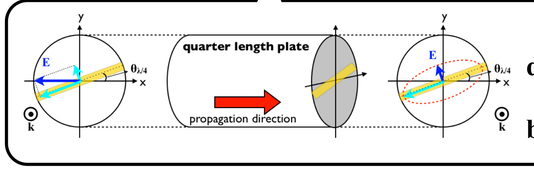
According to the linear mode-conversion theory with the cold plasma resonance absorption model in a slab plasma geometry, mode conversion rate to EBW depends on density gradient near UHR layer.
Optimal polarization on low density gradient is O-mode like, and on high one is X-mode like. As density gradient (∇n) increases, optimal injection polarization varies from O-mode to X-mode-like.

Principle of polarizer



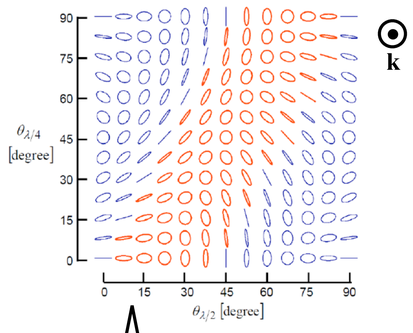


When the angle of plate to the x axis is $\theta_{\lambda/2}$, the angle of wave to the x axis become $2\theta_{\lambda/2}$.
We can inject linearly polarized waves with arbitrary angle to the x axis by rotating half length plate.



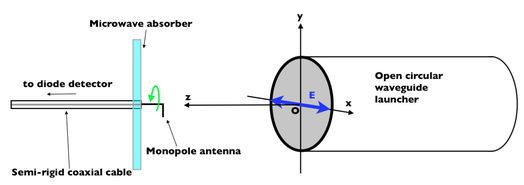
The main axis of elliptically polarized wave is determined by the angle of plate to the x axis($\theta_{\lambda/4}$).
We can inject some elliptically polarized waves by rotating quarter length plate.

cold test

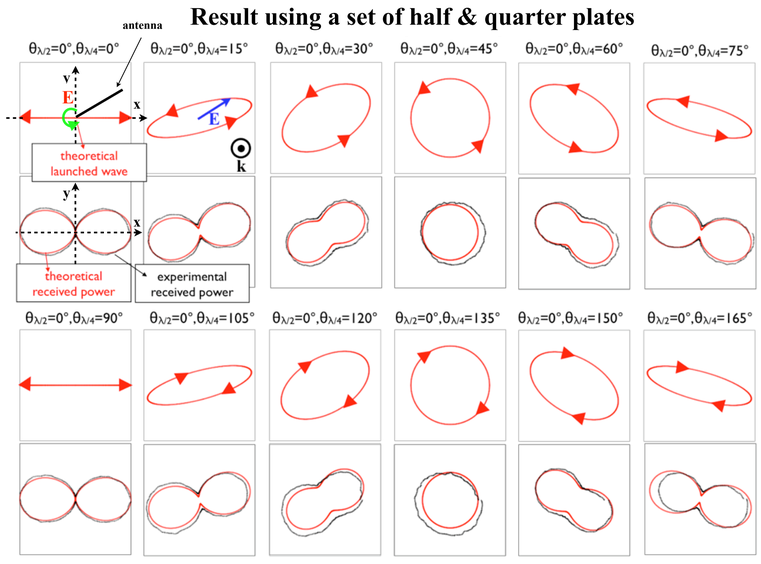


Red denotes left-handed rotation and blue does right-handed rotation to the propagation direction.

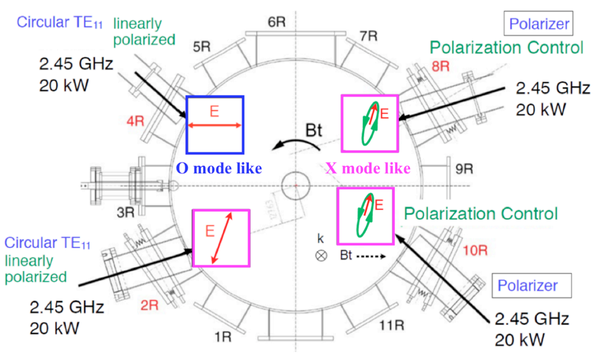
Combination of half wave section and quarter wave section generates every type of elliptically polarized wave from single TE11 wave that has the central E vector on x-axis. I tested if the polarizers work as theory, as right picture.



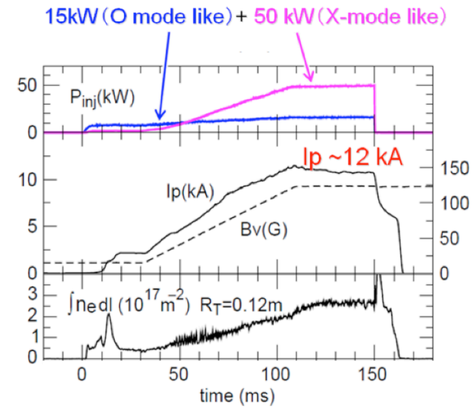
Result using a set of half & quarter plates



One of the Experiments

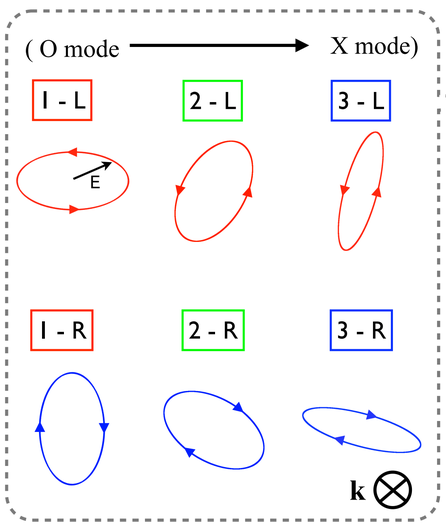


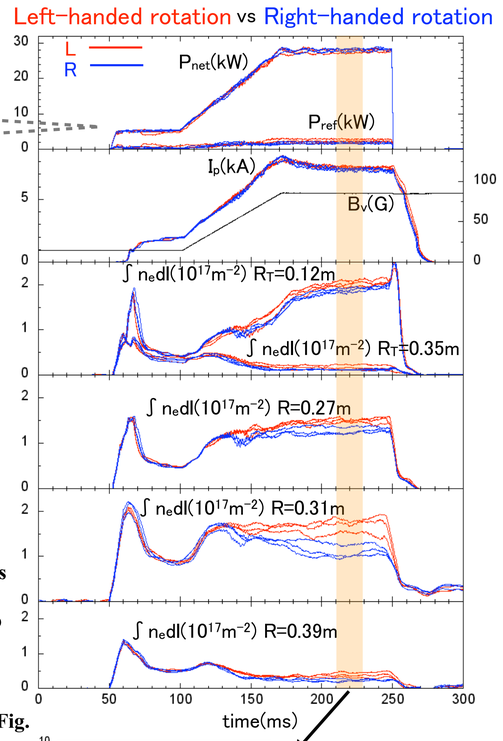
The microwave power of the O-mode like polarization and the X-mode like one are varied by preprogrammed control,respectively.
At first stage of discharge the power of O-mode like polarization is larger than X-mode like one, and at last stage X-mode like one is larger than O-mode like.

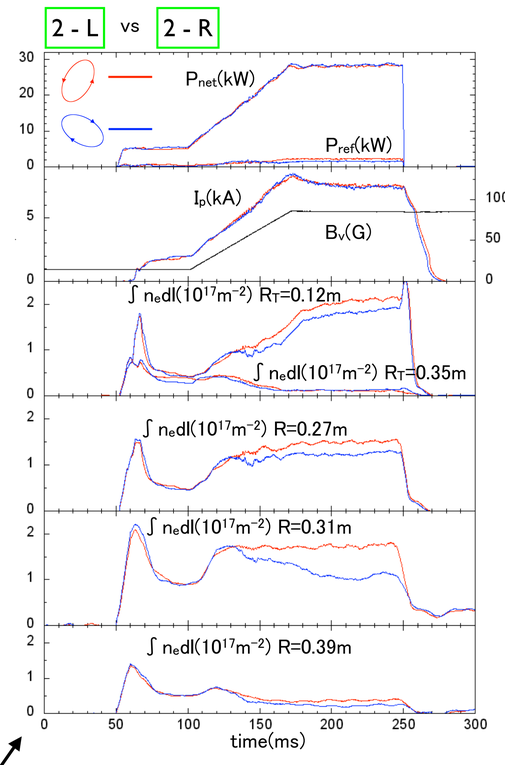


Plasma current increases up to 12kA and sustain steady with low decay index by power-control injection polarization adjustment.

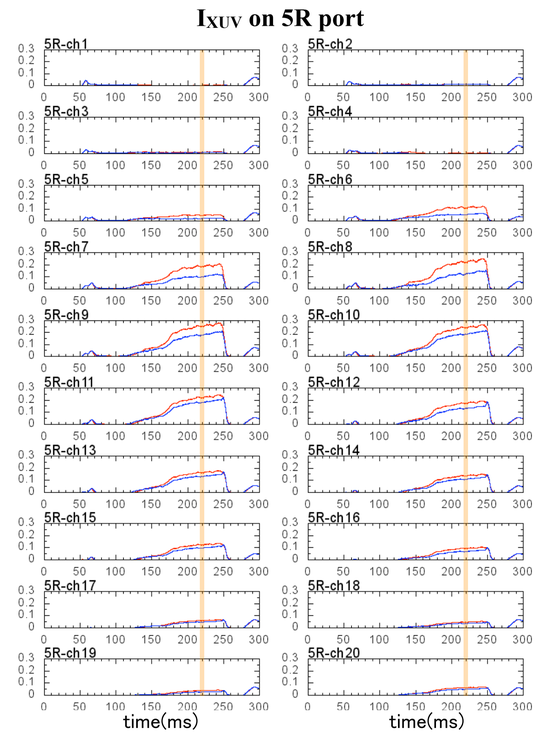
Comparison among discharges using different polarized waves

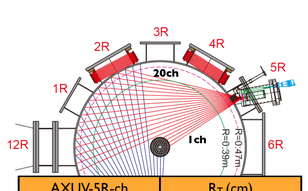




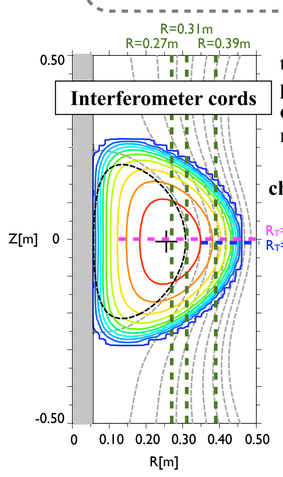


I_XUV on 5R port



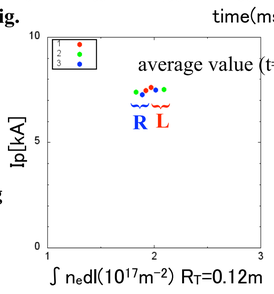


AXUV-5R-ch	R_T (cm)
1	2.6
2	0.4
3	1.9
4	4.2
5	6.6
6	9.0
7	11.5
8	13.9
9	16.4
10	18.8
11	21.2
12	23.6
13	25.8
14	28.1
15	30.2
16	32.2
17	34.2
18	36.0
19	37.7
20	39.3



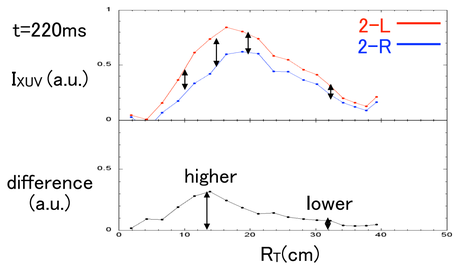
H Igami *et al.*(2006) suggests that right-handed injection polarization at right angle to optimal one have the lowest mode-conversion rate.
I took this theory and then chosen ones 1,2,3-R as above Fig.

I changed only injection polarization a few shots by shots and didn't change injection polarization during a discharge.
Another setups are same.



2 - L and 2 - R have the largest gap on line-integrated density(∫nedl).

These shows that plasma current is almost same value and ∫nedl (R_T=0.12m) has different values with respect to each polarized waves.
Above Fig shows that ∫nedl at inner side on 2-L is higher than one at inner side on 2-R, and ∫nedl at outer side is not different so much between 2-L and 2-R.



The difference of I_{XUV} between 2-L and 2-R shows the value at inner side is higher than one at outer side.
This suggests that electron density at inner side on 2-L is higher than one at inner side on 2-R and electron density at outer side is not different so much between 2-L and 2-R.