Investigation on anisotropic temperature in Ohmic plasmas in TST-2

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1. Introduction

- Non-inductive heating and current drive are essential elements for a steady state plasma in a fusion reactor.
- Temperature anisotropy ($T_{//}$ and $T_{\perp}$) is helpful in understanding the heating and current drive mechanisms.
- **Double-pass Thomson scattering (TS) diagnostics is a non-intrusive method of measuring local electron temperature.**
- There are some work on temperature anisotropy in TST-2 in the past:

1. Double-pass TS measurement in OH plasmas [1-3];
2. Coaxial multi-pass TS measurement in LHW plasmas [4-6].

[1] Hiratsuka J, Ejiri A, Hasegawa M, et al. Plasma and Fusion Research, 2011, 6.
[2] Hiratsuka J, Ejiri A, Hasegawa M, et al. Plasma and Fusion Research, 2012, 7.
[3] Hiratsuka J, Ejiri A, Hasegawa M, et al. Plasma and Fusion Research, 2015, 10.
[4] Togashi H, Ejiri A, Hasegawa M, et al. Plasma and Fusion Research, 2014, 9.
[5] Togashi H, Ejiri A, Hiratsuka J, et al. Review of Scientific Instruments, 2014, 85(11): 11D846.
[6] Togashi H, Ejiri A, Homma H, et al. Journal of Instrumentation, 2015, 10(12): C12020.

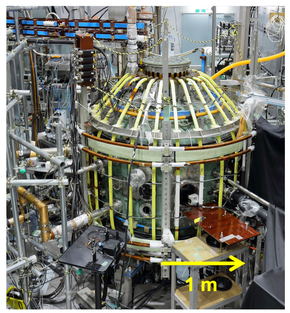
- A couple of drawbacks in the previous work.

(1) Only temperature anisotropy in OH plasma had been investigated;
(2) Timing control of polarization of the Pockels cell driver in the coaxial multi-pass TS configuration is not easy;
(3) Laser rod had been damaged in both configurations;

- **A new double-pass TS system has been developed in TST-2.**

(1) Safety of the laser device (returned YAG laser energy monitor);
(2) Measurement performance (scattering signal collection efficiency).

2. TST-2 spherical tokamak device

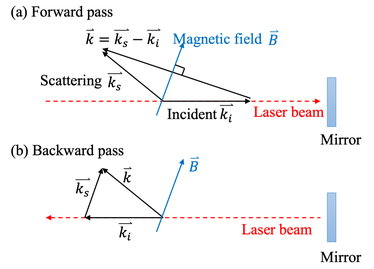


Major radius: 0.36 m
Minor radius: 0.23 m
Toroidal field: < 0.16 T
Plasma current:
OH < 110 kA
LHW < 26 kA

LHW system
Frequency: 200 MHz
Power: 100 kW × 4

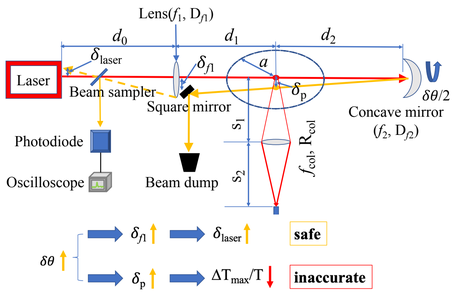
The LHW plasma is currently the main research topic in our lab.

3. Double-pass TS configuration



Principle of double-pass TS measurement

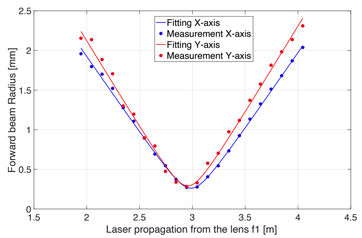
- Incident direction
- Scattering direction
- Magnetic field



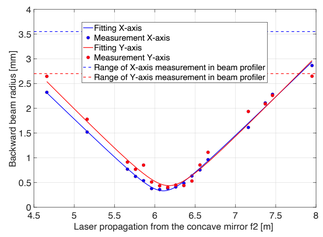
D_{f1} = 45 mm,
D_{f2} = 60 mm,
f_1 = 2.5 m,
f_2 = 2.84 m,
d_0 = 3.5 m,
d_1 = 3.0 m,
d_2 = 5.86 m,
D_{fiber} = 2 mm,
a = 220 mm,
R_{col} = 200 mm,
s_1 = 1 m,
s_2 = 0.4 m.

- A double-pass TS optical path has been determined based on the theoretical investigation on the optimization of the double-pass configuration [7].

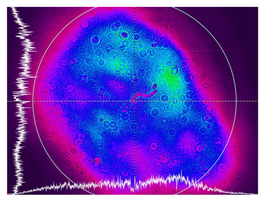
[7] Peng Y, Ejiri A, Takase Y, et al. Plasma and Fusion Research, 2021, 16.



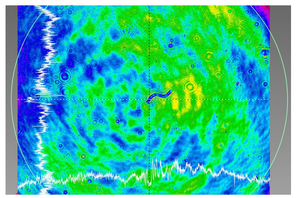
Forward beam radius measurement



Backward beam radius measurement



Beam pattern near the square mirror

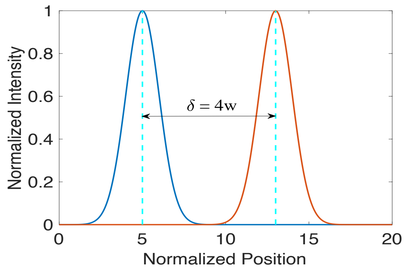


Beam pattern near the YAG laser exit

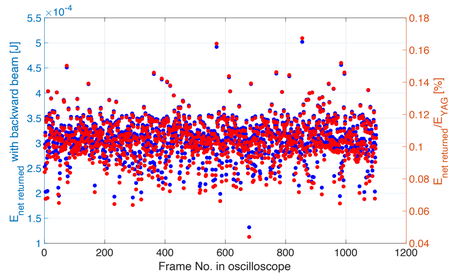
Beam radius of backward beam near the square mirror and YAG laser exit is measured:

- Near the square mirror: 2.86 mm;
- Near the YAG laser device exit: over the range (3.55 mm) of the beam profiler. (It qualitatively indicates the backward beam will not focalize near the YAG laser exit if it returns to the YAG laser, and the safety is acceptable. But I am looking for a reliable way to estimate it beam size quantitatively.)

4. Estimate of returned energy with reduce YAG laser energy (0.3 J)



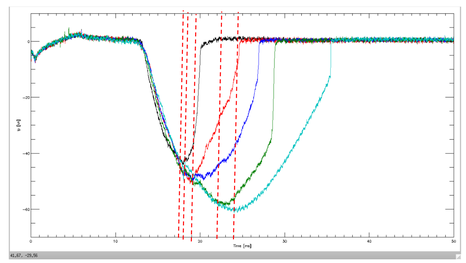
Theoretical estimate of returned energy ratio is 0.03% based on Gaussian model.



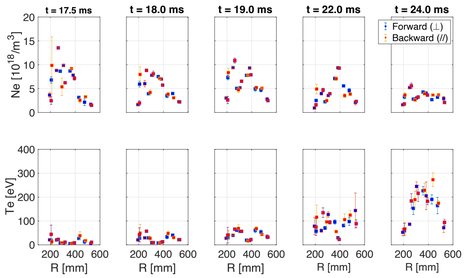
Experimental estimate of returned energy ratio is around 0.1%

The difference between the theoretical and experimental estimate may be caused by the factor that the actual YAG laser beam pattern is not Gaussian model.

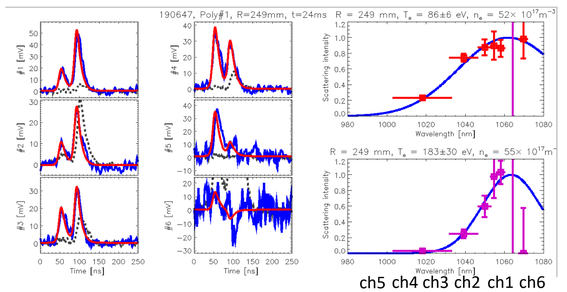
5. Results of Ohmic discharge with reduce YAG laser energy (0.3 J)

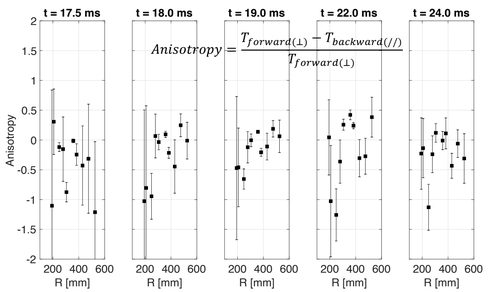


Plasma current and various TS timings



Electron density and temperature profile (time evolution)





6. Conclusions

- The temperature profile evolves from hollow shape with relative low T_e to central peak with high T_e;
- Anisotropy appears at several measurement positions (e.g. t =24 ms, R = 249 mm, Anisotropy = -110% ± 40 %);
- Steady state OH discharge will be investigated for parametric dependence in the next step;
- Studies on anisotropy in LHW discharge will be implemented using full power YAG laser (9 W).

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