# Hot electron and ion spectra on the blow-off plasma free target in the GXII-LFEX direct fast ignition experiment

ID: 834

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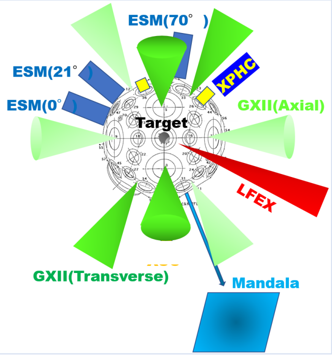
## ABSTRACT

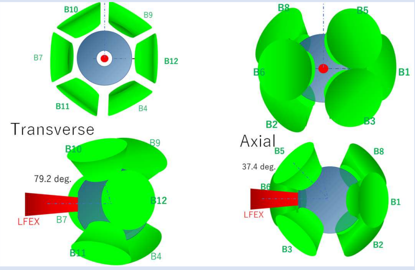
- Polystyrene deuteride shell targets with two holes were imploded by Gekko XII laser and additionally heated by LFEX in a direct fast ignition experiment.
- Lower effective electron temperature ($T_{eff}$) can be realized by reducing the inflow of the implosion plasma on the LFEX path, and high coupling efficiency can be expected.
- The deposited energies of electrons to the core were evaluated to be from electron-ion spectra and a neutron yield.
- The ions have a large contribution against target heating in direct fast ignition.

## BACKGROUND

- Fast ignition is performed by additional heating the imploded core.
- Heating mechanisms consists of the electron/ion drag, the Joule and diffusive.
- The electron/ion drag heating is the most essential heating.
- Low $T_{eff}$ is important in order to obtain the high coupling efficiency.
- Minimizing the pre-formed plasmas is a key to achieve low $T_{eff}$.
- Pre-formed plasmas are produced by pre-pulse and by blow-off.
- Direct heating is disturbed by blow-off plasma.
- Cone attached target to reduce blow-off plasma is a recent mainstream, but it is complicated.
- To reduce blow-off plasma, we use a shell target with holes.

## EXPERIMENTAL SETUP



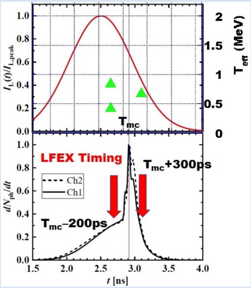


*Irradiation arrangement*

*←Diagnostics arrangement*

- Imploding laser: Gekko XII (GXII) 1.545-1.738 kJ 1.3ns.
- Heating laser: LFEX 243-343J, 1.3ps, 50 μmϕ, $10^{19}$ W/cm$^2$.
- Target :$(C_8D_8)_n$-shell 500 μmϕ,7 μm$^t$, two holes of 100 μmϕ.
- Transverse irradiation 6 beams (B04,07,09,10,11,12).
- -->The blow-off plasma is small on the LFEX axis.
- (ref.(Axial irradiation, B01,02,08,03,05,06))
- Diagnostics; Three ESMs(electron, ion) at 0, 21 and 70 degrees from LFEX.
- Mandala(neutron), CR-39(ρR), XPHC(size).

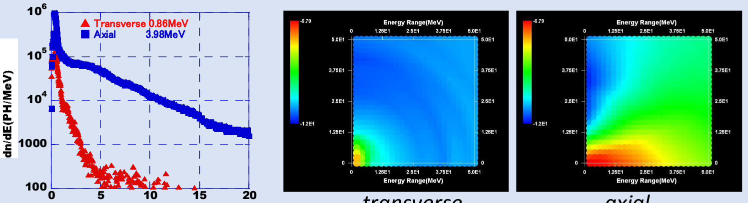
## LASER INJECTION TIMING



*Pulse waveform of GXII and $T_{eff}$ from ESM, LFEX injection timing and X-ray history from STAR2D[1].*

- GXII is Gaussian shape of pulse duration.
- Three shots have been performed at two different injection timings.
- Peak of X-ray wave form is assumed to be the maximum compression timing ($T_{mc}$).
- In transverse irradiation, $T_{eff}$ keeps low.

## ELECTRON HEATING

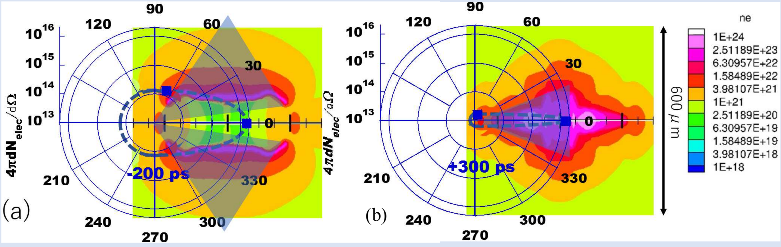


*transverse* *axial*

*Comparison of $T_{eff}$ between in transverse and in axial irradiations*

- Electron energy spectra at 0 degrees are compared between in transverse and axial irradiations.
- $T_{eff}$ in transverse irradiation is lower than that in axial irradiation,
- Because there is small ablation plasma due to holes.
- And the pre-pulse of LFEX has passed during implosion through holes.
- Therefore, $T_{eff}$ keeps low in transverse irradiation.

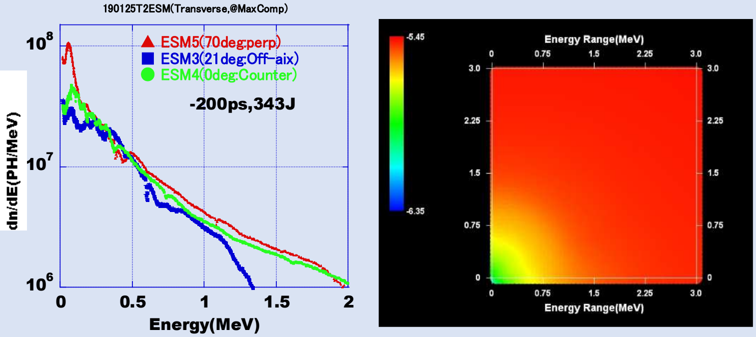
## ELECTRON HEATING (..continue)



*Electron number distribution and STAR2D simulation*

- The electron number is calculated by $N_{elec} = E_L \times 75\% \div T_{eff}$,
- 25% of laser energy $E_L$ has reflected from the results of other experiment.
- The Laser plasma interaction position and the solid angle Ω are estimated by simulation.
- The $dN_{elec}/d\Omega$ is determined from the momentum preservation.
- The deposited energies of electrons to the target above the electron stopping range are almost same (each electron 0.0077 MeV at ρR =0.012 g/cm$^2$).
- Finally, total electron drags are 5.5 J (−200 ps) and 2.8 J (+300 ps)

## ION HEATING



*Ion spectra and distribution*

- Ponderomotive acceleration of ions acts the core heating.
- Ion number $N_{Dbeam}$ can be calculated from on spectrum (ESM) and neutron yield $N_y$(Mandla), as $N_{Dbeam} = N_y / \{\sigma_{DD} \times N_{Dtarget} \times l_{Range}\}$ (2) where $\sigma_{DD}$, $N_{Dtarget}$ and $l_{Range}$ are DD reaction cross section (at $T_{ion}$) ion energy. D number in target and stopping range.
- Here, $N_{Dtarget} \propto l_{Range} \times \rho$, $l_{Range}$ at $T_{ion}$ from SRIM code, density ρ:(CR-39 knock-on ＋ XPHC)
- Therefore, deposited ion energies can be evaluated to be 8.4 J (−200 ps) and 0.7 J (+ 300 ps).

## SUMMARY

*Electron heating*

| Irradia. | Shot | Delay (ps) | $E_{LFEX}$(J) | $T_{eff\_avg}$ (MeV) | ω/4π | EρR (MeV) | $N_{elec}$ ($10^{15}$) | $E_{e-drag}$(J) | ρR (g/cm$^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Trans. | 190125T2 | -200 | 343 | 1.05 | 0.217 | 0.079 | 1.53 | 5.5 | 0.012 |
| Trans. | 190125T5 | +300 | 309 | 1.06 | 0.022 | 0.079 | 1.37 | 2.8 | 0.012 |
| Axial | 190124T3 | +200 | 262 | 2.06 | 0.413 | 0.096 | 0.60 | 2.3 | 0.016 |

*Ion (+electron) heating*

| Irradia. | ρ (g/cm$^3$) | Range (μm) | $N_{DTarget}$ ($10^{14}$) | $T_{ion}$ (MeV) | $\sigma_{DD}$(b) | $N_y$($10^8$) | $N_{Dbeam}$ ($10^{13}$) | $E_{i-drag}$(J) | $E_{drag}$(J) | $\Delta E_{int}$(J) |
|---|---|---|---|---|---|---|---|---|---|---|
| Trans. | *1.67?* | 3.75 | 6.44 | 0.46 | 0.100 | 2.47 | 9.17 | 8.4 | 13.9 | ? |
| Trans. | 1.90 | 2.30 | 4.47 | 0.33 | 0.076 | 0.268 | 0.99 | 0.7 | 3.5 | ? |
| Axial | 2.86 | 2.14 | 25.4 | 0.44 | 0.107 | 0.397 | 1.41 | 1.2 | 3.5 | 3.4 |

## CONCLUSION

- Laser plasma interaction region should be closed to the imploded core.
- Lower $T_{eff}$ can be achieved by reducing pre-formed plasma on LFEX path by using a target with holes.
- The contribution of ion heating is plenty large in the direct ignition.
- The coupling efficiency of 2.5 times can be expected by preventing blow-off completely, for example, by using holes with a fin.

## ACKNOWLEDGEMENTS / REFERENCES

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[1] A. Sunahara, et al., J. of Phys.717(1) 012055.