IFE

Demonstration of direct fast heating of counter-imploded core plasma by LFEX laser

Y. Kitagawa[1], Y. Mori[1], K. Ishii[1], R. Hanayama[1], S. Okihara[1], Y. Arikawa[2], Y. Abe[2], E. Miura[3], T. Ozaki[4], O. Komeda[5], H. Suto[5], Y. Umetani[5], A. Sunahara[6], T. Johzaki[7] , H. Sakagami[4], A. Iwamoto[4], Y. Sentoku[2], N. Nakajima[2], S. Sakata[2], K. Matsuo[2], S. R. Mirfayzi[2], S. Fujioka[2], J. KAWANAKA[2], K. TSUBAKIMOTO[2], K. SHIGEMORI[2], K. YAMANOI[2], A. YOGO[2], A. NAKAO[2], M. ASANO[2], H. SHIRAGA[2],T. Hioki[8], T. Motohiro[8], and H. Azuma[9]

The Graduate School for the Creation of New Photonics Industries, [2]I LE, Osaka Univ., [3]AIST, [4]NIFS, [5]Advanced Material Engineering Div. TOYOTA Motor Corporation, [6]Purdue Univ. CMUXE, [7]Hiroshima Univ., Eng. [8]Nagoya Univ. GREMO, [9]Aichi SCR. <kitagawa@gpi.ac.jp>

The heating efficiency η of the fast heating was investigated, when the imploded core is directly illuminated with an ultraintense laser. η is 2\% or less for Axial mode and 5\% or less for Transverse mode. η is large for Transverse at high LFEX power.

1. Introduction:Counterbeam Reactor:CANDY

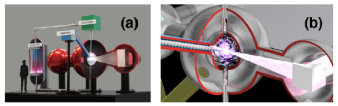
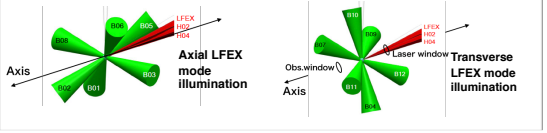


Fig.1(a) Image of the Counter implosion fast ignition reactor CANDY.
(b) Reactor chamber of CANDY[Movie:CANDY2015-English-0505-MPEG-4-1080-12000Kbps]

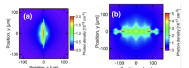
2. Experimental setup and Core plasma: Two illumination mode



Core areal density by DD-reacted protons

STAR2D-ALE simulation of x-ray emision at max compression

Core density: 2.8 g/cm^3
Temperature: 750 eV

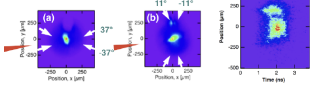


Target is a CD shell

Axial mode at +330 ps Transverse mode at +360 ps

Core emission

GXII (white arrows): pulse shape 1.1ns, 1.64kJ,
LFEX (red arrow): 1.05μm 1.5ps, 245J on target. F/10.
The intensity on target is 0.5~ 1x10^{19}W/cm^2.
CD target: diameter 500μm, thickness 7μm.

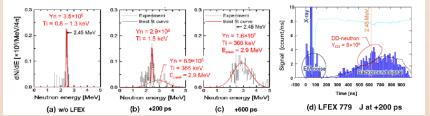


Axial mode, Core size: x = 37μm and y = 56 μm.
Transverse mode, Core size: x = 81μm and y = 32 μm.

3. Axial mode heating

Heating efficiency η = Heated core energy/LFEX energy

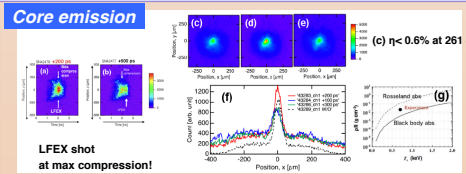
Mandala TOF DD neutrons



(a) w/o LFEX (b) +200 ps (c) +600 ps (d) LFEX 779 J at +200 ps

LFEX:261 J LFEX:336 J η= 1.9 %

Core emission



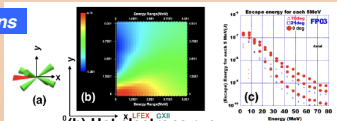
LFEX shot at max compression!

(c) η< 0.6% at 261 J.

(d) η= 0.2 % at 779 J.

(g) Emission is likely in Planck state

Hot electrons

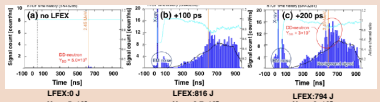


(b) Hot electrons run away lying to x axis.

η= 0.9 %

4. Transverse mode Heating

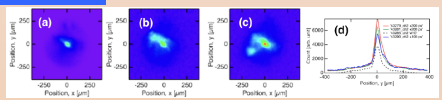
Mandala TOF DD neutrons



LFEX:0 J LFEX:816 J LFEX:794 J

η= 1.9 %

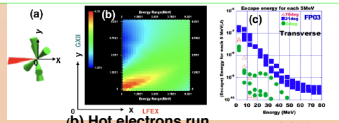
Core emission



LFEX:0 J (b)LFEX:816 J+100 ps (c)LFEX:794 J+200 ps

η= 1.2 %

Hot electrons

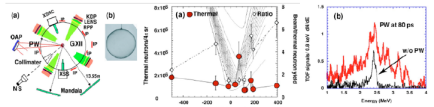


(b) Hot electrons run away 21° to x axis.

η= 9.9 %

5. Uniform mode Heating

Petawatt-laser direct heating of uniformly imploded deuterated-polystyrene shell target
PHYSICAL REVIEW E 71, 016403 (2005)



(b)PW:190 J
Neutron
η= 3.0 %

Core emission
η= 3.9 %

4. Estimation of core heating efficiency

Table 1: η from x-ray, neutron, and hot electron, respectively.

Mode	shot number	GXII	LFEX	η from x-ray	neutron	hot electron
Uniform	[7]	1870 J	190 J	3.9 %	3.0 %	-
Axial	♯24T3#42478	1657 J	261 J	< 0.6 %	-	2.1 %
Axial	♯4T1#43283 High power	1428 J	779 J	0.2 %	1.9 %	0.9 %
Transverse	♯25T2#42483	1740 J	342 J	> 0 %	-	6.4 %
Transverse	♯3T2#43279 High power	1378 J	887 J	1.2 %	5.4 %	9.9 %

(♯ is the shot number, and # is the serial number from the first light of GXII.)

The heating efficiency η of the fast heating was investigated, when the imploded core is directly illuminated with an ultraintense laser. η is 2\% or less for Axial mode and 5\% or less for Transverse mode. η is large for Transverse at high LFEX power.

REFERENCES

[1] Nuttal W J et al., ``Commercializing Fusion Energy: How Small Businesses are Transforming Big Science",
(IOP Publishing Ltd., London,2021) Chapter 6 Laser Fusion CANDY GPI/Hamamtsu by Y. Mori.
: CANDY2015-English-0505-MPEG-4-1080-12000Kbps
[2] Kitagawa Y et al 2004 IEEE J. Quantum Electron. **40** 281.
[3] Kitagawa Y et al. 2005 Phys. Rev. **E71** 016403: J. Plasma Fusion Res. **81** 384 (2005).
[4] Kitagawa Y et al 2012 Phys. Rev. Lett. **108** 155001.
[5] Mori Y et al 2016 Phys. Rev. Lett. **117** 055001.
[6] Kitagawa Y et al. 2015 Phys. Rev. Lett. **114**195002.
[7] Kitagawa Y et al 2017Nucl. Fusion **57** 076030.
[8] Miura E{et al.2020 High Energy Density Physics **37**100890.
[9] Arikawa Yet al 2012 Rev. Sci. Instrum. **83** 10D909.
[10] Abe Y et al. 2020 High Energy Density Phys. **36** 100803.