Pathways to Fusion Beyond NIF

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Fusion Power Associates Mtg.   2013. 12. 10.

Fast Ignition Realization EXperiment

FIREX-I Fast Heating to 5 keV
FIREX-II Ignition and Burn

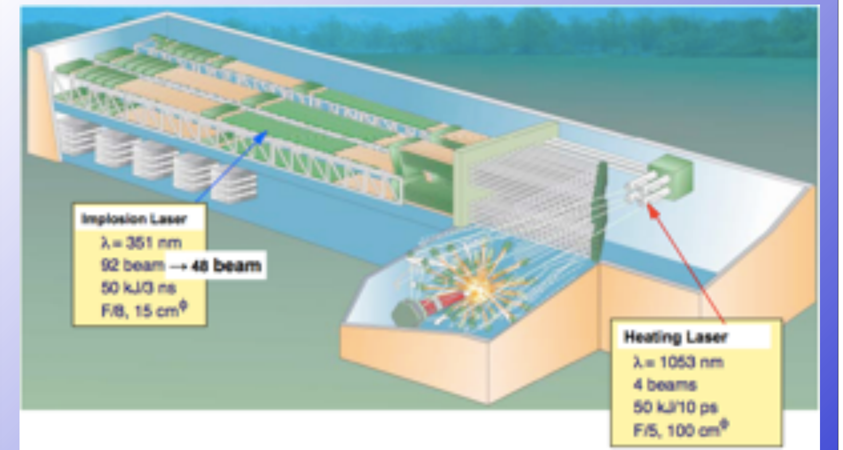
So far, 1 keV achieved.
Ignition temperature to be achieved.

Strategy towards Fusion Power Generation

~2010

FIREX-I: Ignition Temp

~2020



FIREX-II: Ignition&Burn

~2030

LIFT: Power Generation

Atomic Energy Commission of Japan reported (Oct. 2005):

"Based on its (FIREX-I) achievement, decide whether it should be advanced to the second-phase program aiming at the realization of ignition and burning"

*Laboratory Inertial Fusion Test

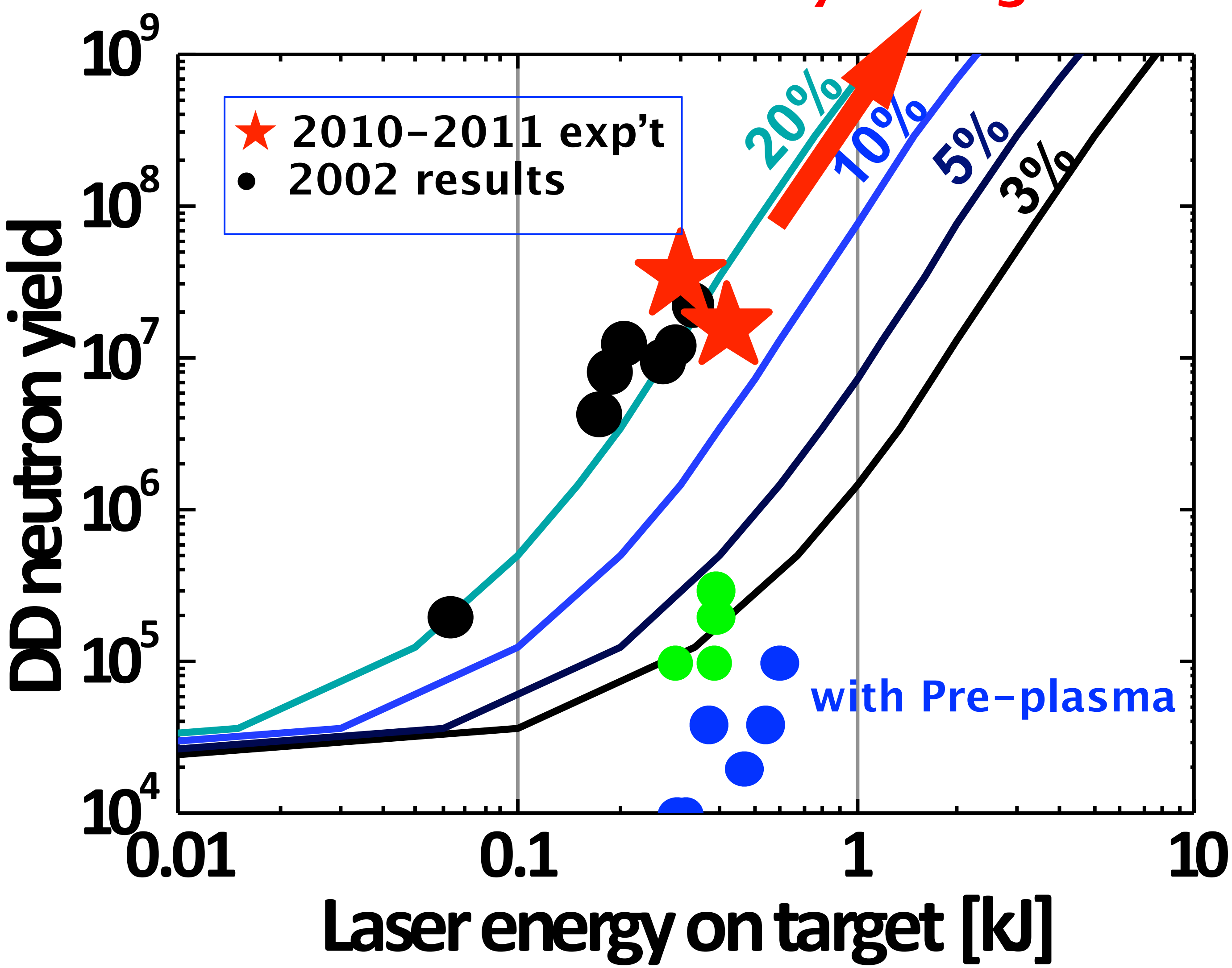
Are we ready?

✓ Reactor Core Plasma
Reactor Technology Elements
- Laser
- Target injection and tracking
- Reactor System

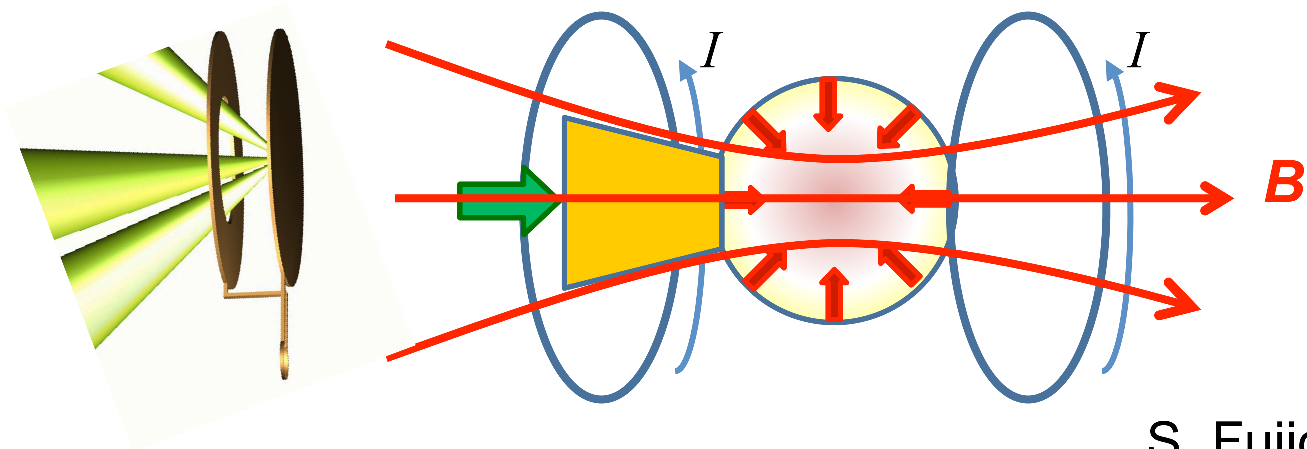
Alliance

Yield increase

Can we keep the coupling efficiency at higher intensity?



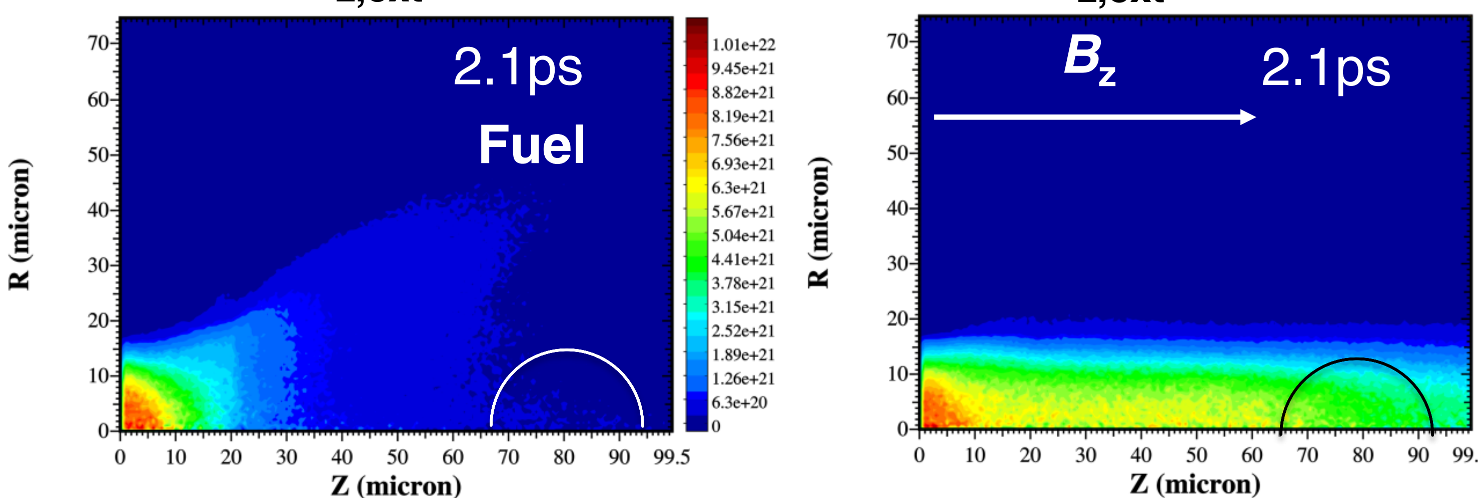
Magnetized Fast Ignition: Collimation



S. Fujioka

$B_{z,ext} = 0$ $\qquad$ $B_{z,ext} = 2$ kT

n_b (cm^{-3})

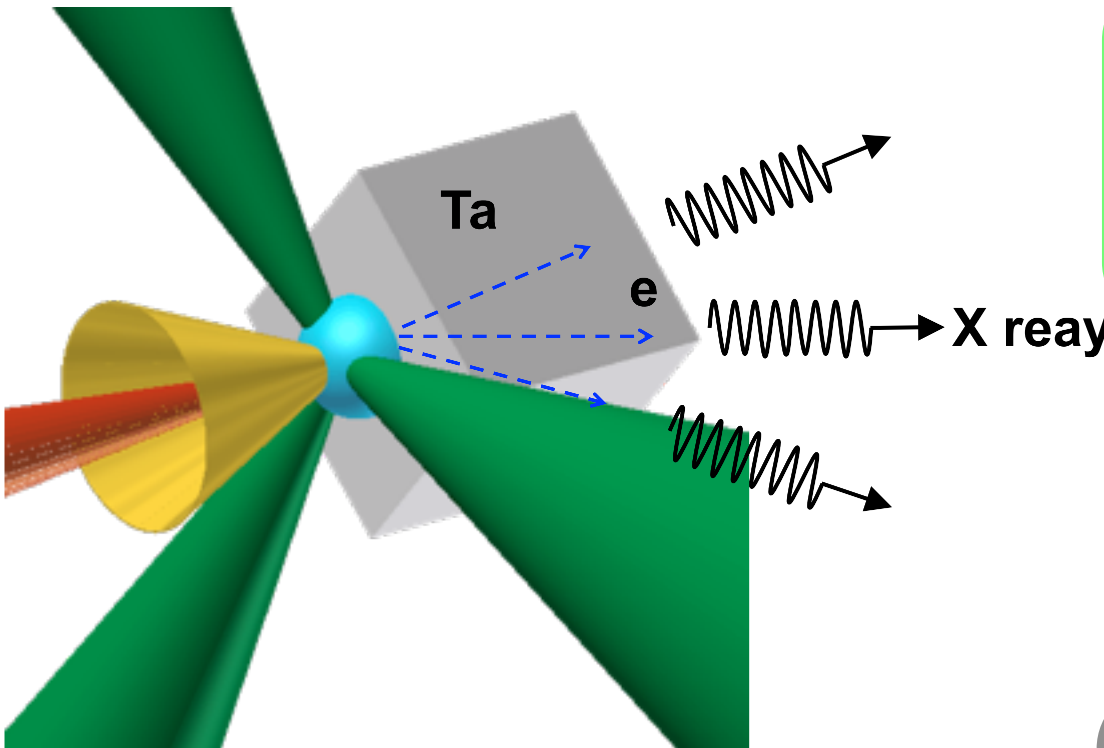


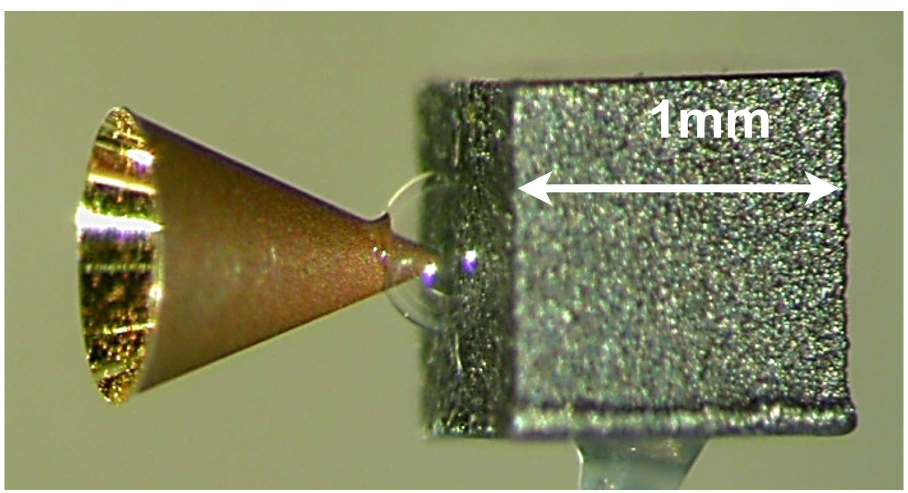
de-collimating
field at interface

Simulation by J. Honrubia

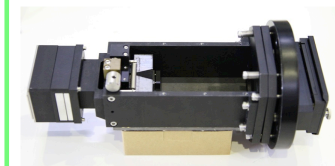
Necessary field is demonstrated.

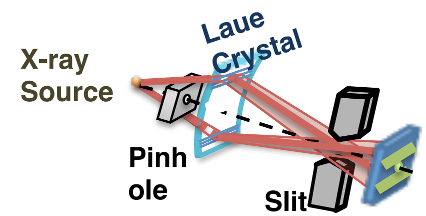
Magnetized Fast Ignition: Diagnostics



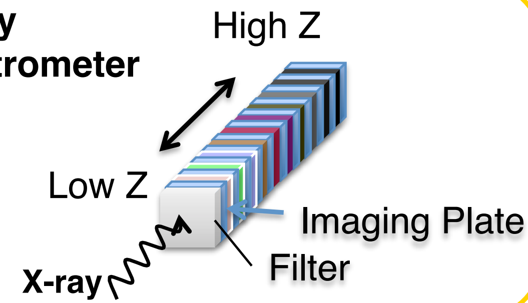


LAUE Spectrometer (<0.1 MeV)

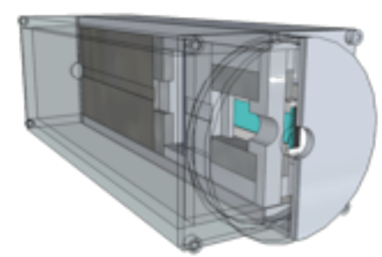




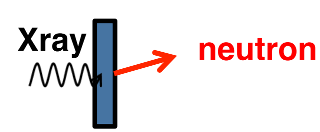
High Energy X-ray Spectrometer (< 1 MeV)



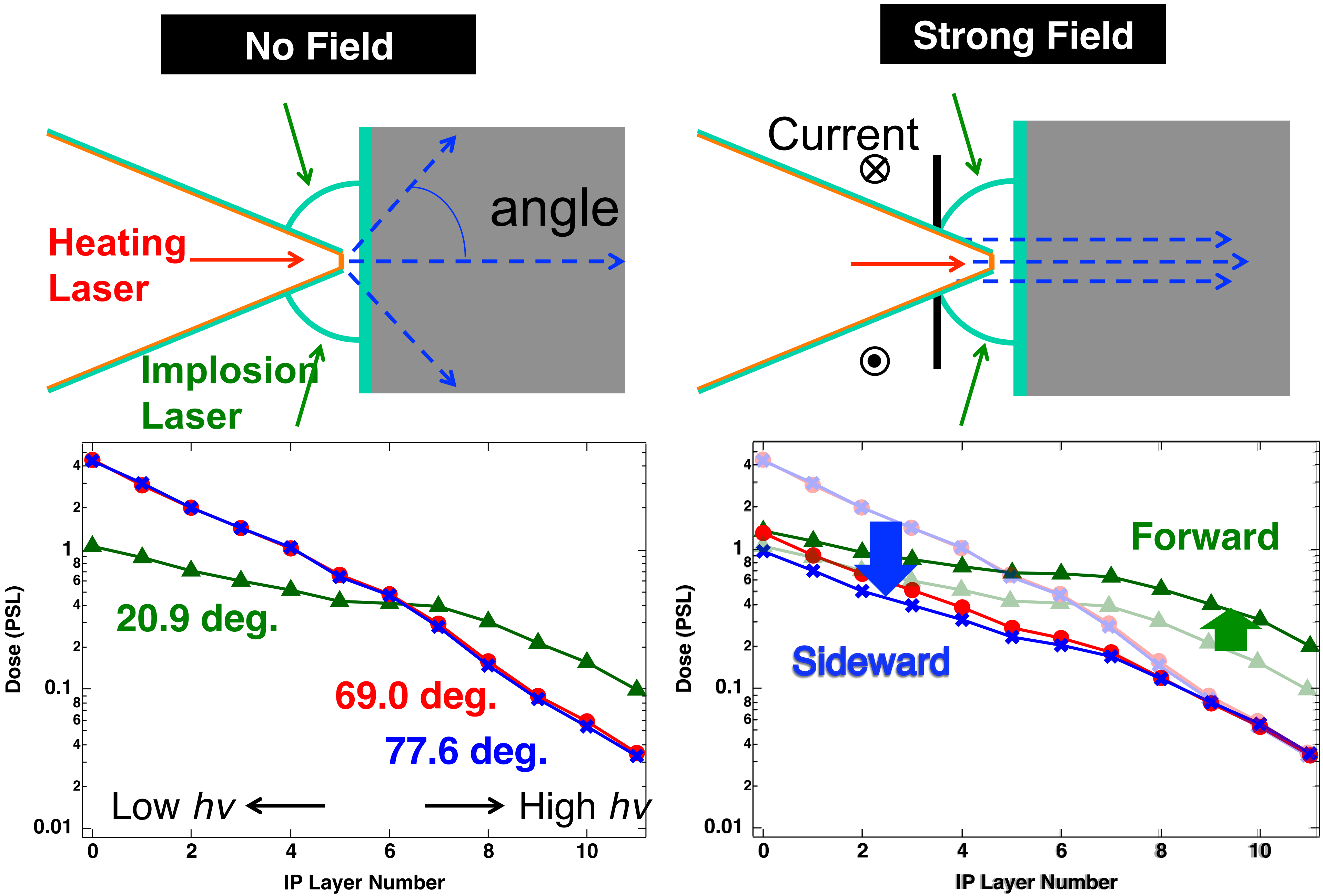
Compton γ-ray spectrometer (0.5 - 5 MeV)



(γ,n) reaction γ-ray spectrometer (3 - 30 MeV)

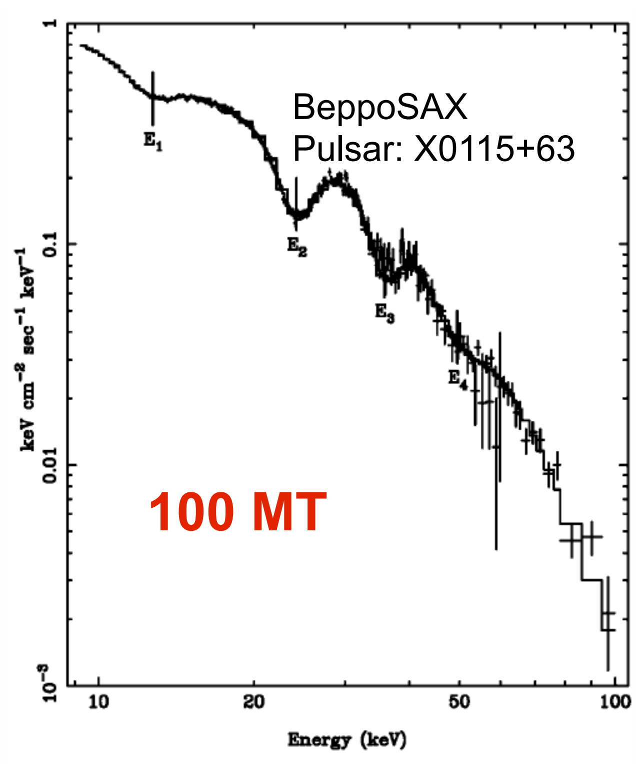


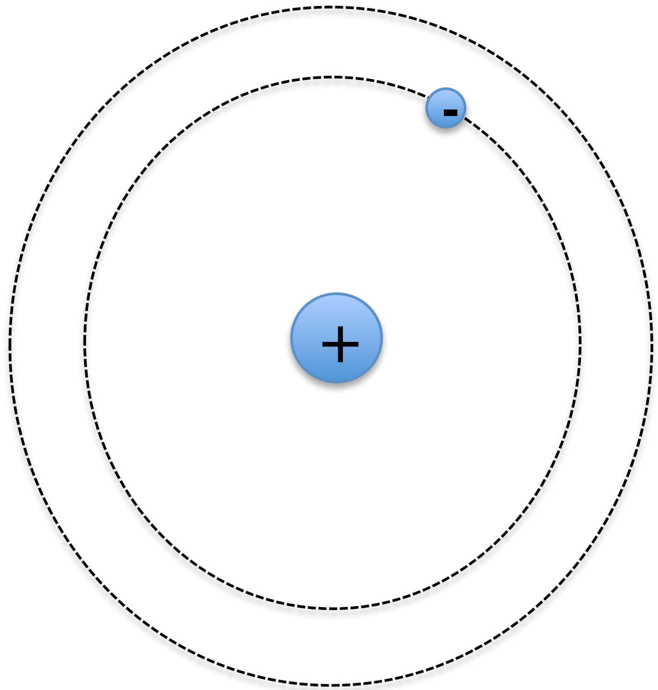
Magnetized Fast Ignition: Collimation



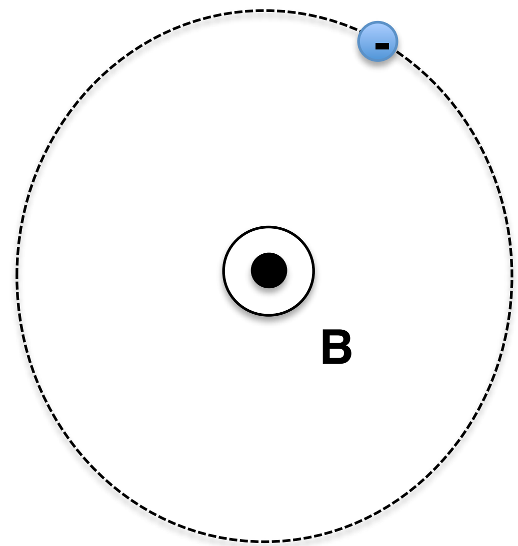
Amusement: Landau quantization

Electron around B-field	Electron around Nucleus	Electron around B-field





1 eV@10 kT

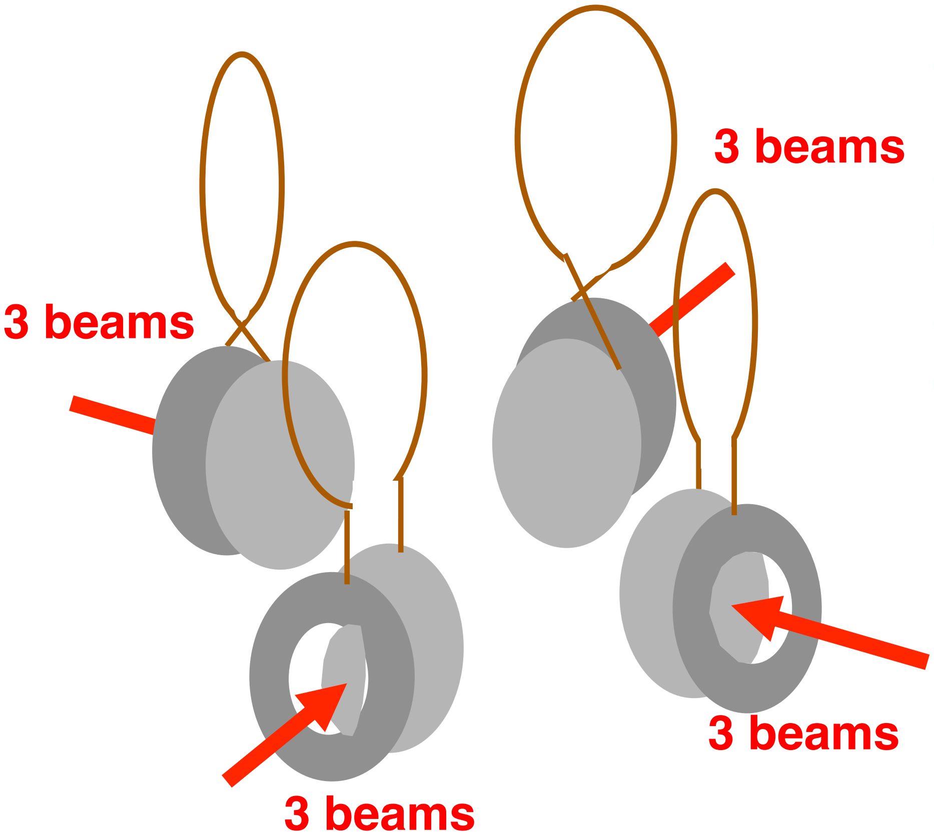


$$E = -\frac{2mZ^2e^4}{n^2\hbar^2}$$

$$E = n\hbar\omega_c = n\hbar\frac{eB}{m}$$

Amusement: Micro Tokamak

Cusp

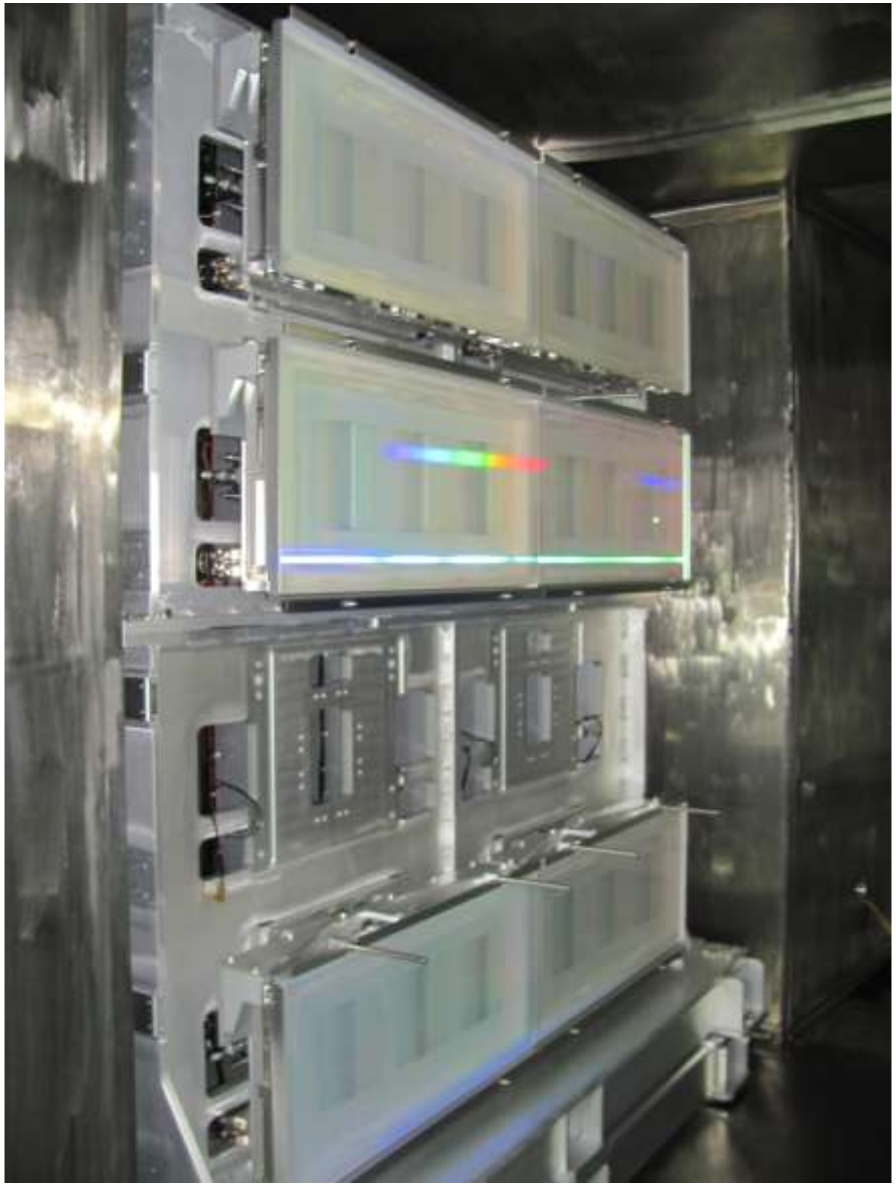


Tokamak

Driven by ....

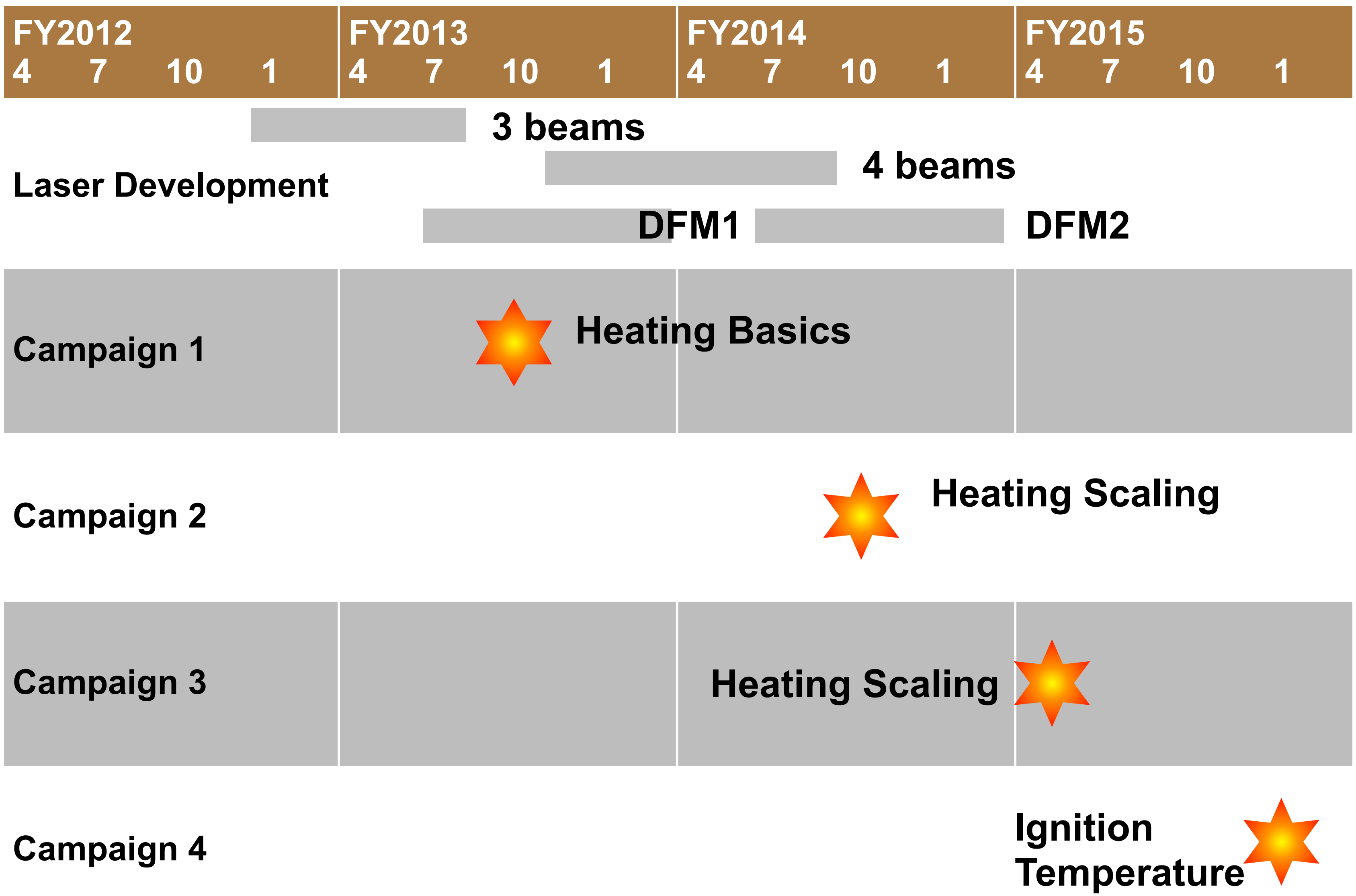
10^4 times B field sustains 10^8 times density plasma: mm Tokamak!?

Full operation of LFEX on Nov. 2014.




Currently, compressor grationgs are installed for three beams.

Four Campaigns in three years



Are we ready?

Reactor Core Plasma

✓ Reactor Technology Elements

- Laser
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- Reactor System

Alliance

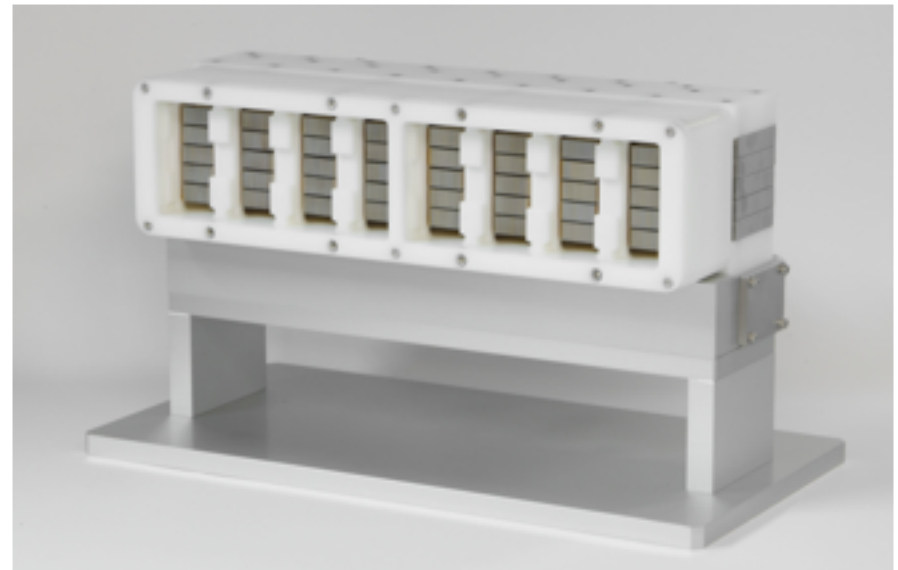
From Flush Lumps to Laser Diodes

OSAKA UNIVERSITY Institute of Laser Engineering

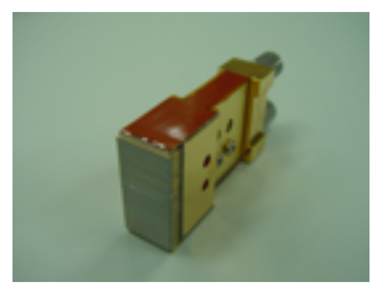
Flash Lamps

Broad emission spectra
Inefficient & low rep

Laser Diodes



Emission matches absorption line



HAMAMATSU
PHOTON IS OUR BUSINESS

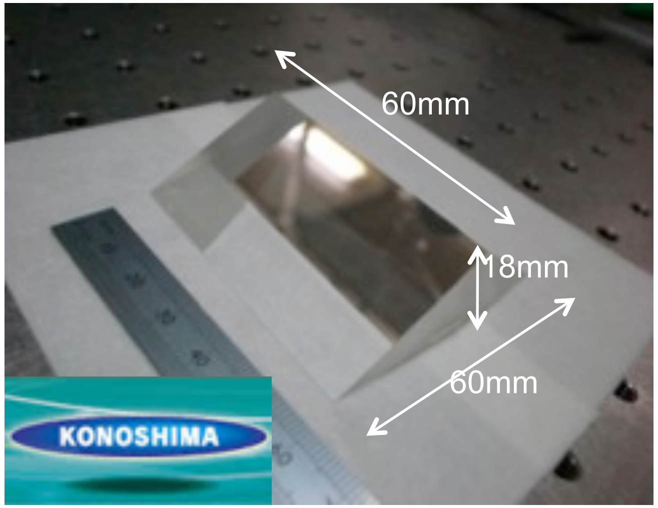
1x1.5 cm^2
5-kW module
15 k$→500 $

high efficiency and heat suppression

From Glasses to Ceramics

Laser Glasses

Yb: YAG Cooled Ceramic Crystal



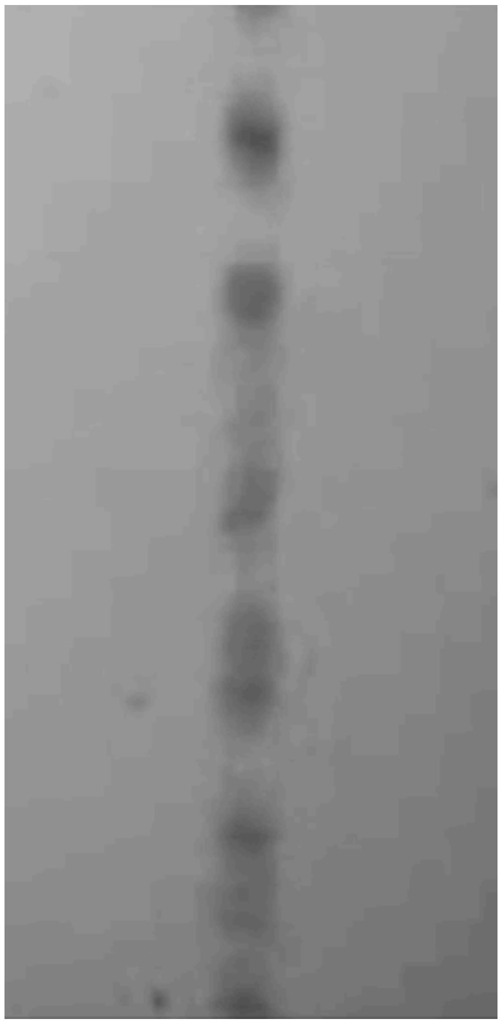
- Glass→Large optics
- Glass→Very low thermal conductivity

- Crystal→High thermal cond.
- Ceramic→Large optics

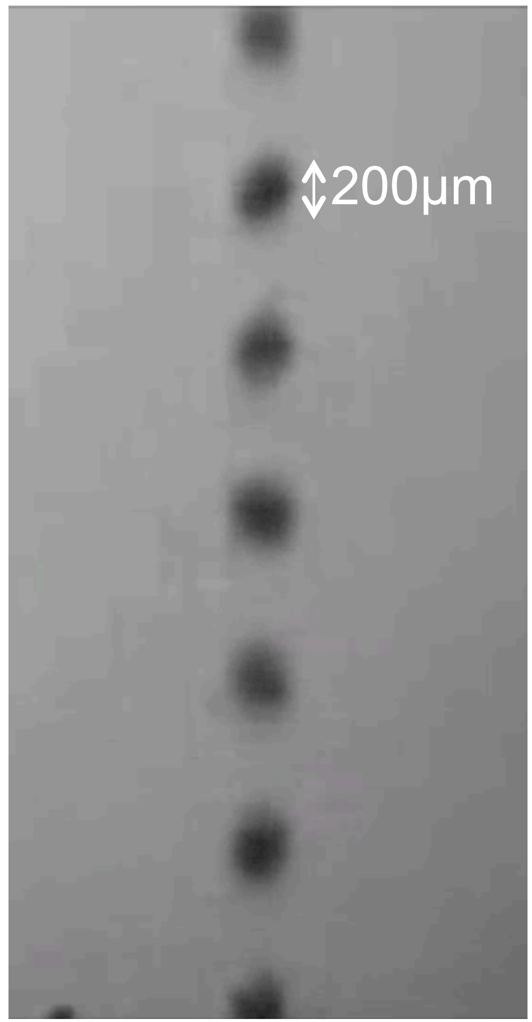
Several 100s increase of thermal conductivity enables 500 Hz rep rate, much higher than reactor requirement.

Target Injection and Beam Pointing

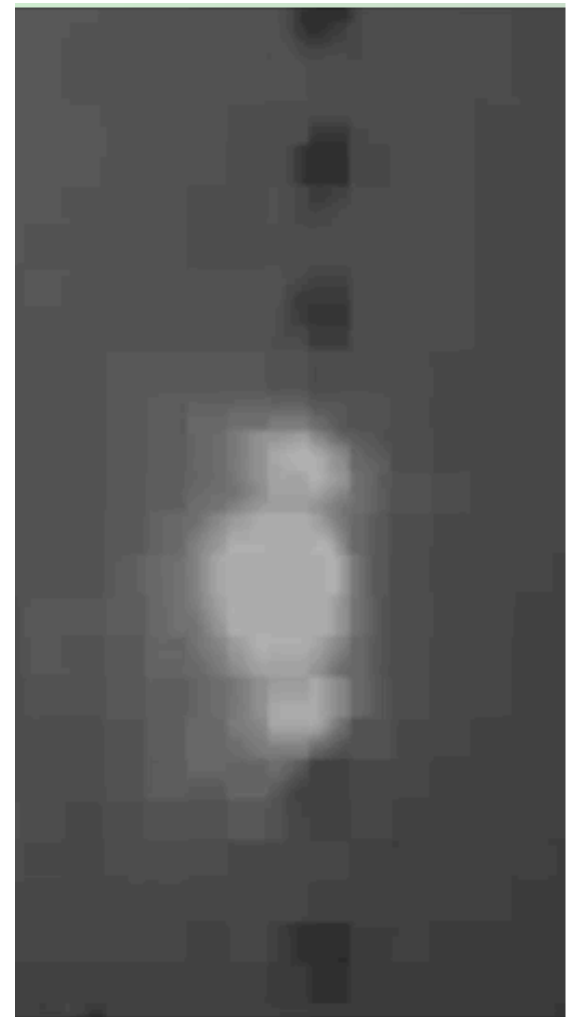
Strobe backlight



Synchronized



Laser fire
百発百中



Injection is demonstrated
→Demo of reactor core plasma is critical

Are we ready?

Reactor Core Plasma
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- Laser
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- Reactor System

✓ Alliance

Industry's Engagement into IFE Field

**President Emeritus,
Shoichiro Toyota, visited
ILE, Osaka**

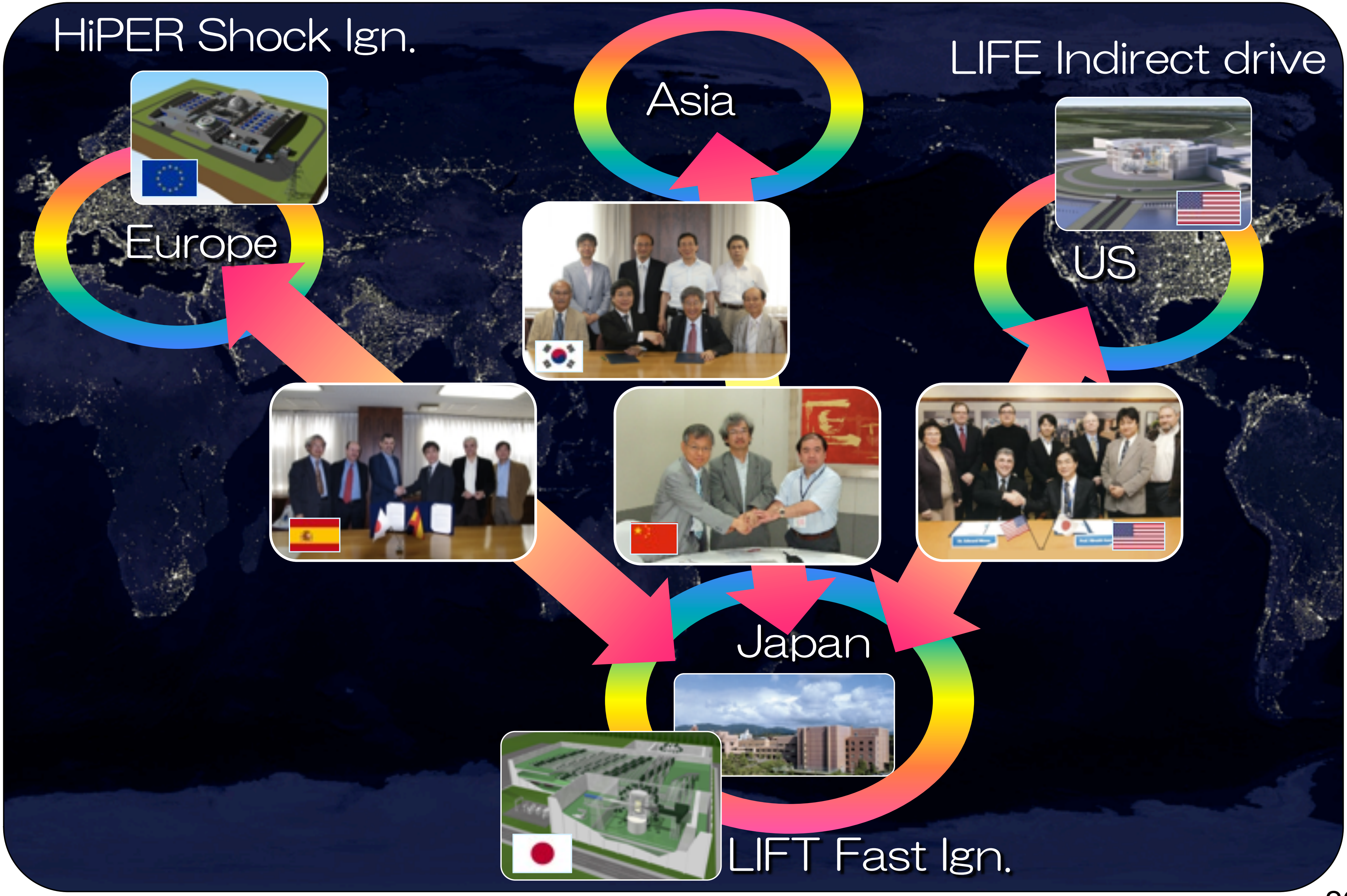
**Air & Water Jet Loom@
Toyota Techno Museum**

**Wept injection: >10 Hz, 80 m/s
<<mm accuracy**

Hamamatsu and Toyota have started private Laser Fusion Program.

OSAKA UNIVERSITY Institute of Laser Engineering

International Alliance on IFE



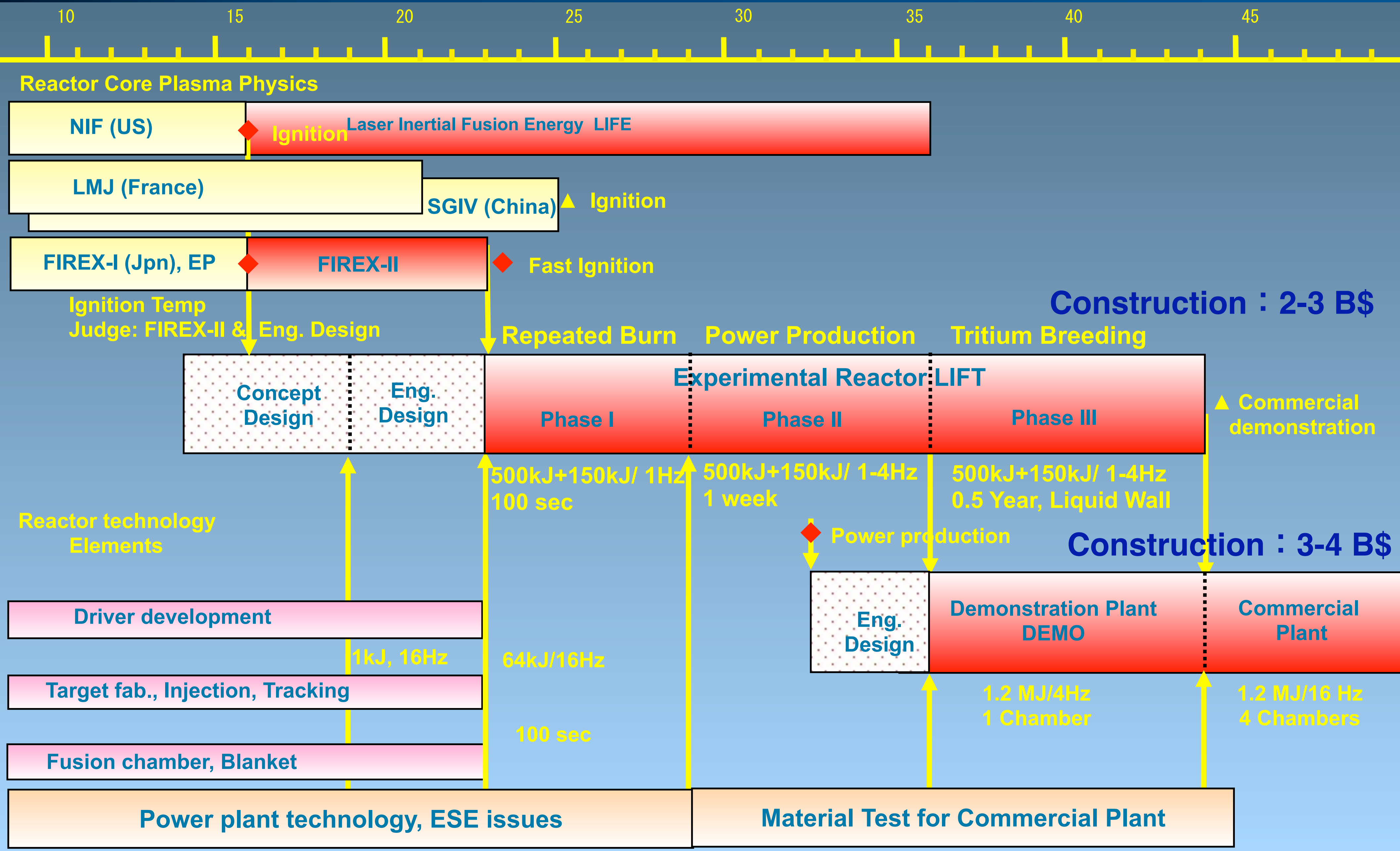
400 people got together.

The Eighth International Conference on Inertial Fusion Sciences and Applications

IFSA2013 Nara

September 8 – 13, 2013 Nara Prefectural New Public Hall, Nara, Japan

Experimental reactor LIFT integrates all physics and engineering activities.



Summary

- **Fusion provides limitless energy source, has no danger of nuclear runaway, and emits neither warming gas nor high-level radioactive waists.**
- **After 50 years from the innovation of lasers, it is an eve of the first controlled fusion burn in humankind history.**
- **Compactness of fast ignition will accelerate inertial fusion energy development.**
- **IFE physic and engineering programs would converge onto an experimental reactor, that will LIFT up people's spirits.**