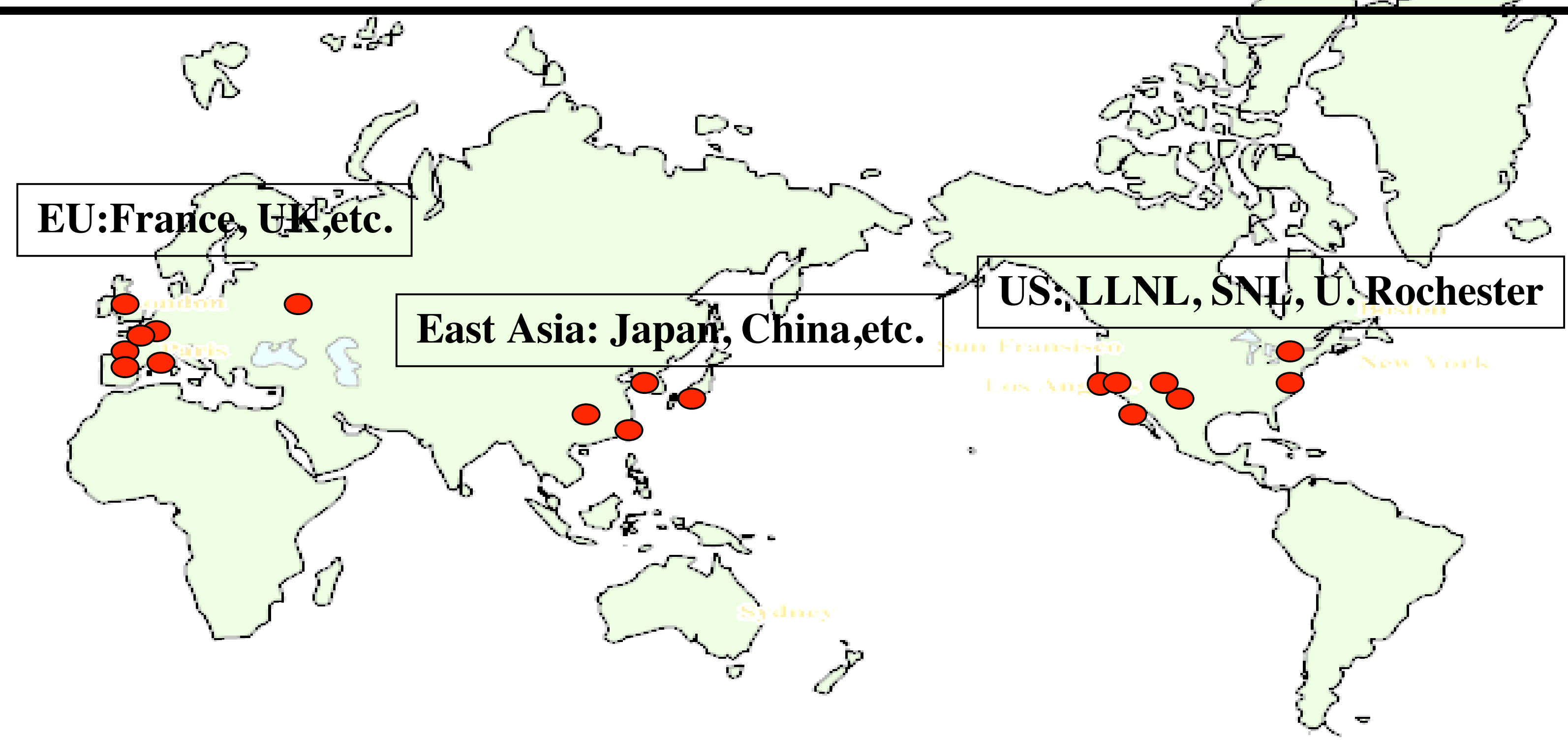
Inertial Fusion Power Development:Path for Global Warming Suppression



Kunioki Mima

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IAEA- FC 2008, 50 years’ Ann. of Fusion Res. , Oct.15, 2008, Geneva, SW

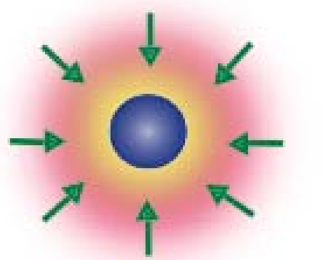
Outline

- Brief introduction and history of IFE research
- Frontier of IFE researches
  Indirect driven ignition by NIF/LMJ
  Ignition equivalent experiments for fast ignition
- IF reactor concept and road map
  toward power plant

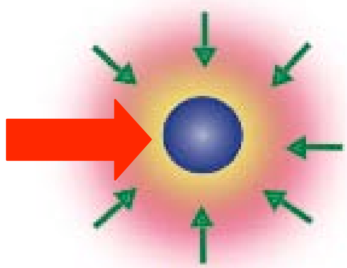
IFE concepts

Several concepts have been explored in IFE.

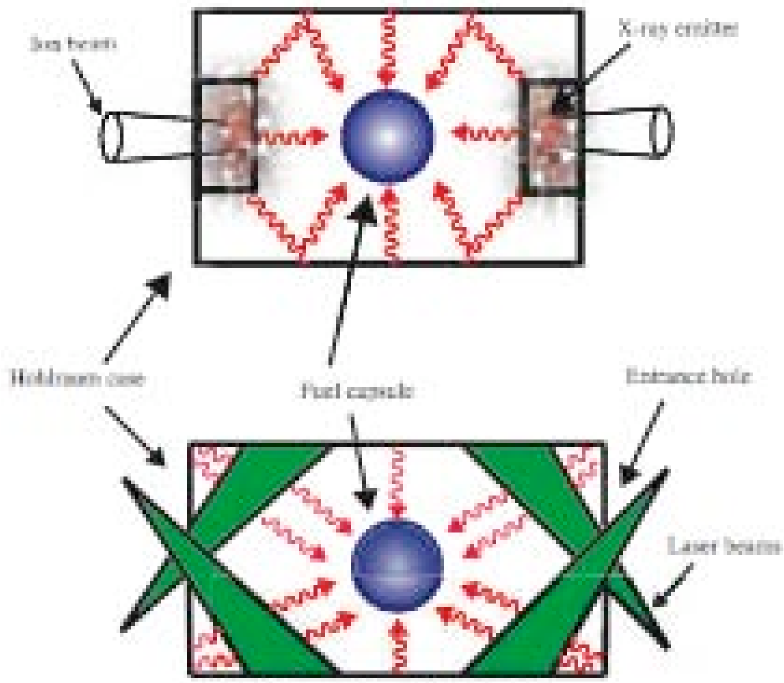
Driver	Irradiation	Ignition
Laser	Direct	Central hot spark Ignition
HIB	Indirect	Fast ignition
		Impact ignition
Pulse power		Shock ignition



Direct drive illumination
Laser beams rapidly heat the surface of the fuel capsule.



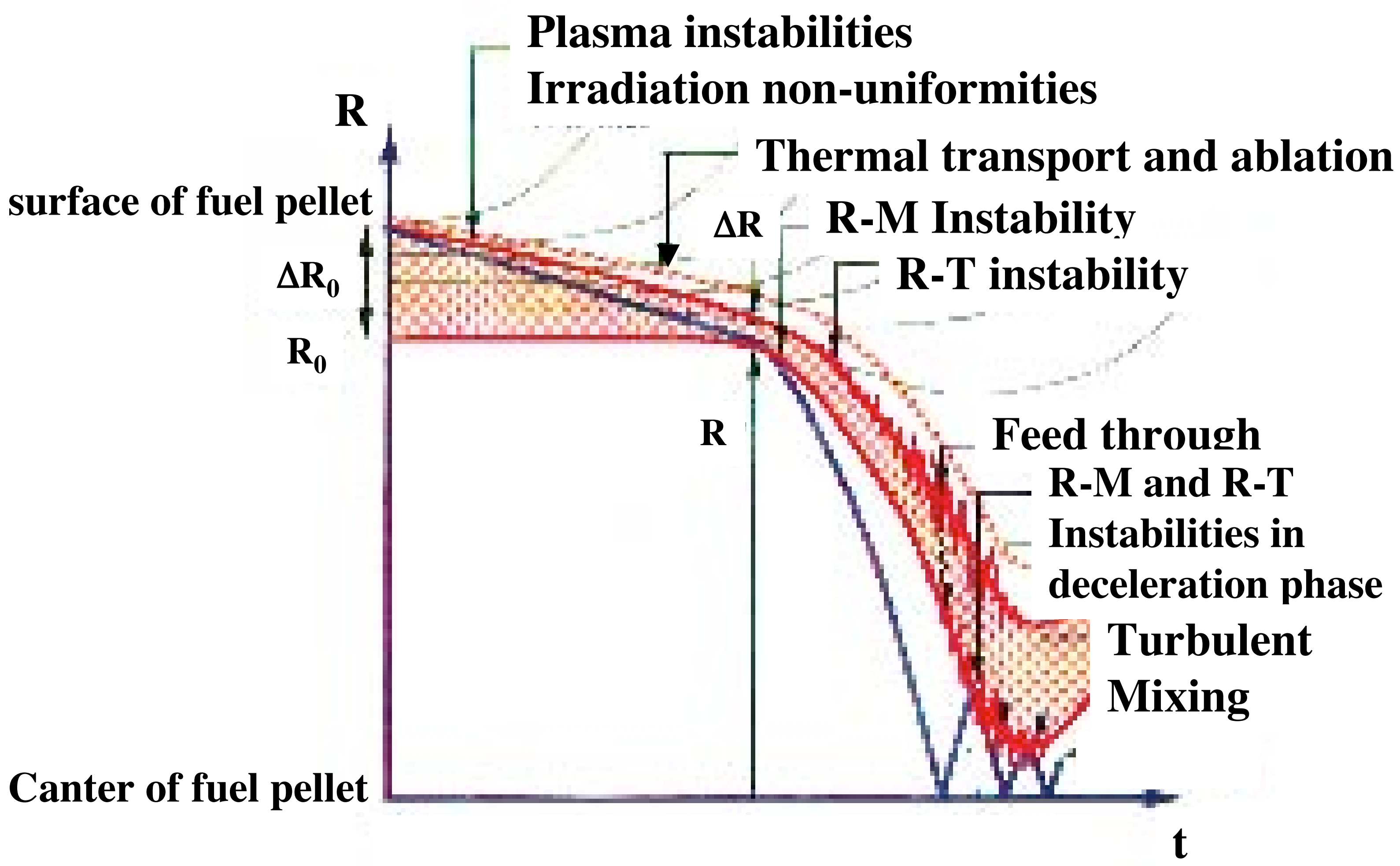
Direct drive illumination
Laser beams rapidly heat the surface of the fuel capsule.



Indirect drive illumination
X rays from the hohlraum or emitter rapidly heat the surface of the fuel capsule.

The key issue of IFE is implosion physics which has progressed for more than 30 years

Producing 1000times solid density and 10^8 degree temperature plasmas



Major Laser Fusion Facilities in the World

ILE OSAKA

NIF, LLNL, US.

LMJ, CESTA, Bordeaux, France

SG-III, Menyang,CAEP, China

GXII-FIREX, ILE, Osaka, Japan

OMEGA-EP, LLE, Rochester, US

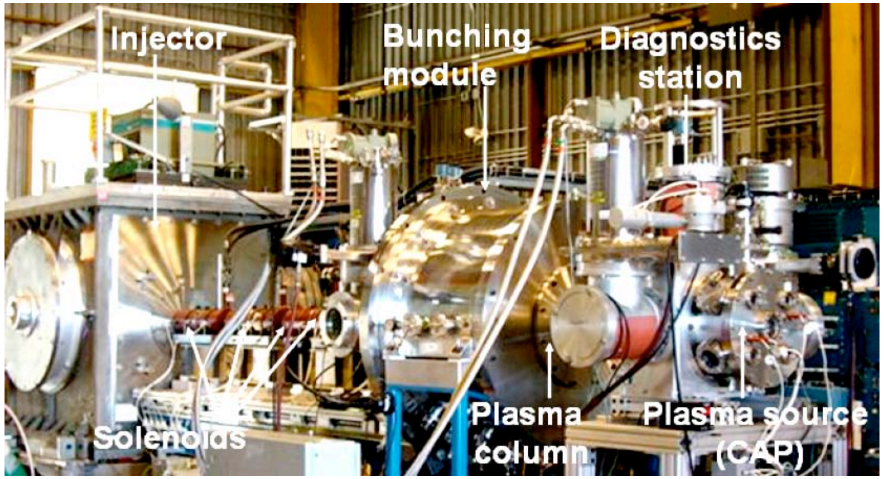
HiPER, RAL, UK

Heavy Ion Beam Fusion:
The advanced T-lean fusion fuel reactor

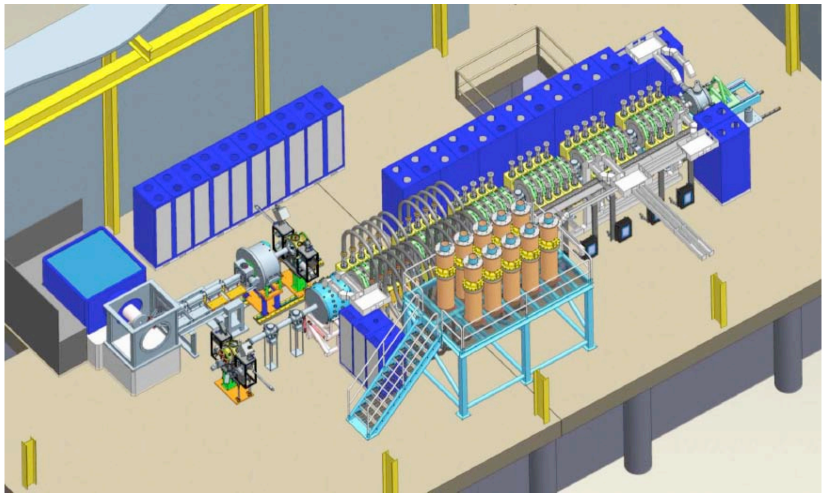
US HIF Science Virtual National Lab.(LBNL, LLNL,PPPL)
has been established in 1990.
(Directed by G Logan)

- Implosion physics by HIB
- HIB accelerator technology
  for 1kA, 1GeV, 1mm^2 beam:
  Beam brightness, Neutralization,
  Collective effects of high current
  beam, Stripping.(R.Davidson etal)
- Reactor concept with Flibe liquid jet wall
  (R.Moir: HYLIF for HIF Reactor)

Test Stand at LBNL NDCX-I

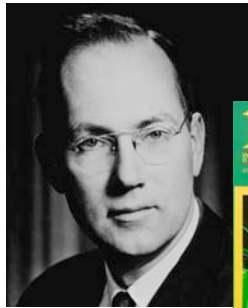


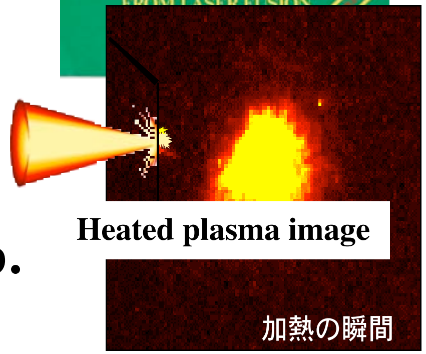
NDCX II



History of IFE Research

1960: Laser innovation (Maiman)
1972: Implosion concept (J. Nuckolls)
1980~ 1995: Understanding of Implosion progressed.
GXII, Nova, OMEGA, NRL-KrF, Sandia-Z Pinch.
Laser tech.: harmonic irradiation, Smoothing (RPP, SSD)
10-keV temperature demo:Japan and US $\sim 10^{13}$ neutrons
High-density demo
US 100-200 times liquid density
Japan 600 times liquid density
2000~ CPA laser R&D: PW laser heating demo. J-UK joint exp.



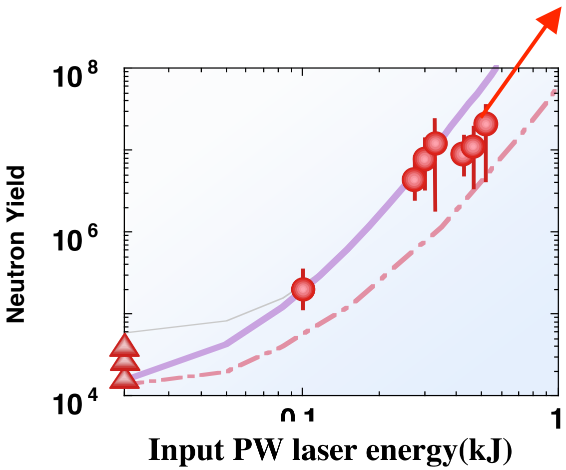


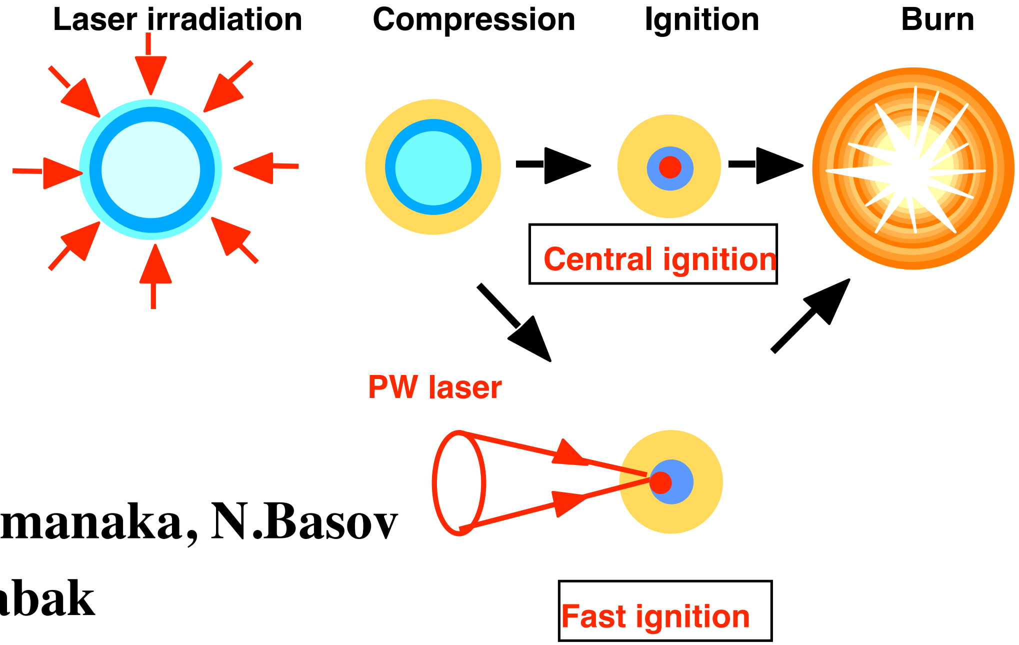
Nature (2001.8.23)

Central ignition	Fast ignition
NIF project, LMJ project. SNL-Z project	-FIREX, OMEGA-EP, HiPER

First thermonuclear ignition in laboratory will be demonstrated in the next decade.

Fast Ignition opens a new rout to compact IF Reactor





1983-92 Concept Exploration: T.Yamanaka, N.Basov

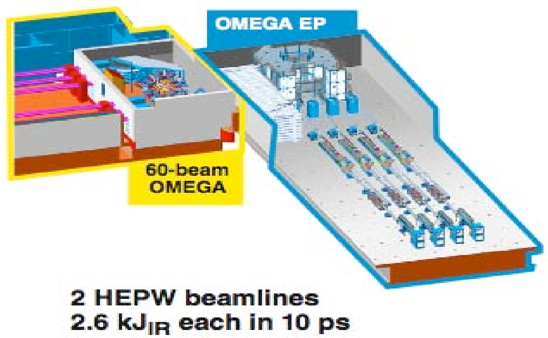
1994 Concept Innovation: M. Tabak

2002 1-keV heating by fast ignition scheme:

Japan-UK Joint Exp.

GXII-LFEX (FIREX)

OMEGA-EP



Recent achievement at LLE, University Rochester

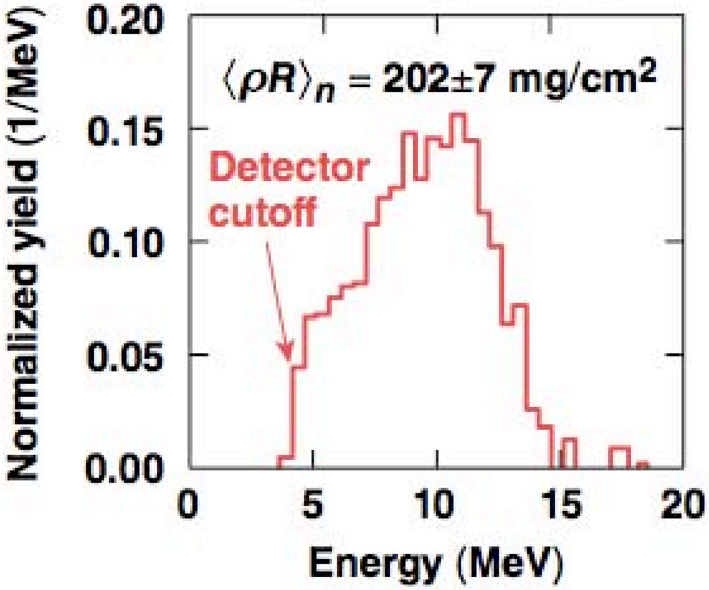
Ignition-relevant D_2 areal densities (~200 mg/cm^2) are achieved in cryogenic implosions

UR LLE

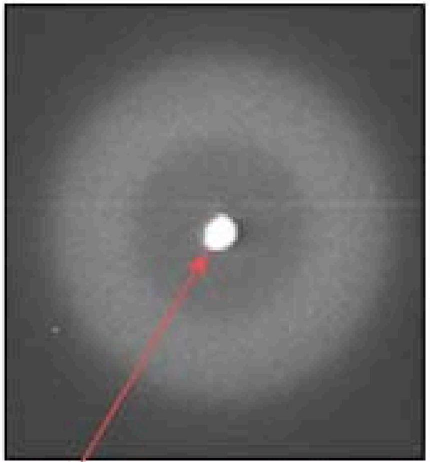
- Target design tuned to be insensitive to the thermal transport model and has low hard x-ray signal.

10-μm CD cryogenic implosion

Secondary D^3He proton spectrum

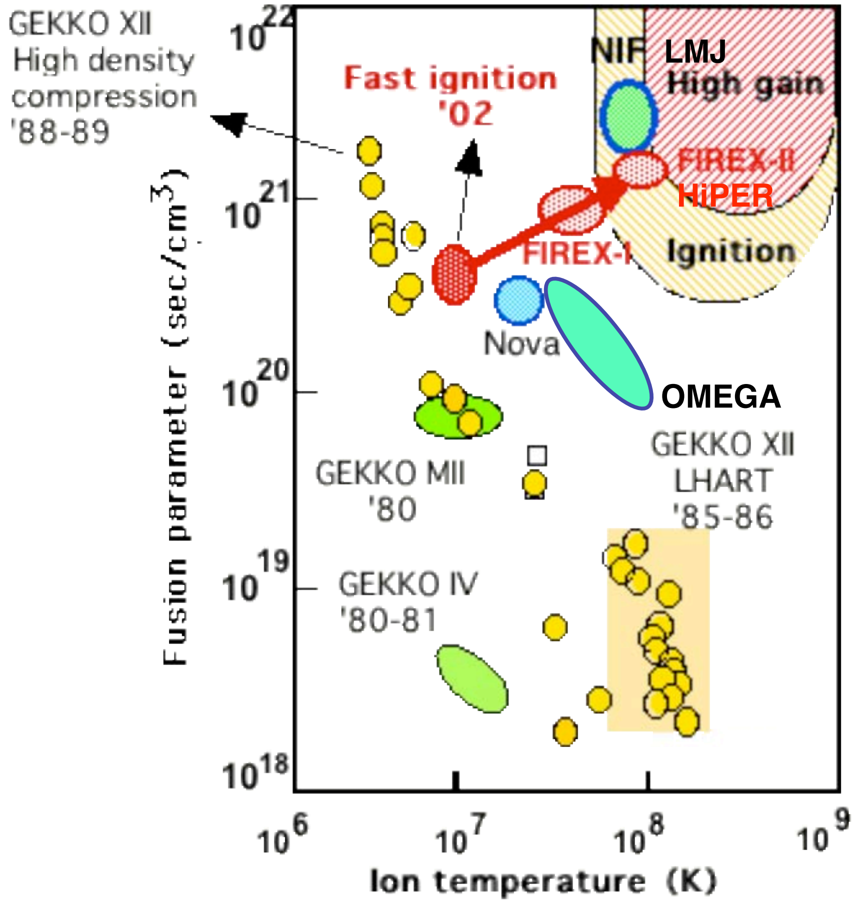


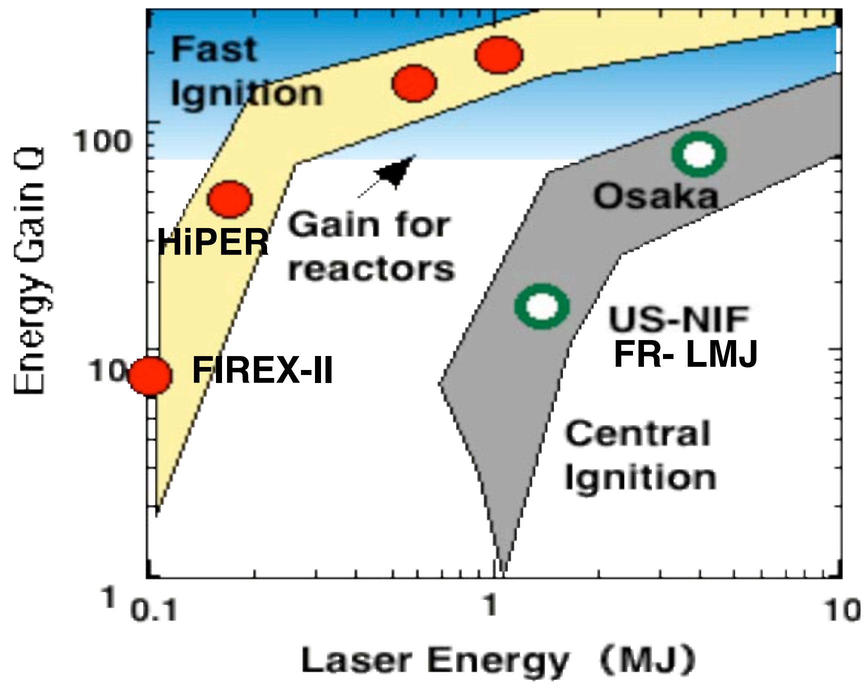
X-ray pinhole camera



D_2 fuel density reaches ~100 g/cc (500× liquid density)

Progress of plasma parameters toward high gain





Overview of Indirect Drive Ignition Facilities (Under Construction)

[Common features]

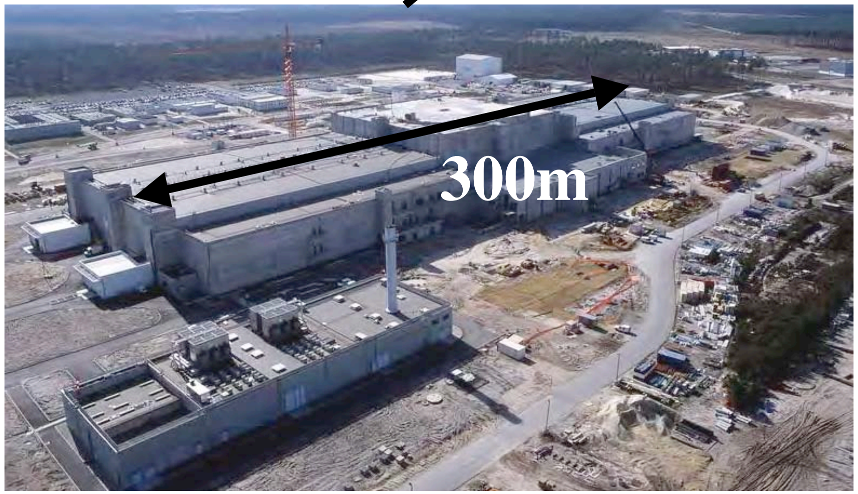
Laser beam shape: square 40x40 cm^2, Wavelength: 0.35μm, Laser energy:1~1.8MJ on target
Power: 300~800TW, Pulse duration: 1ns~17ns

[Different features]

NIF	LMJ
NIF const. (1997-2008)	LMJ const. (2003~2012)
Ignition exp. (2010)	240 beams(60quads)
192beams (48quads)	Irradiation symmetry: 2x3 cones
Irradiation symmetry:2x2 cones	Grating focusing
Lens focusing	

NIF, US.

LMJ, France



Basic strategy of Laser Fusion Projects

- International scale laser is required to establish the route to affordable IFE.
- A fully civilian approach is essential.
- Flexibility will be required to address new, emerging classes of fundamental science applications.
- Forming network of international developments (NIF, FIREX, EP, LMJ, HiPER, …)
- Acceptance as the international laser fusion roadmap for average power large-scale facilities
- International Laser IF Test reactor is possible candidates

FIREX-II(Japan) and HiPER-EU (RAL, UK) are planed with linkage to the international projects

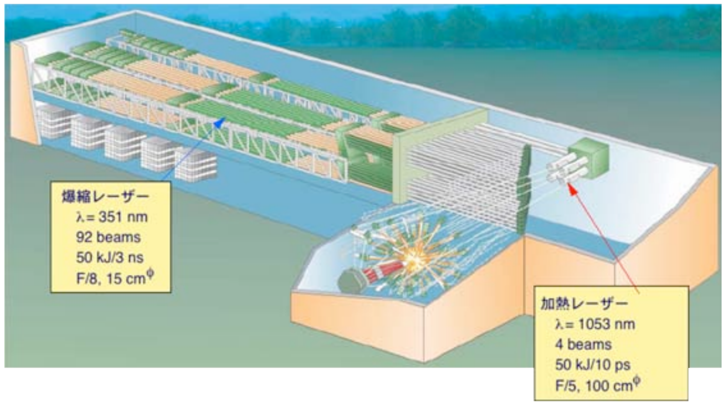
HiPER and FIREX-II are aiming at ignition and burn with fast ignition

The 3 year project for detail design of HiPER has started in this year.

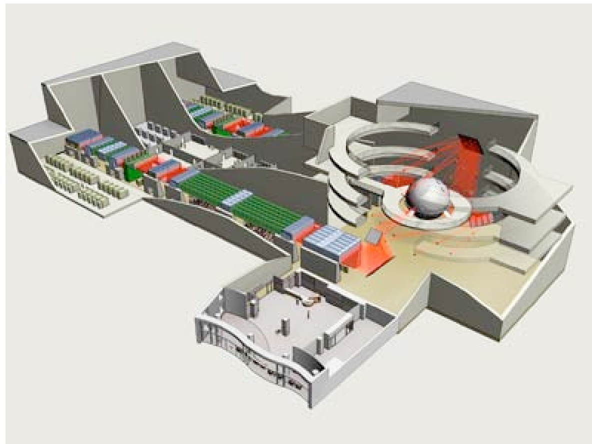
Coordination with other international partners

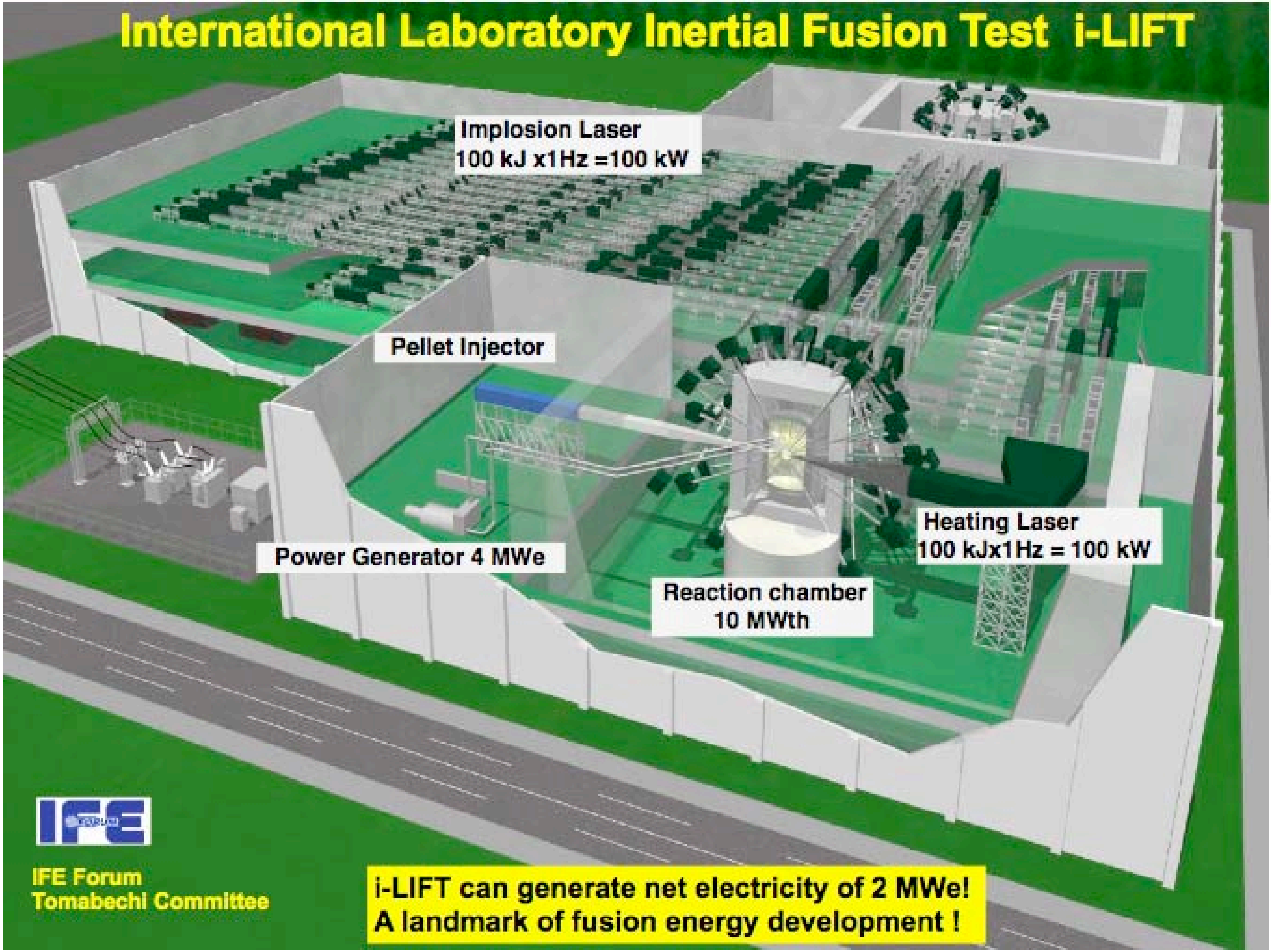
- **USA, Japan, Canada, Korea, China, Russia,**

Proposed FIREX-II

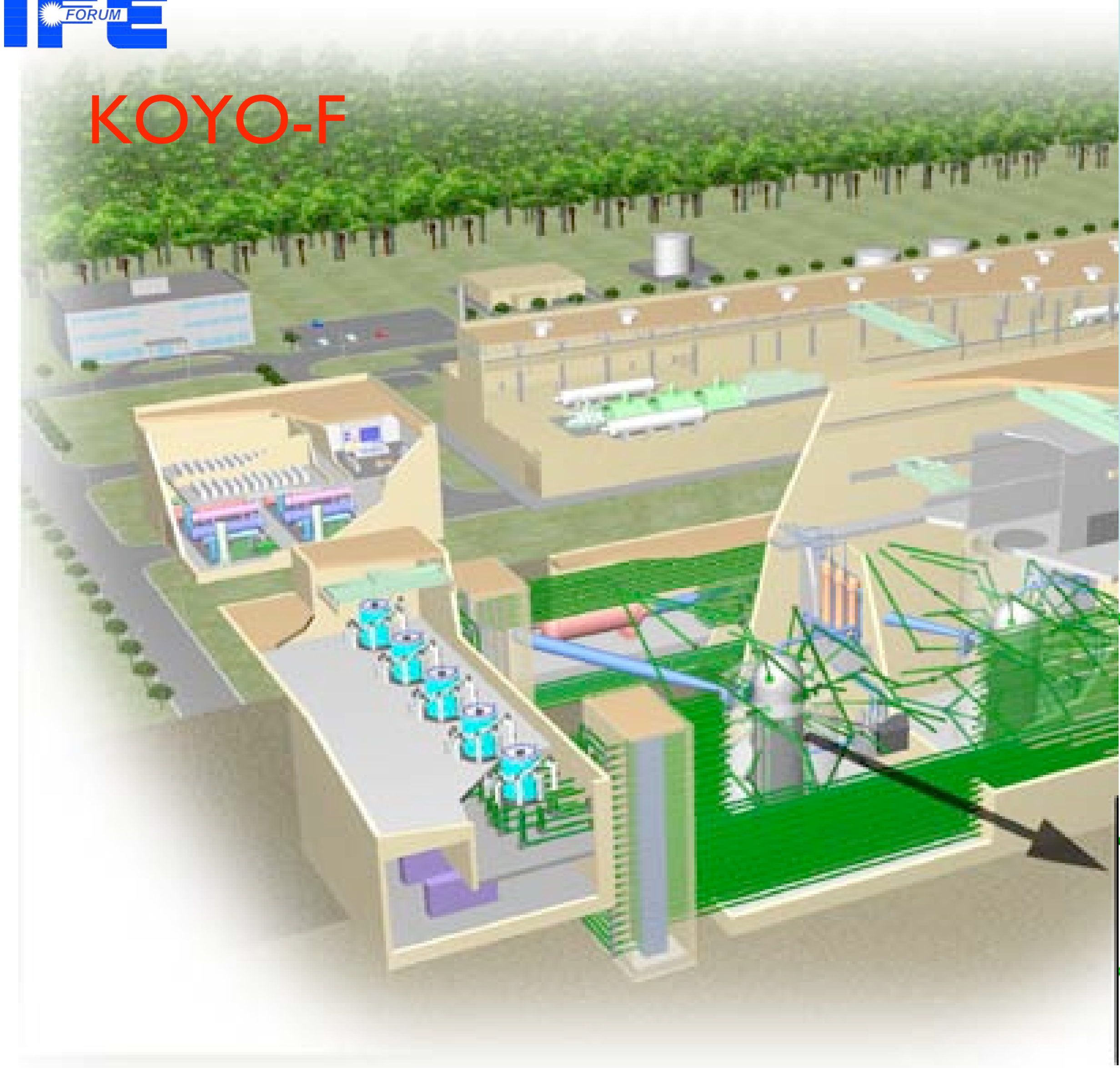


1. **PW heating beam:**
   50~70kJ/10ps, 2ω
2. **Implosion beam:**
   50~200 kJ
   5ns
   ~40 beams
   10 m chamber

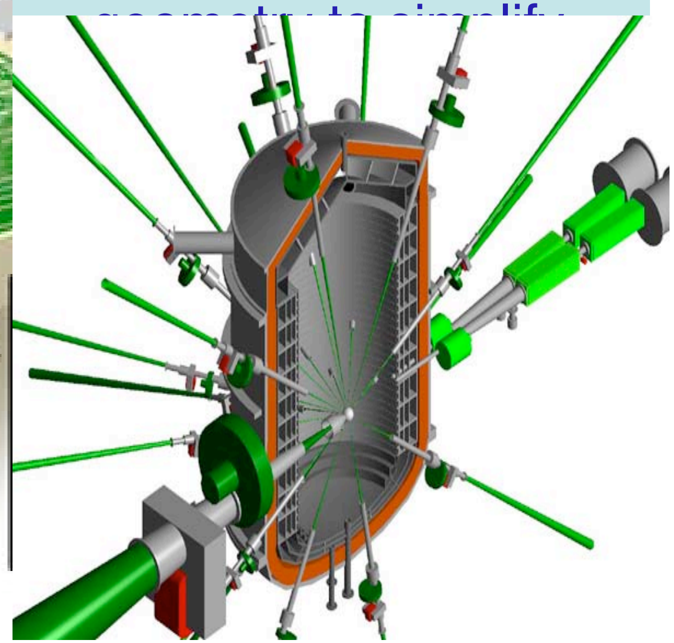


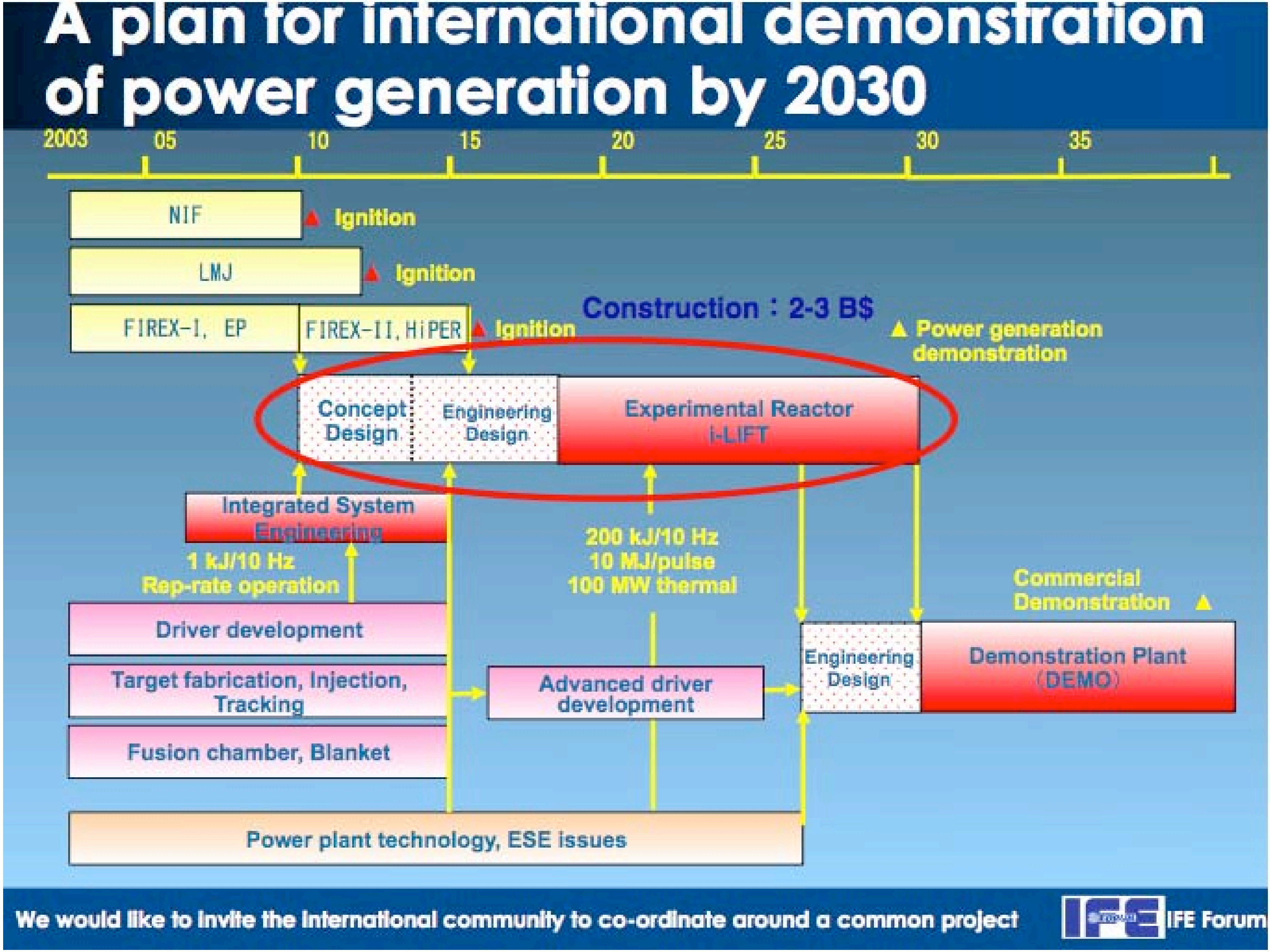

International Laboratory Inertial Fusion Test i-LIFT
Implosion Laser
100 kJ x1Hz =100 kW
Pellet Injector
Power Generator 4 MWe
Heating Laser
100 kJx1Hz = 100 kW
Reaction chamber
10 MWth
IFE Forum
Tomabechi Committee
i-LIFT can generate net electricity of 2 MWe!
A landmark of fusion energy development !

KOYO-F



- KOYO-F has 1.1 MJ, 32 beams for compression, 100kJ heating laser and two target injectors.
- Thermal out put: 200 MJ/shot
  Rep-rate 4 Hz
- KOYO-F has vertically off-centered irradiation




A plan for international demonstration of power generation by 2030
2003
05
10
15
20
25
30
35
NIF
Ignition
LMJ
Ignition
FIREX-I, EP
FIREX-II, HiPER
Ignition
Construction：2-3 B$
Power generation demonstration
Concept Design
Engineering Design
Experimental Reactor i-LIFT
Integrated System Engineering
1 kJ/10 Hz Rep-rate operation
200 kJ/10 Hz
10 MJ/pulse
100 MW thermal
Commercial Demonstration
Driver development
Target fabrication, Injection, Tracking
Fusion chamber, Blanket
Advanced driver development
Engineering Design
Demonstration Plant (DEMO)
Power plant technology, ESE issues
We would like to invite the international community to co-ordinate around a common project
IFE Forum

Concluding Remarks:
Advantages of Inertial Fusion Energy

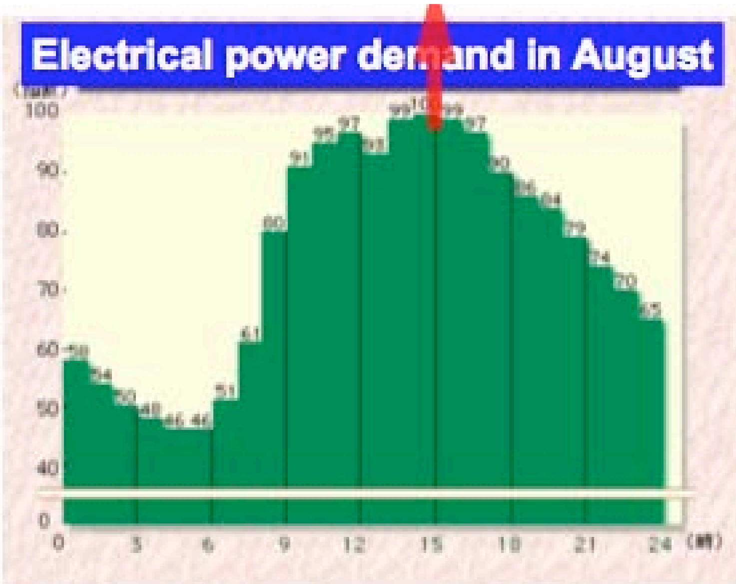
ILE OSAKA

1) IFE power reactor can be compact (200MW $_e$)

2) Electric power of IFE reactor is variable
because of pulse operation

3) Easy in power plant site selection

These advantages will contribute to the efficient energy use and the global warming suppression.



Day by day and daily variation of consumed Electric power.

Role share: MFE for the base, IFE for the peak.