Laser Fusion in Japan: Combat with global warming

Fusion Power Associates
Washington DC
2009.12.2-3

H. Azechi
Director
Institute of Laser Engineering
Osaka University

Haunting face crying a river of tears as glacier melts into the sea
Photo By Michael Norman
Why Fusion?

• We need large size electric power plants without warming gas emission.

• The only solution at present is atomic power.

• But, nuclear waist problems (long life safety, proliferation etc.) requires other power plants which emit non-warming gas and negligibly small amount of nuclear waist.

• Fusion energy is the ultimate large energy source.
Why Inertial Fusion

• After 50 years from the innovation of lasers, the community is ready to ignite a fusion fuel: the first controlled fusion ignition in humankind.

• Once the ignition is achieved, the energy gain is increased simply by increasing the size of the core. The burning proceeds no matter what the fuel size is.

• Physics of reactor core plasma will be completely explored and established in this phase. This is why ignition and burn is so important.
Why Fast Ignition?

- Since the fuel contains no central hot spark, the Fast Ignition can ignite with 1/10 of laser energy that is necessary for conventional central ignition.

- This compactness strongly accelerates Inertial Fusion Energy development.
Fast Ignition Realization Experiment (FIREX) Program for Inertial Fusion Energy

- Proof-of-concept: Scalable to 600 times liquid density
  Demo of 1 keV temp. by 0.5kJ/0.5ps.
- FIREX-I: Demo of 5-10 keV temperature by 10kJ/10ps.
- FIREX-II: Demo of significant burn
LFEX:
10-kJ Short Pulse Laser

Chirp Pulse Amp.
- Large grating

Compression

Amp

Stretch

Time

92 cm

World Largest and Finest Grating

575 nm
First integrated FI experiment has just started.

First plasma on June 26th, '09

Diamond compressor

Shadow of cone

Initial Shell
FIREX-I Integrated Experiment

X-ray image from cone side (Time integrated)

X-ray streak image (Time resolved)

Heating beam (LFEX) injection

Heating time determination

Emission by Heating Laser

Emission by implosion
Neutron yield increases with heating laser injection

Strong pulse width dependence was found. It seems 5-keV heating is plausible.
Near Term Schedule and Future Plan
<table>
<thead>
<tr>
<th>Year</th>
<th>Laser Construction</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>One-beam operation</td>
<td>Repeat <em>Nature</em> exp’t</td>
</tr>
<tr>
<td>2010</td>
<td>Two-beam operation</td>
<td>Surpass <em>Nature</em> exp’t</td>
</tr>
<tr>
<td>2011</td>
<td>Four-beam</td>
<td>CD heating (<em>5keV</em>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Goal of FIREX-I</strong></td>
</tr>
<tr>
<td>2012</td>
<td>Wavefront control</td>
<td>Advanced targets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CD heating (<em>&gt;5keV</em>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Excess achievement</strong></td>
</tr>
</tbody>
</table>
Nest Step 1: Ignition and Burn by Fast Ignition

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”
It’s time to bring a paradigm shift in inertial fusion.

- By the time of NIF ignition, it will have passed more than 20 years since the end of the Cold War.
- Global warming is becoming the serious problem.

A flagship program is necessary to lift up inertial fusion community’s spirits.
Next Step 2: Laboratory Inertial Fusion Test  LIFT

i-LIFT can generate net electricity of 2 MWe! A landmark of fusion energy development!
International Laboratory Inertial Fusion Test: i-LIFT

i-LIFT can generate net electricity of 2 MWe! A landmark of fusion energy development!
Experimental reactor i-LIFT integrates all physics and engineering activities.

NIF (US)
Ignition

LMJ (France)

SGIV (China)

FIREX-I (Jpn), EP

FIREX-II

Integrated Engineering Test

Experimental Reactor LIFT

Concept Design
Eng. Design

1 kJ/1Hz x 10
200kJ/1Hz

1.2 MJ/4Hz
1 Reaction Chamber

1.2 MJ/16 Hz
4 Reaction Chamber

Continuity
Endurance

1-month operation

Blanket test

Commercial demonstration

Construction : 2-3 B$

Demonstration Plant DEMO

Commercial Plant

Advanced reactor technology

Driver development

Target fab., Injection, Tracking

Fusion chamber, Blanket

Power plant technology, ESE issues

i-LIFT is Laser based Fast Track. 09/11/7
Reactor Lasers
Pumping: from Flash Lamps to Laser Diodes

Laser absorption lines and Pumping Source spectra

Flash Lamps
- Most energy goes into heat

Laser Diodes
- Emission line can coincide with absorption line
- 100 W/bar
- Present 3$/W → Goal 0.1$/W

Laser Diode Pumping opens the possible high-rep high-efficient lasers
Several 100s increase of thermal conductivity enables 100 Hz rep rate, much higher than reactor requirement.
Summary

- After 50 years journey, the IFE community is ready for ignition at NIF.

- Compactness of fast ignition will accelerate inertial fusion energy development.

- IFE physic and engineering programs would converge onto an experimental reactor, i-LIFT, that will lift up people’s spirits.

ILE/Osaka, as a National Joint Research Facility, strongly encourages national and international collaborations.