Present Status of Fast Ignition Realization EXperiment (FIREX) and Inertial Fusion Energy Development

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PHOTO: NASA/SDO

Fast Ignition Realization EXperiment

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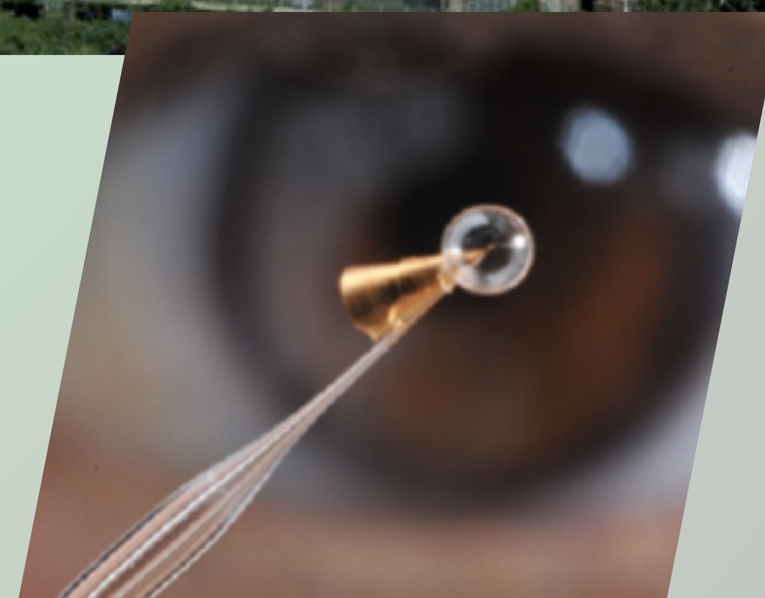
FIREX-I: Fast Heating to 5 keV
FIREX-II: Ignition and Burn



So far, 1 keV achieved.
Ignition temperature is not yet.

Strategy towards Fusion Power Generation

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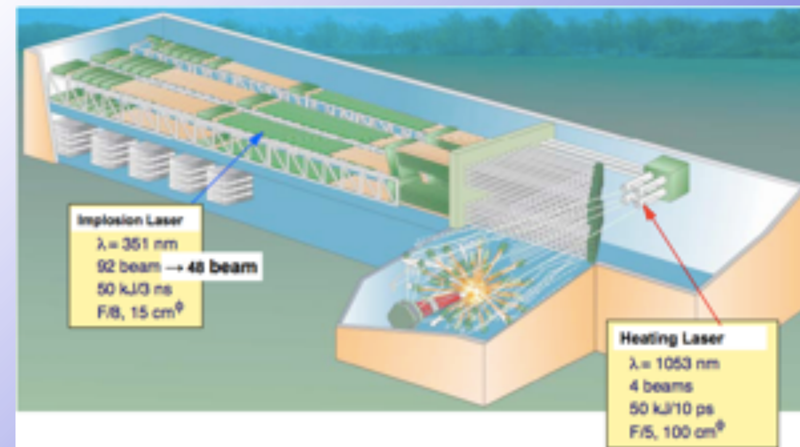
～2010

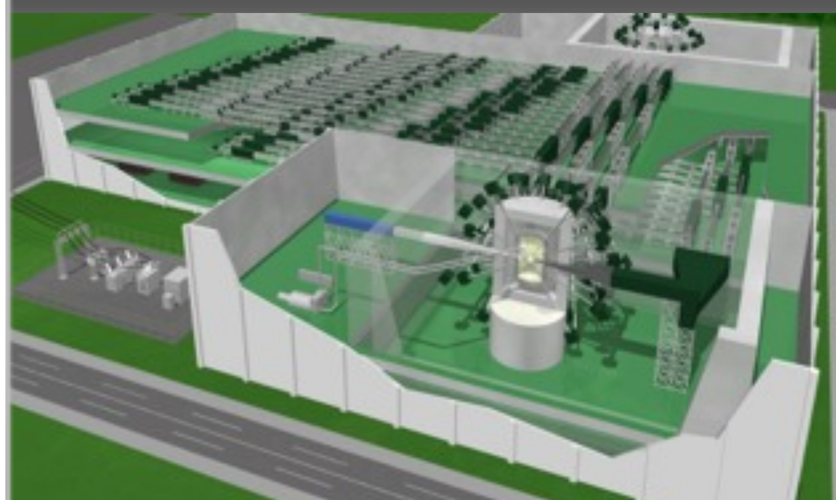
FIREX-I: Ignition Temp

～2020



FIREX-II: Ignition&Burn

～2030



LIFT: Power Generation

*Laboratory Inertial Fusion Test

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"

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Are we ready?

Reactor Core Plasma
  Electron Fast Ignition
  Impact Ignition
Reactor Technology Elements

Alliance

FIREX-I Integrated Exp’t

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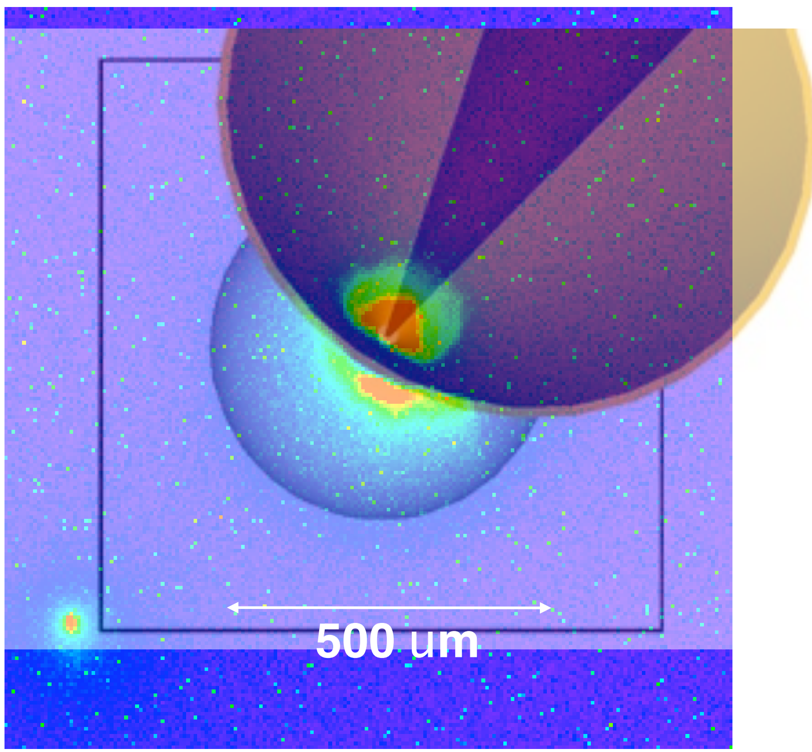
X-ray image from cone side (Time integrated)

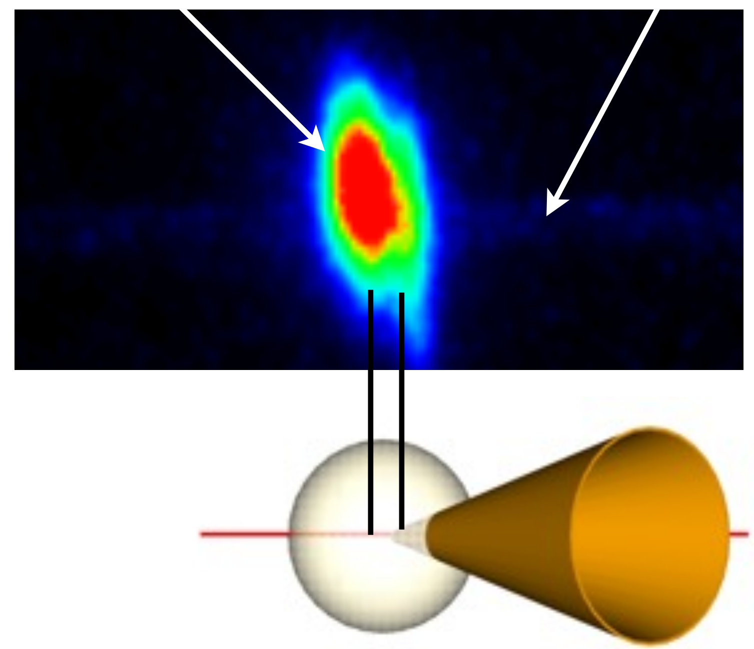


Time 500 ps

X-ray streak image (Time resolved)

Emission by Implosion

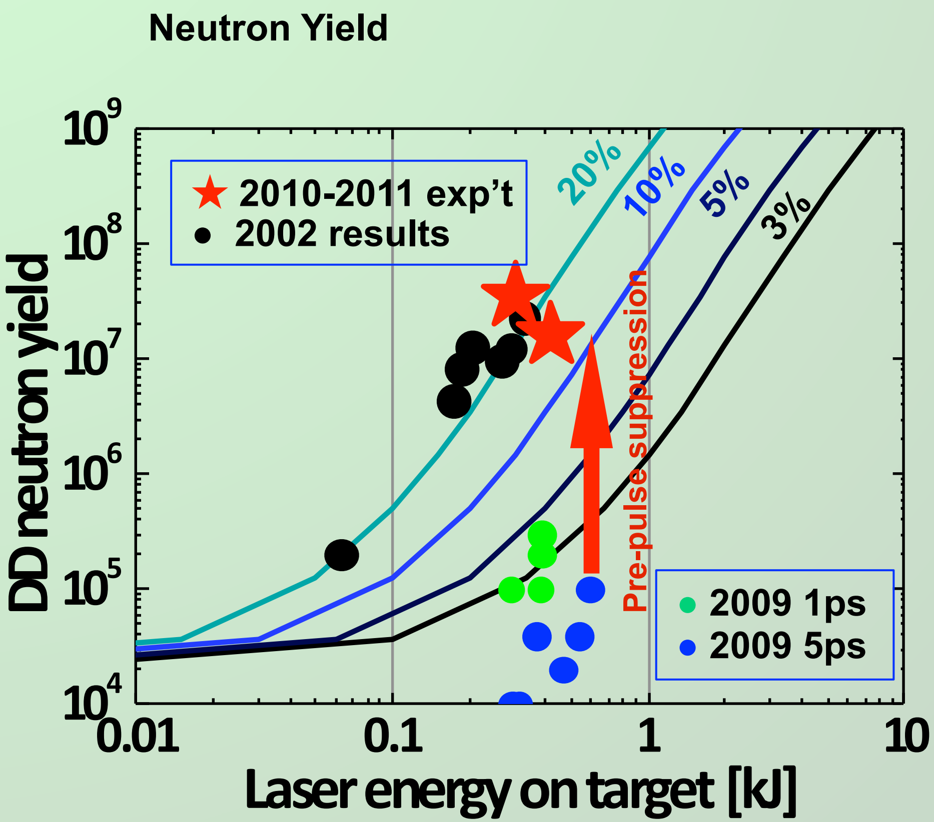
Emission by Heating laser

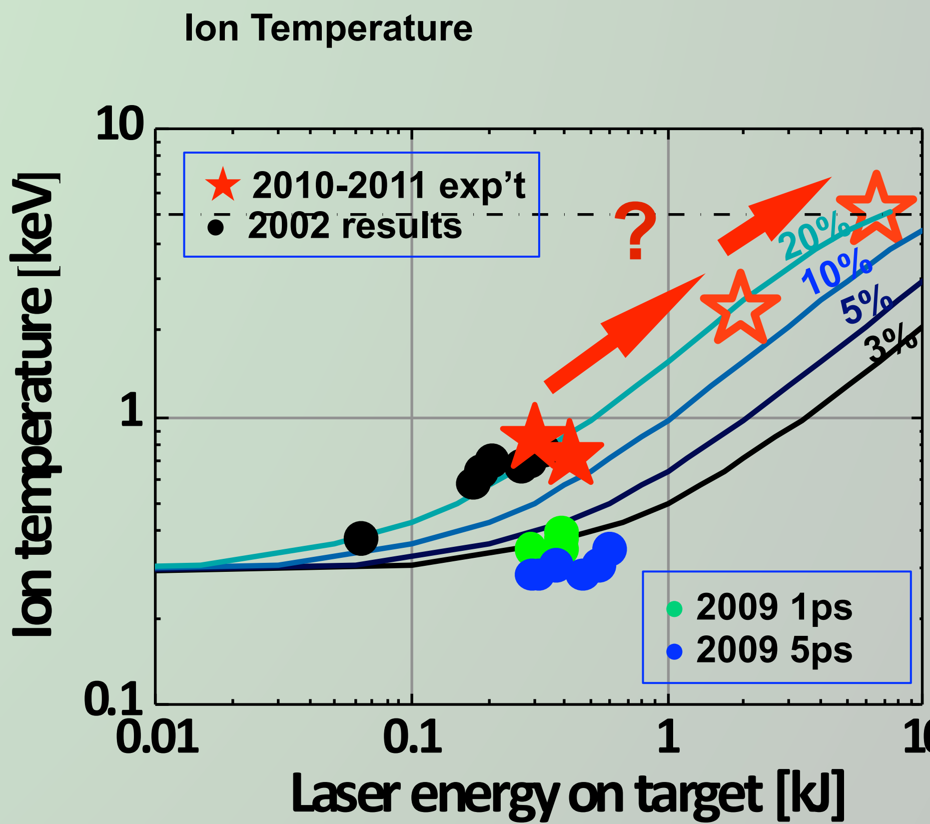


Heating beam (LFEX) injection

Heating time determination

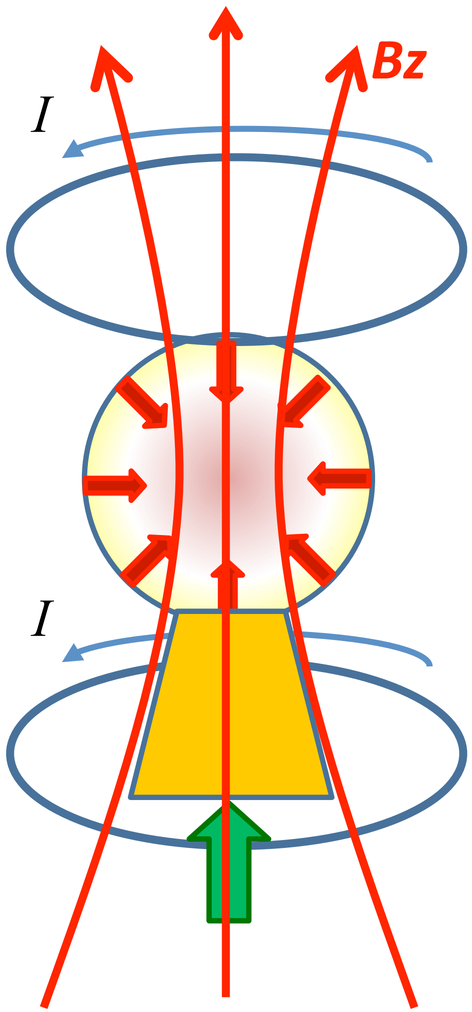
Yield and Temperature have exceeded 2002 records.



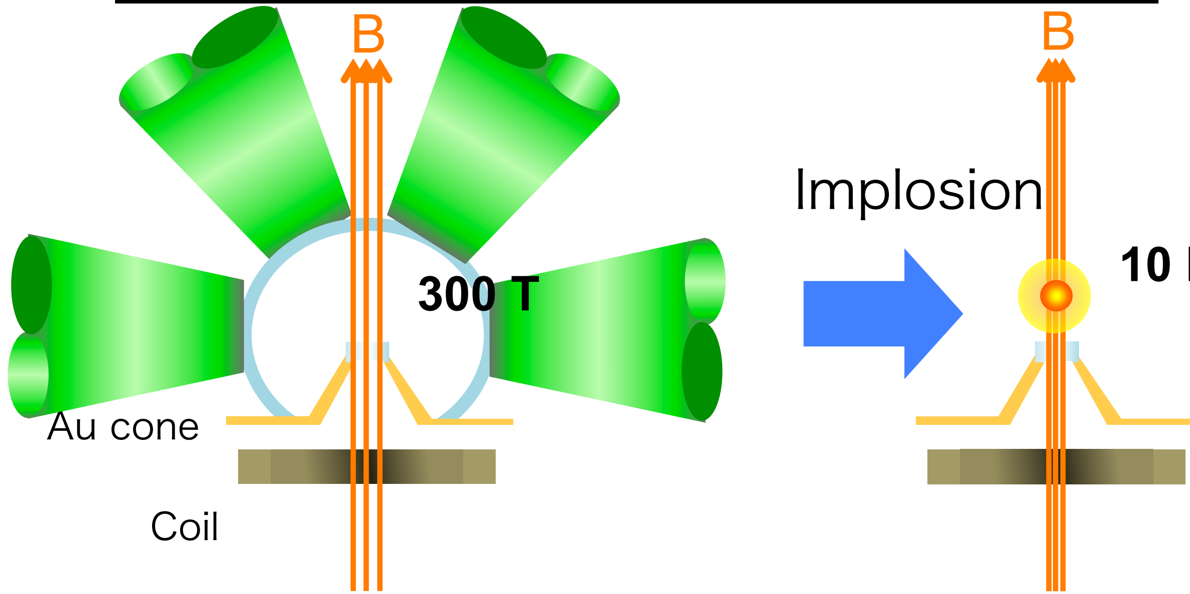


The coupling efficiency may be decreased at higher energy.

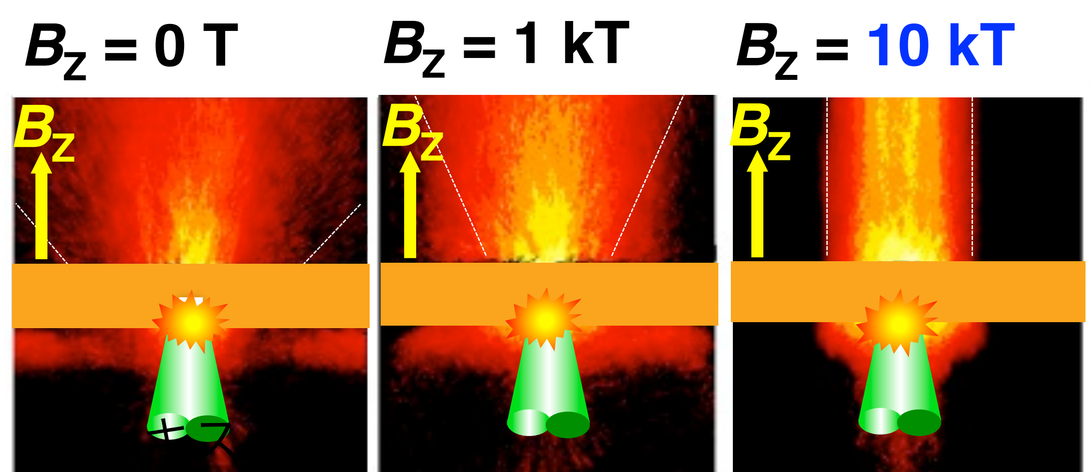
Magnetic Field Guiding of Hot Electron Stream



B amplification by implosion



PIC simulation



Can one make high initial B field?

Laser Driven Magnetic Field: Faraday rotation of initial B field

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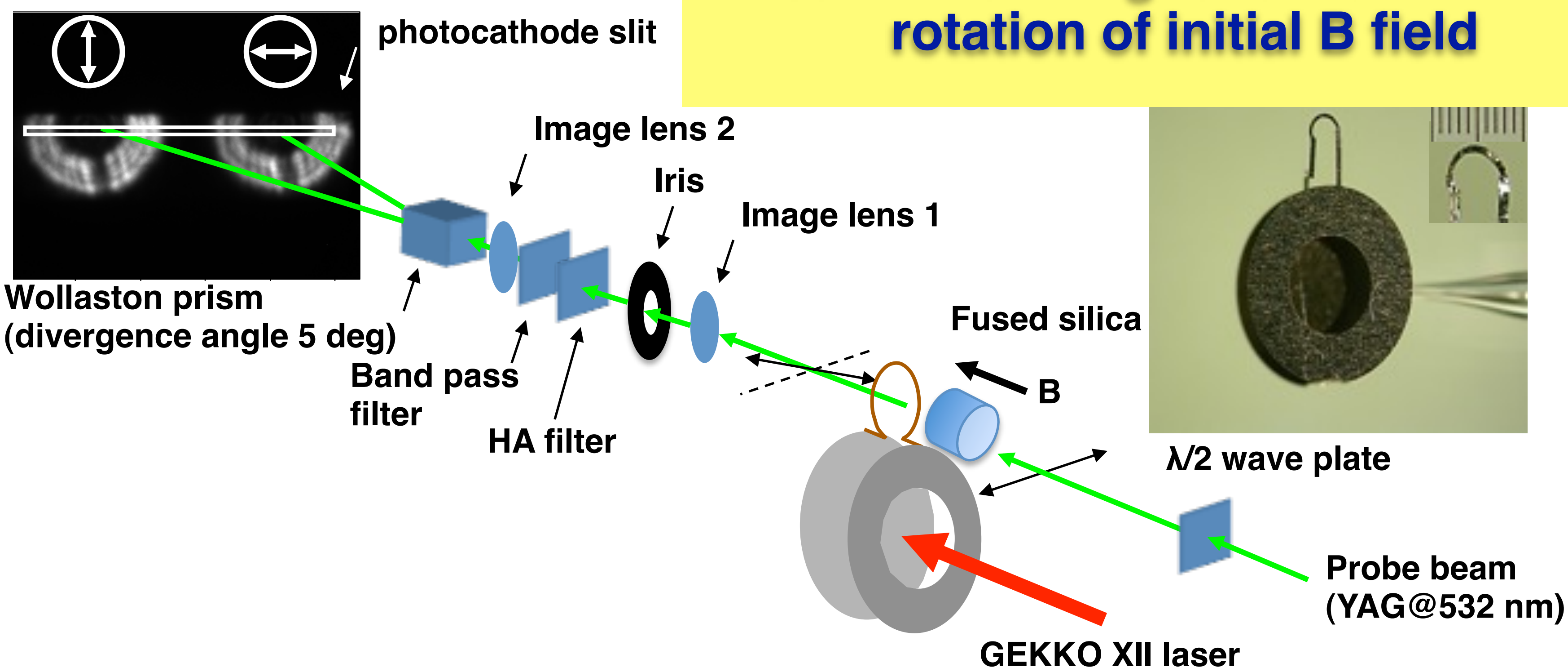

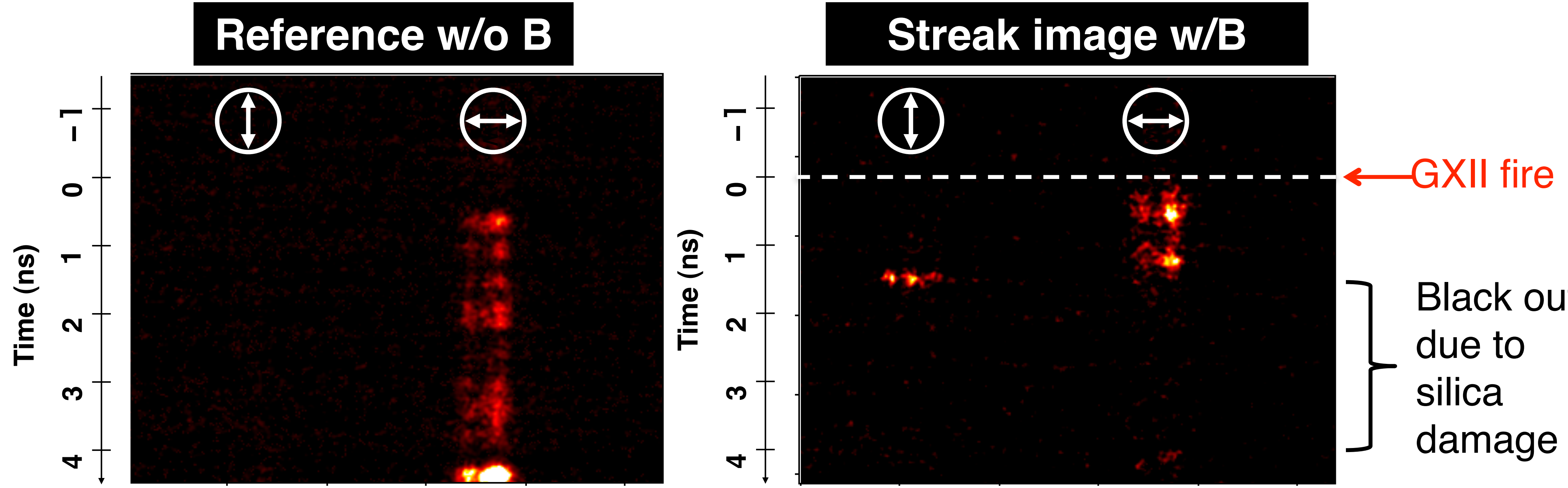

Excess B field of ~kTesla (10 MGauss) is created.

Collimating E-beam by strong-B_z

Divergence, energy distribution and flux of e-beam by using x-ray convertor attached target.

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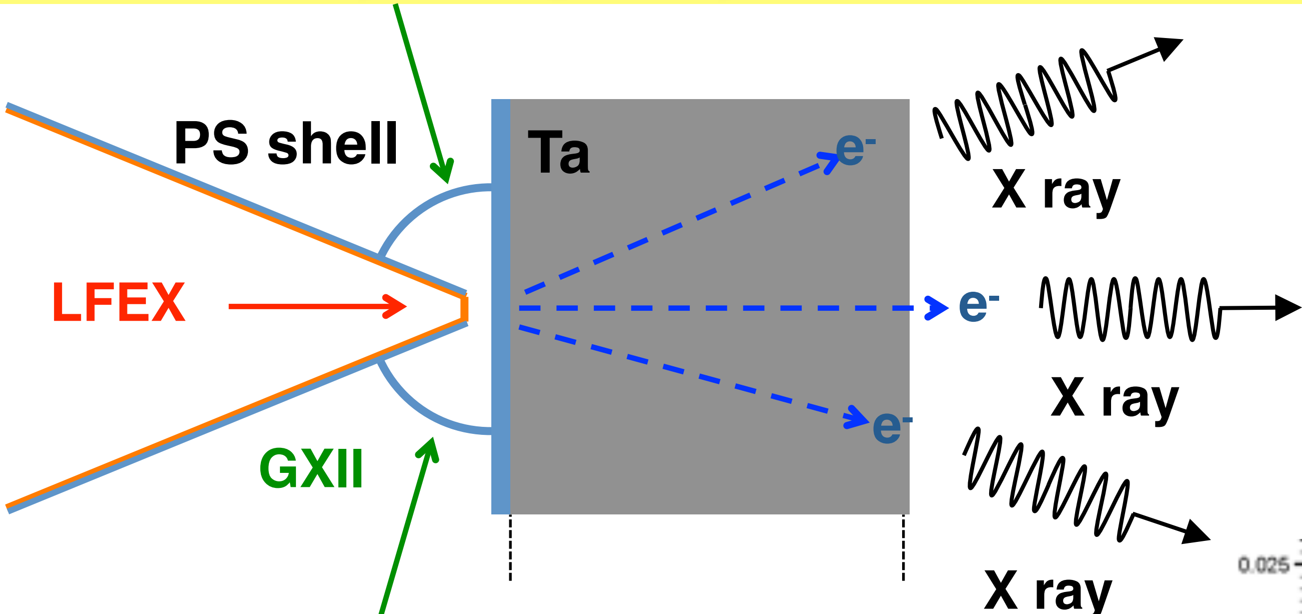

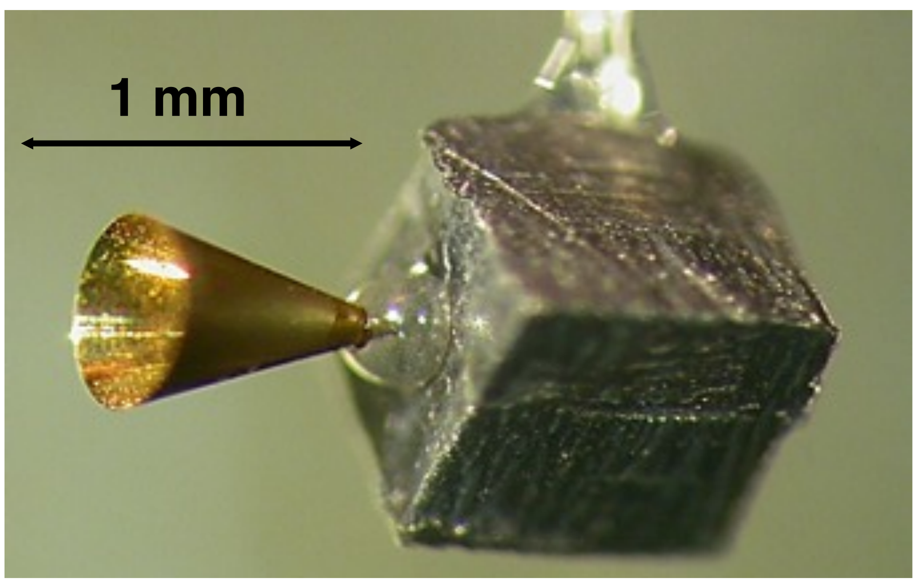

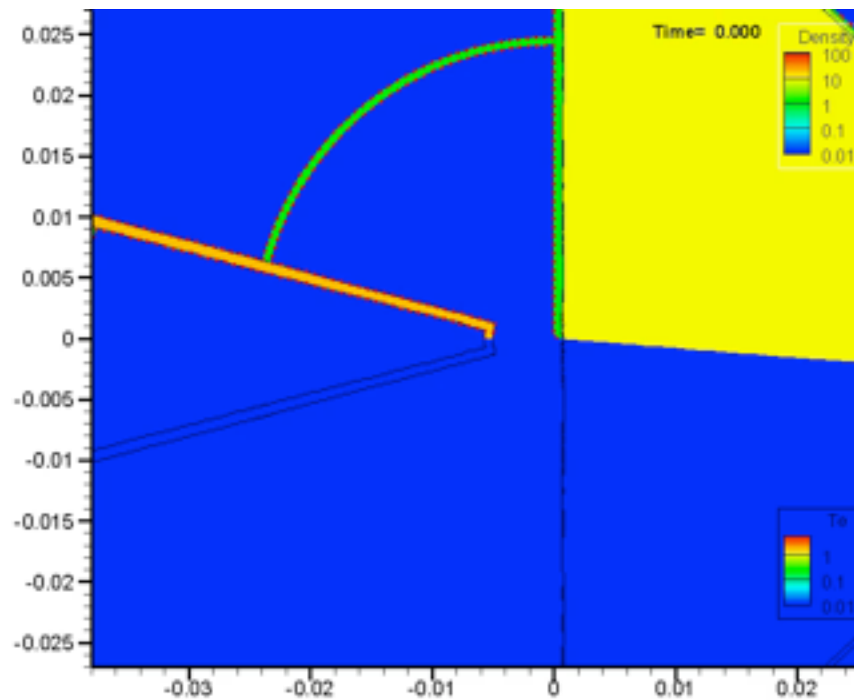

Spectrum, angular distribution, image of x-rays are measured.

Angular distribution of bremsstrahlung x-ray indicates collimation of electron beams by external B-field.

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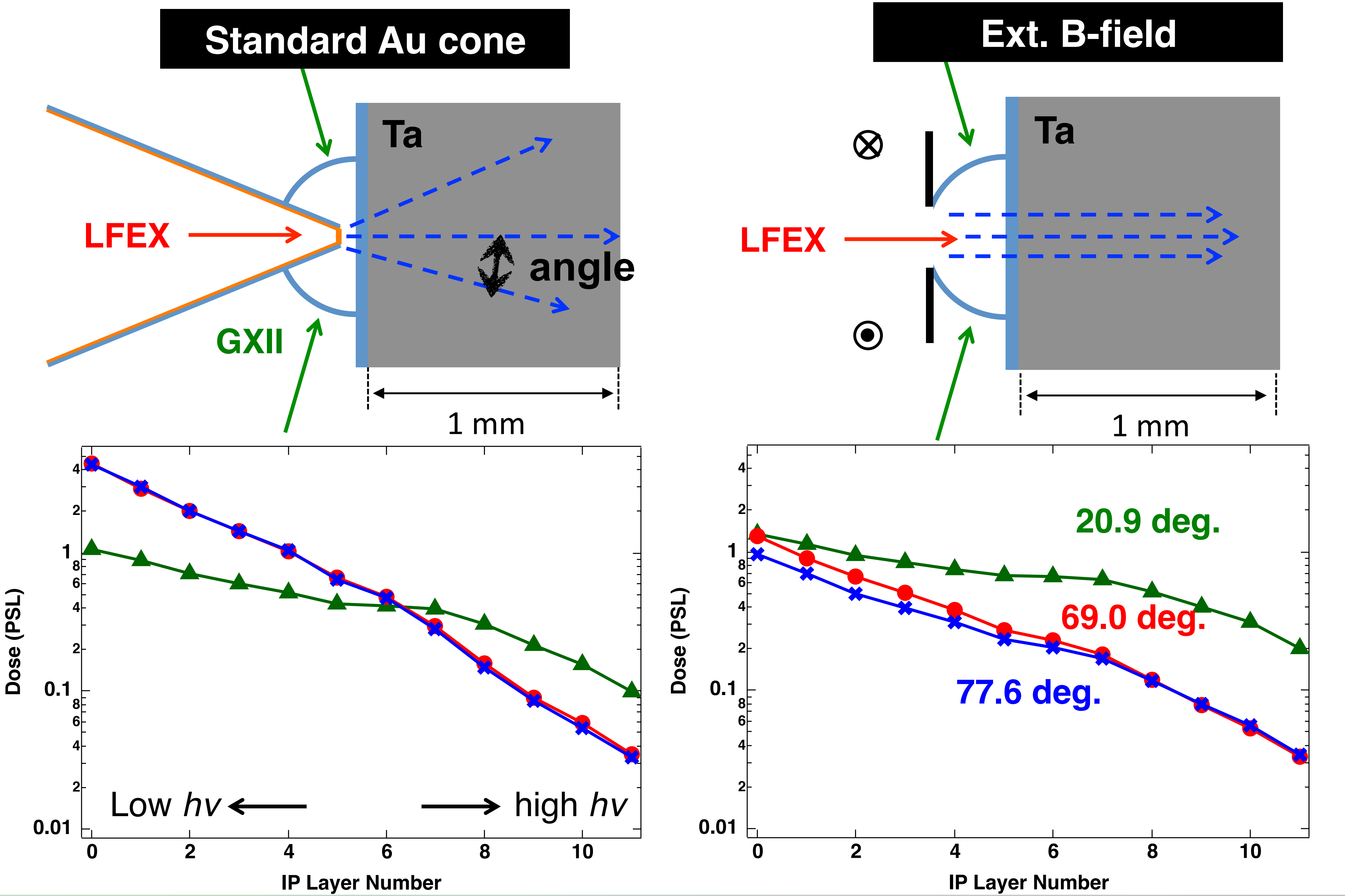
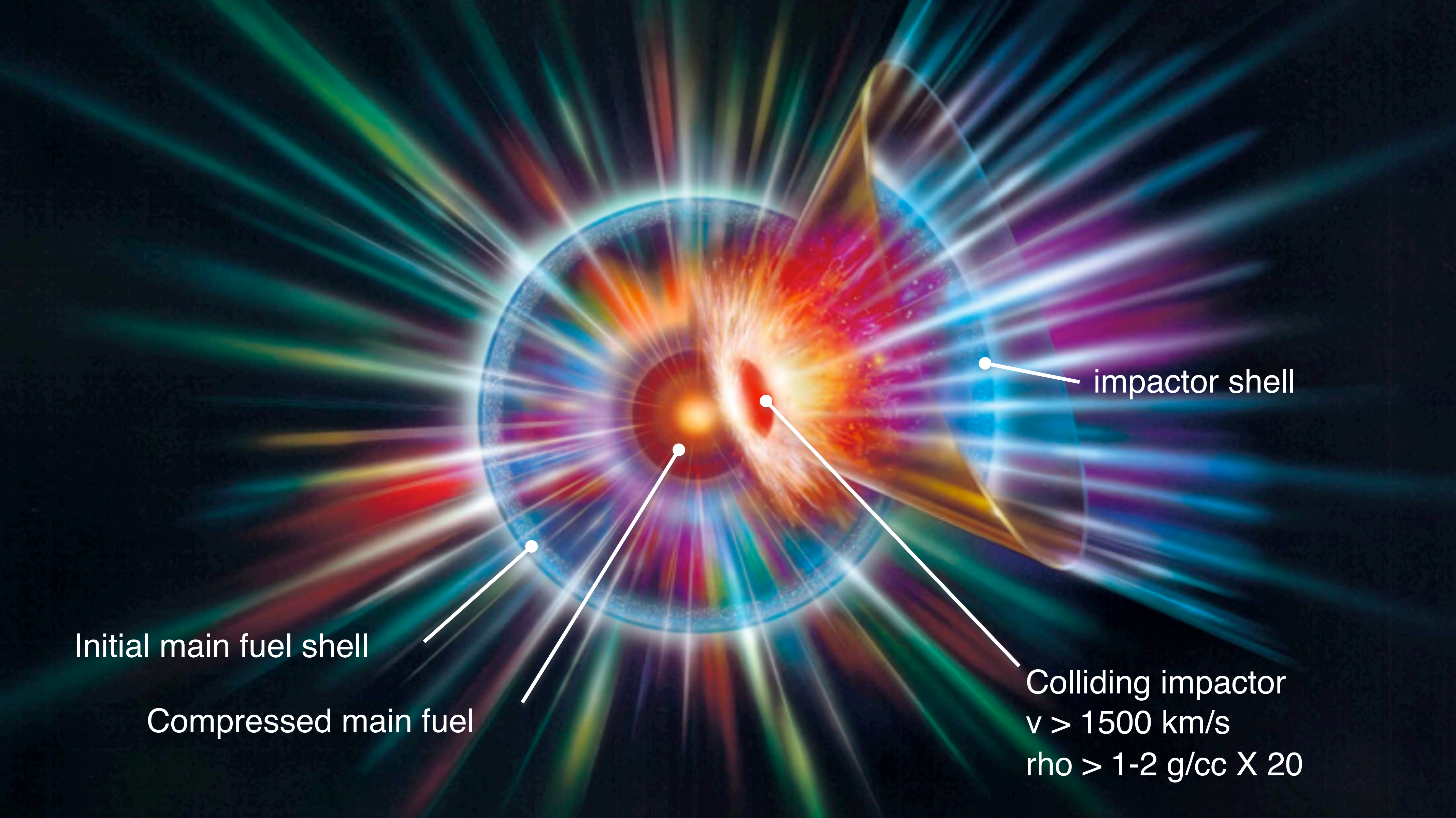


Experimental Evidence of **Impact Ignition**

Azechi *et al.*, PRL **102**, 235002 (2009)



Impact ignition almost completely eliminates plasma physics uncertainty in fast ignition.

Ignition takes place at 1700-km/s velocity and 50-g/cc impactor density.

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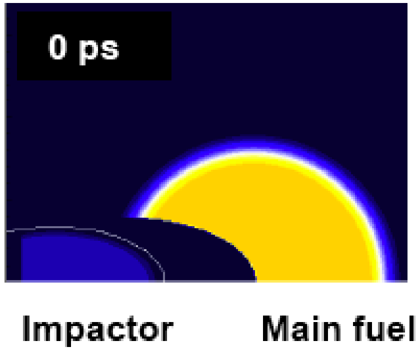

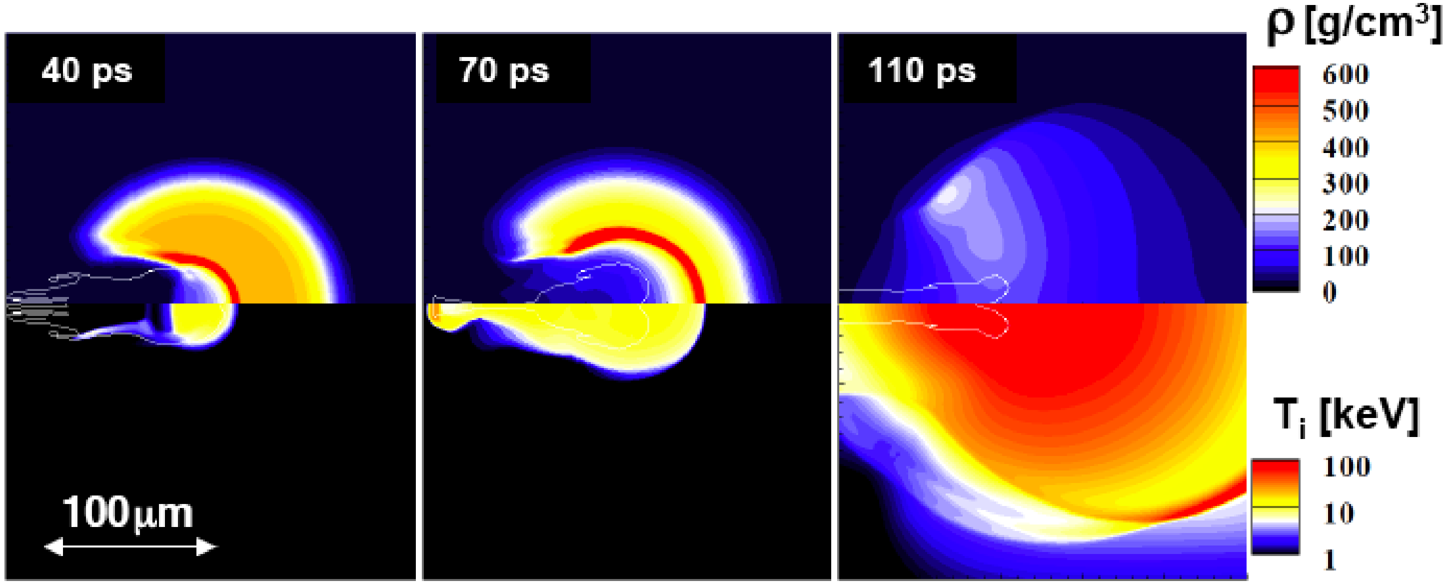

100-Fold Increase of Neutron Yield by Impactor Collision

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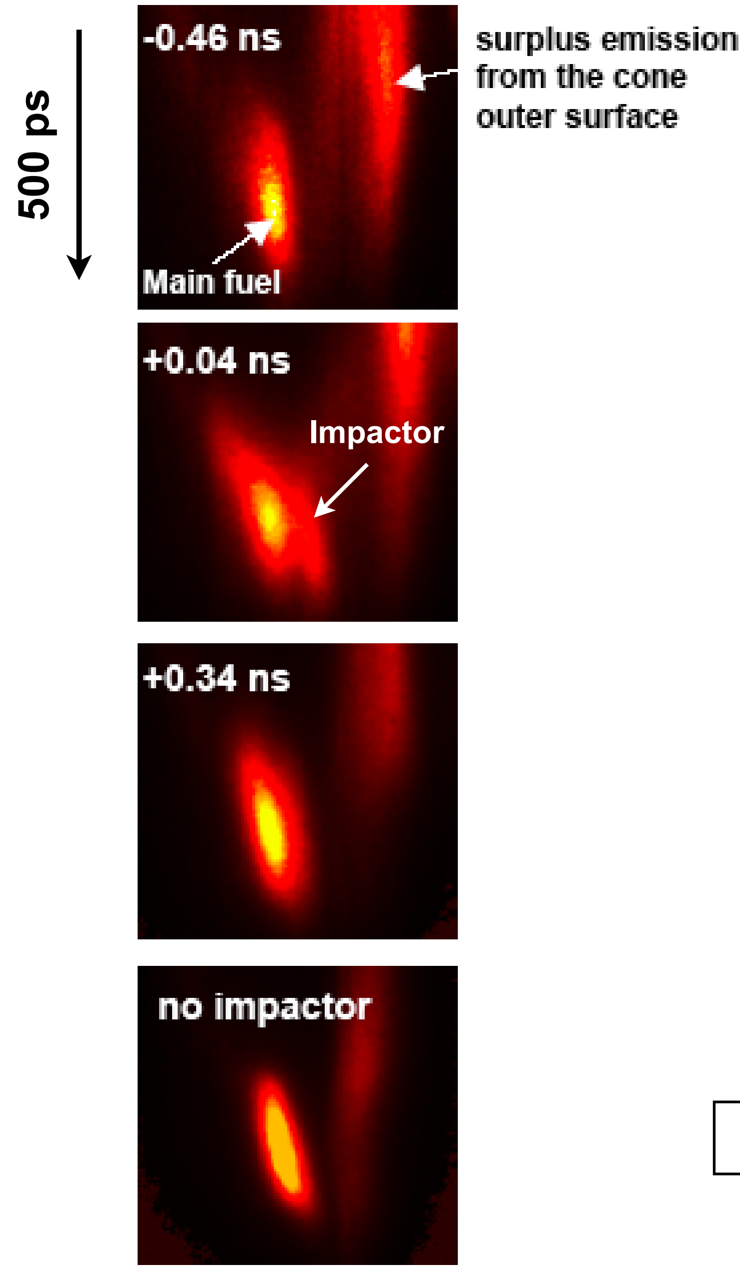

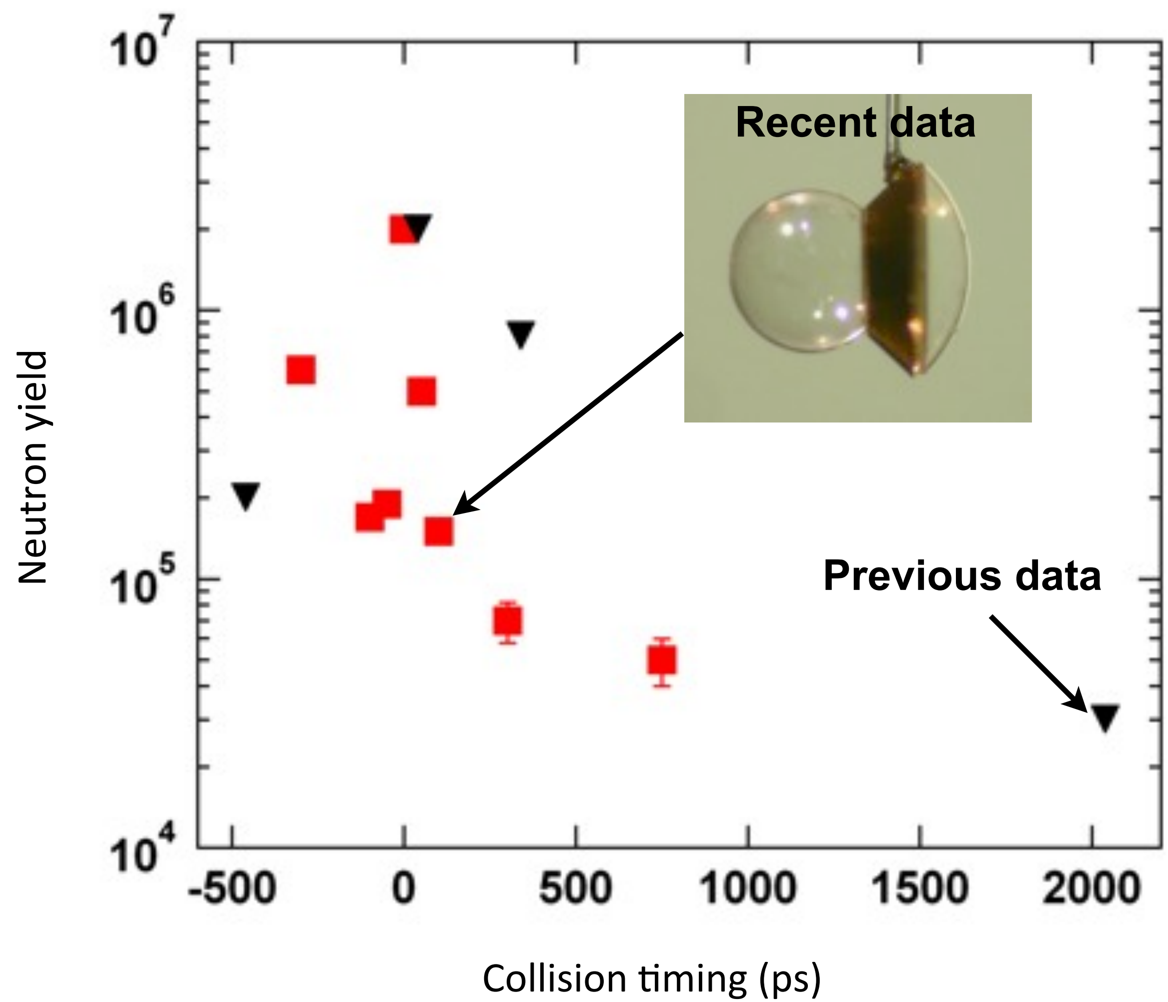

Neutron increases only at the right timing.

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Are we ready?

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

Alliance

Pumping: from Flash Lamps to Laser Diodes

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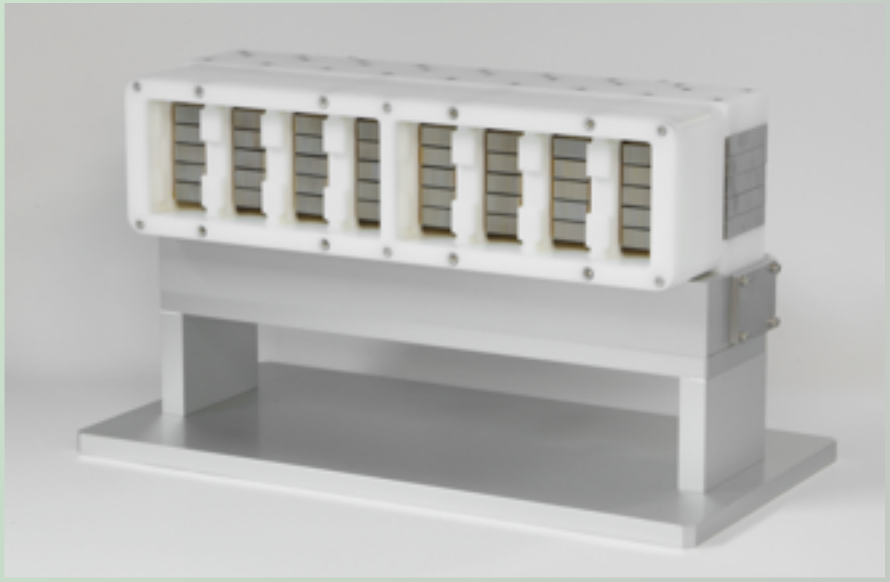
Flash Lamps

Broad emission spectra
Inefficient & low rep

Laser Diode



Emission matches absorption line

1x1.5 cm^2
5-kW module
15 k$→500 $

Two remaining issues: Diode cost, Laser material

High-Rep Laser Program GEMBU

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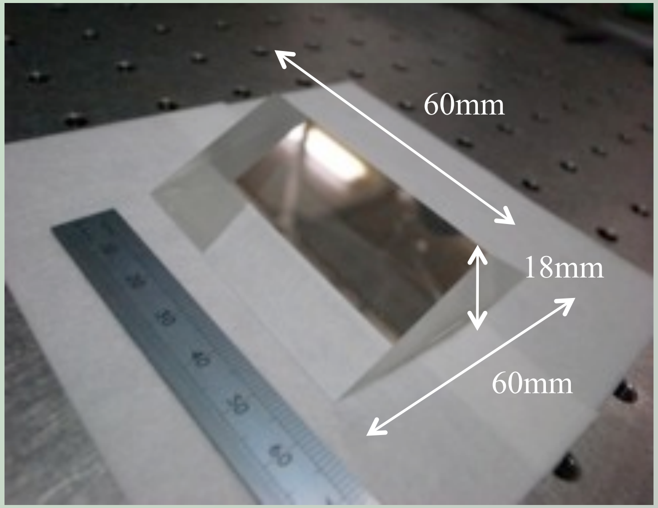
Laser medium: from glasses to ceramic crystal

Laser Glasses

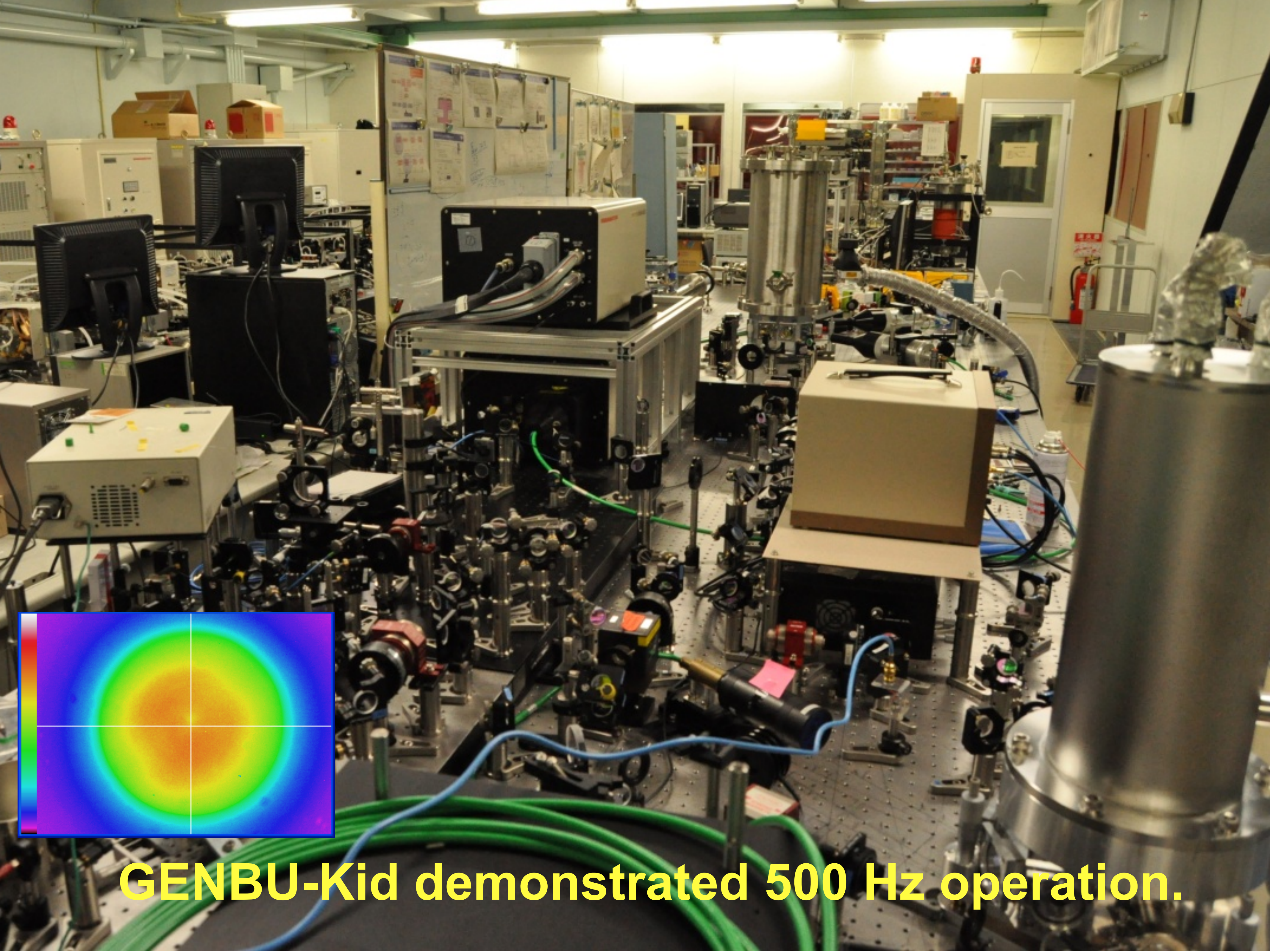
Yb: YAG Cooled Ceramic Crystal



- 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.


GENBU-Kid demonstrated 500 Hz operation.

Most Critical Elements of IFE Reactors Have Been Addressed or Demonstrated.

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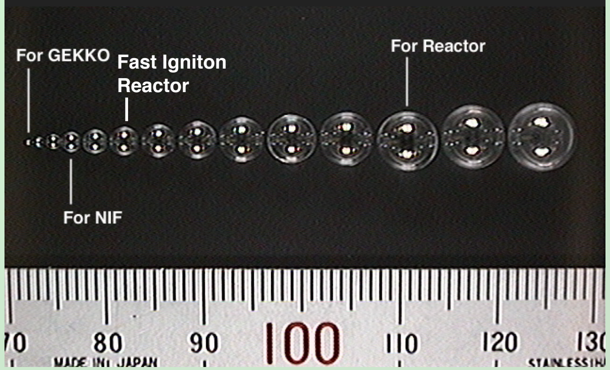
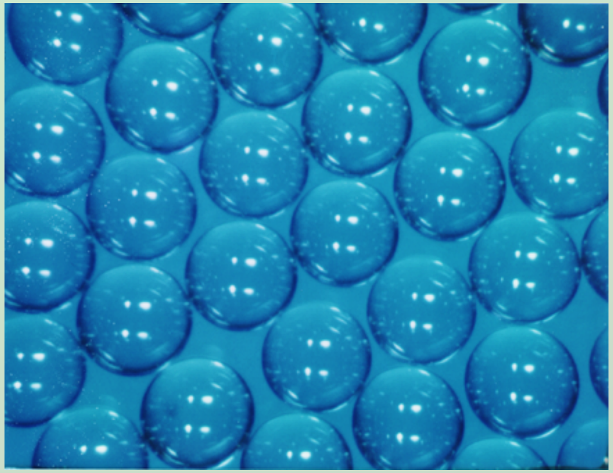
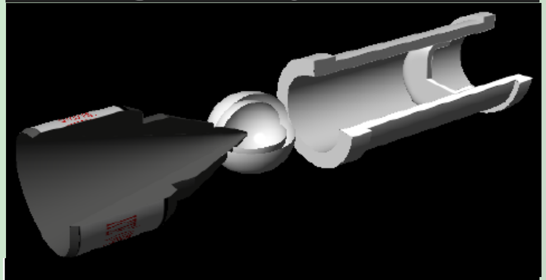
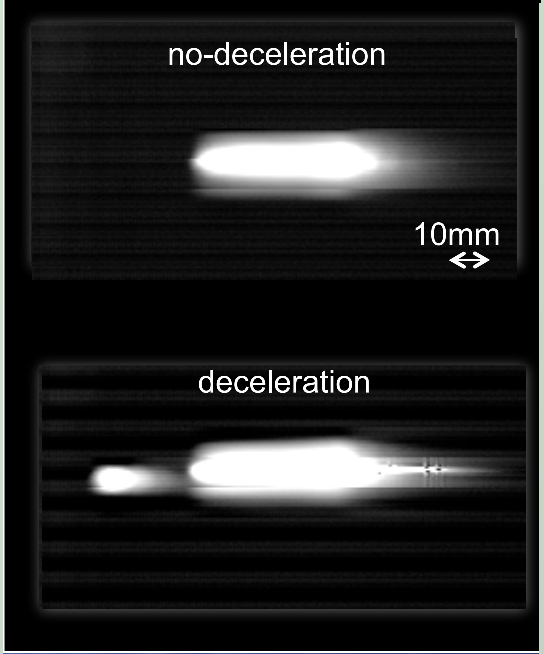
Mass production of targets



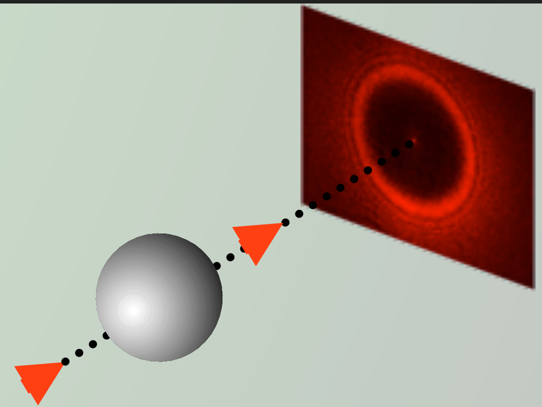


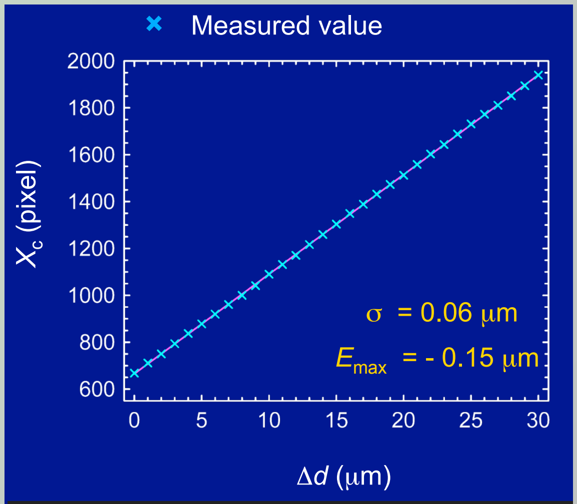
Target injection





Target tracking





1-μm precision demonstrated

Injection, Tracking, and Beam Pointing are already demonstrated in EUV project.

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Industry's Entering into IFE Field

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President Emeritus,
Shoichiro Toyota, visited
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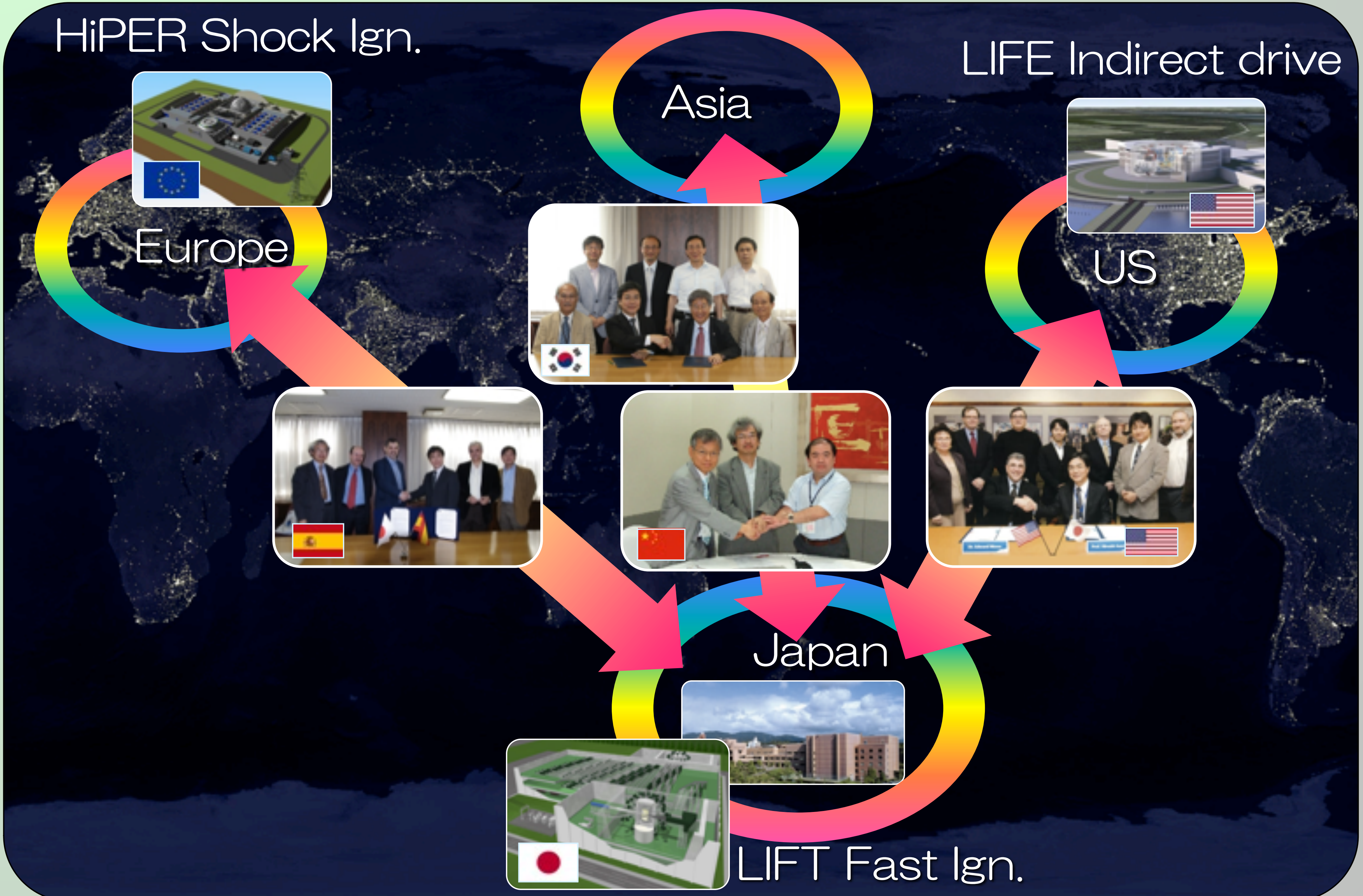
Air & Water Jet Loom@
Toyota Techno Museum

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

International Alliance on IFE



Summary

- After 50 years from the innovation of lasers, it is an eve of the first controlled fusion burn in humankind.

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

- IFE physic and engineering programs would converge onto an experimental reactor, such as LIFE, HiPER and LIFT, that will lift up people's spirits.

Get Together at IFSA2013 in Nara
September 8-13, 2013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