ICF Research Developments at LFRC

Presentation to 3rd Moscow Workshop TARGETS & APPLICATIONS

Tang Yongjian

Research Center of Laser Fusion CAEP

P. O. Box 919-981, Mianyang,Sichuan, P.R.China. 621900.

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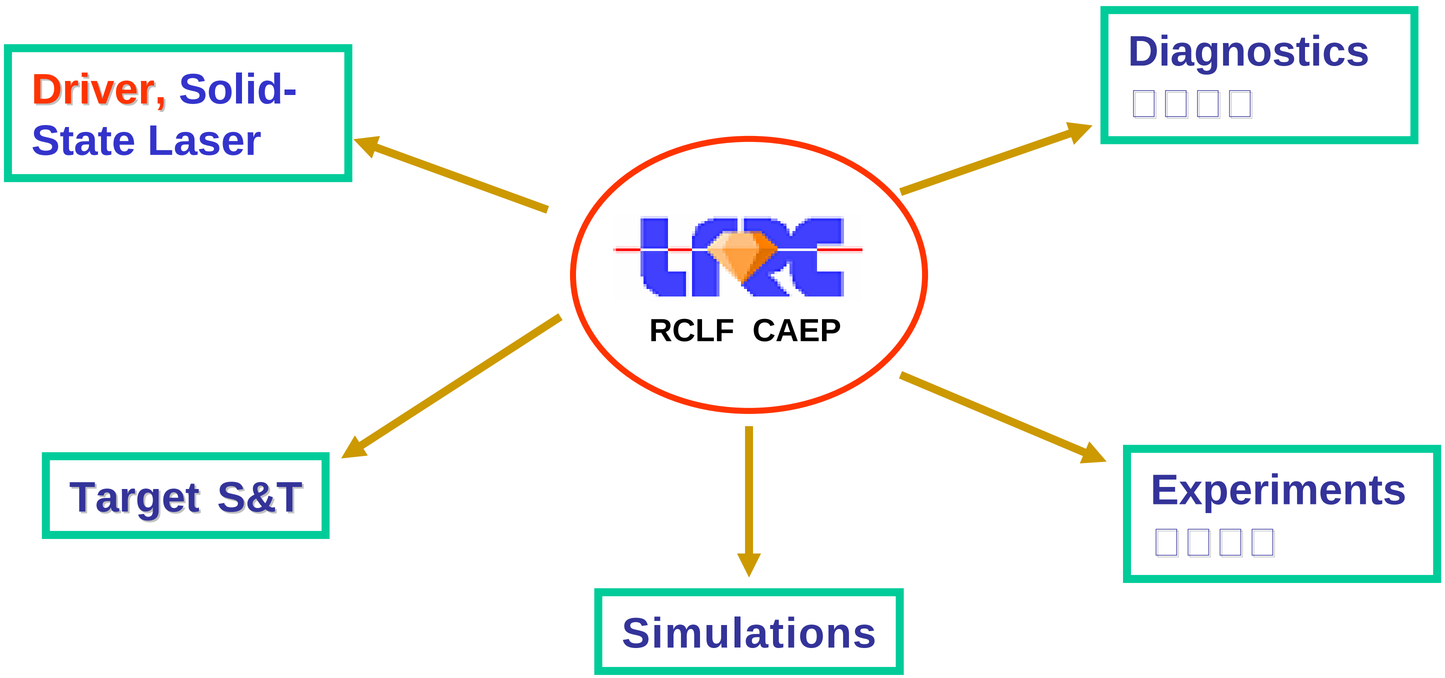
ICF Research Contents



Outline

1. Progress of High Power Solid-State Laser

2. ICF Experiments

3. Target Fabrication

1. Progress of High Power Solid-State Laser

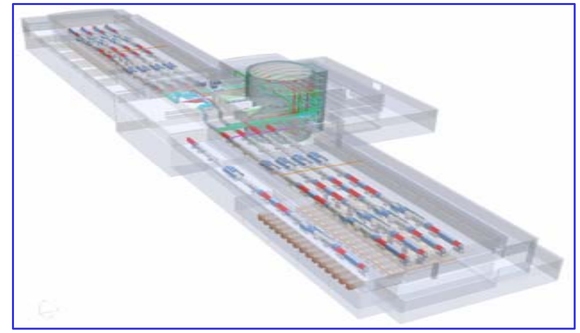
Introduction

High power solid-state laser research activities in LFRC include:

- **Ultrahigh intensity, ultrashort pulse lasers development;**
- **Shenguang-III project;**
- **Key techniques support for these lasers.**

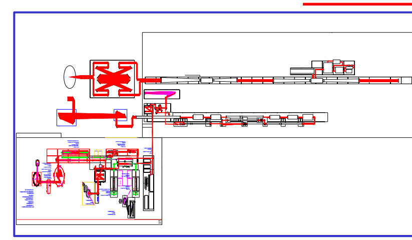
■ High power solid-state laser facility R&D plan at LFRC

SG-III 2012



TIL 2006

XG-III 2007



Xingguang 1985,1993

Silex-I 2004

Introduction of TIL(Technical Integration Lines)—Goals

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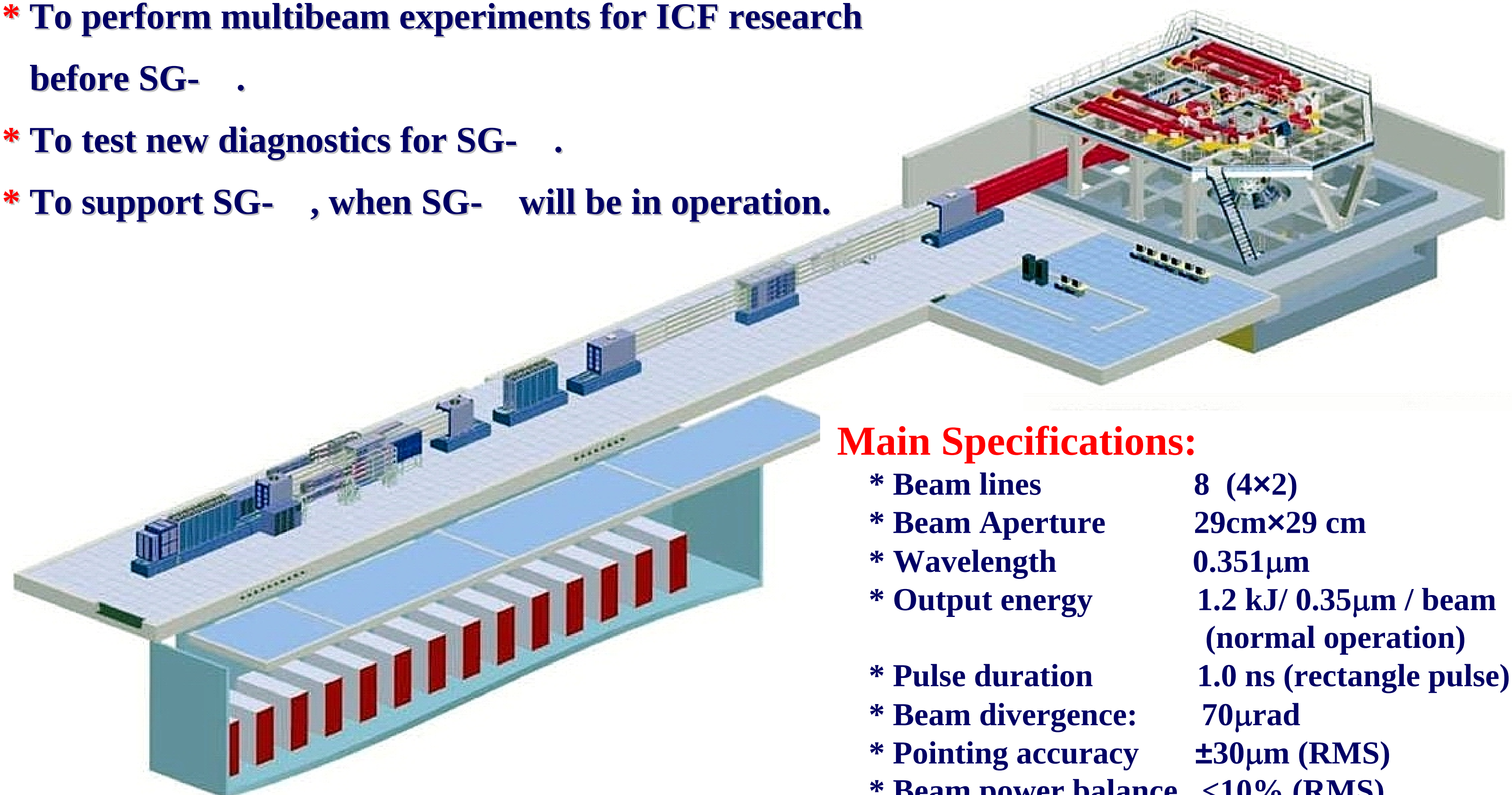
- **To validate the technologies for SG- and to qualify the beam performance.**
- **To perform multibeam experiments for ICF research before SG- .**
- **To test new diagnostics for SG- .**
- **To support SG- , when SG- will be in operation.**



Main Specifications:

* Beam lines	8 (4×2)
* Beam Aperture	29cm×29 cm
* Wavelength	0.351μm
* Output energy	1.2 kJ/ 0.35μm / beam (normal operation)
* Pulse duration	1.0 ns (rectangle pulse)
* Beam divergence:	70μrad
* Pointing accuracy	±30μm (RMS)
* Beam power balance	<10% (RMS)

Introduction of TIL—Schedule

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2000 Design of TIL

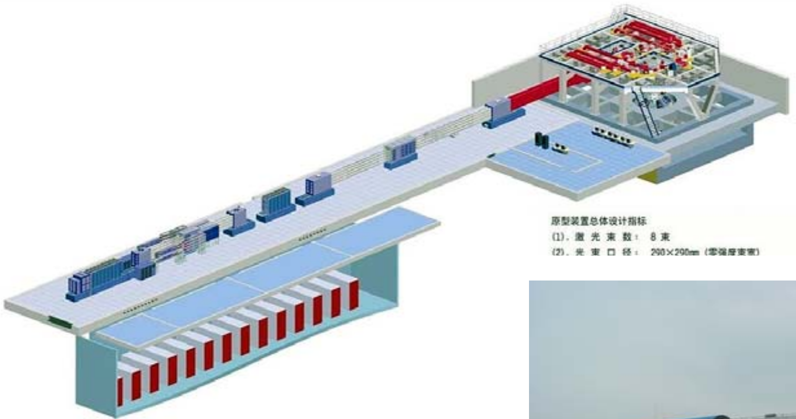
2003 Completed the construction of buildings hall and the installation of the optical chain

2004 Integrated experiment on the first beam

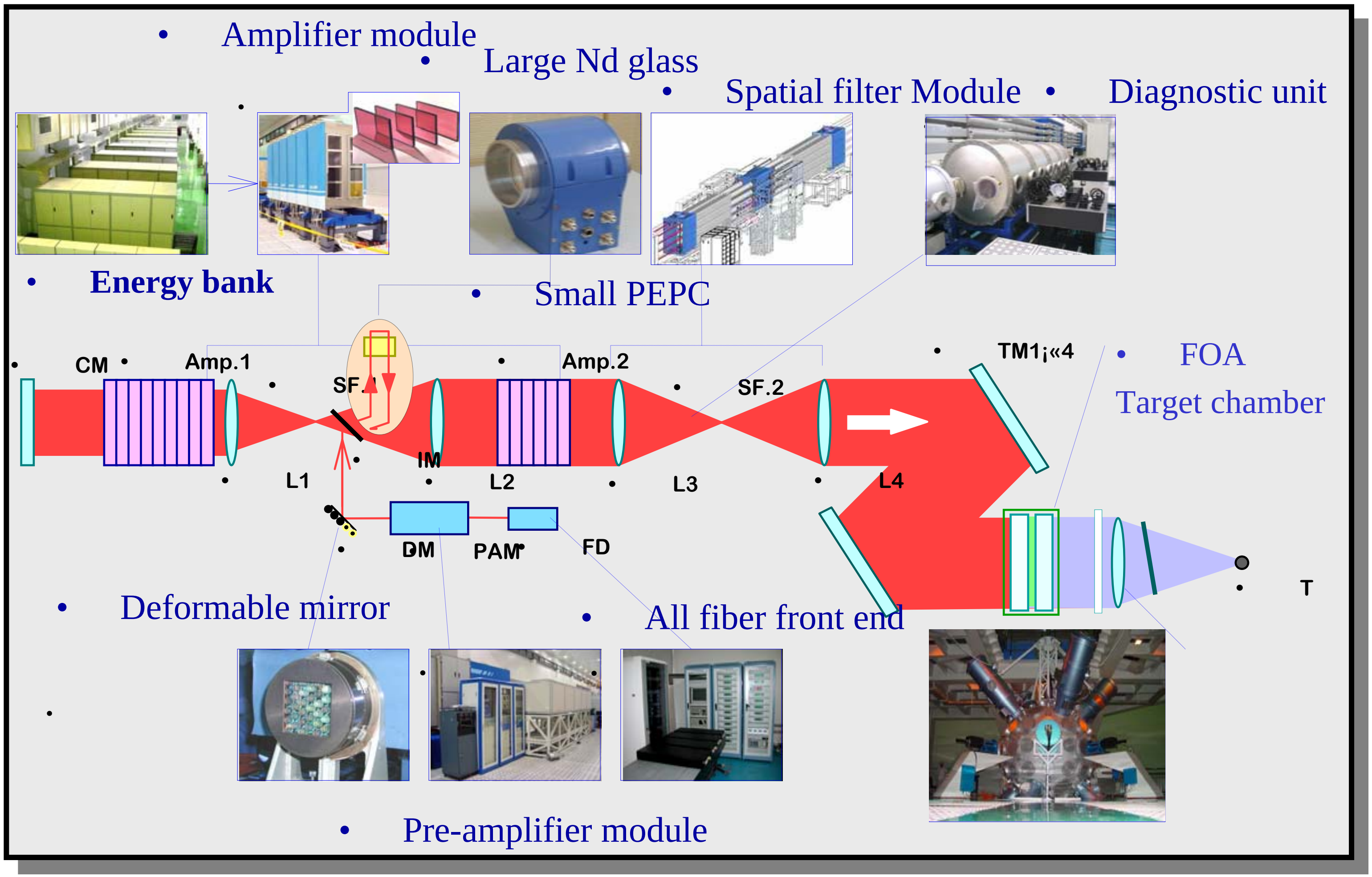
2005 Integrate the 8 beams

2006 Begin to preliminary operation for physical experiments

2007 Routine operation



Main subsystems of TIL—Key subsystems

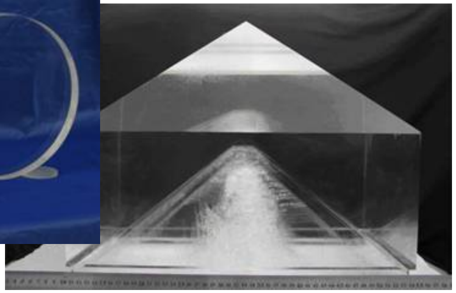


SG-III TIL—Key Units Technique

Large neodymium (Nd) glass

SG-III TIL All fiber front end

SG-III Technical Integration Lines



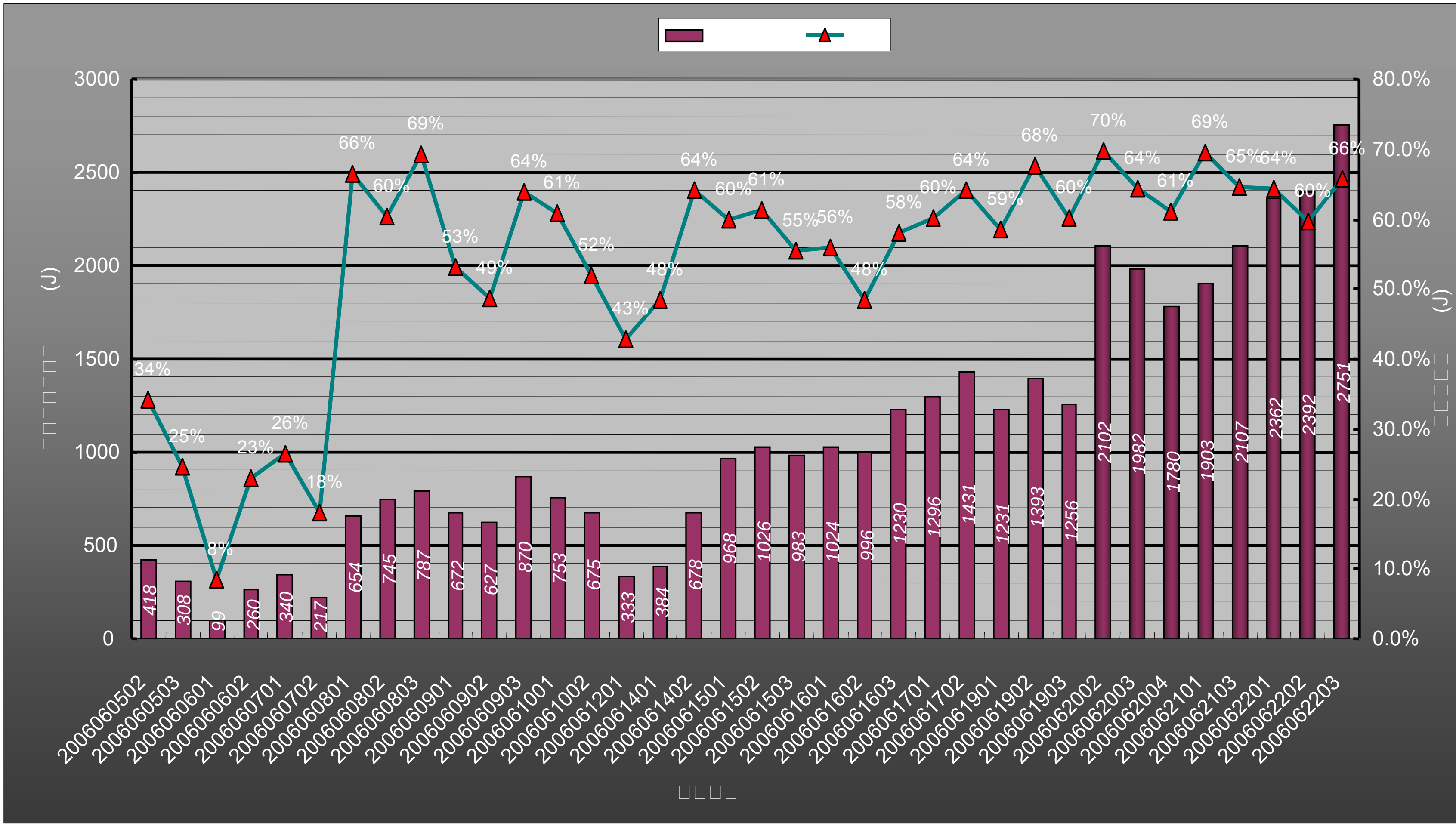
80mm□□□□□□□2×1□□□300mm□□□□□□ - PEPC

400mm×400mm KDP crystal and Φ500mm fused silica

Target chamber system

Main experimental results

Statistical 3ω output Energy and conversion efficiency of main shots



2. ICF Experiments in LFRC

Topic of Experimental Physics

Hohlraum Physics

Laser Plasma Interaction

Directly drive explosion

Radiation drive explosion

Equation of State

Radiation ablation

Radiative opacity

R-T instability

Others,

ICF Experiment at SG II

Hohlraum target physics

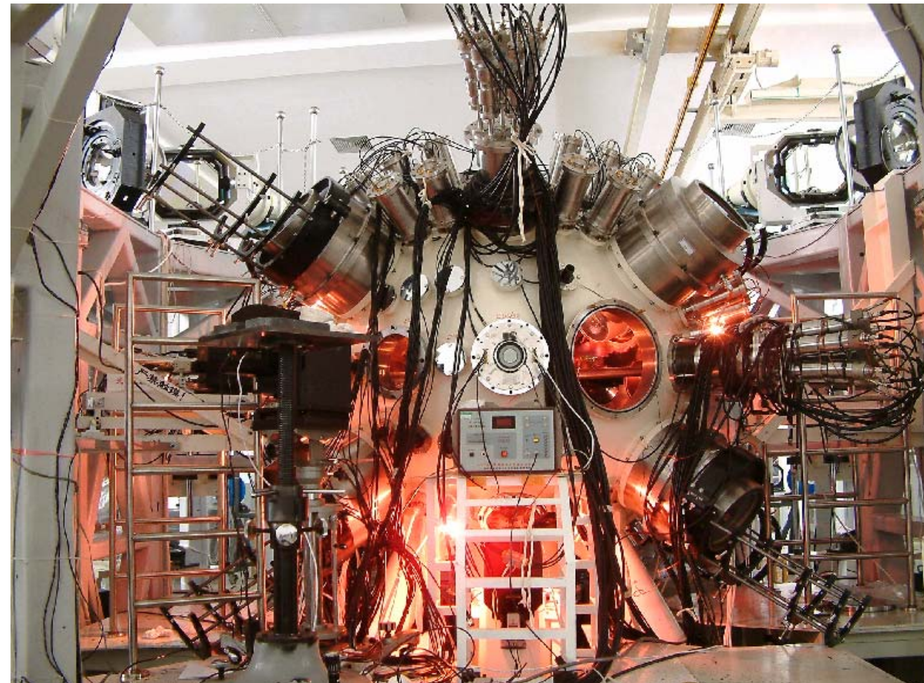
Radiation ablation

Direct Drive Implosion

Indirect drive implosion

Radiation drive R-T Instability

Opacity Measurement



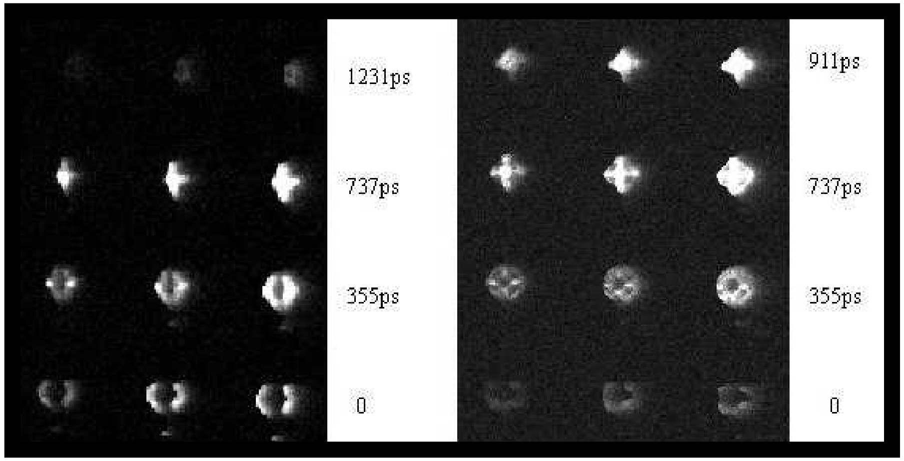
Implosion experiments

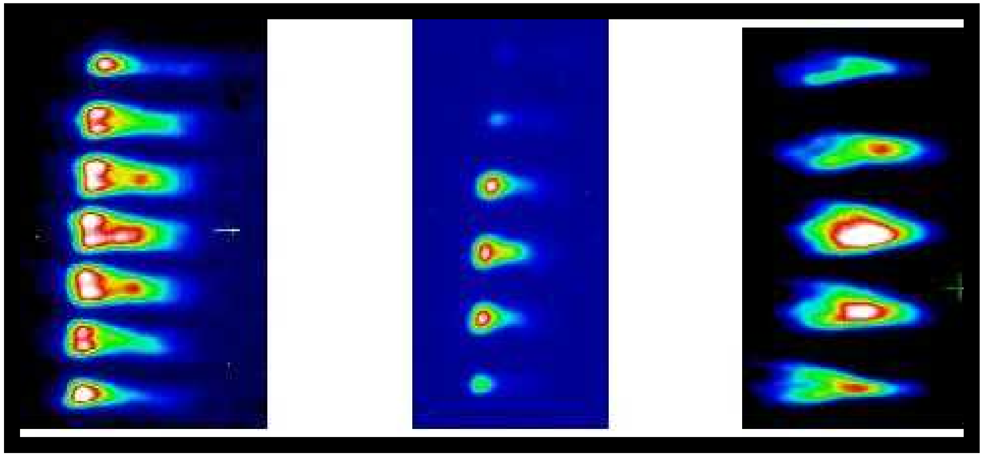
□1□ Direct Drive Explosion neutron yield(DT) $4*10^9$

□2□Radiative temperature Tr :170 eV

Indirect Drive Explosion neutron yield (DD) $>10^7$

Ten-fold of liquid deuterium fuel were obtained.





Direct Drive Explosion

Implosion experiments

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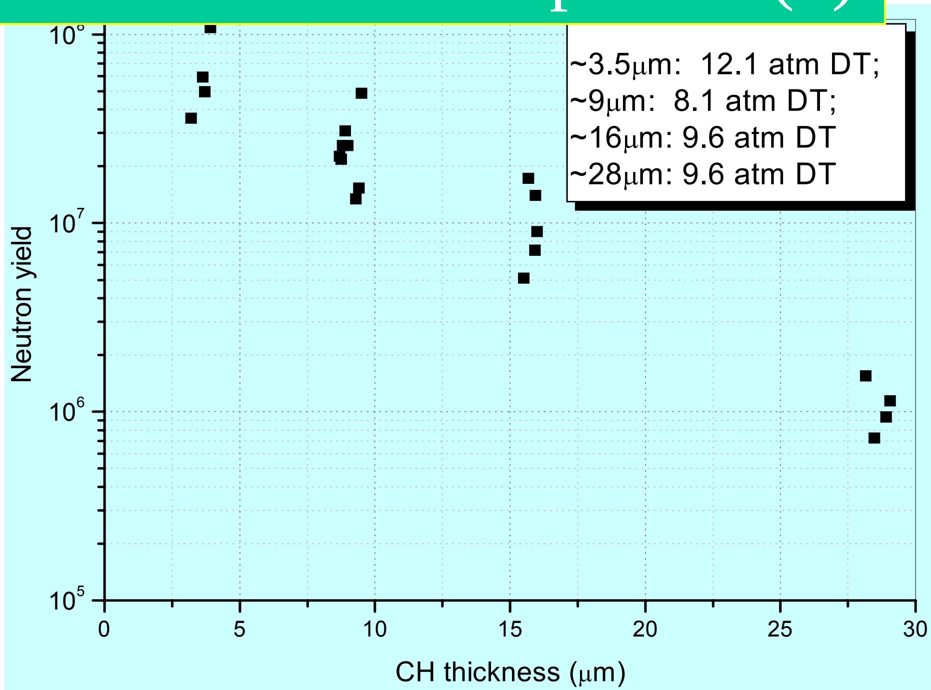
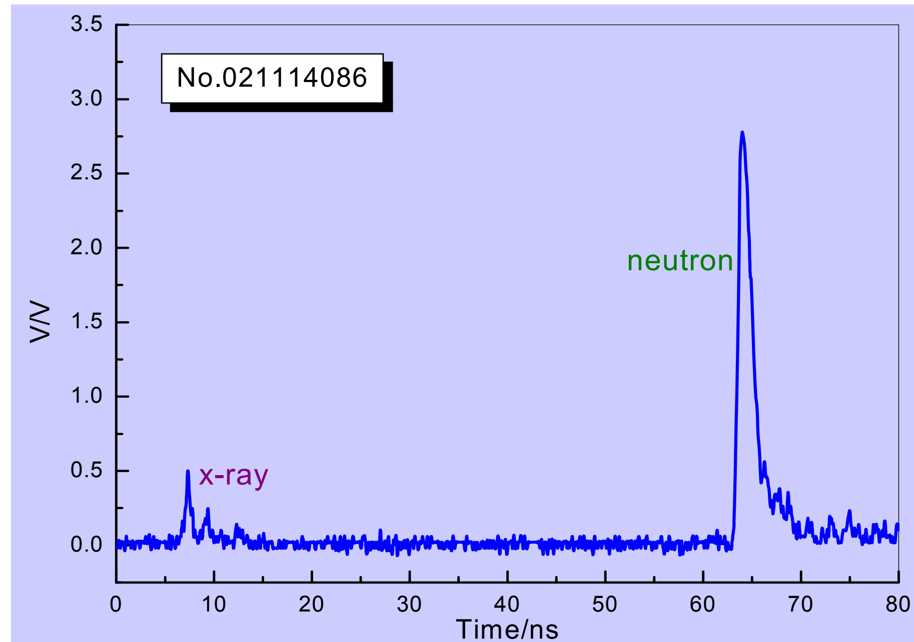
Indirect Drive Explosion(3)



Cavity: ϕ800μm×1350μm
Capsule: ϕ200μm, shell-x μm
CH+2μmSiO_2

Variations of Neutron Yield with Ablator Thickness



Neutron TOF spectrum

Doppler broading dt~0.5ns ,T_i~3.5KeV

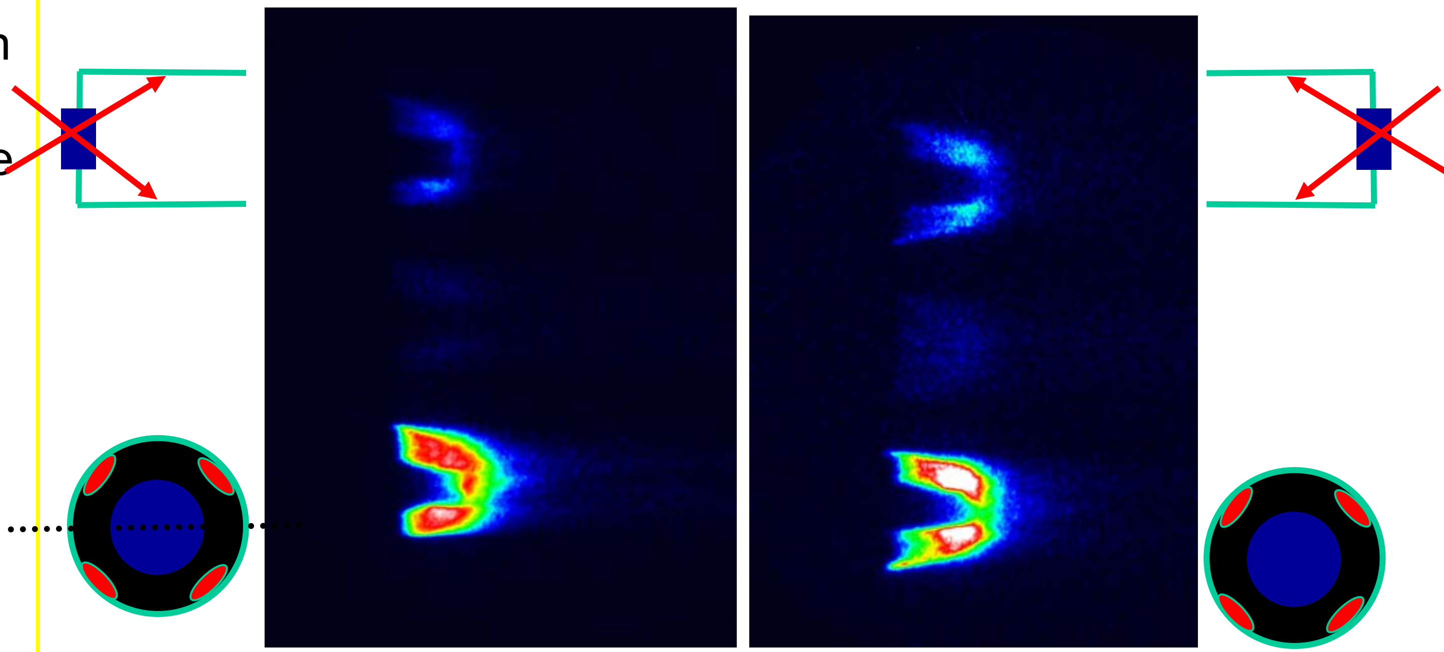
DT neutron yield >107

$$\Delta E_n = 177\sqrt{KT_i(KeV)}\,(keV)$$

Hohlraum target physics

Characteristic of Spatio-temperal plasma radiation inside hohlraum(1)

Movements of X-ray emission region inside hohlraums plays important role to radiation symmetry and x-ray energy output from hohlraums. Experimental results can also help us understand radiation hydrodynamics process in laser heated hohlraums.



Radical movement of thermal radiation in hohlraums

Half-hohlraum with ϕ380 μm LEH

Characteristic of Spatio-temperal plasma radiation inside hohlraum(2)

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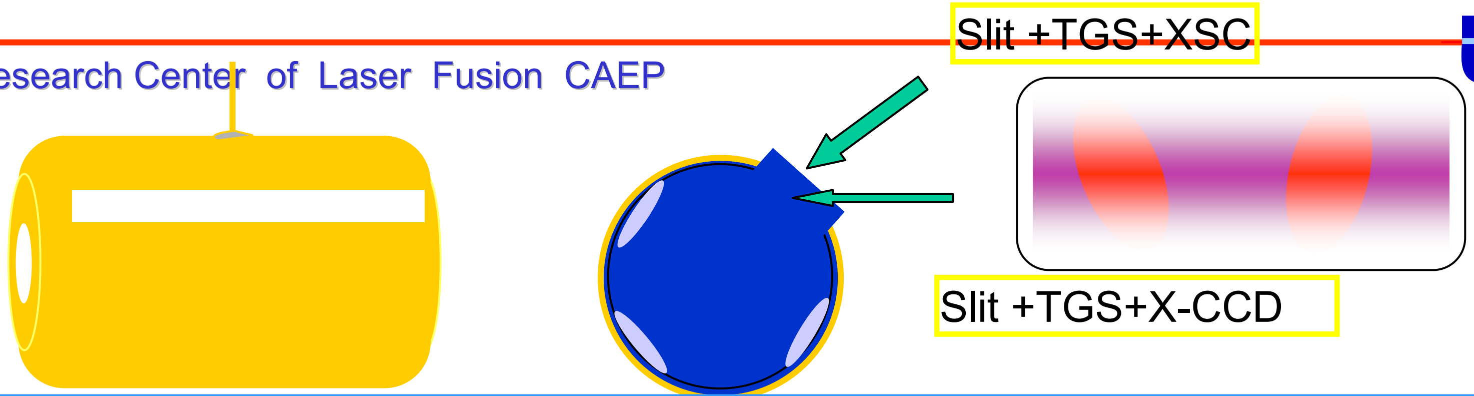
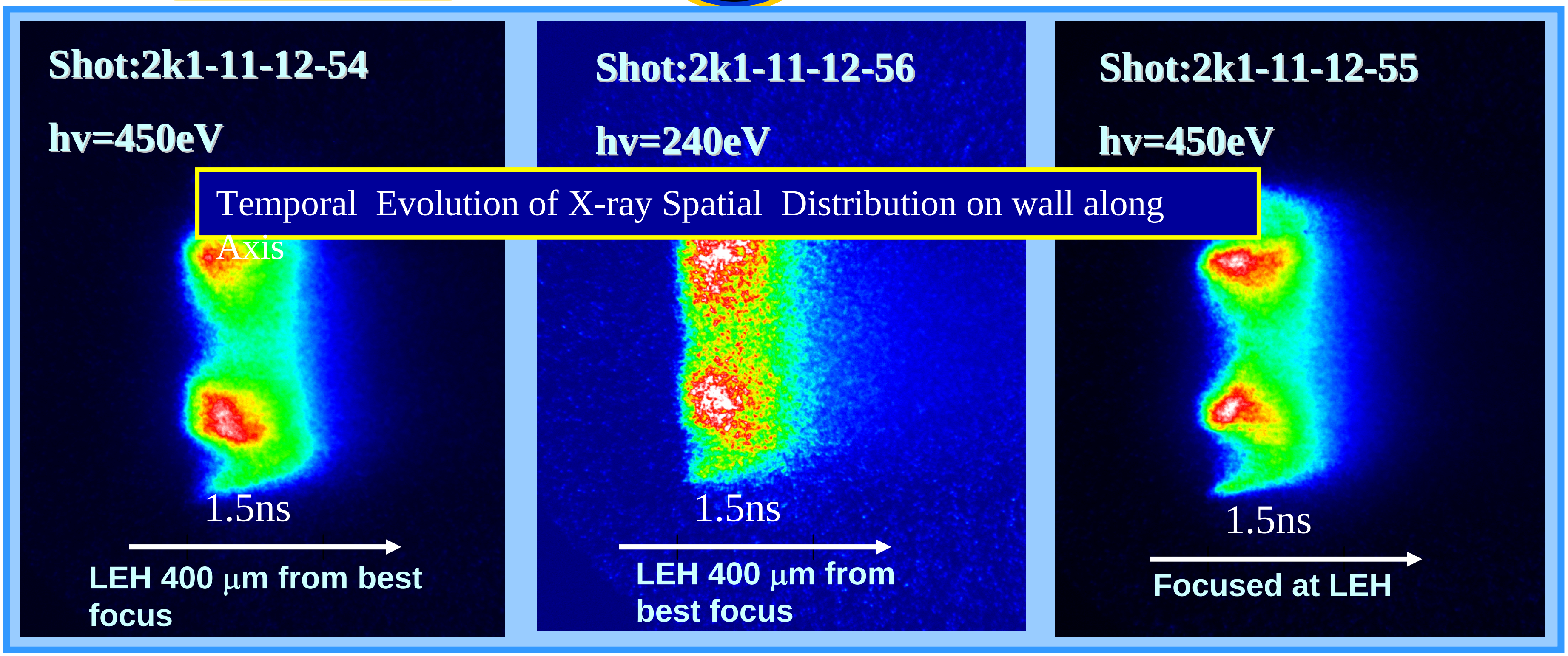
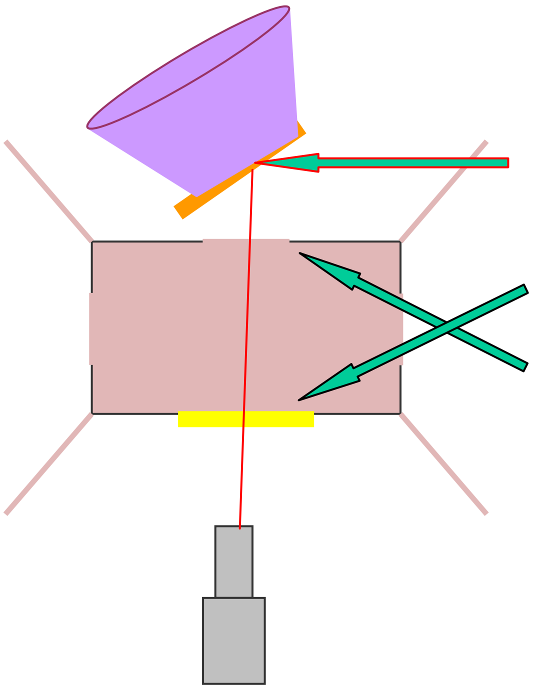
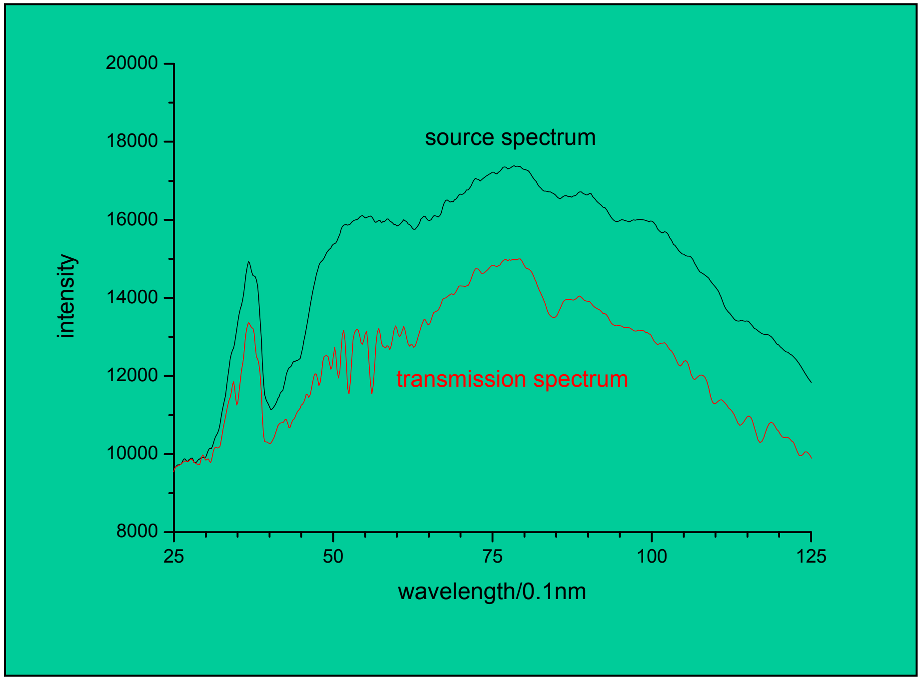




Opacity

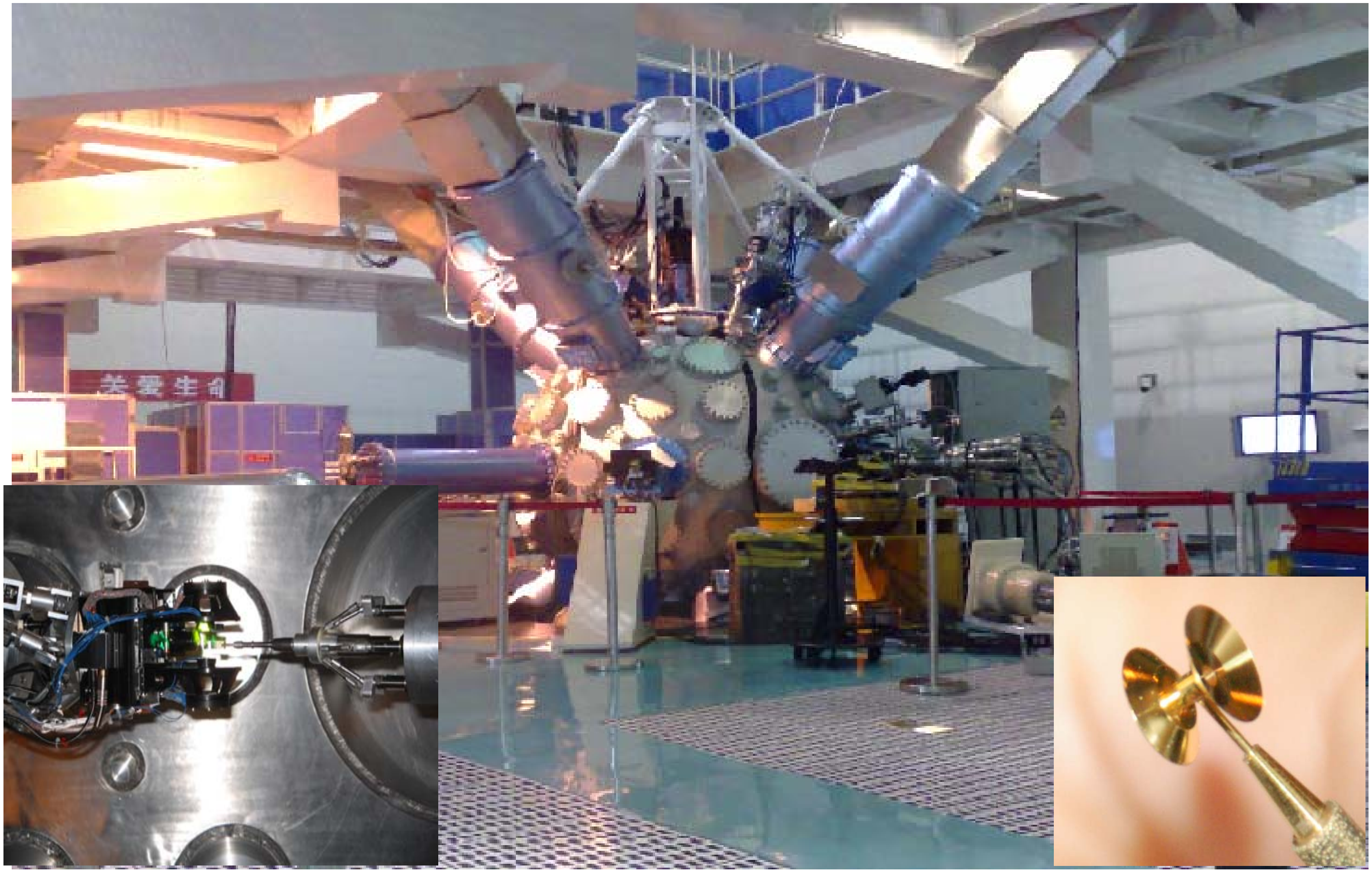


Backlight Opacity

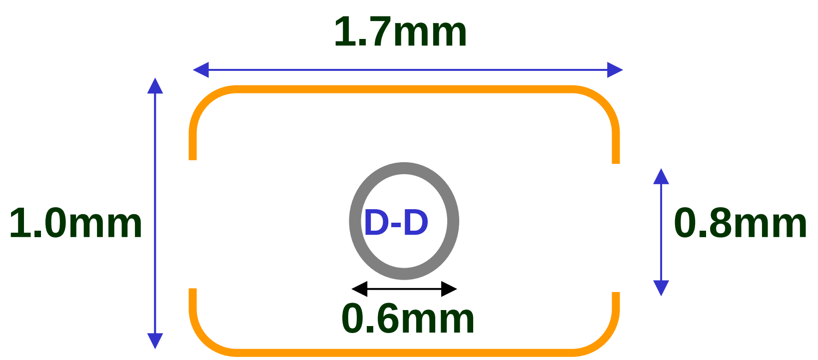


Transmitted spectra from radiative heat sample

SG-III TIL **Experiments**



Requires

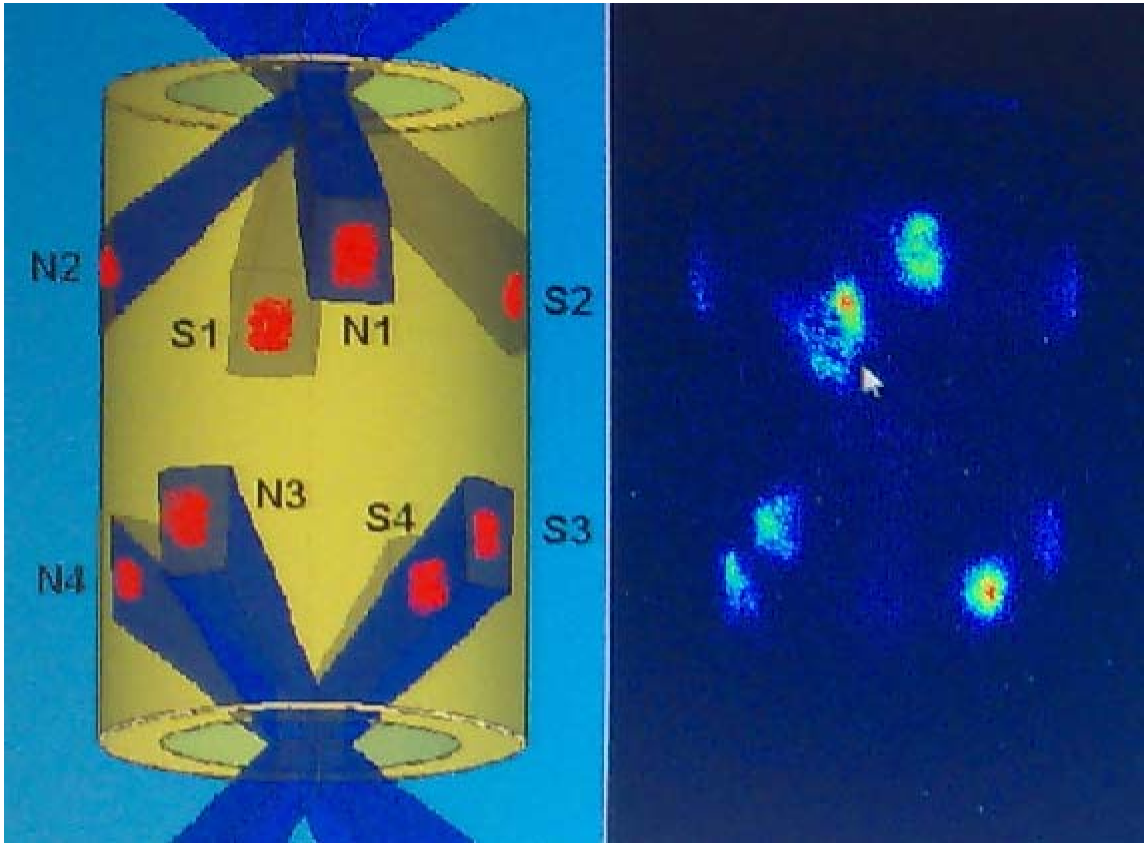


- E_L□ 4kJ□□$\omega_{□}$/1ns

SG-III TIL **Experiments**

- *Hohlraum* Radiative temperature: Tr □ 220eV
- Shot Point:
- Indirect Drive -neutron yield (DD): Yn □ 10^8/shot

Hohlraum shot point experiments



The X ray images of pinhole camera with beryllium filter-film , the thickness is 100μm , the X ray energy is more than 2keV.

3. Target Fabrication

ICF Target Technology

ICF Target

- 1
  - 1.1 □□□□
  - 1.2 □□□□
  - 1.3 □□□□
  - 1.4 □□□□
  - 1.5□□□□
  - 1.6 □□□□
  - 1.7 □□□□
  - 1.8 □□□□
- 2
  - 2.1 Be□□
  - 2.2 CH□□
  - 2.3 □□□□
  - 2.4 □□□□
  - 2.5□□□□
  - 2.6 □□□□
  - 2.7 □□□□
  - 2.8 □□□□
- 3
  - 3.1 BeDT
  - 3.2 C□DT□
  - 3.3 □□□□
  - 3.4 □□□□□□□□
  - 3.5 □□□□□□□
- 4
  - 4.1 DT□□
  - 4.2DD□□
  - 4.3CH□□□
  - 4.4 Be□□□
  - 4.5□□□□
  - 4.6 □□□□
  - 4.7 □□□□
  - 4.8 □□□□
- 5
  - 5.1 □□□□
  - 5.2 □□□□
  - 5.3 □□□□
  - 5.4 □□□□
  - 5.5 □□□□
  - 5.6 □□□□
  - 5.7 □□□□
- 6
  - 6.1□□□□
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  - 6.4 □□□□
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  - 6.6□□□□□
  - 6.7 □□□□
  - 6.8 □□□□

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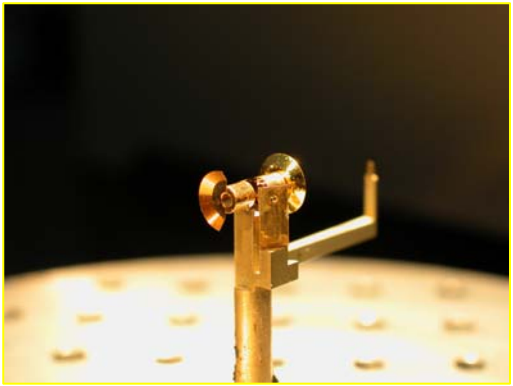
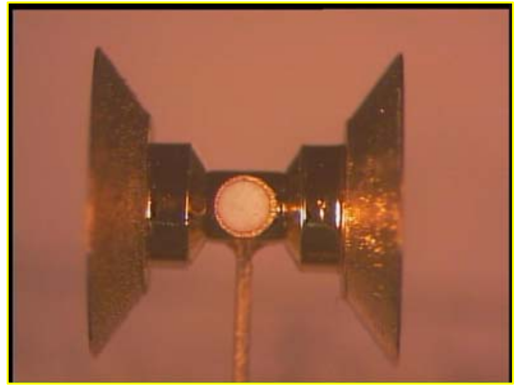
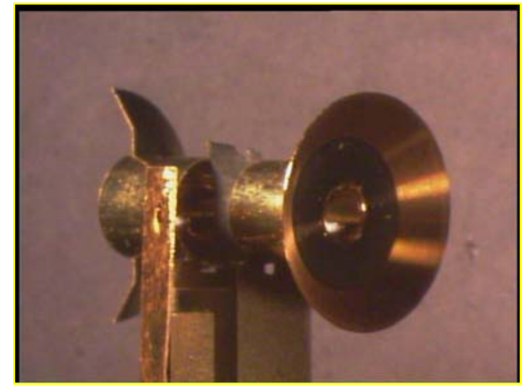
Target Manufacture



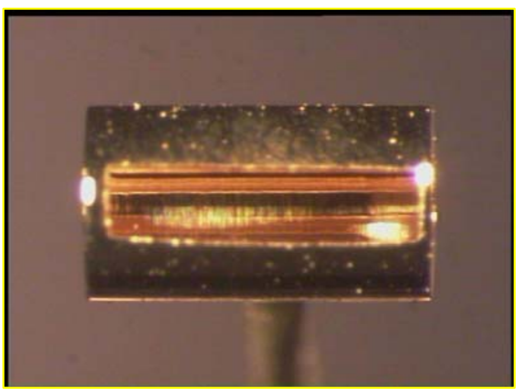
1 .Target for Opacity experiment



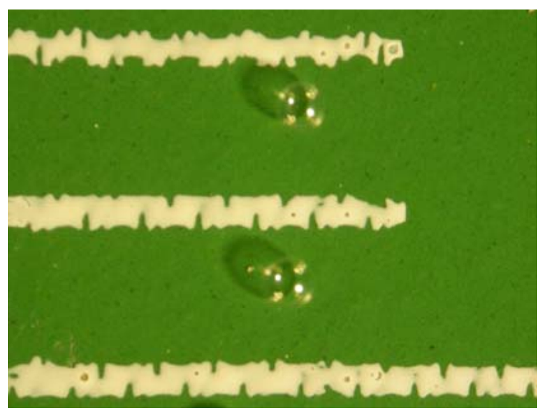
2.Target for Radiative flux



3.Double backlight ablation target



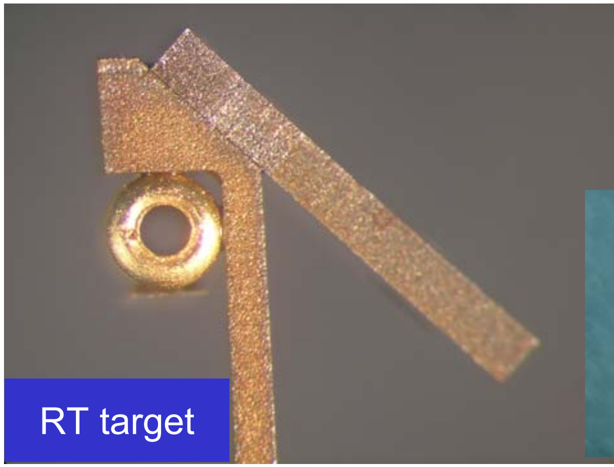
4.

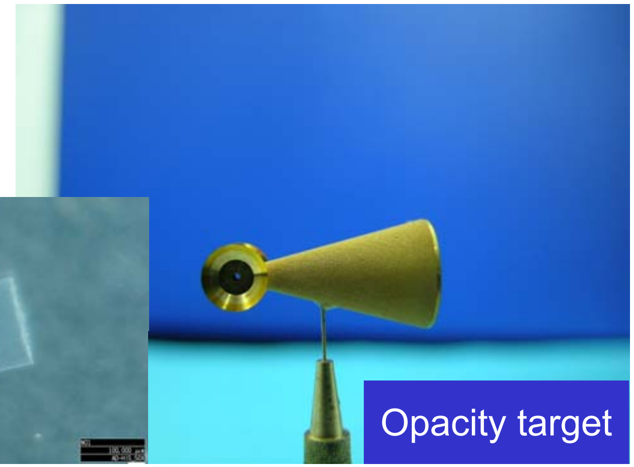


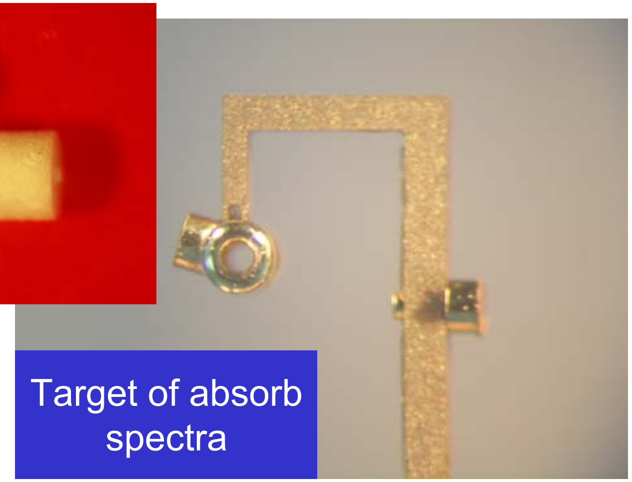
5.mm

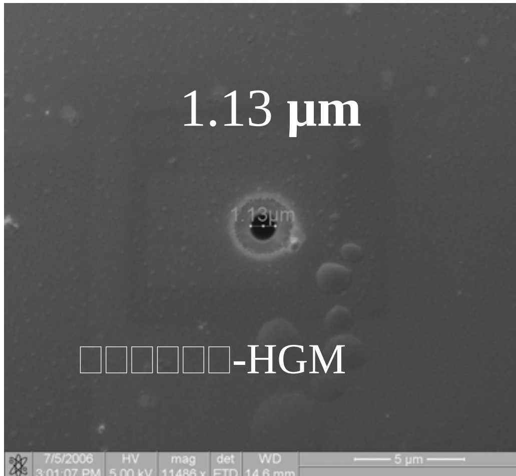
9.

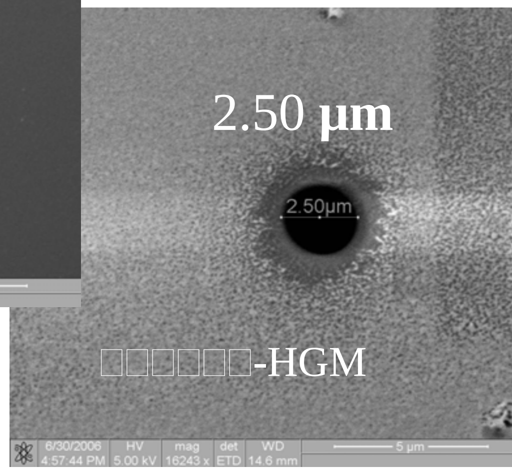
Experiment Targets

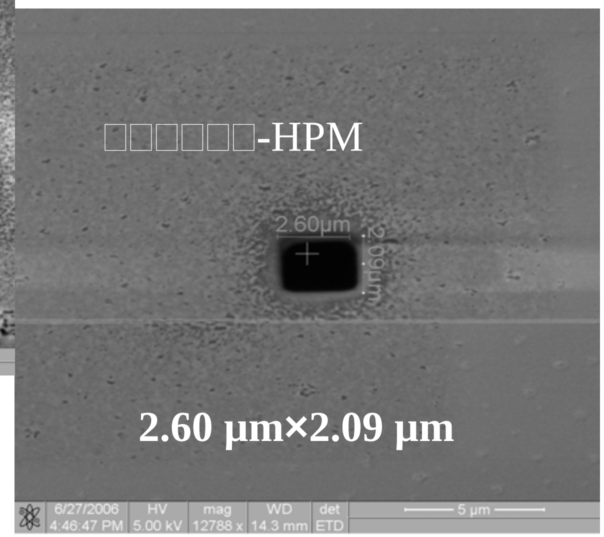












□□□□□□□□□□□□□□□□□□□SEM□□

Drilling hole using FIB on the shell of ICF capsule

Target Manufacture

capsule

CH—Ablation layer,

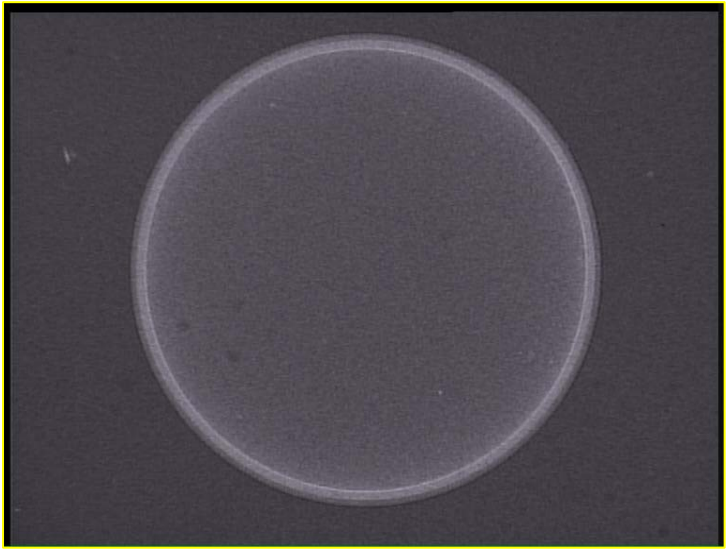
PVA—Gasproof layer,

PS—Radiation protection layer.

Wall thickness---15μm

Diameter 200   400μm

Filled with D_2 3   15atm 3   Ar



PS-PVA-CH Multi-layer plastic

CRF Foam Targets

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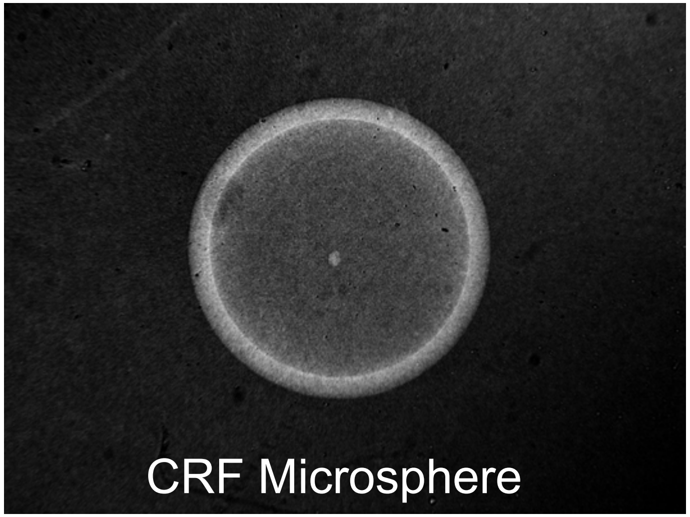
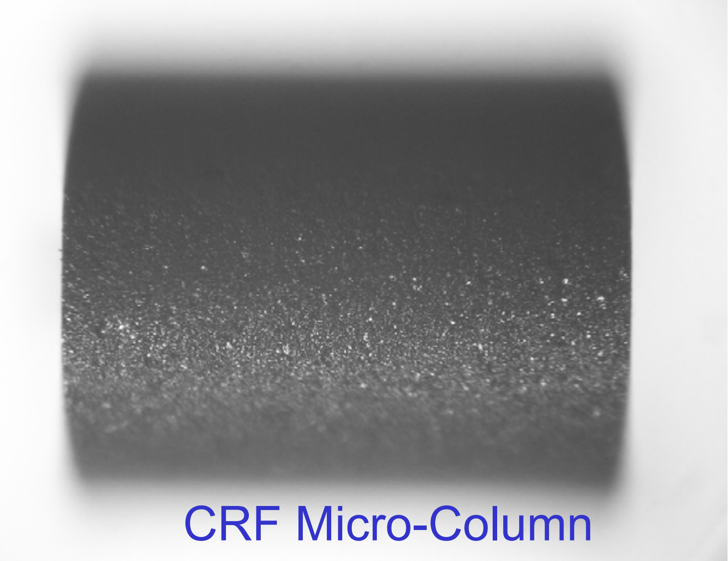


CRF Microsphere

Carbon foam

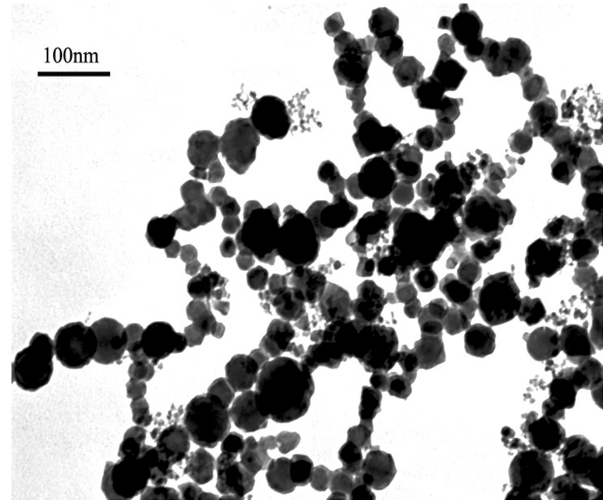
- Density: 788mg/cm3
- Micro-column: $\phi 600 \times 650$ μm

CRF Micro-Pan



CRF Micro-Column

Device of Nanometer-metal Using flow-levitation method



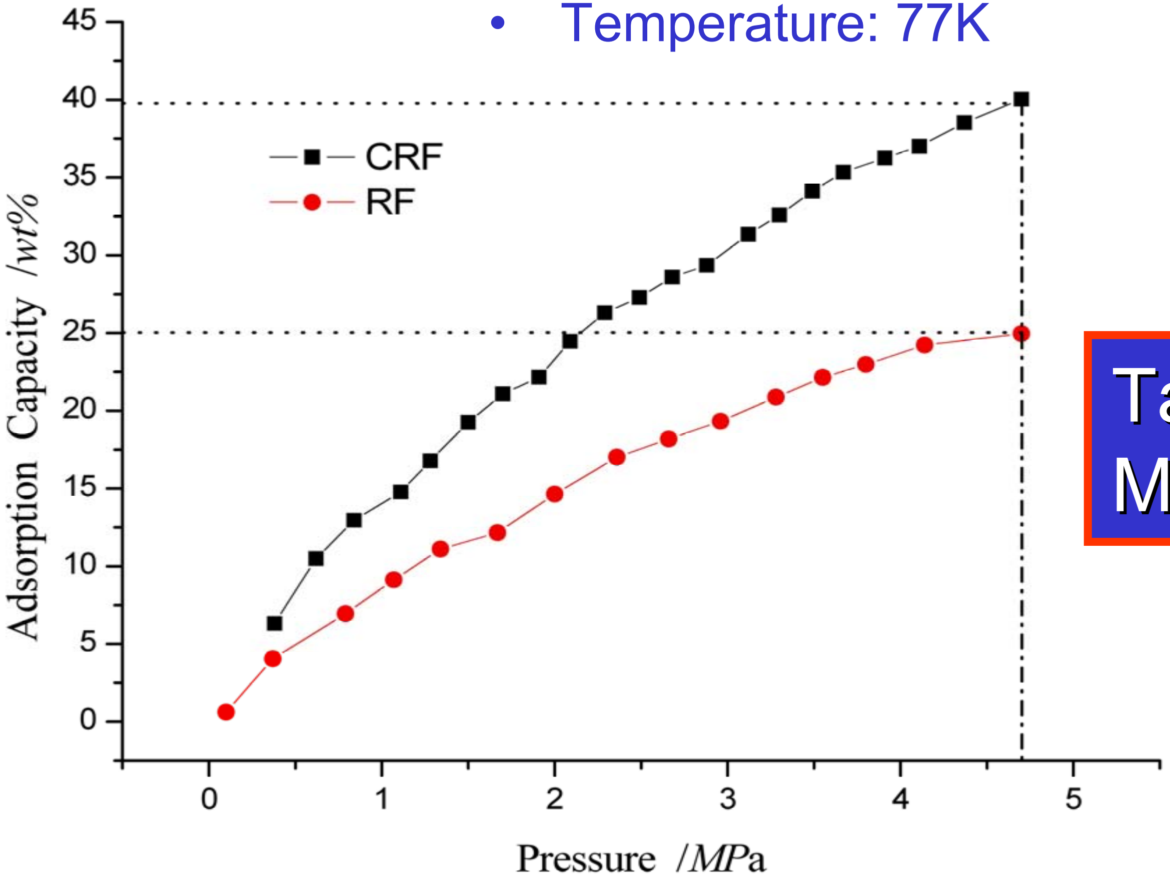
Electron micrographs of Fe nanoparticles, Fe□□□□□□□□□□□30□50nm□□.

Target Materials

□

Hydrogen adsorption
are made by RF&CRF solgel onto capsule shells

- Density: 100mg/cm^3
- Temperature: 77K



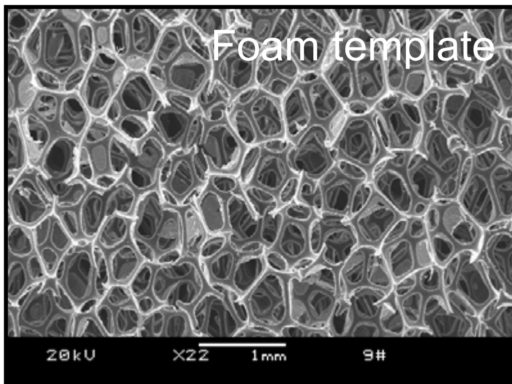
Target Materials

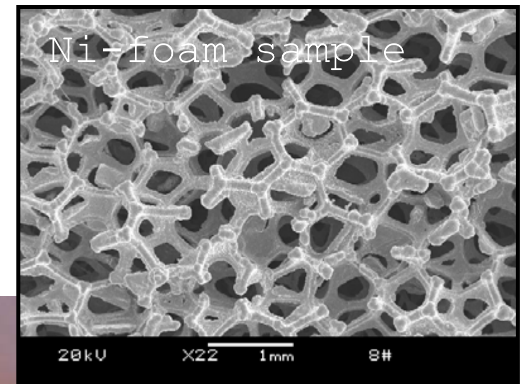
Metal Foam Preparation of Nickel and Copper-Oxygenation

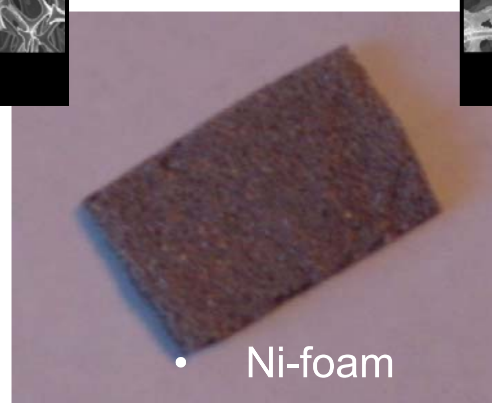
- By use of chem-electroplate and solgel technology.

  Nickel foam density: 0.74g/cm^3□Small hole rate: 91.7□□

  Cupper foam density: 125mg/cm^3

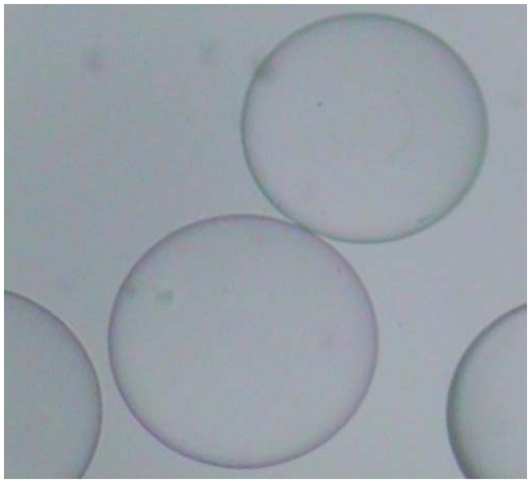




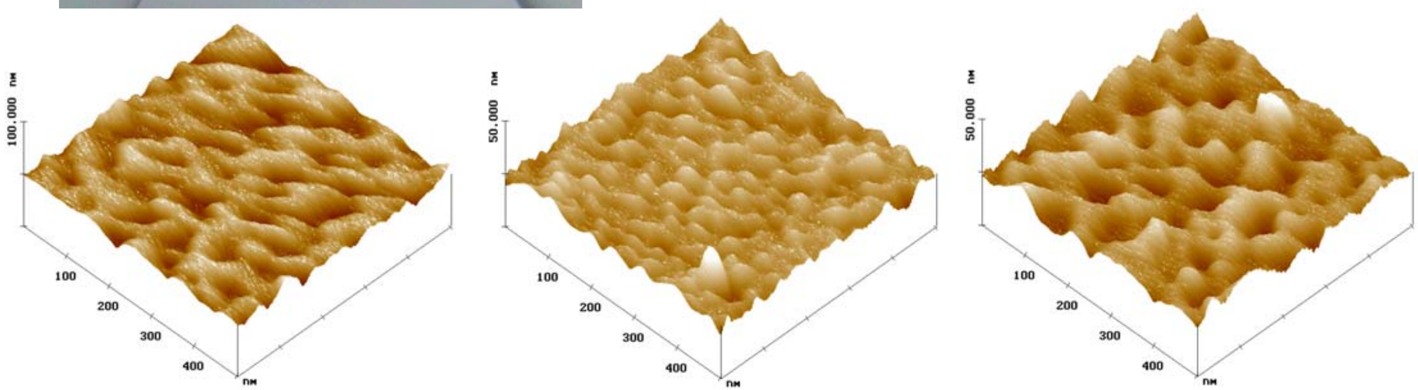


Target Materials

PAMS mandrels



PAMS hollow micro-sphere
Diameter: 1~1.6mm,
Thickness: 2~6μm



a b c

PAMS surface roughness vs concentration variety.

□a: 10%(w/w), RMS~7.9nm□ b: 15%(w/w), RMS~3.4nm□c: 20%(w/w), RMS~8.5nm□

BeH_2Film Preparation Using CVD Technology

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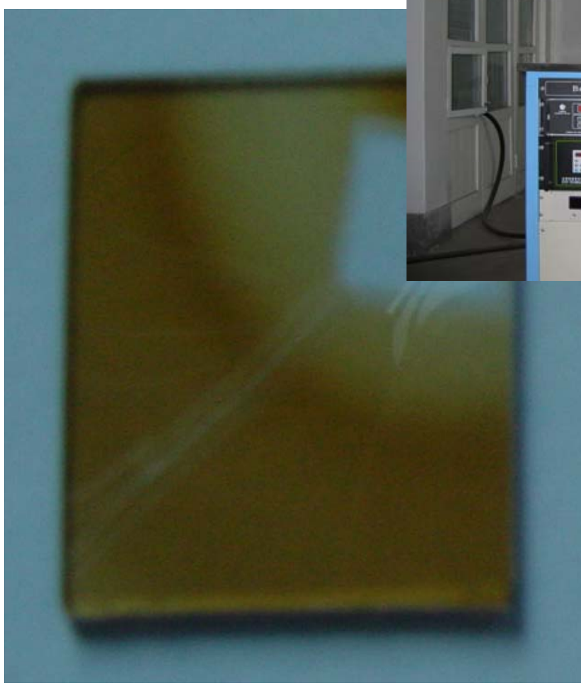

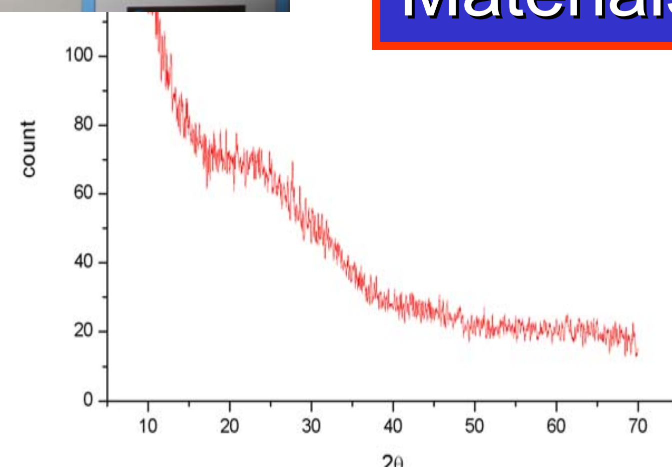

Target Materials

Noncrystalline BeH_2 film.

X-ray diffraction spectrum of BeH_2 Film□□ 2θ□23°□25°□□□□“□□”□□□BeH2□□XRD □□□□□□□□

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