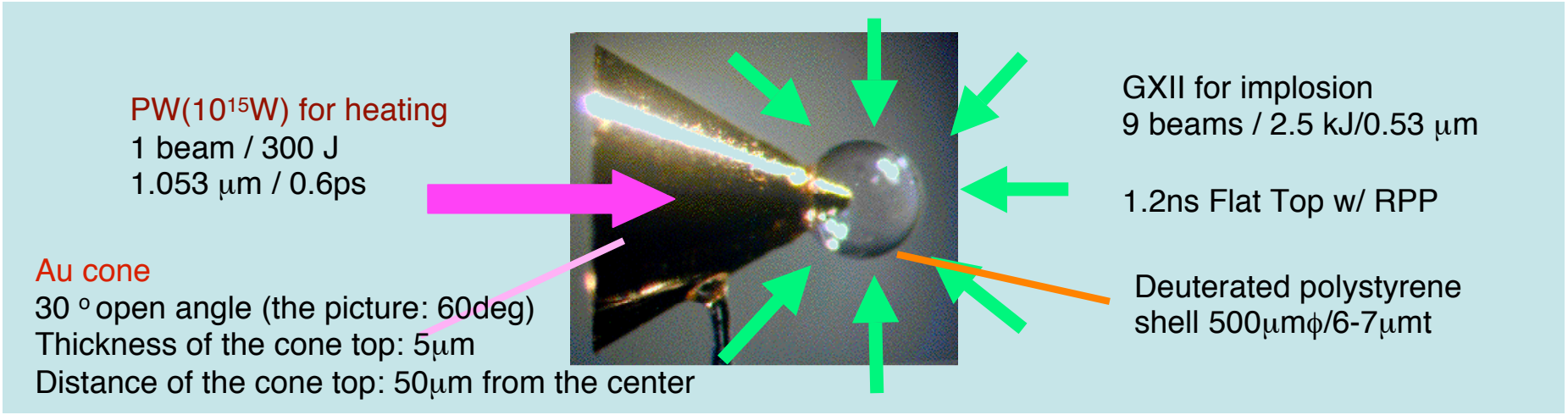
Current status of LFEX laser and Target fabrication for FIREX-I project

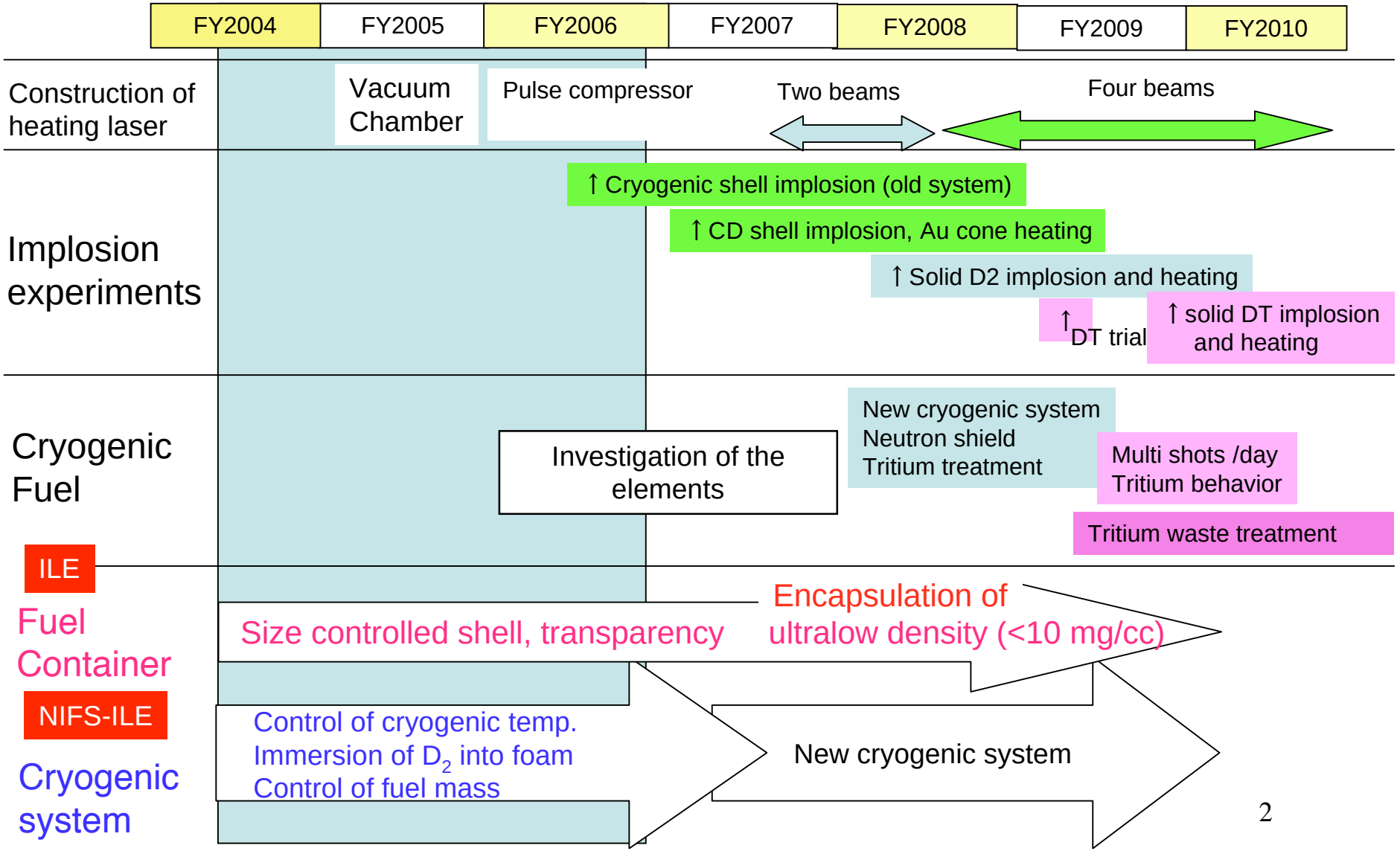


NAGAI Keiji, YANG Han, YAMANAKA Kentaro,
FUJIMURA, Takashi, NEMOTO Nobukatsu[1], NAKAI Mitsuo,
NORIMATSU Takayoshi, IWAMOTO Akifumi[2], SHIRAGA Hiroyuki,
AZECHI Hiroshi, and MIMA Kunioki

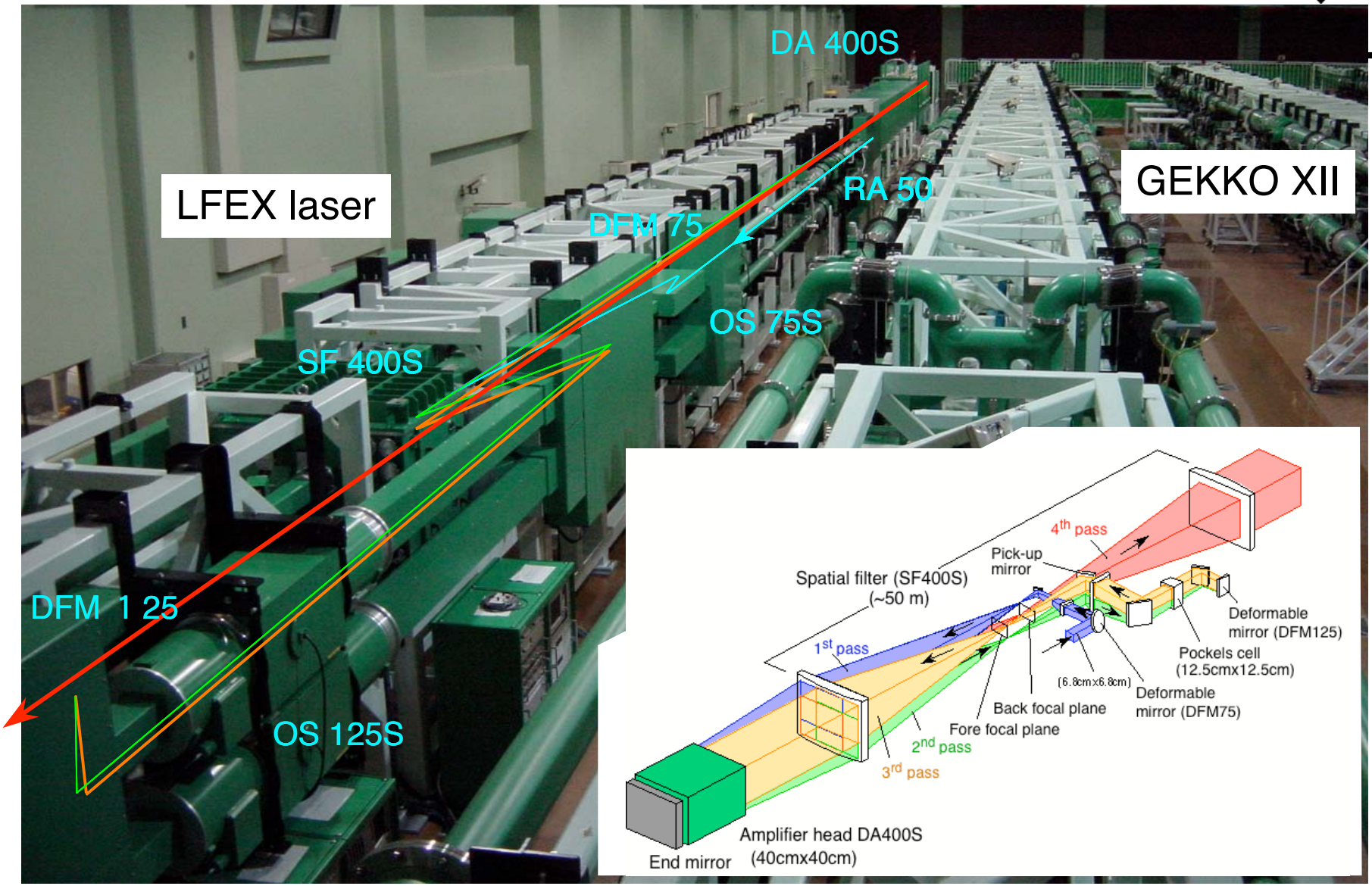
ILE Osaka Univ., Nihon Univ.[1], NIFS[2]

Cryogenic target for FIREX-I

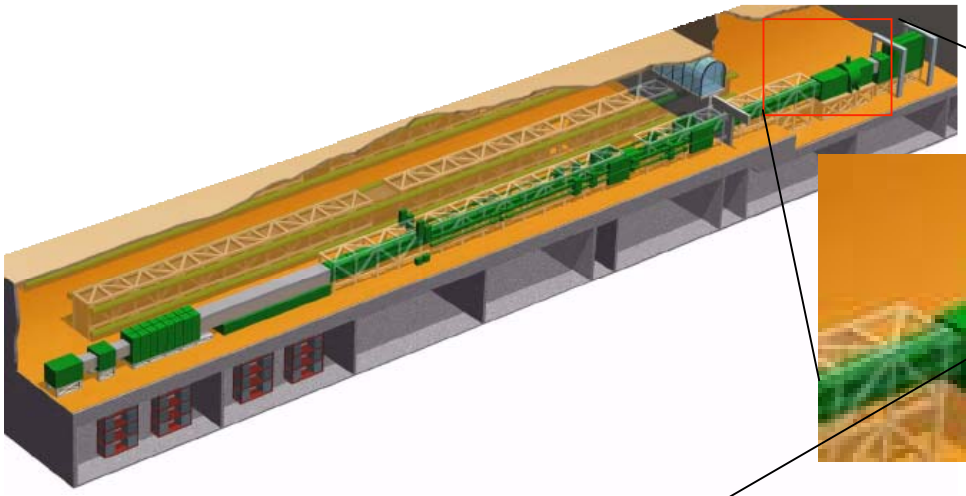
LFEX (10kJ, 10ps, 1PW) (2 ps, 5PW)+ GEKKO XII
Heating of cryogenic target to 10keV

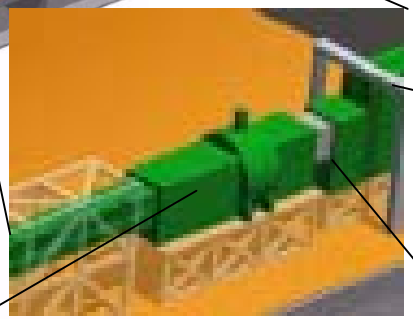


2x2 amplifier chains of LFEX laser

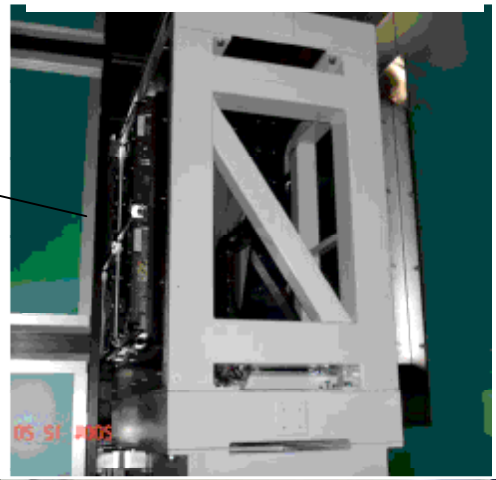


1.2-m, 2x2 Faraday rotator

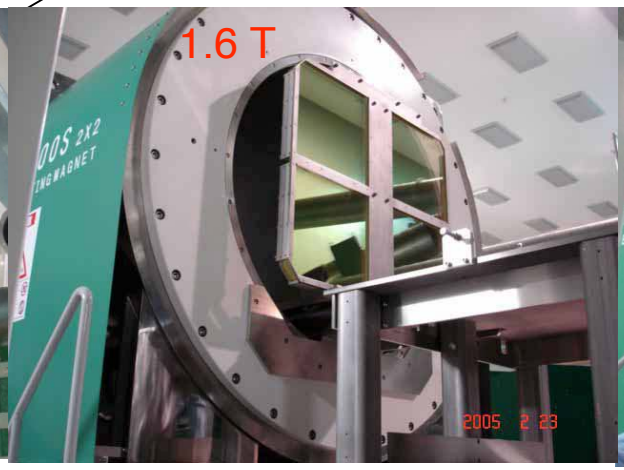




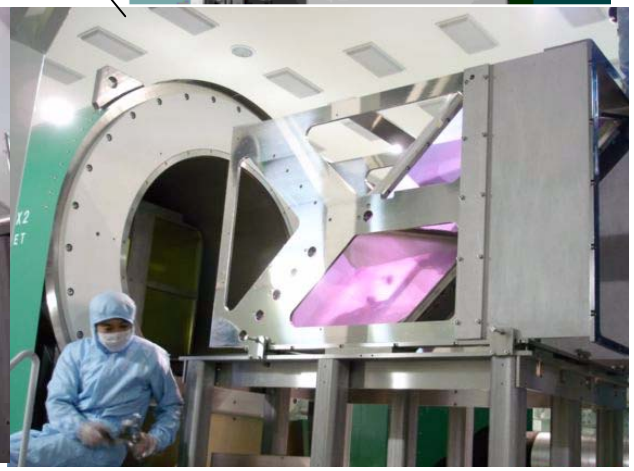
U-turn mirror arrays



Front polarizer arrays

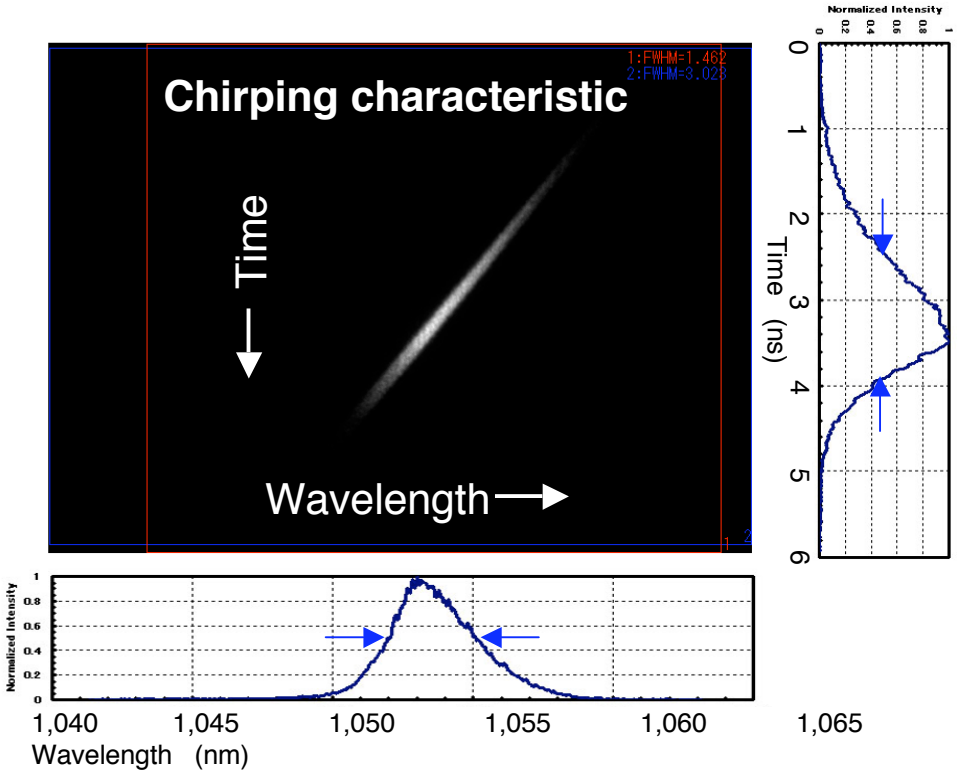


Superconducting magnet and Faraday glass arrays



Rear polarizer arrays

Broad-band (CPA) activation test of main amplifier



Spectral width: 3.1 nm

Pulse width: 1.45 ns

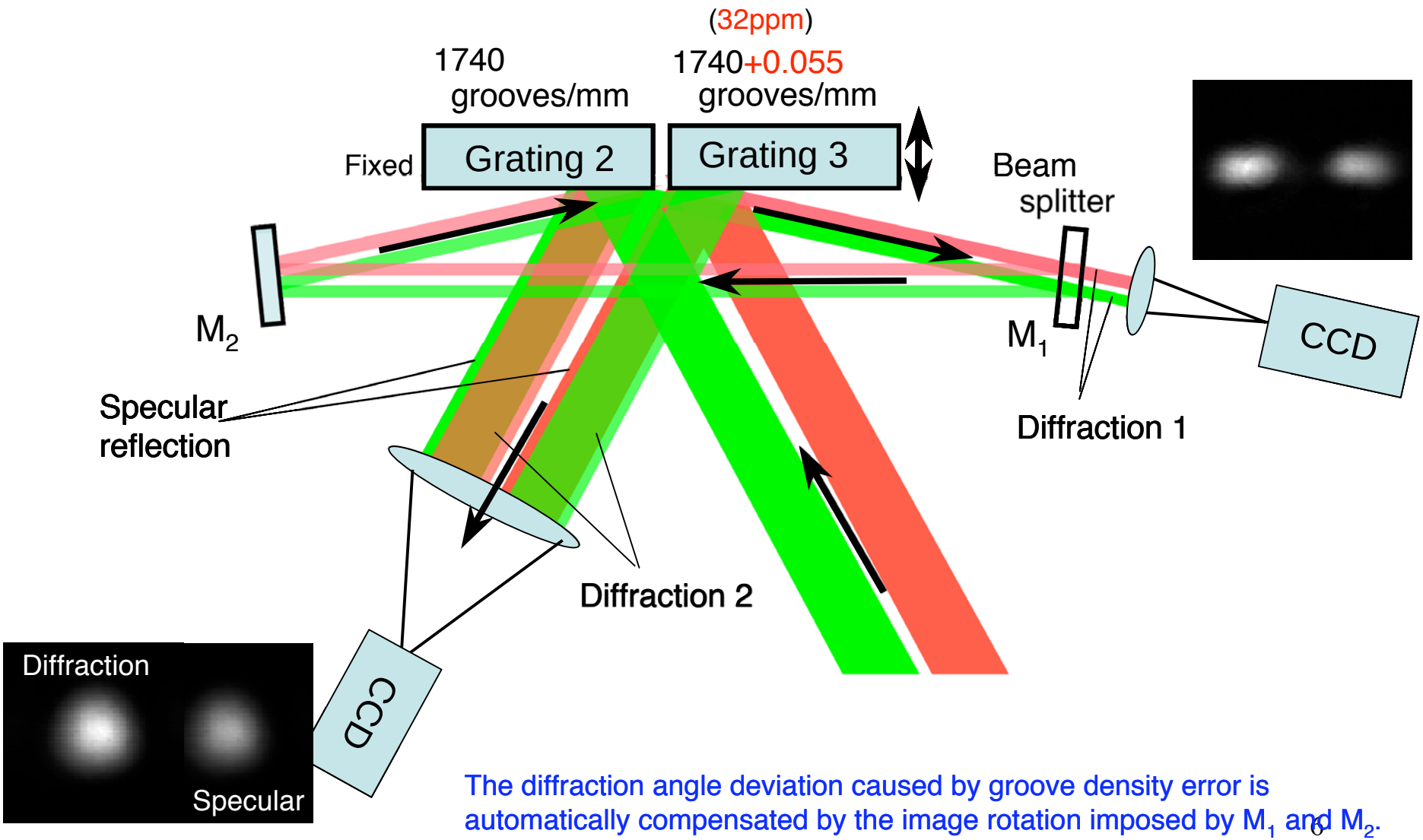
(to be extended to 2.2ns)

Beam energy

2.3 kJ/ 37x37cm^2

Final test will start soon aiming at 12kJ/4 beams.

Proof-of-principle experiment of automatic compensation

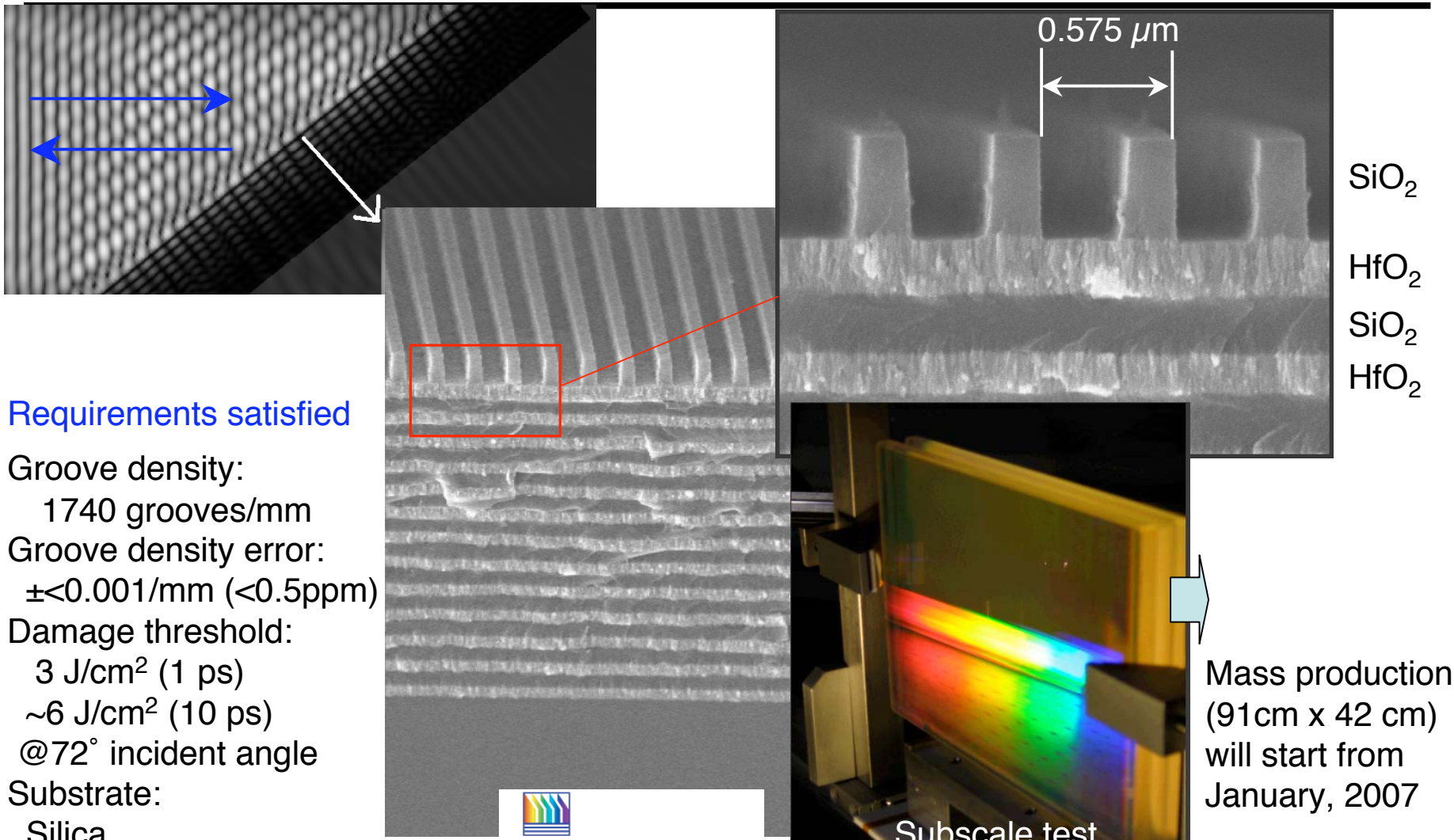


The diffraction angle deviation caused by groove density error is automatically compensated by the image rotation imposed by M_1 and M_2.

High-DT, precision multi-layer dielectric grating

Design using FDTD code

Fabricated sample (10 cm diameter)



Requirements satisfied

Groove density:
1740 grooves/mm
Groove density error:
±<0.001/mm (<0.5ppm)
Damage threshold:
3 J/cm^2 (1 ps)
~6 J/cm^2 (10 ps)
@72˚ incident angle
Substrate:
Silica

Plymouth Grating Laboratory
Plymouth, Massachusetts

Mass production (91cm x 42 cm) will start from January, 2007

Cooperative production system of MLD gratings

Japan

Quartz material

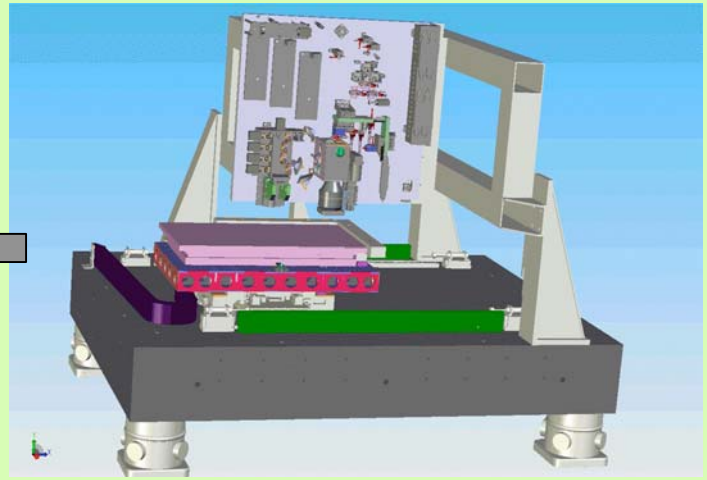
Polish and inspection

Multi-layer dielectric coating

ILE, Osaka

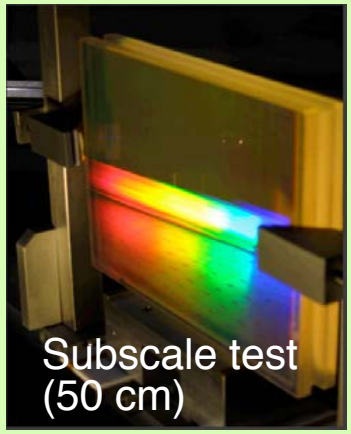
USA

Resist coating

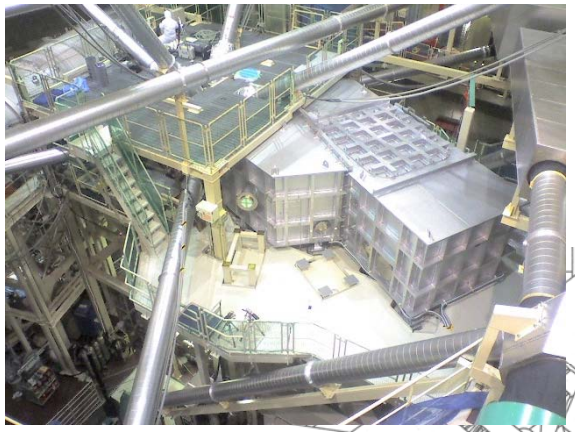


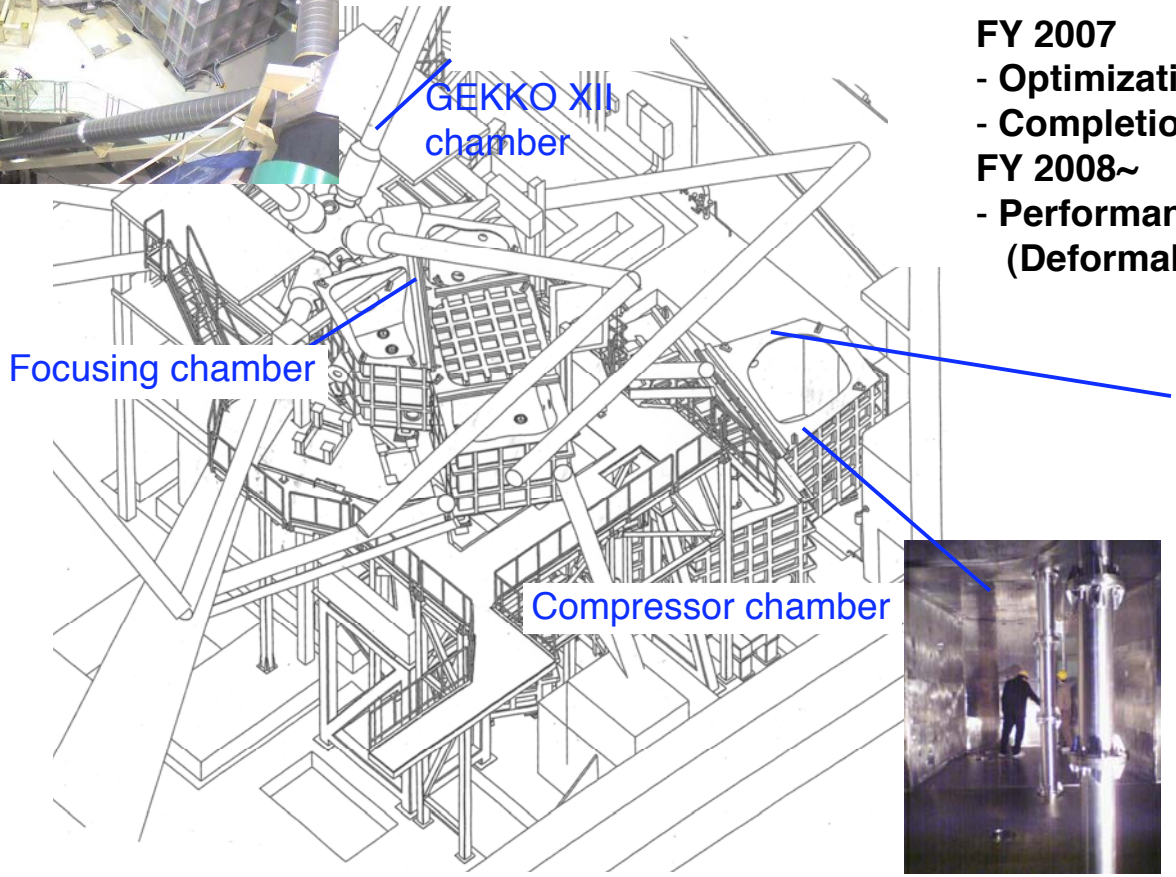
Scanning exposure (nanoruler II)

Ion etching



Construction schedule and summary





FY 2006 (by the end of March, 2007)
- Beam transport optics (2 beams)
- Pulse compression / focusing (1 beam)
FY 2007
- Optimization of CPA / compression
- Completion of 4 beams
FY 2008~
- Performance improvements (Deformable mirrors in rear end, 4-beam phase locking)

Grating mechanics holder

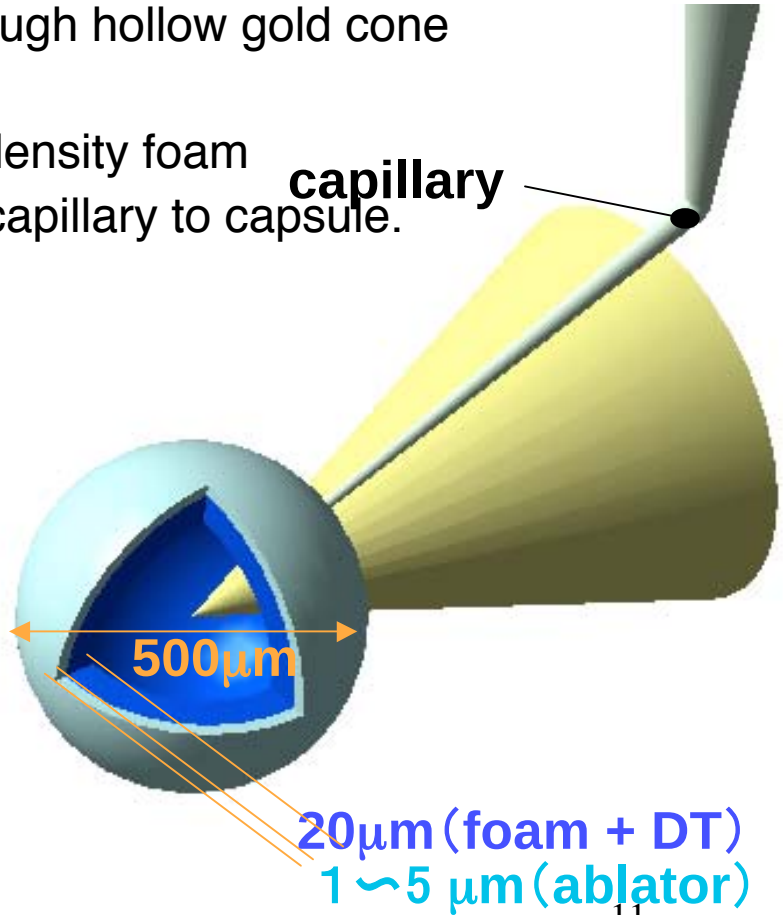
Target Fabrication

1. Introduction of LFEX
2. Specification of target for FIREX-I
3. Materials for the processes … RF and a new derivative
4. Catalyst of gelation…phase transfer catalyst
5. Deformation of emulsion
6. Characterization
7. Hole drilling and attaching cone

Low density materials for cryogenic foam targets

- Compression of fuel (spherical DT) using Gekko XII laser.
- Heating by LFEX (new petawatt) laser through hollow gold cone

- The fuel capsule was prepared using low density foam and liquid DT will be infiltrated through an capillary to capsule.

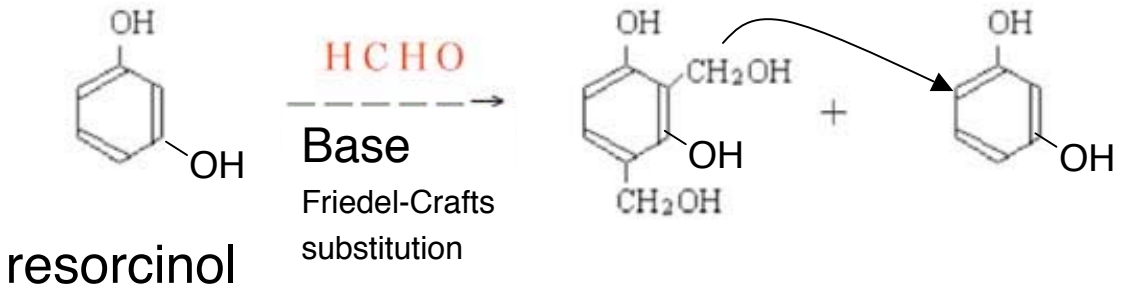


Specification

·D_2 or DT fuel is infiltrated into a foam shell.
·Shell diameter：500 μm
·Thickness of DT：～20 μm
·Ablator thickness：～5 μm

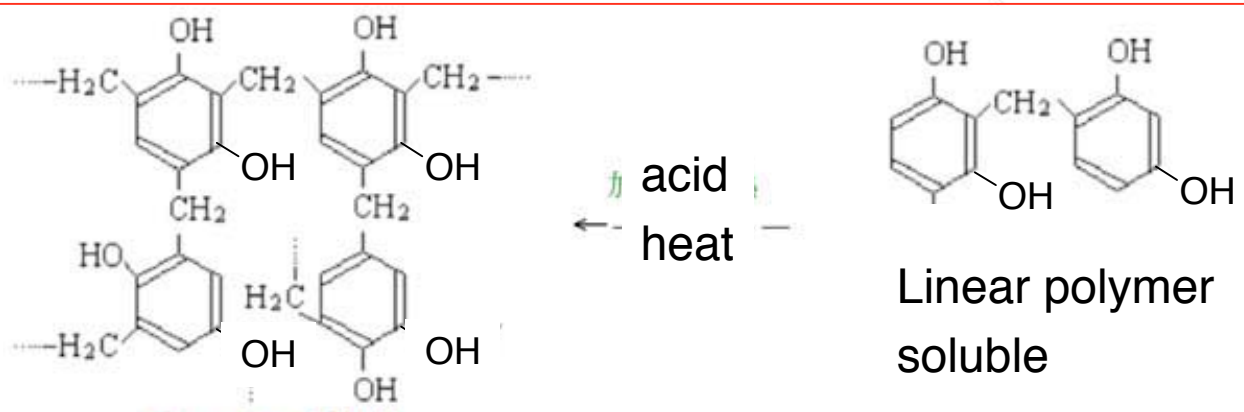
Gelation process is key issue to control density and capsule morphology, and it is chemical process of crosslinking of polymer chain.

•In the case of RF,



resorcinol

polymerization



3-d network (gel)

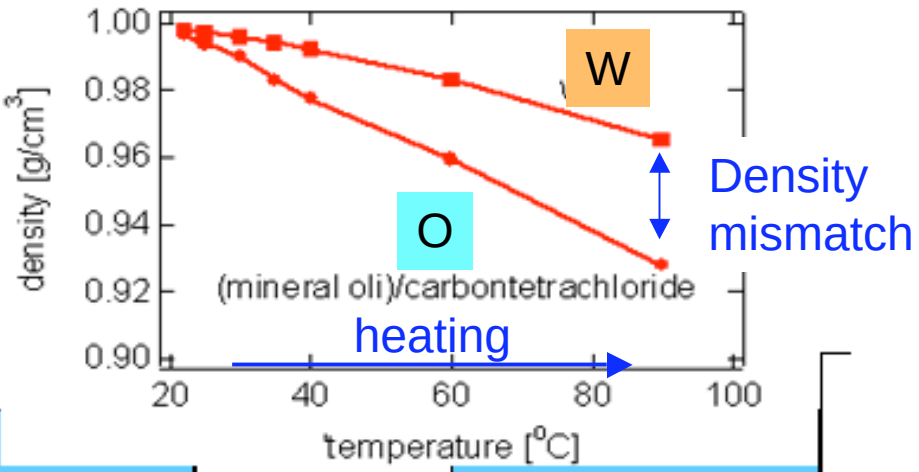
Linear polymer soluble

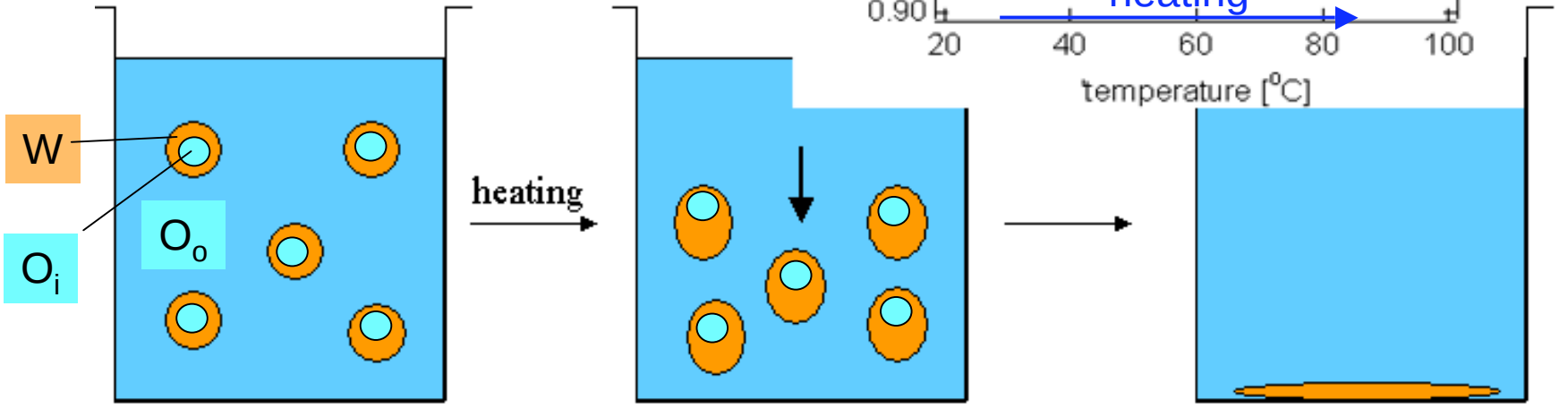
gelation process

3. Catalyst of gelation… phase transfer catalyst

Foam capsules are also prepared by density matching emulsion method.

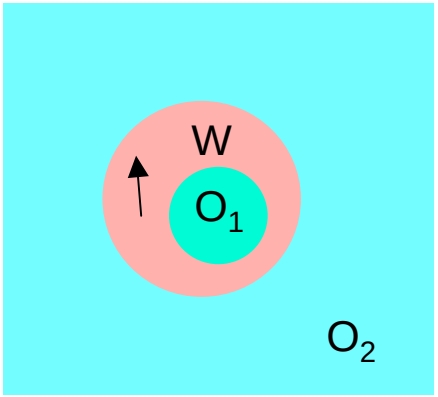
To activate catalyst, the emulsion was heated. But, heating induced density mismatch.
Before complete gelation, the emulsion was decomposed.



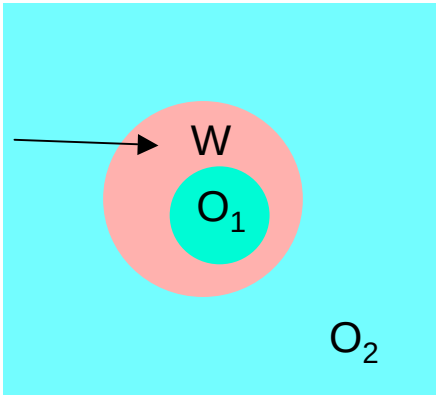


Phase-transfer catalyst induced gelation at room temperature, and kept the density matching of emulsion.

Previous method



New method



A catalyst for gelation was dissolved in W (RF solution) phase, and activated by heating.

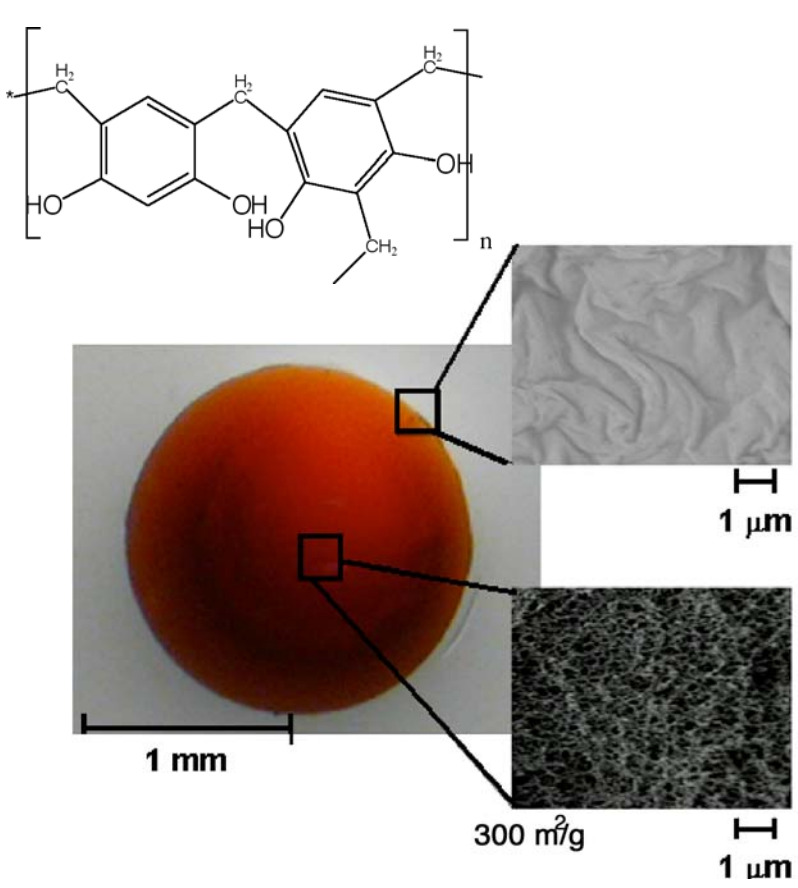
→ catalyst motion

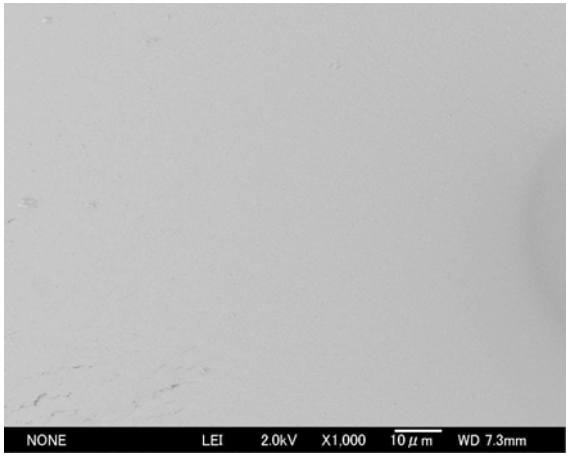
A catalyst for gelation transfers from O to W (RF solution).

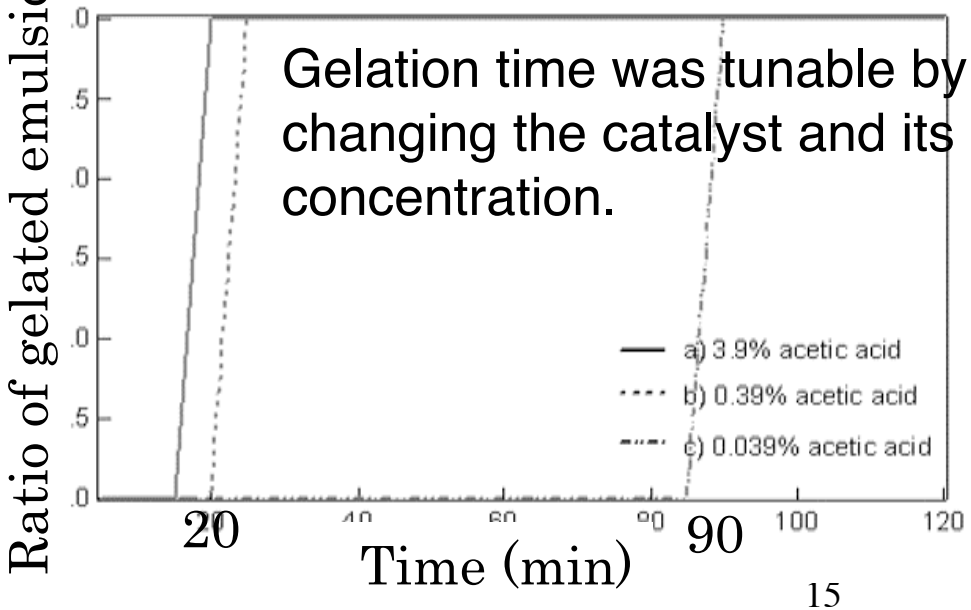
F. Ito, et al., *Macromol. Chem. Phys.*, **206** (21), 2171-2176, (2005).

4. Catalyst of gelation… phase transfer catalyst

Resorcinol/formaldehyde (RF) balls were prepared using phase-transfer catalysts.



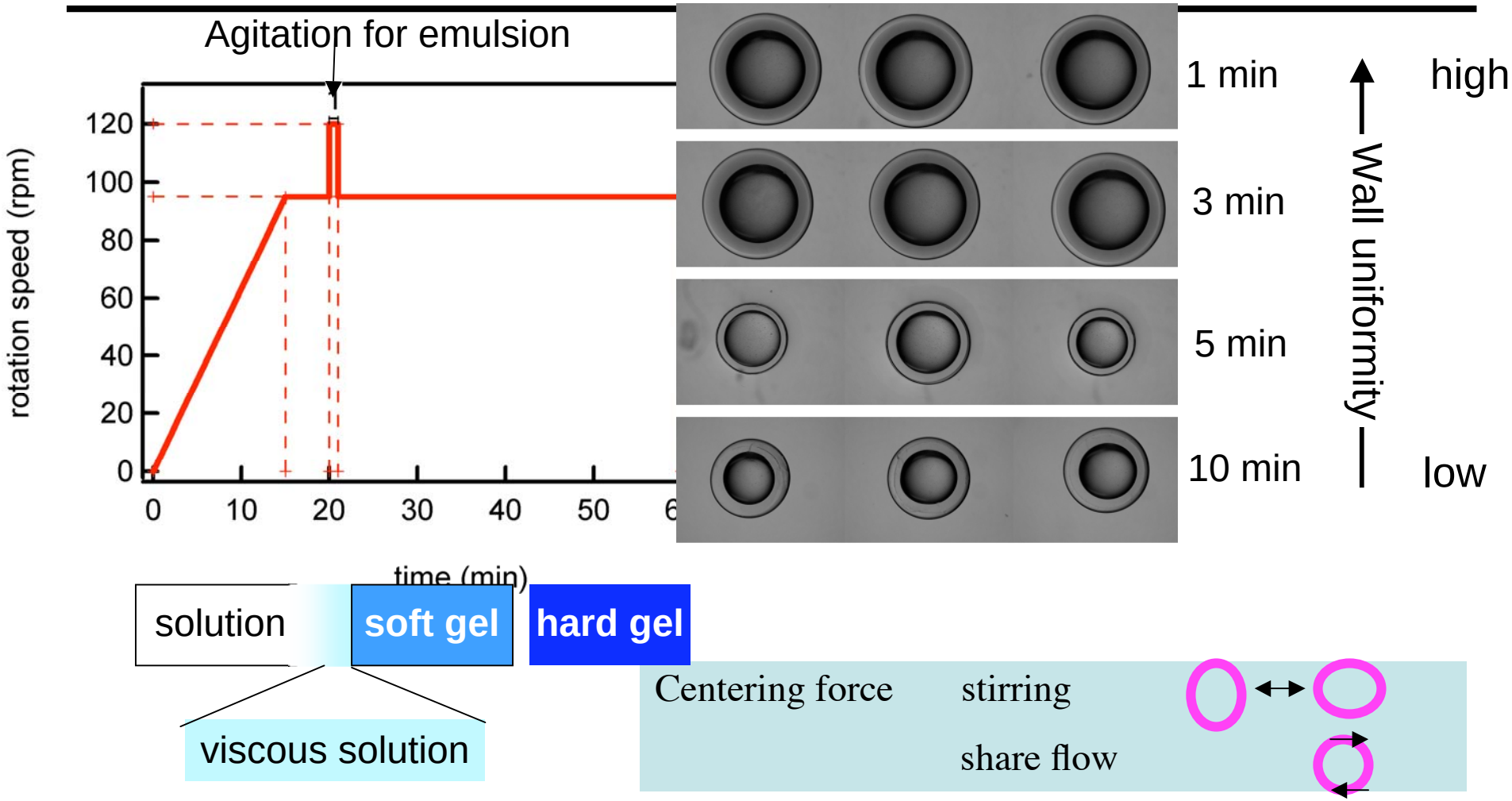




Gelation time was tunable by changing the catalyst and its concentration.

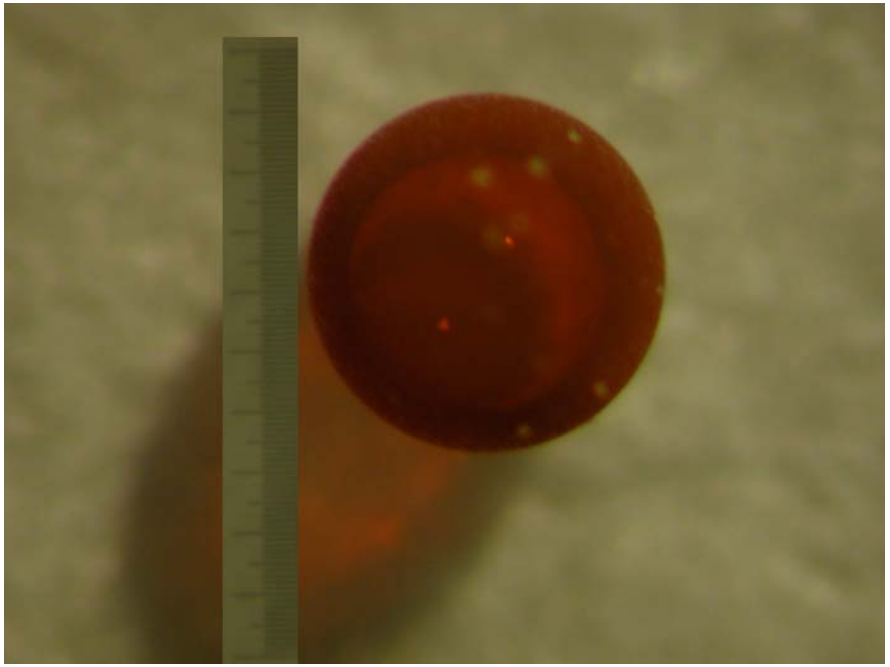
5. Deformation of emulsion

Three parameters were optimized in order to obtain concentric gel.
1) rotation rate, 2) when it starts, 3) how long it is kept.



F. Ito, et al., *Fusion Sci. Technol.*, **49** (4), 663-668, (2006).

RF did not satisfy the specification.



Diameter : 600μm

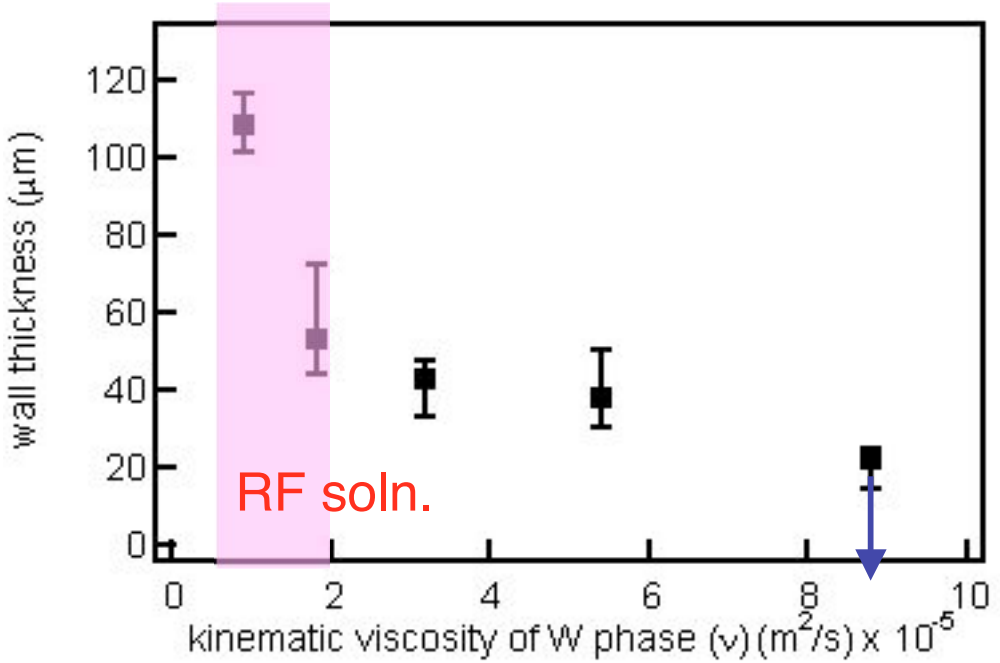
Wall thickness : 100μm

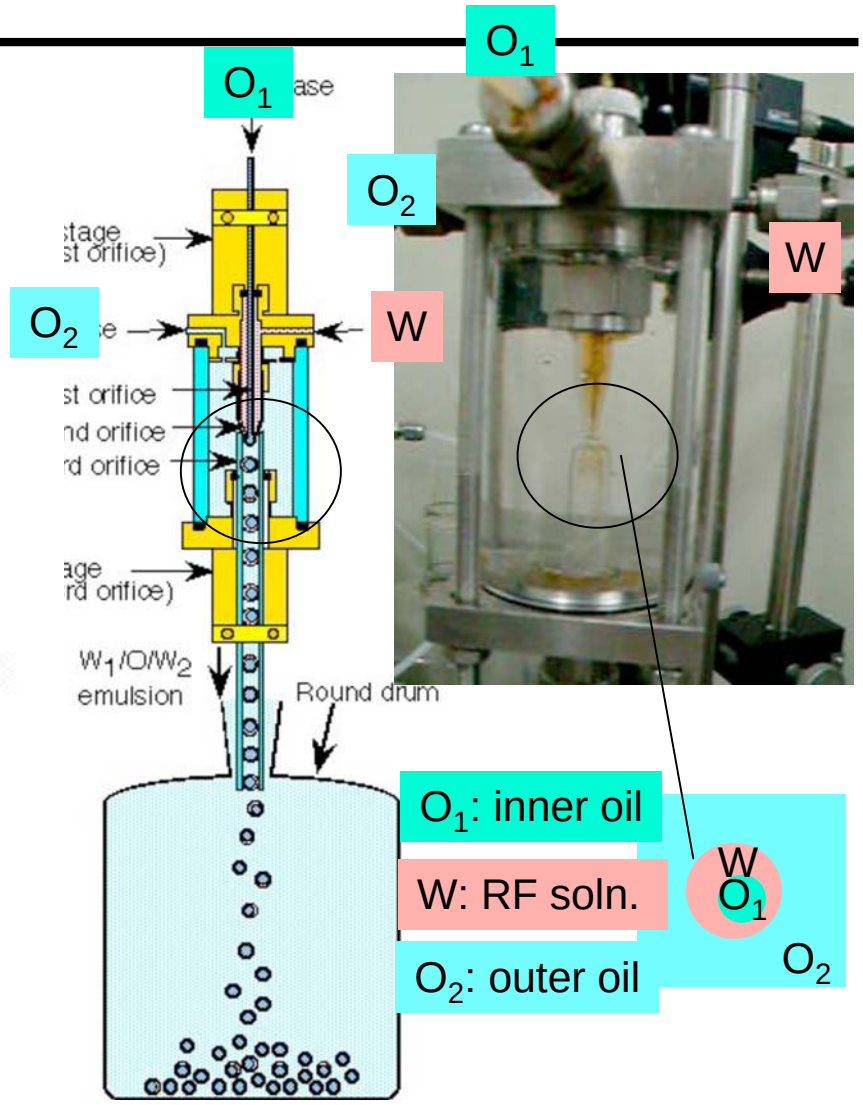
The wall was too thick.

RF solution has narrow window of its viscosity, and is hard to control thickness of the capsule.

The viscosity of RF solution should be increased.

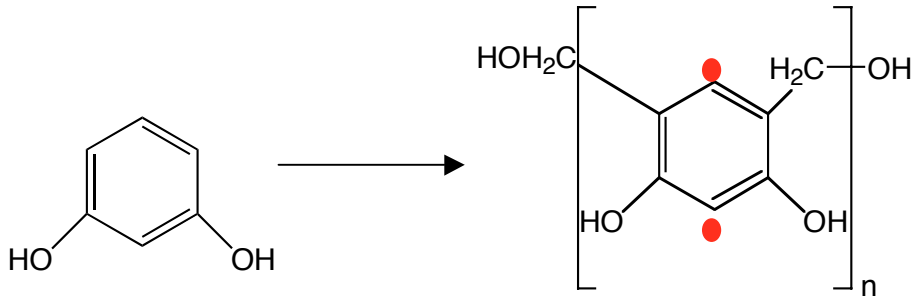
The thickness of W depends on its viscosity.





- The high viscosity induced thin wall thickness.
- Viscous RF solution is high concentration and cannot be applied for the emulsion process due to gelation.

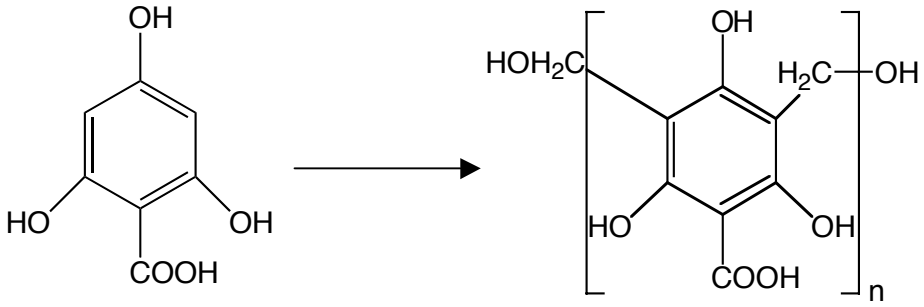
Linear polymer without crosslinker (•) was added to RF solution in order to increase the viscosity.



resorcinol

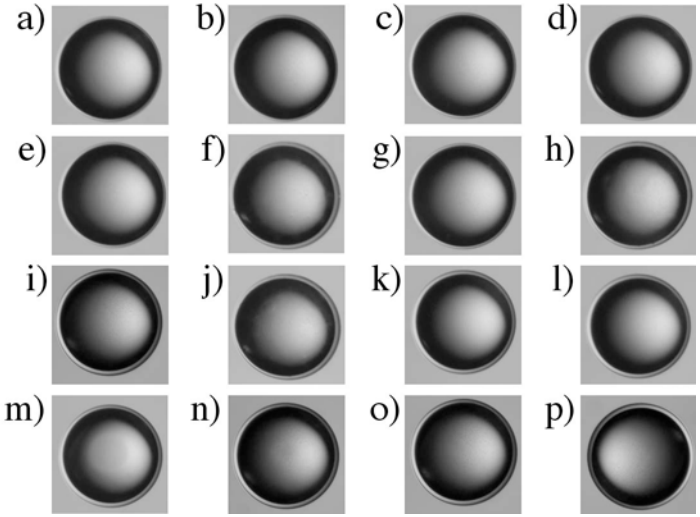
resorcinol/formalin (RF)

(linear)



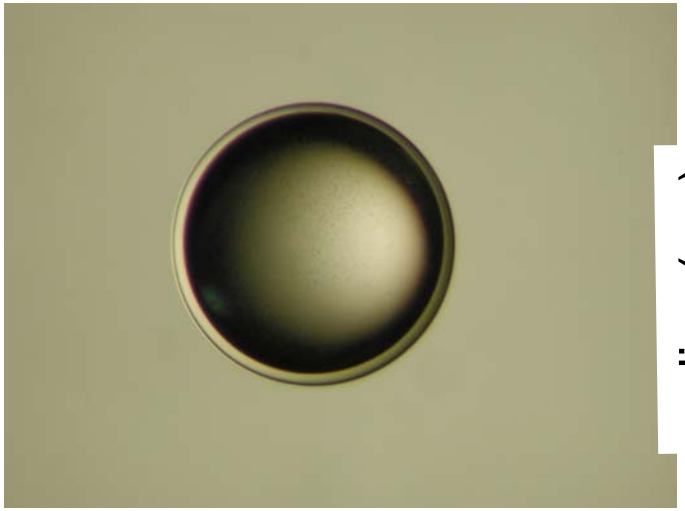
phloroglucinolcarboxylic acid

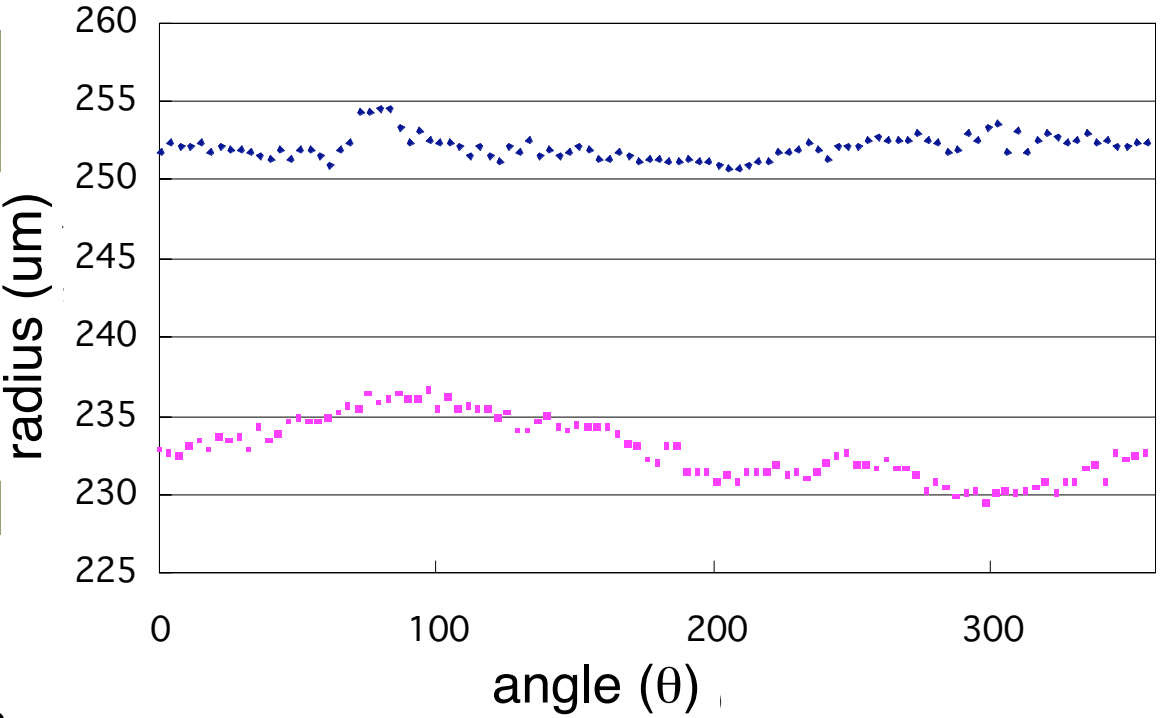
phloroglucinolcarboxylic acid)/formalin (PF)



Hollow gel of RF/PF

RF/PF foam shell



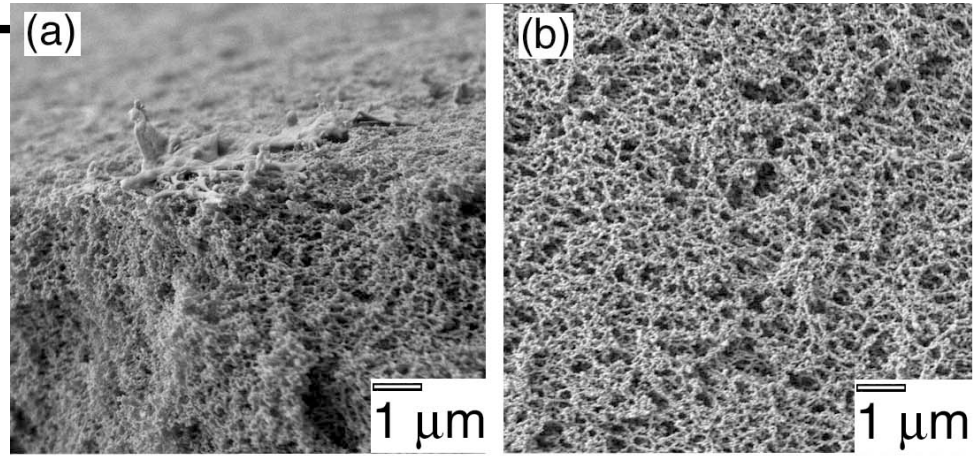


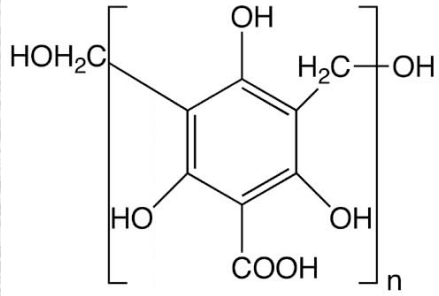
radius 252±0.3μm
Wall thickness 19.3±1.3μm

RF-PF has a fibrous network structure which is similar to that of RF.

outer surface inner surface

RF-PF

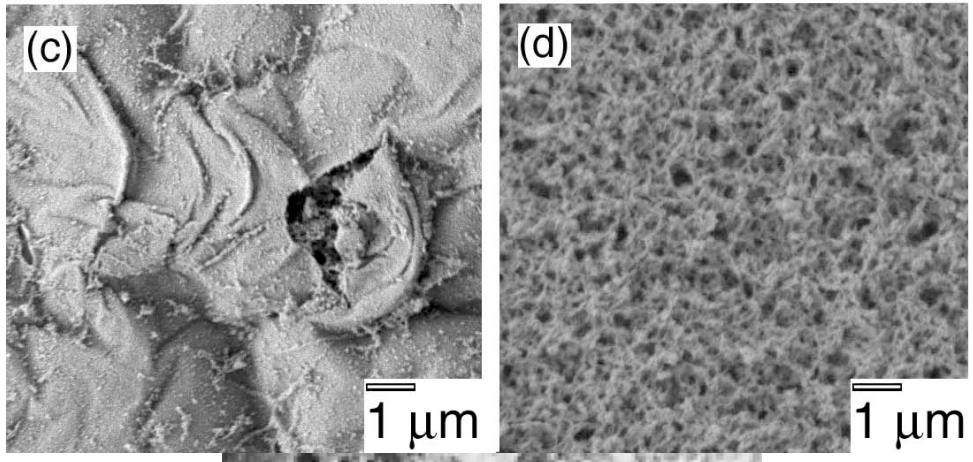


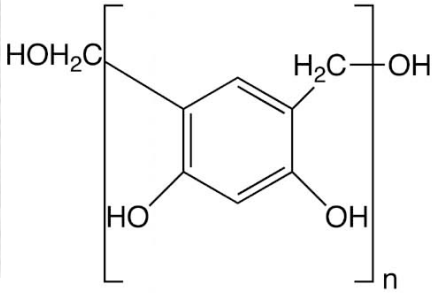


phloroglucinolcarboxylic acid)/formalin (PF)

180 ~ 220 nm pore

RF

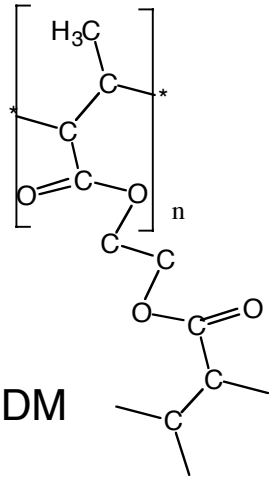




resorcinol/formalin (RF)

~ 290 nm pore

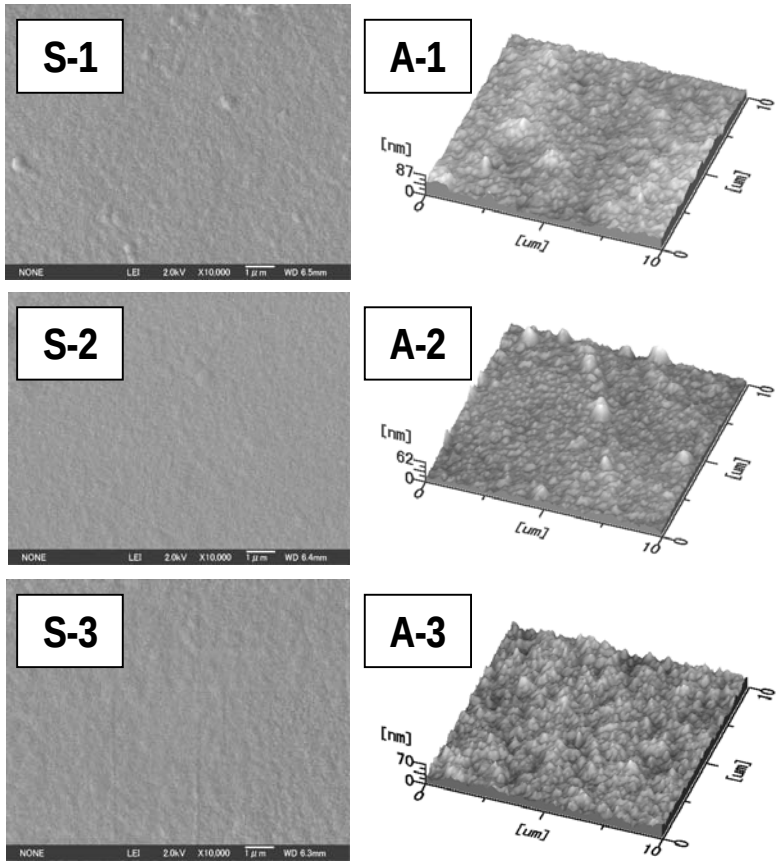
P-EGDM



P-EGDM

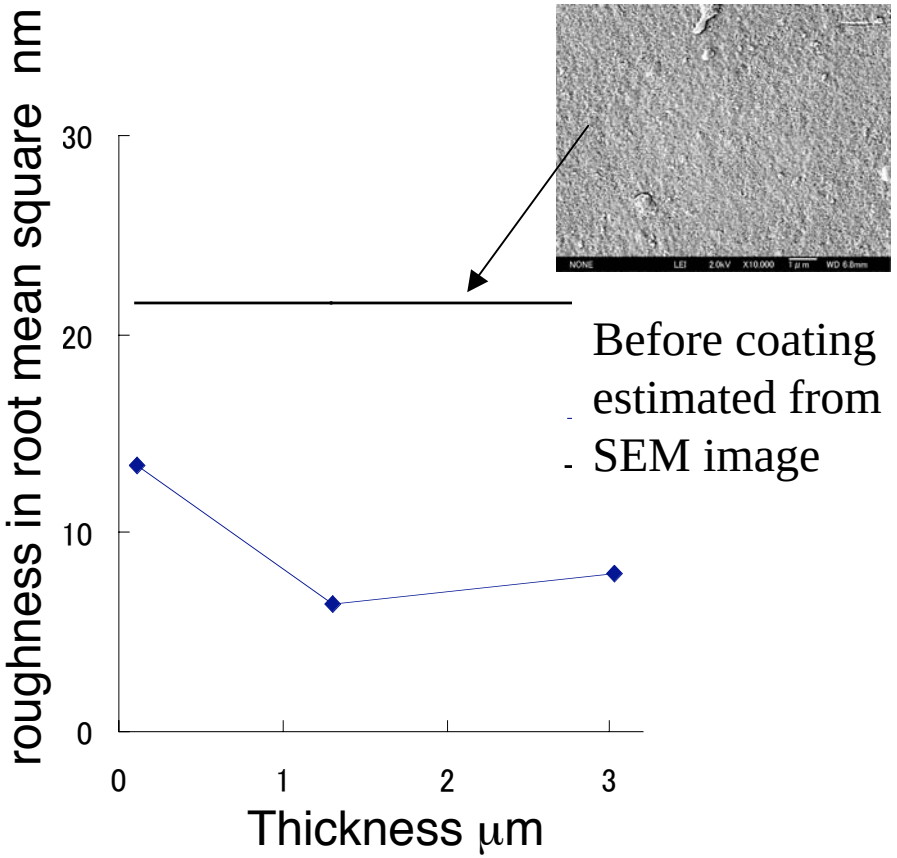
~ 1 μm

Outer surface of poly(p-xylylene) film on RF-PF



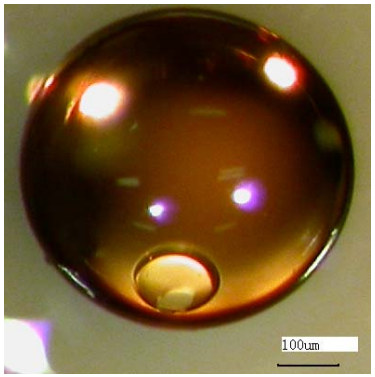
SEM(S) and AFM (A) images

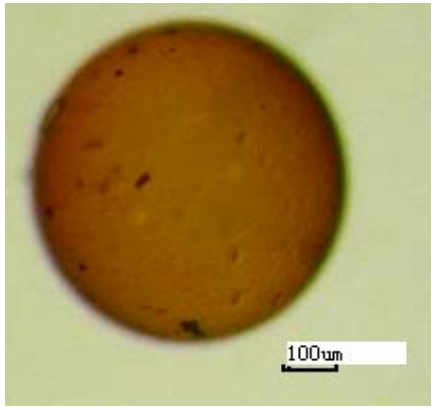
1, 0.12μm; 2, 1.03μm; 3, 3.06μm

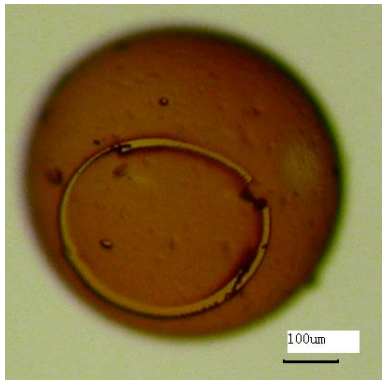


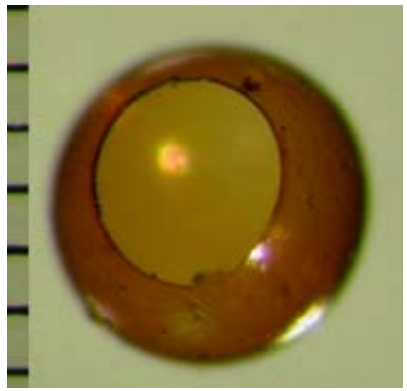
Roughness estimated from AFM images depending on thickness

Aerogelation and laser machining









Before extraction:
Diameter = 585um
Wall thickness = 23um

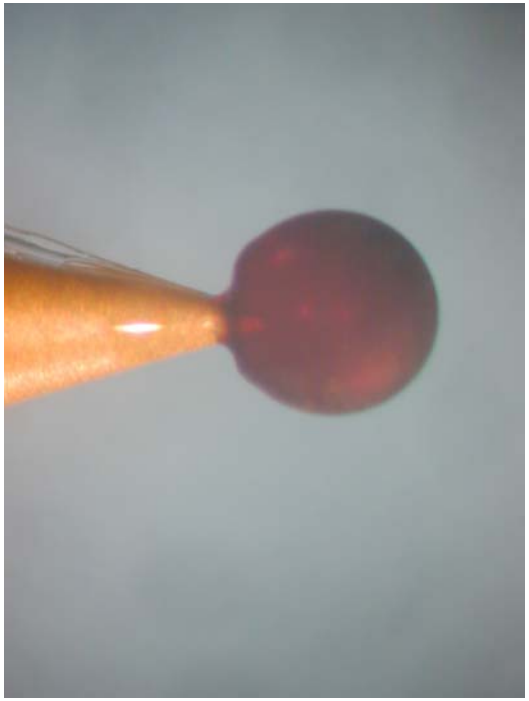
After extraction:
Diameter = 578um

with a hole of 300um using laser process

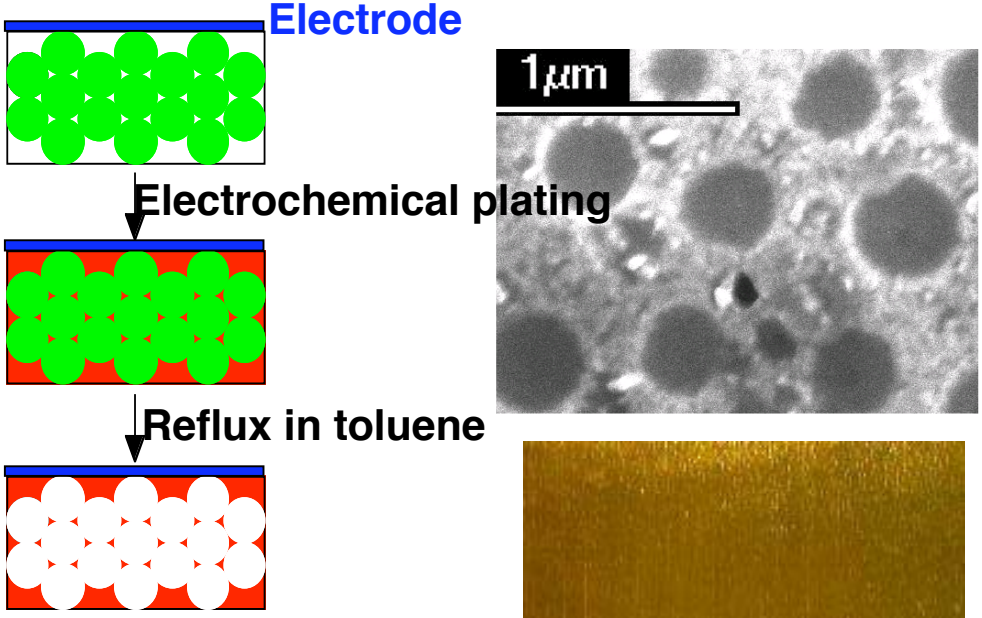
Parameter of laser process:
Power of laser: 2.6mW
Operation Times: 1
Stage moving speed: 10um/sec.

T. Fujimura, et al., *Fusion Sci. Technol.*, **51** (4), 677-681, (2006).

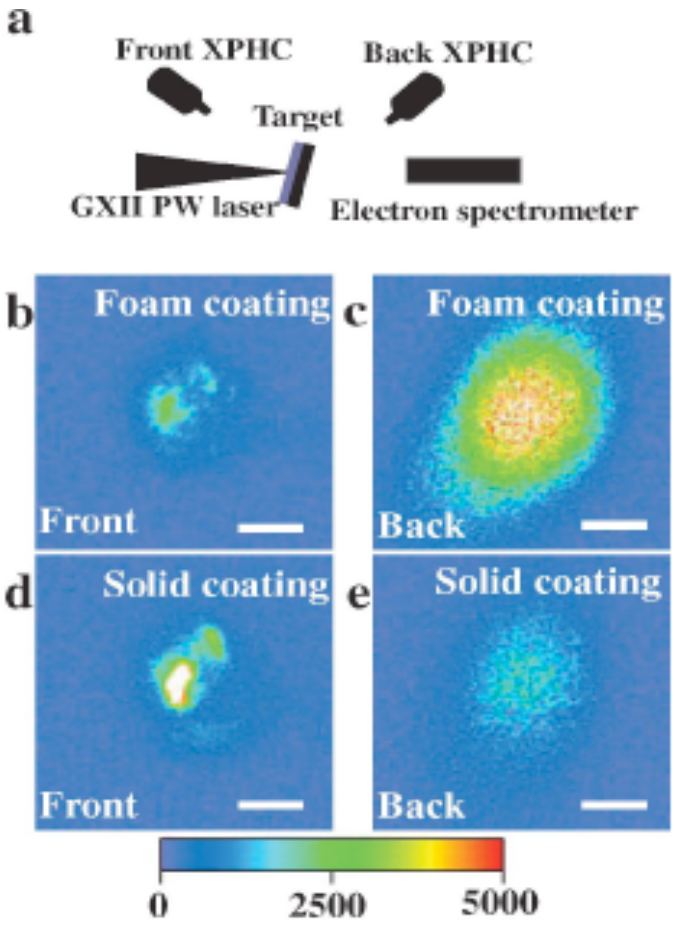
Attachment of gold cone and glass capillary.



Au foam was prepared using nanosphare template.
And increase the conversion efficiency from high power laser (10^{17}W/cm^2) to fast electron with keeping similar energy spectra and angular distribution.



Thickness: 2 μm,
Density: 4.3g/cm^3 (23% of Au)

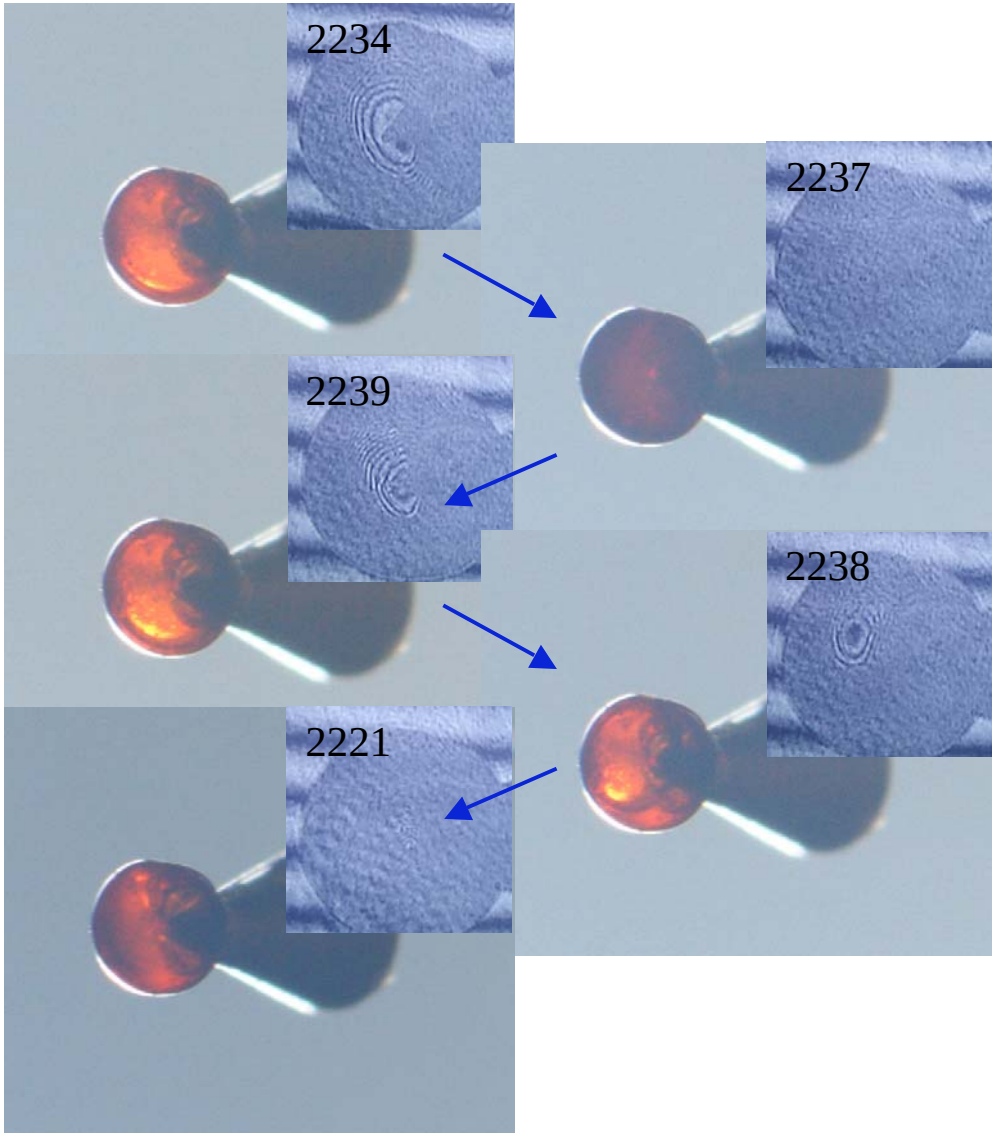


Fusion Sci. Technol., **49** (4), 686-690, (2006).

Phys. Rev. Lett., **96** (25), 255006, (2006).

Infiltration of liquid H_2 into RF (not RF-PF) foam shell

- empty
- During infiltration
- Whole foam shell was filled.
- Excess H_2
- Whole shell was filled



conditions

- gas temperature : 12.5 K
- H_2 pressure : 7.3 kPa

Summary

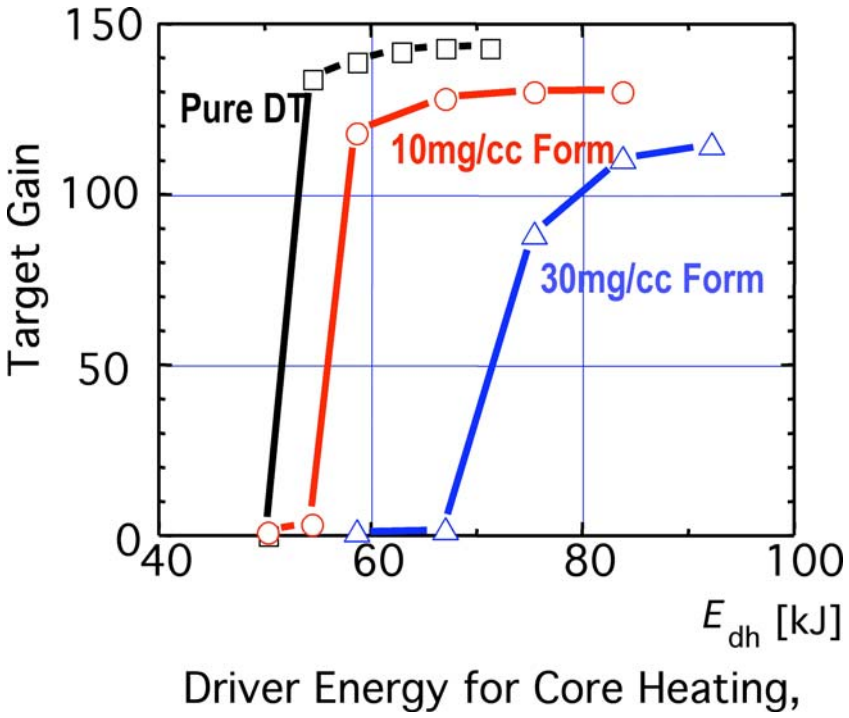
Low density foam capsules were prepared using density-matching emulsion and sol-gel-aerogel processes.

Phase-transfer catalysises enabled gelation at room temperature and kept the density matching.

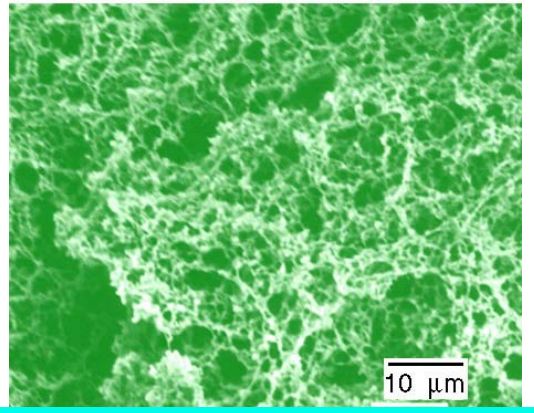
The viscosity of polymer solution was adjusted by adding new linear polymer (PF) to be 90cSt, and the specification (500μm diameter, 20 μm thickness) was satisfied.

The mass production and detailed characterization are on-going.

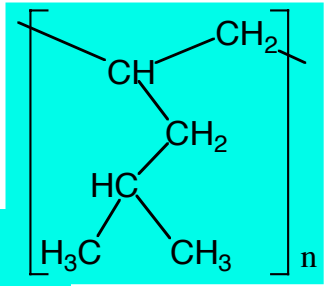
Several kinds of foam materials have been investigated.



In the case of FI, heating efficiency is primary no dependence with the foam density. As the result, the gain directly depends on the density and driver energy.



poly(4-methyl-1-pentene)



Coagulant	*foam density* (mg/cm^3)	*disk size* (μm)
1-hexanol	12	~10
2-methyl-1-pentanol	5.0	~3
2-ethyl-1-butanol	2.0	~6
1-butanol	~3	~1
2-butanol	~3	~2
2-methyl-1-propanol	~3	~1
2-methyl-2-propanol	~3	<1

NAGAI Keiji