Development of Target Fabrication and Injection for Laser Fusion in Japan

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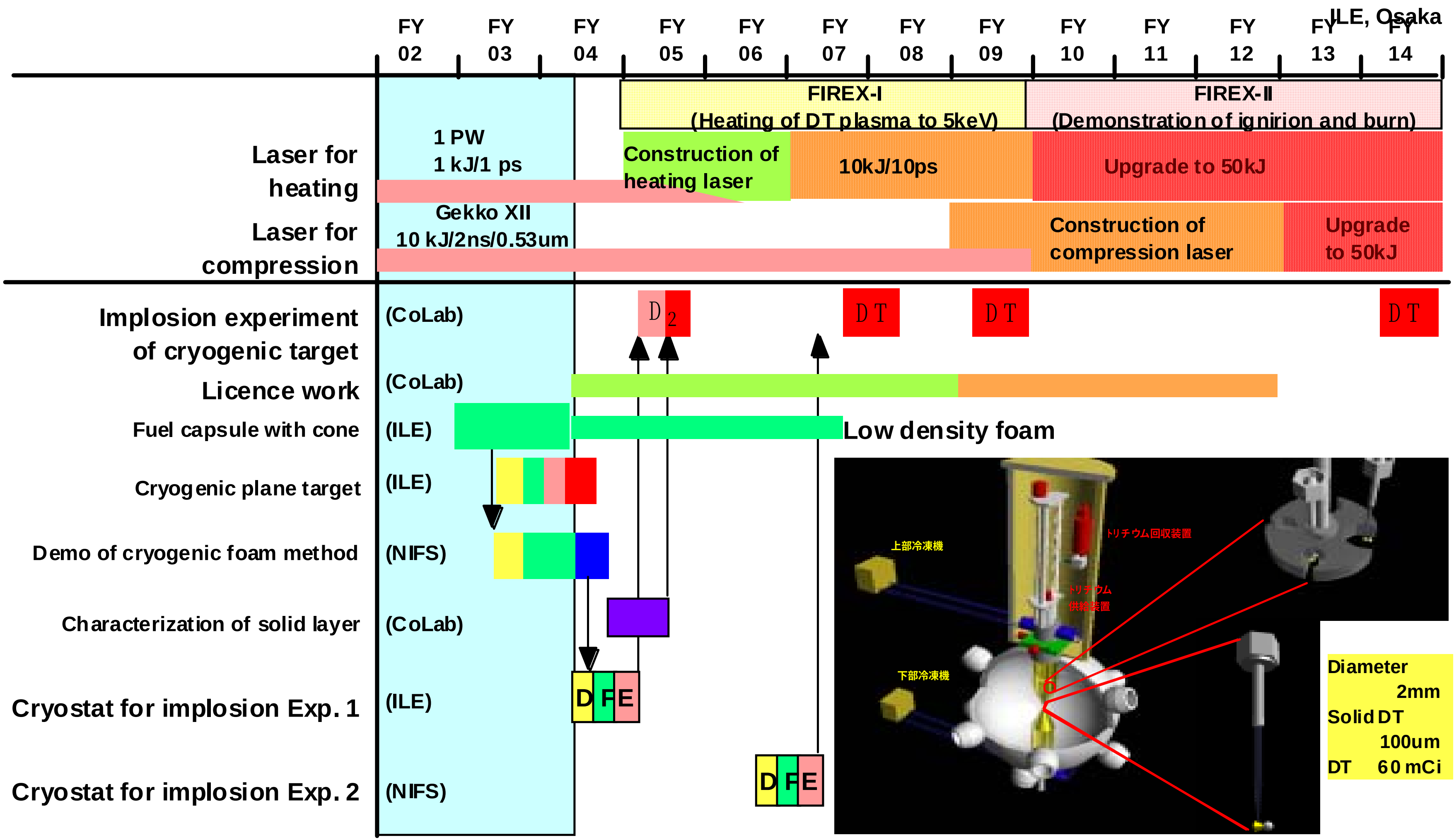
Outline

ILE, Osaka

- Introduction
  - Program,
- Target Fabrication
  - Polyimide shell, (ILE)
  - FI target with reentrant cone, (ILE)
  - Laser lathe (Fukuoka Univ)
  - Test of cryogenic foam (NIFS)
- Target Injection
  (Hiroshima and Gifu Univ.)
- Coil Gun and Target tracking
  (Gifu Univ.)

The FIREX-I project has been started under collaboration with National Institute for Fusion Science.



Fabrication of transparent foam shell for FIREX-I, low density foam shell for FIREX- II and LiPb cone for reactor are critical issues.

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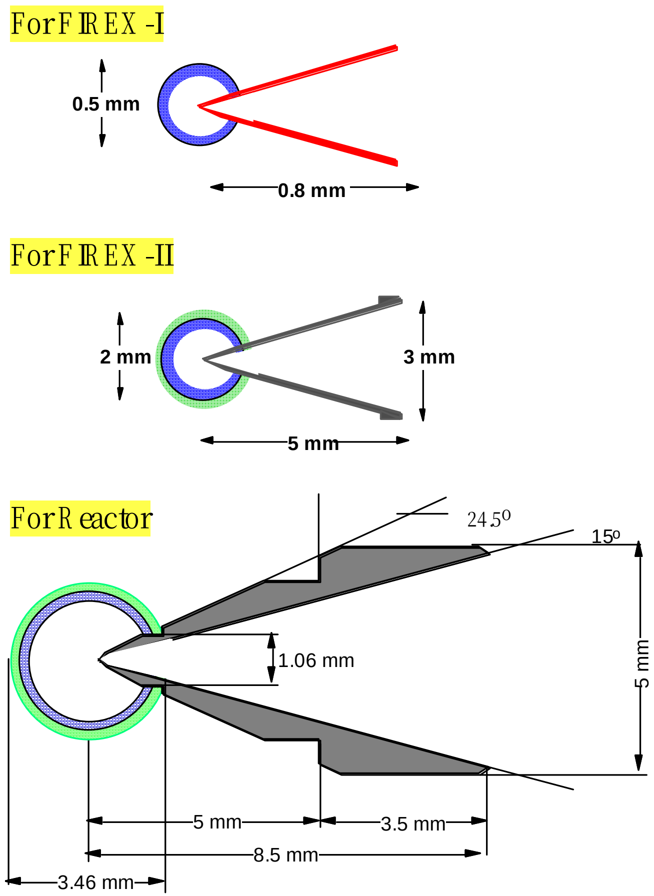

- FIREX-I (Heating to 5keV)
  - Fabrication of Transparent foam shell to allow characterization
  - Machining of fragile foam shell
- FIREX-II (Ignition and burn)
  - Low density foam
- Reactor (Gain >170)
  - Mass production of LiPb cone
  - Fuel loading

We are going to demonstrate RF foam method with NIFS. Specification of Cryogenic Target and Apparatus are;

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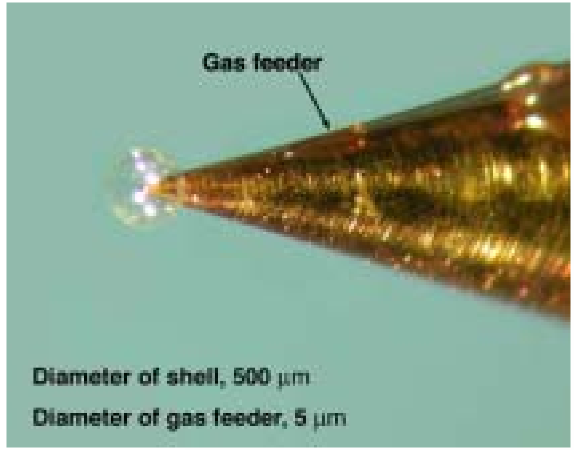
For FIREX-I

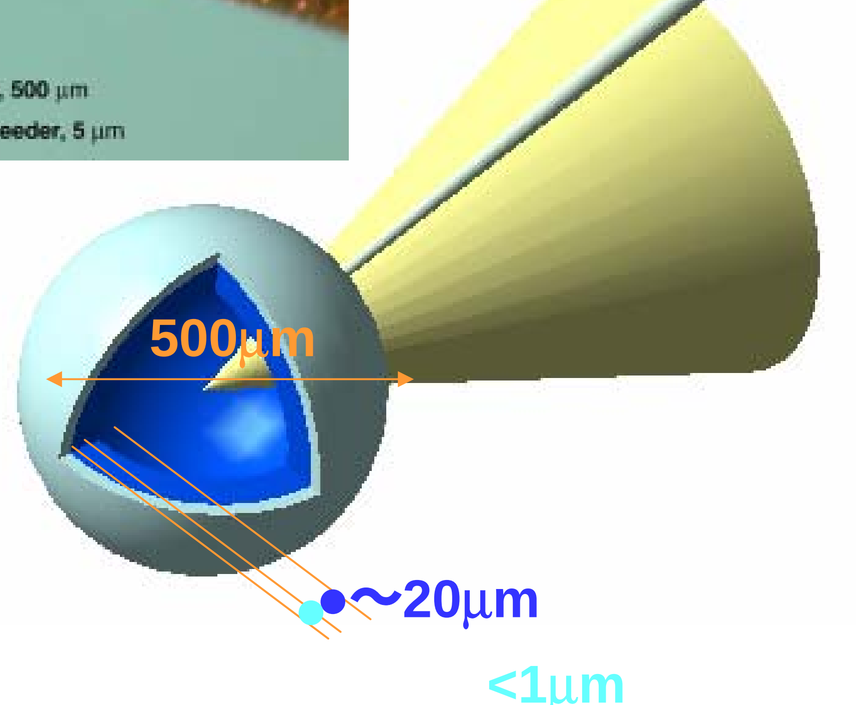
Cryogenic Target

- Form target
- Diameter：500µm
- Fuel layer：〜20µm
- With glass tube
- D_2 or DT fuel



Apparatus

- 4K-GM Cry cooler
- Minimum temperature：<10K
- With four view ports
- Prevent target vibration：<several µm



Apparatus to demonstrate foam method is almost fabricated. Cooling test will start soon at NIFS.

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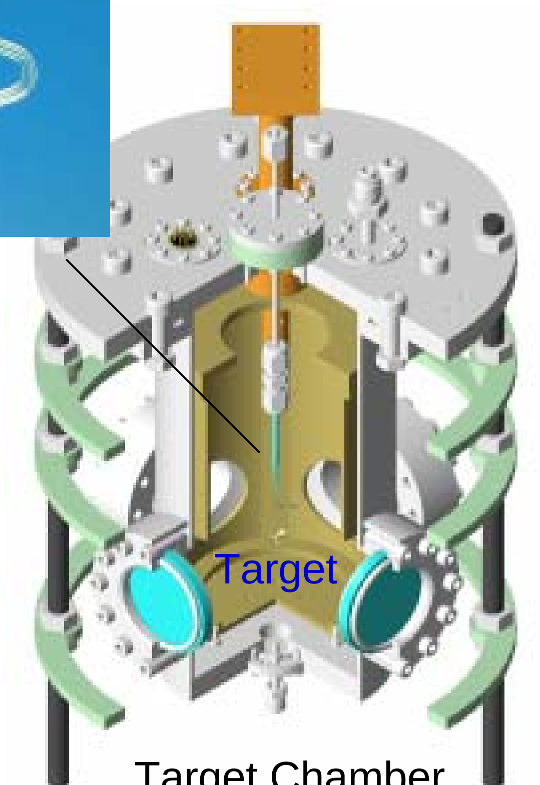
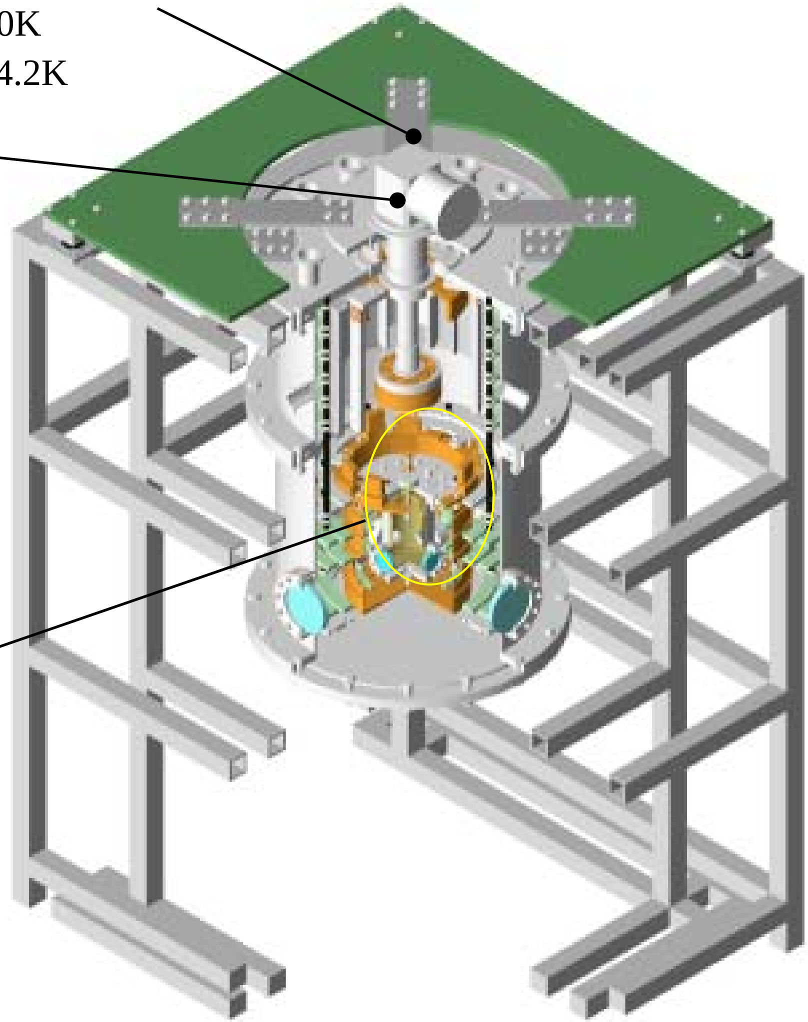
4K GM Cry cooler
- 1st Stage: 45 W @50K
- 2nd Stage: 1.5 W @4.2K

Welded Bellows



Target Chamber



Target Fabrication

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- For central ignition
  - Fabrication of polyimide shell by emulsion process
- For fast ignition
  - Foam shell
    - PMMA, TMPT foam
    - RF foam
  - Parabroide Cone
    - Diamond lathe
    - Laser lathe (Y. Kawamura, Fukuoka Institute of technology)

If the foam is PMMA, we can make required foam shell with gas barrier and reentrant cone.

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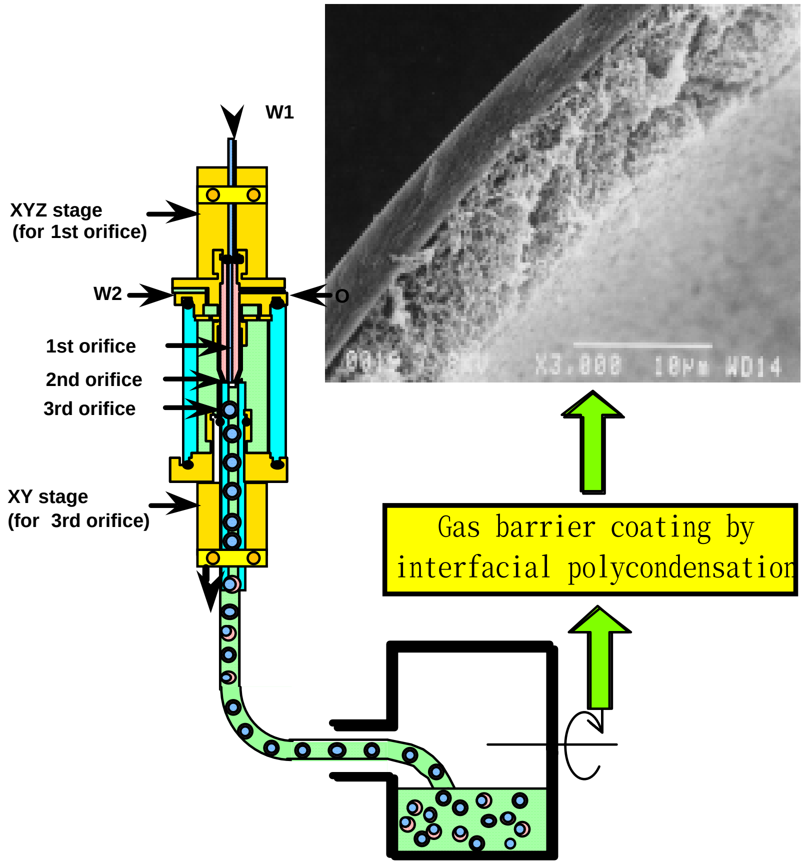
- Fuel shell
  - Emulsion method followed by interfacial polycondensation method
  - Hole boring on frozen foam shell
- Cone
  - Electro plating on removable mandrel machined with diamond lathe



Hole for cone could be bored into frozen foam with normal drill. Large scattering, however, disables optical characterization of cryogenic layer.

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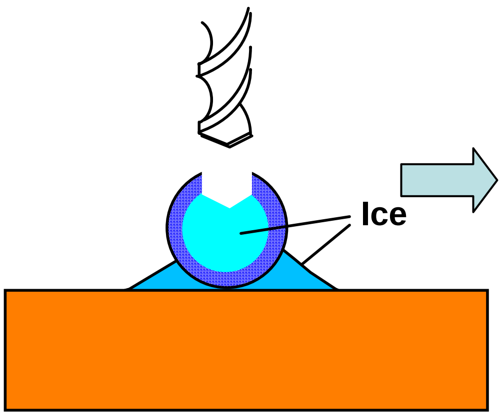
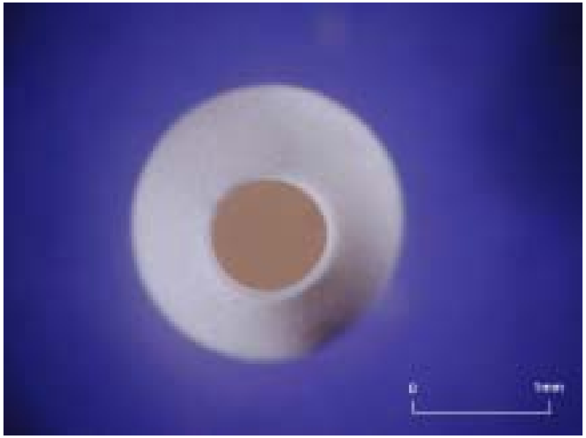
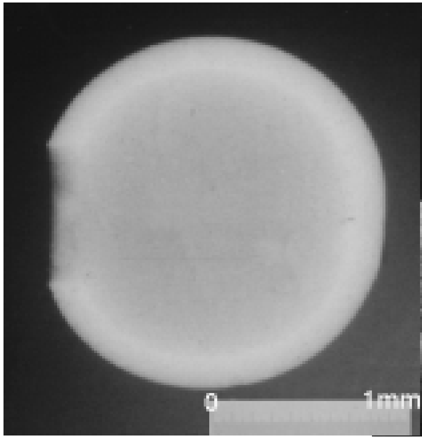
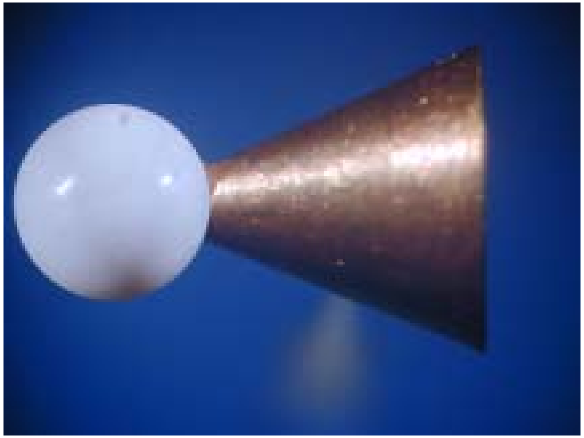


Freeze dry of foam shell







X-ray image   SEM image of hole side

We are now applying previous method [1)] for shell process

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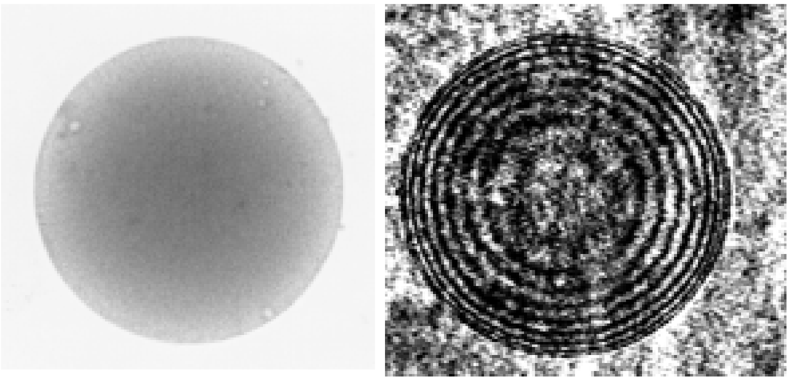
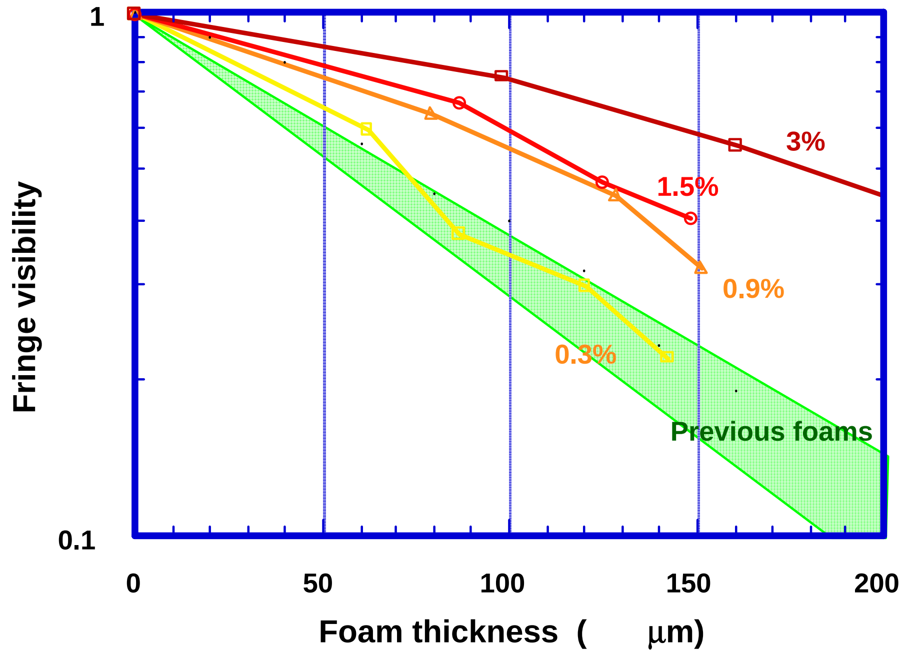
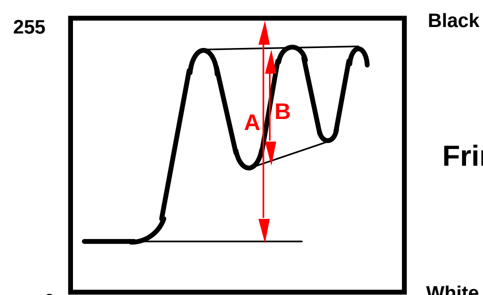




Optical image of a 220 µm diameter foam ball in the air. TMPT 3%, AIBN 3%, Thermally initiated polymerization.



Fringe visibiliy = B/A

1) M. Takagi, T. Norimatsu, Y. Izawa and S. Nakai Mat. Res. Soc. Symp. Proc. 372 199-202 (1995)

We have started fabrication of Resorcinol - Formaldehyde (RF) foam [1)] that is transparent due to its fine structure.

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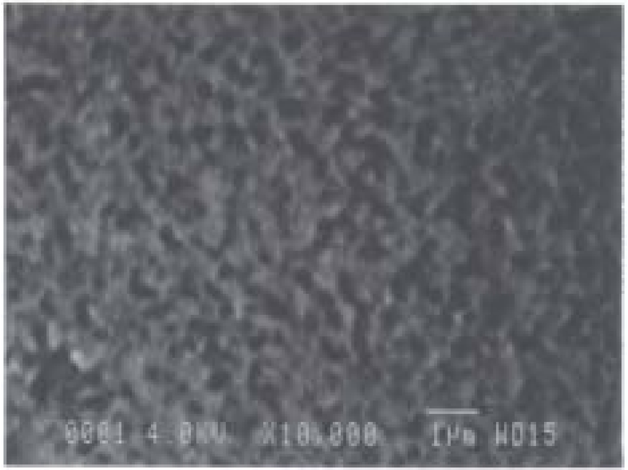

RF foam shells with the density ranging 150-250 mg/cc are successfully fabricated but further effort is necessary to improve the uniformity.

•In the case of RF foam, freezing method can not be used to hold the shell during drilling because phase separation takes place, which increases the scattering of light.

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Excimer laser etching

1) Stephen M. Lambert , George E. Overturf Journal of Applied Polymer Science, Vol.65,2111-2122(1997)

To make a hole on fragile RF foam shell with gas barrier [1)], we used excimer laser etching followed by punching.

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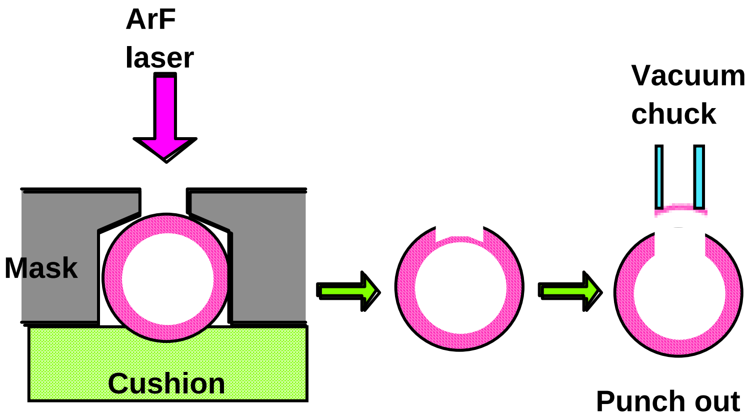
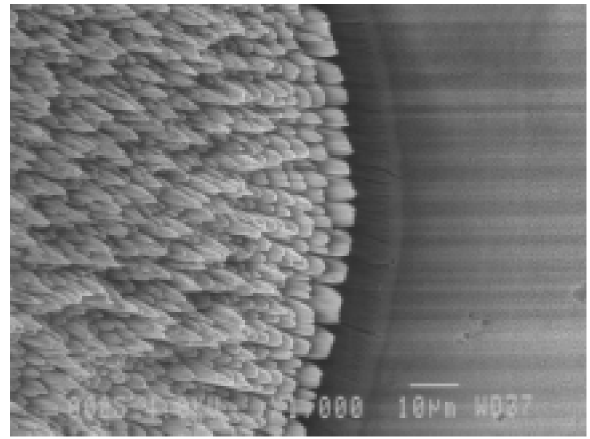
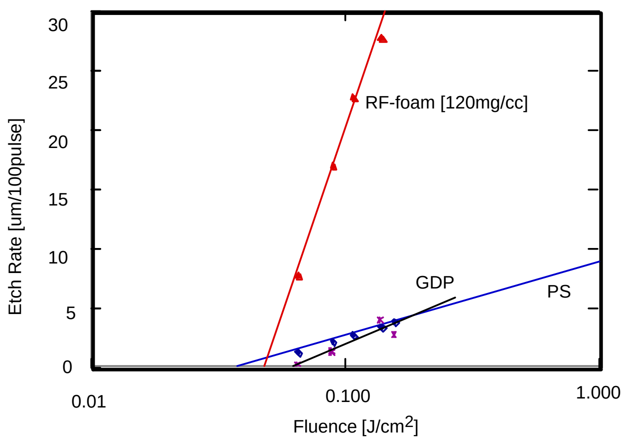
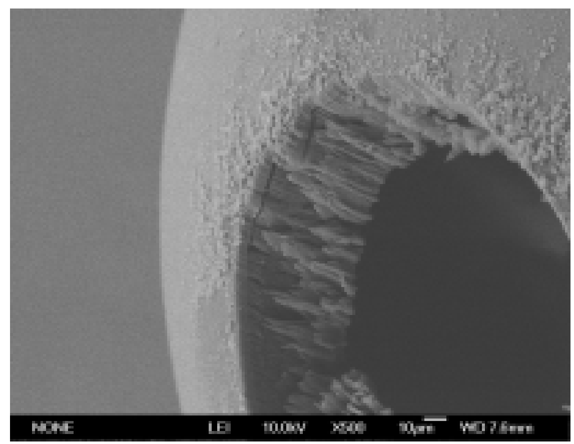




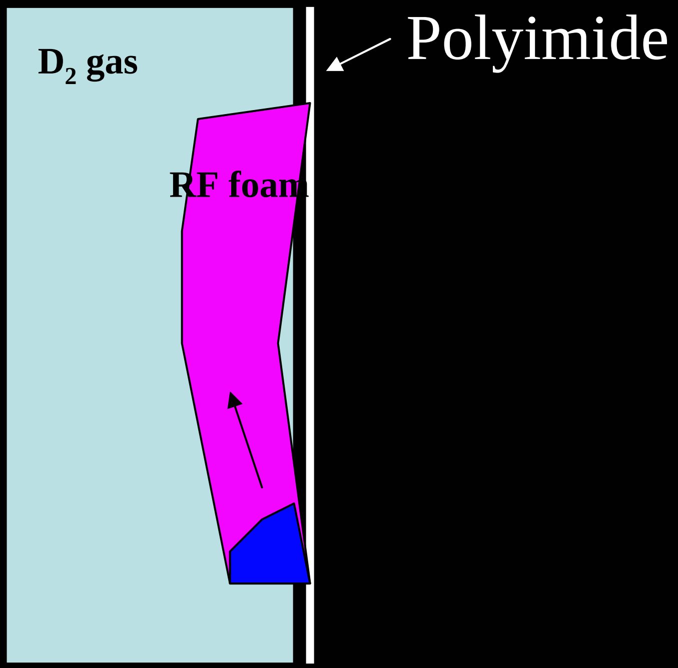




1) Shells were presented by GA.

Penetration of liquid D_2 into RF foam was experimentally confirmed, like down at NRL.

- Speed of liquid D_2 front was ~ 500 μm/sec, which is sufficient to fill future IFE target.



We are now testing transmittance at solid phase. Because of large optical absorption of RF foam, we could expect smoothing effect like IR heating.

Fabrication of parabolic cone as a focusing device.

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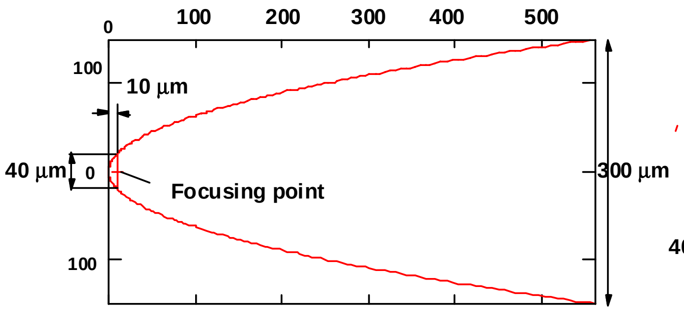
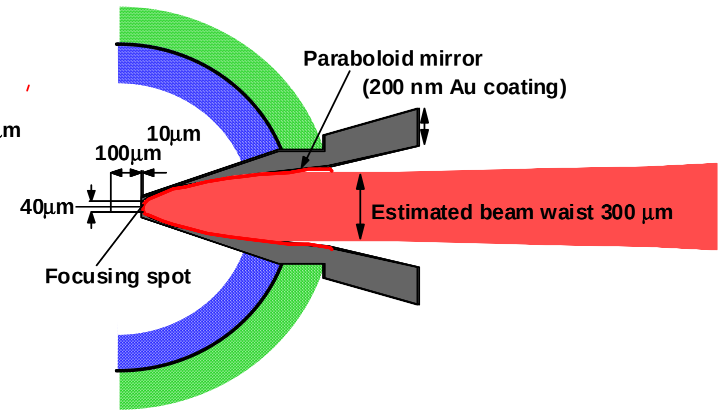
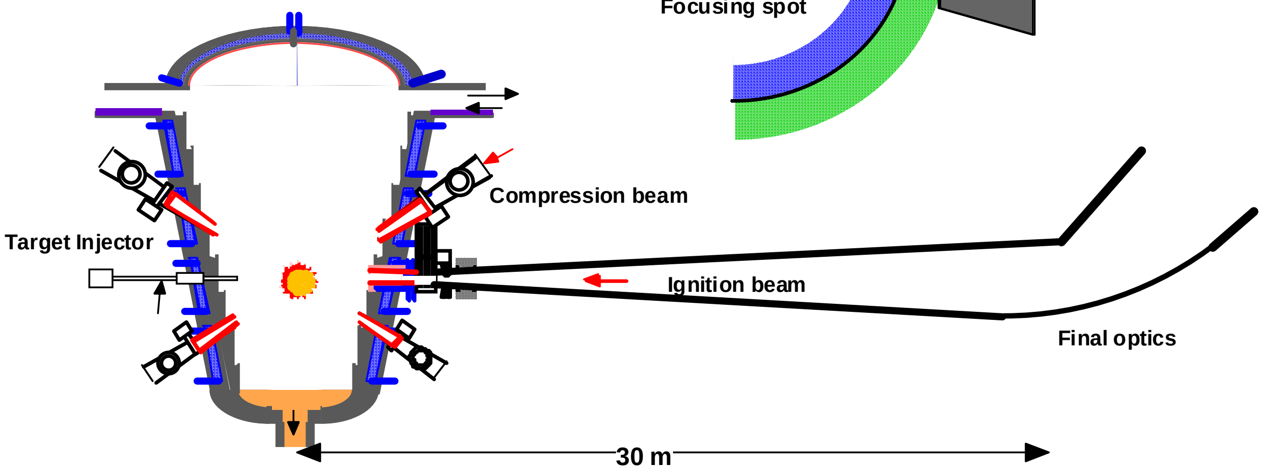
- In a future power plant, some focusing mechanism is necessary to heat the compressed core up to the ignition temperature because of diffraction limit of the final optics.
- This paraboloid mirror design enables 80% of laser energy in 300 μm spot focused on the 40 μm diameter spot with one bounce.







To test the focusing effect, paraboloid cone was fabricated with diamond lathe.

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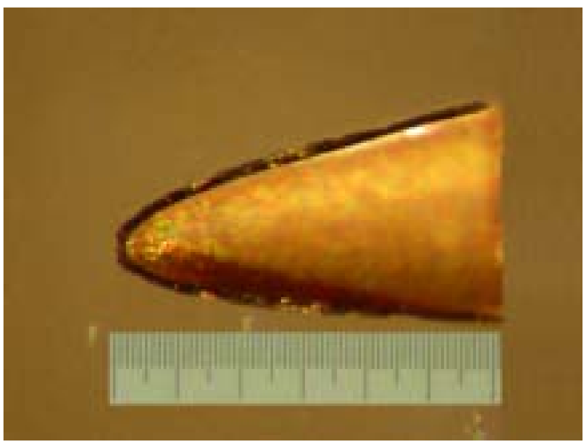
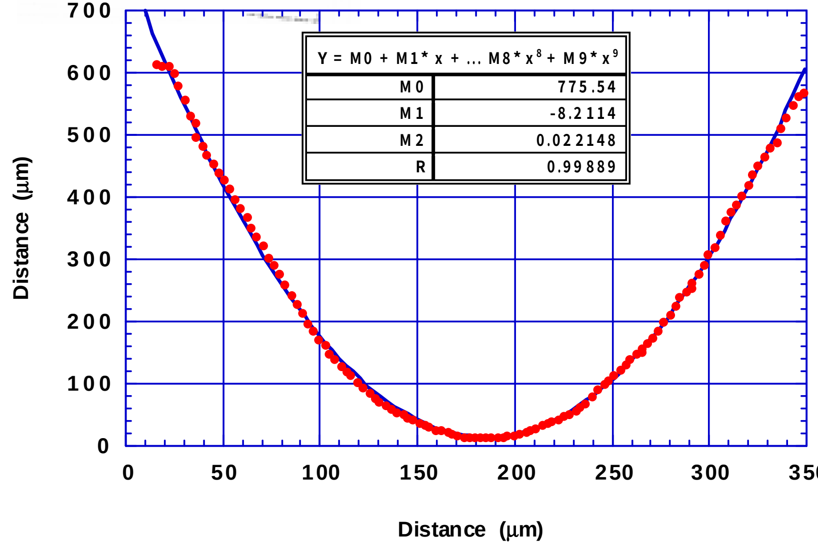


After edge detection, inner surface finish is calculated to be 2μm in RMS.



Laser lathe system developed by Y. Kawamura shows new feasibility of target fabrication.

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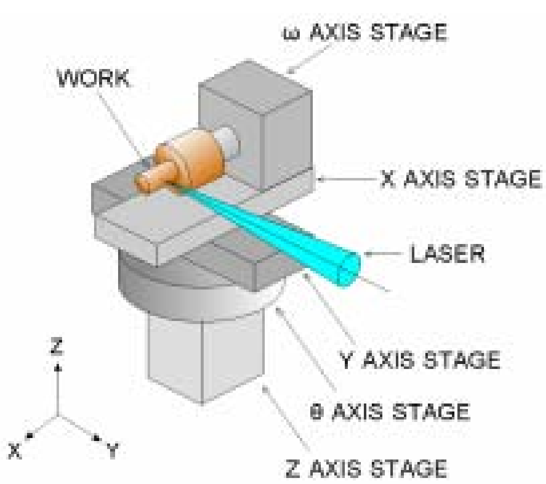
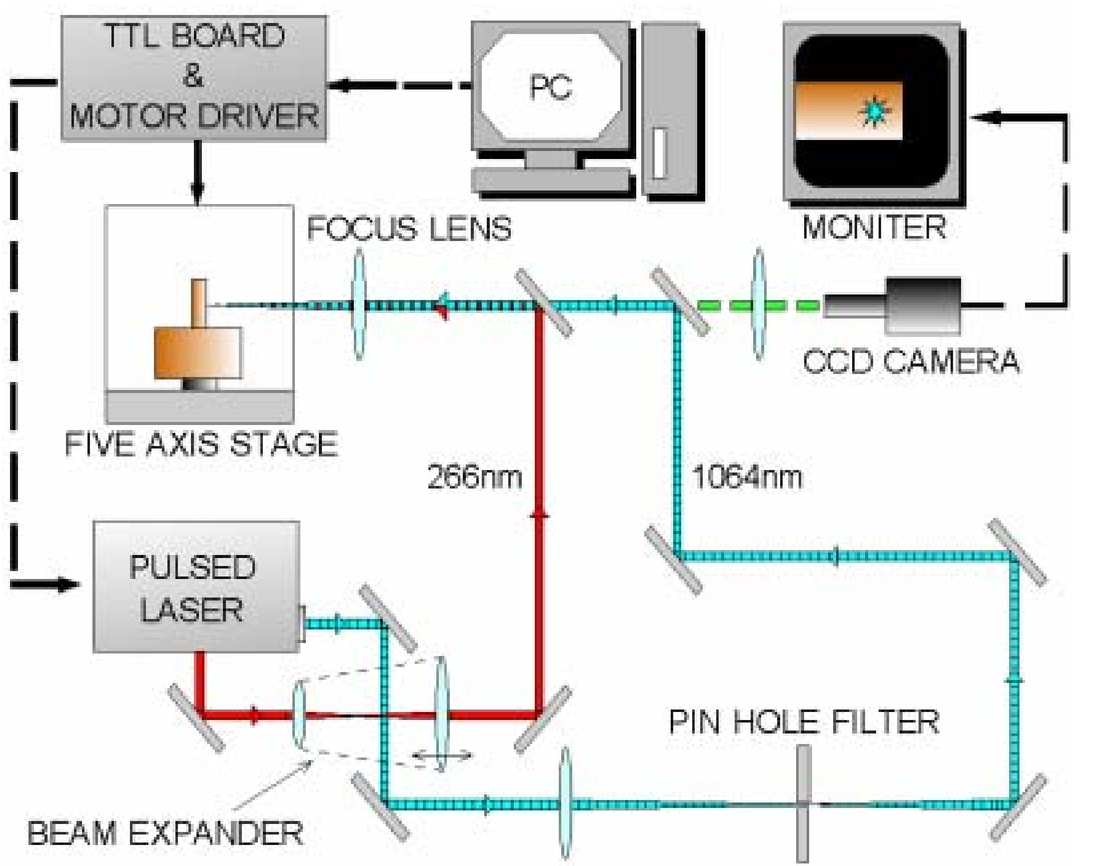
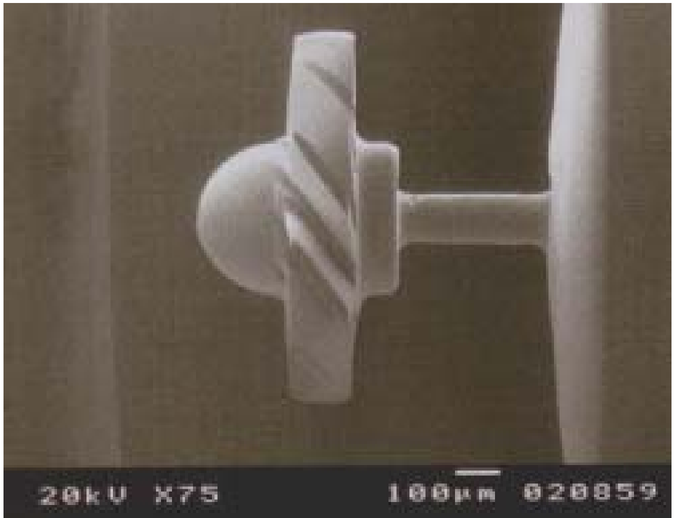
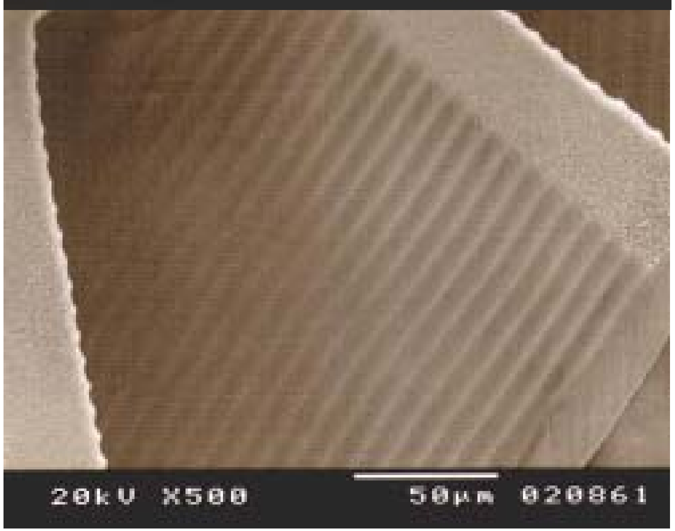
The motion of work and laser are simultaneously controlled with a computer, which enables machining of nonconcentric works.





Example of laser lathe





- Mircoturbin (700 μm in diameter) rotates at 300,000 rpm with gas flow.

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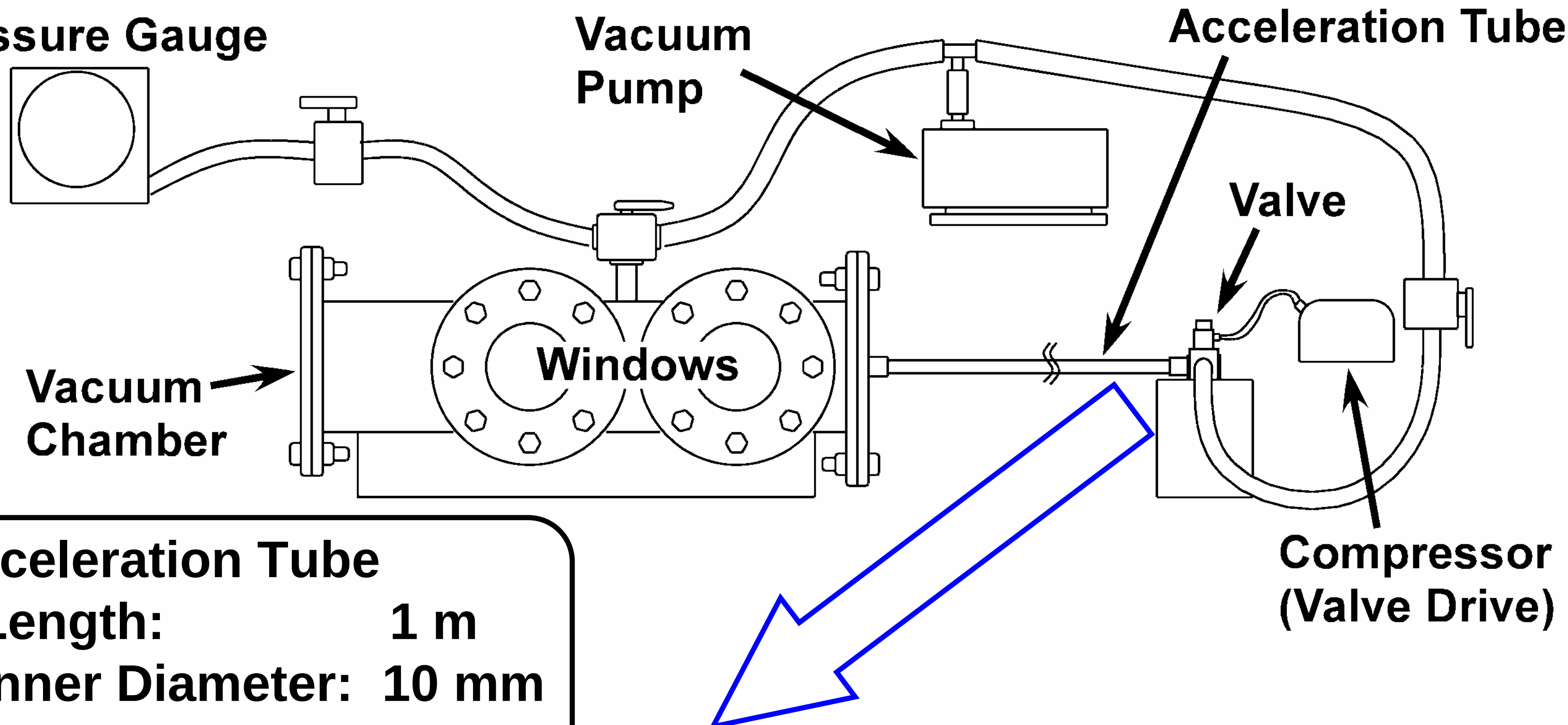
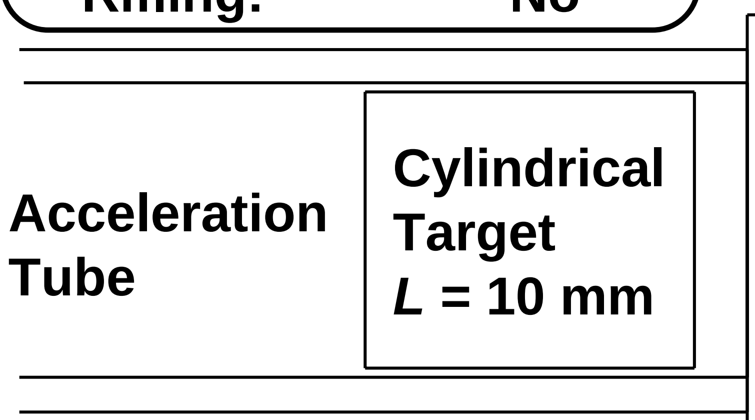
We started preliminary experiments



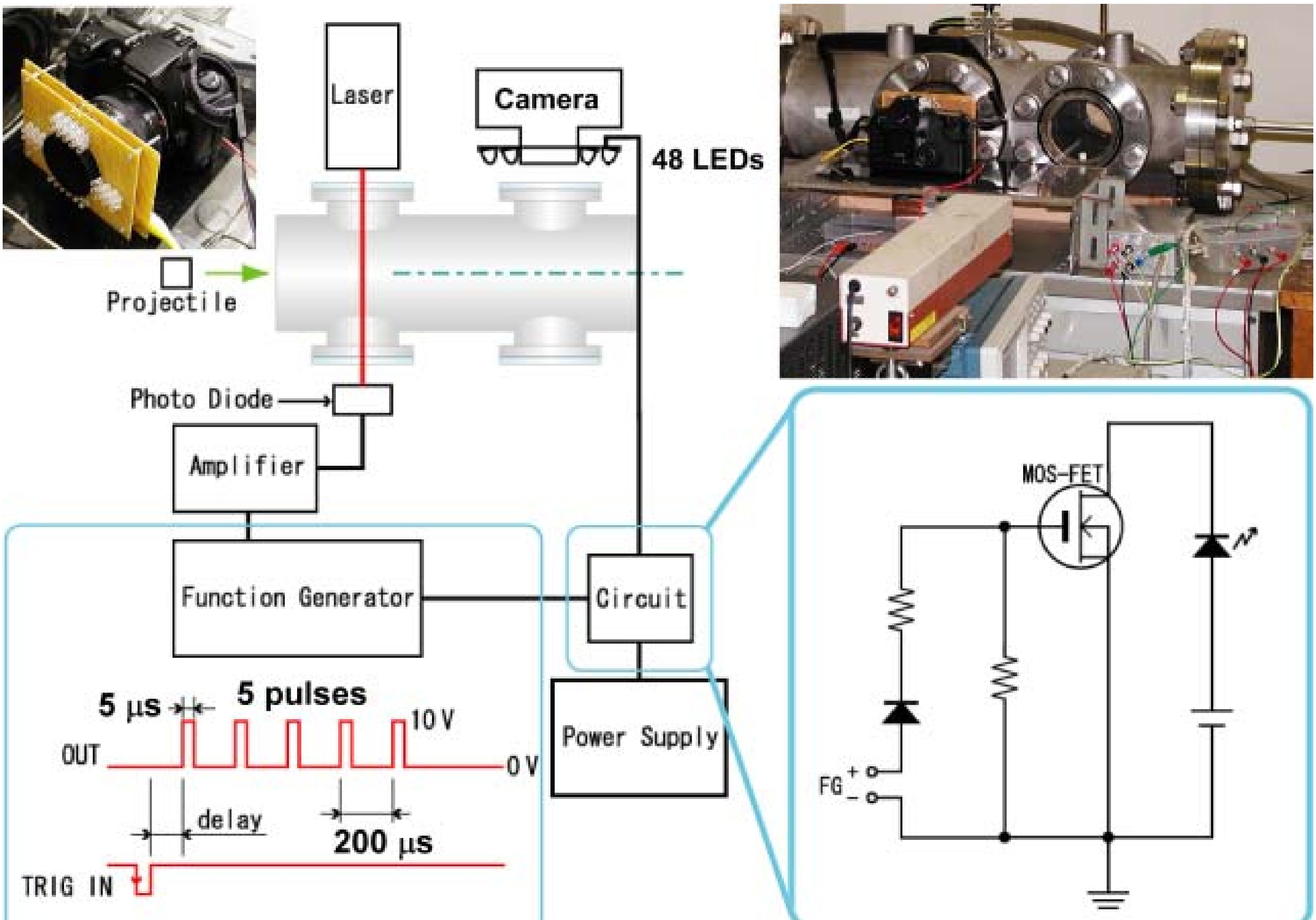
Acceleration Tube
- Length: 1 m
- Inner Diameter: 10 mm
- Rifling: No



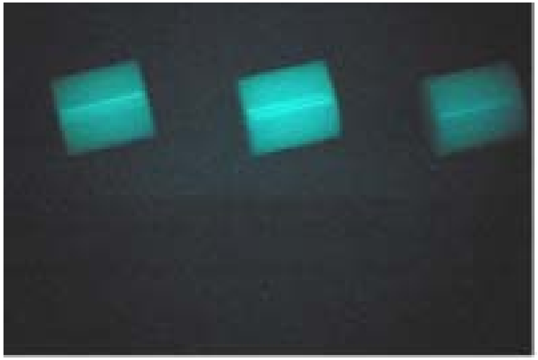
Acceleration Tube — Vacuum Pump / Room (Air, 1 atm)

Valve (3-way)
- Orifice: d = 8 mm
- Vacuum to Atmosphere: 5 ms
- Atmosphere to Vacuum: 6 ms

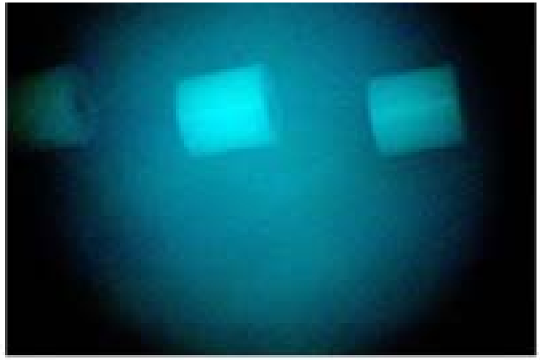
We used LEDs and a digital camera for diagnostics



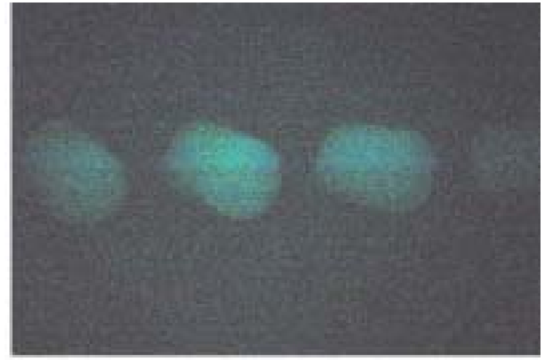
Measured target speeds were slightly lower than the expected speed: 120 ∼ 142 m/s



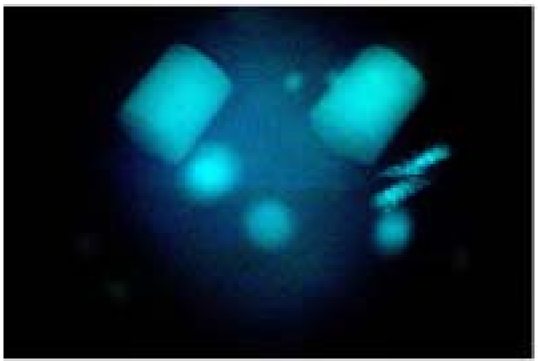
#030114-03, d = 9.60 mm,
$p_{chamber}$ = 90 Torr,
U = 109 m/s



#030114-01, d = 9.80 mm,
$p_{chamber}$ = 90 Torr,
U = 113 m/s



#030109-02, d = 9.95 mm,
$p_{chamber}$ = 90 Torr,
U = 85 m/s



#030116-01, d = 9.60 mm,
$p_{chamber}$ = 7 Torr,
U = 116 m/s

#030116-02, d = 9.80 mm,
$p_{chamber}$ = 8 Torr,
U = 112 m/s

Targets were flying with rotation.

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Rifling will be tested soon.

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Experimental setup of coil gun

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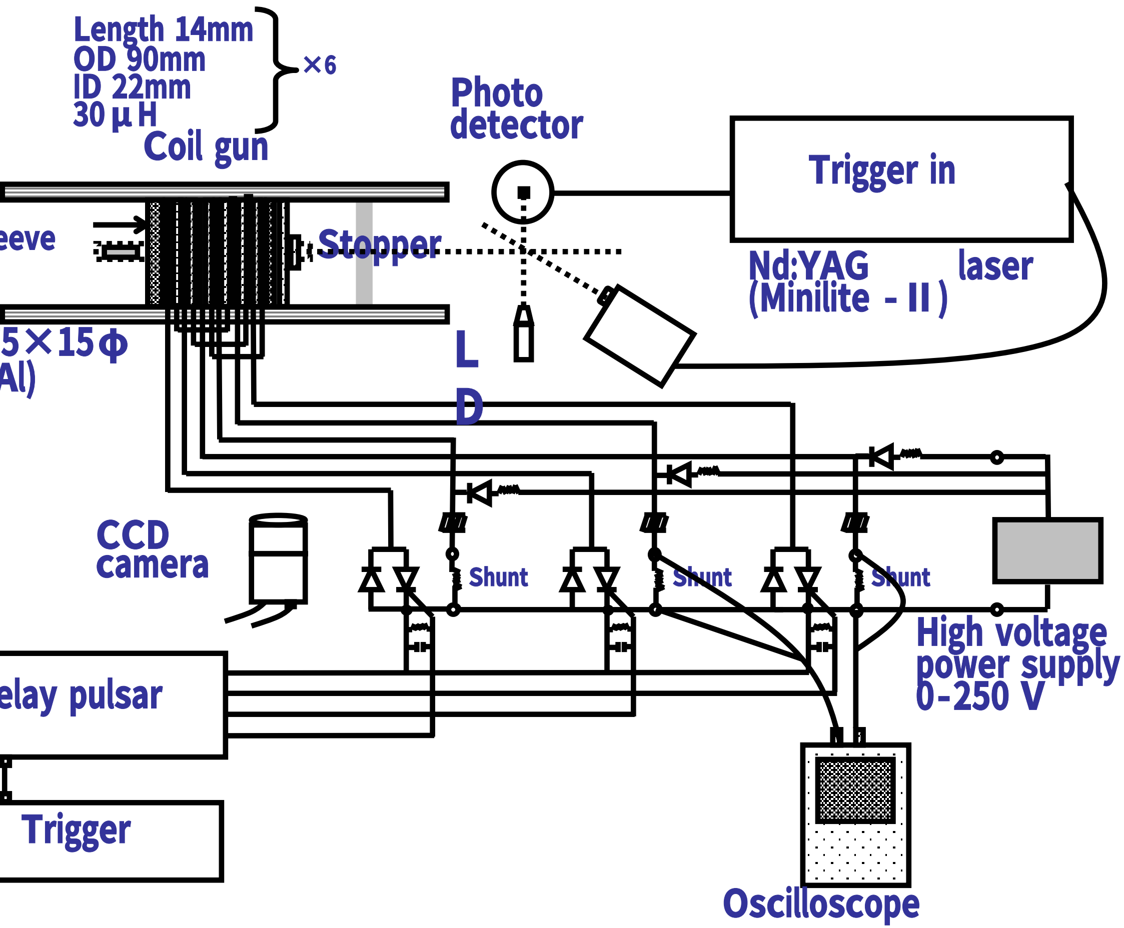

Coil gun

Length	104 mm
Number of phases	3
Number of barrel coils	6

Barrel

Length	14 mm
Outer diameter (OD)	88 mm
Inner diameter (ID)	20 mm
Number of turns	12
Self inductance	30 μH
Capacitance	1980 μF
Charge voltage	≦ 300 V

Sleeve

Length	75 mm
Outer diameter	15 mm
Thickness	1 mm
Mass	8.86 g
Material	Aluminum

Maximum acceleration was 580G, which is sufficient to accelerate a target to 300m/s in 20m.

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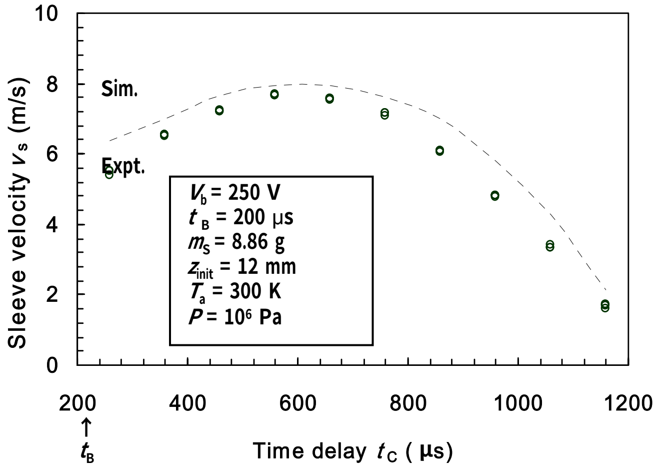

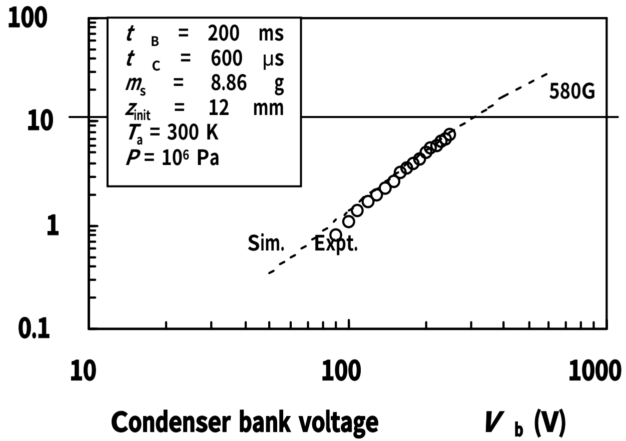

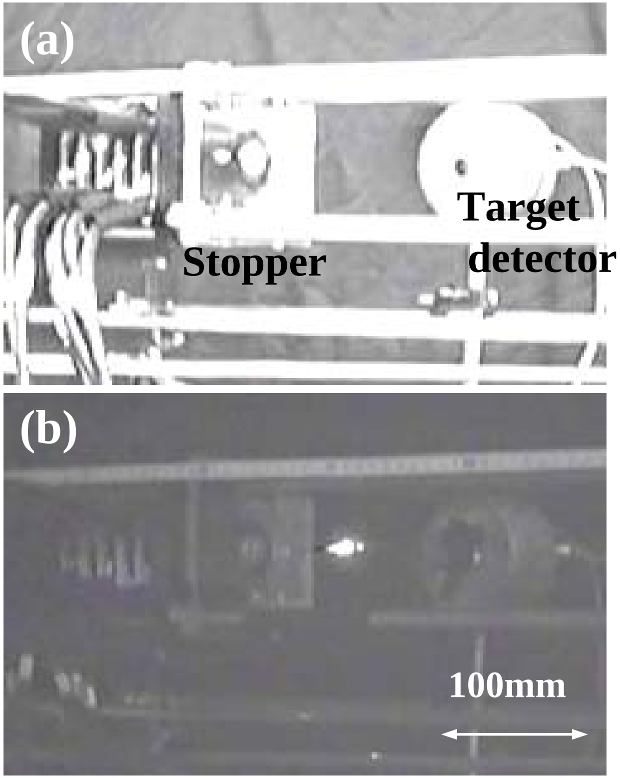

(a) The coil gun before target shot and (b) the irradiated target by Nd:YAG laser.

Gifu Univ.

Correlational detection by matched filter

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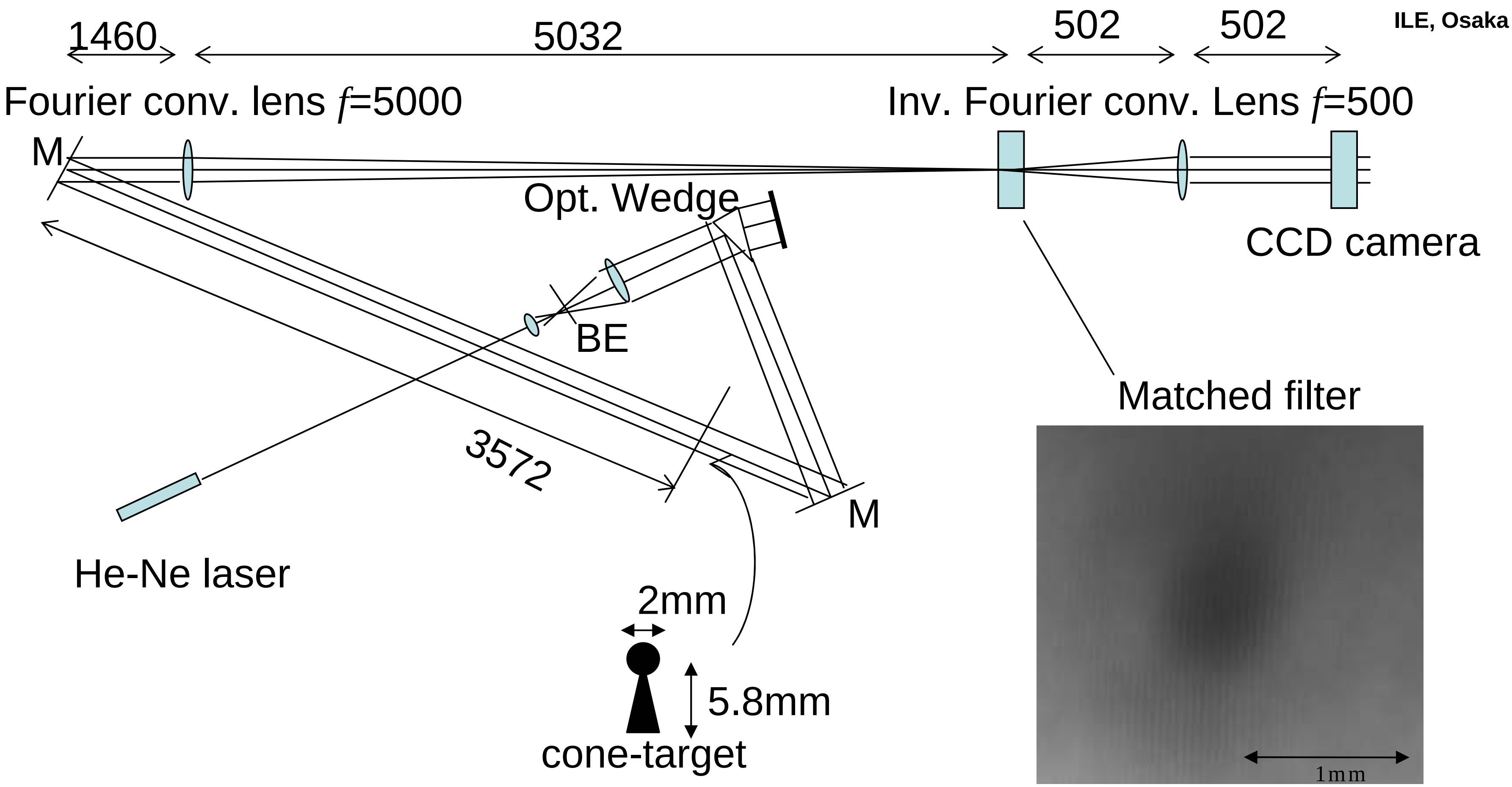
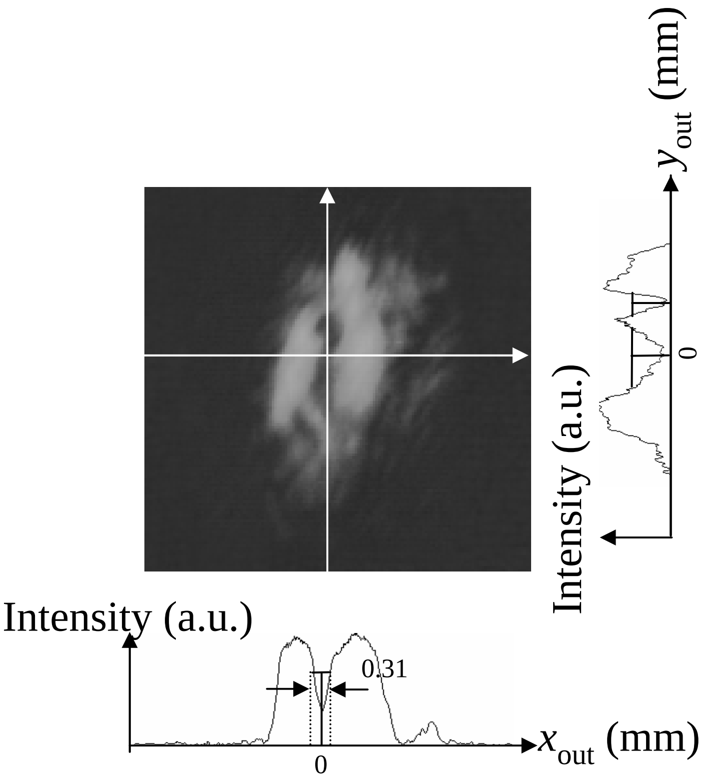
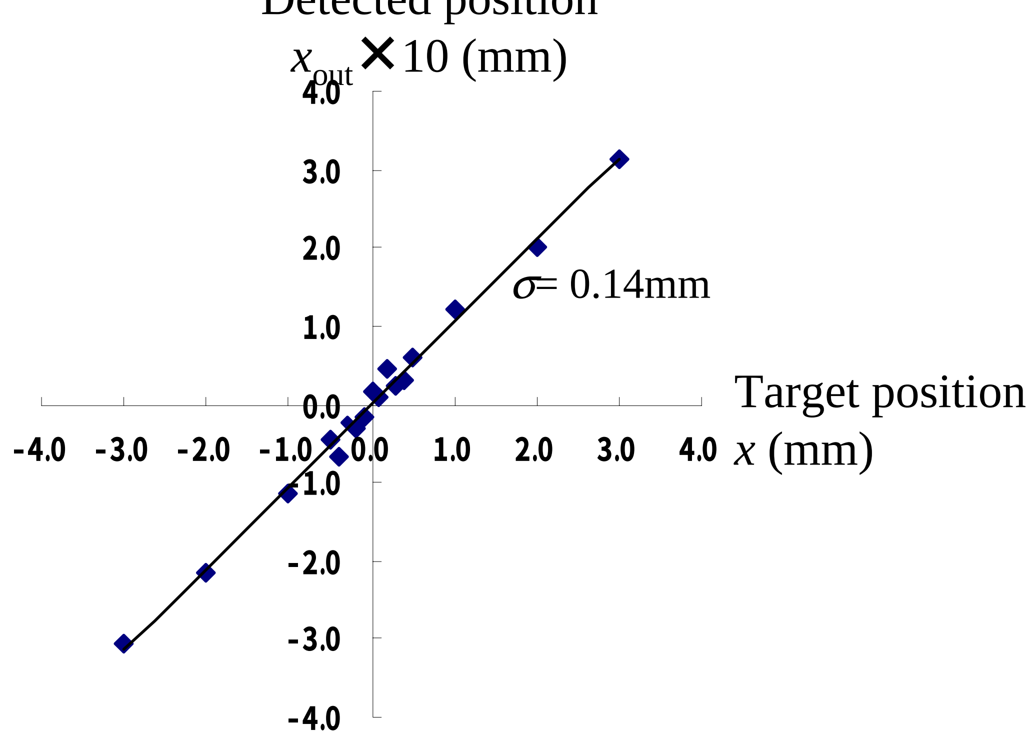


Accuracy of detection was 140 μm at 5 m apart.





The accuracy will be improved with
- uniform irradiation,
- f-number,
- linearity of film to make filter.

Summery

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- Elemental researches to make cryogenic FI targets have been conducted at ILE and NIFS.
  We need more progress in foam, hole boring, and characterization of the solid fuel layer.
- The acceleration of 580 G was achieved with the coil gun in Gifu University, which is scalable for future injector for a reactor.