Current Status of Target Fabrication for Inertial Fusion Research at HAMAMATSU

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20th Target Fabrication Meeting
Eldorado Hotel and Spa, Santa Fe, NM

HAMAMATSU PHOTONICS K.K.
Contents

1. Introduction of HAMAMATSU group and GPI
2. Target technology development in our lab.
3. Civilian project for fusion research
4. Summary and conclusion
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HAMAMATSU group network in the world

Established Sept. 23, 1953
Number of Employees 4,188
Net Sales 102 billion yen ($1323 million)
Capital stock 35 billion yen ($453 million)
[September 30, 2011]
Hamamatsu Photonics K.K. in Japan

Factories
- Opto-semiconductors: Main factory (Ichino), Mitsue factory
- Electron tube products: Toyooka factory, Tenno glass works
  Beijing Hamamatsu photon techniques Ltd. (China)
- System products: Joko factory
- Laser products: Miyakoda factory

Laboratories
- Central research laboratory
- Tsukuba research laboratory
- Industries development laboratory

Domestic sales offices
- Tokyo branch office
- Osaka sales office
- Sendai sales office
- Tsukuba sales office

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Industries development laboratory and GPI

The Graduate School for the Creation of New Photonics Industries (GPI)
HAMAMATSU Products by our factories

Laser group, Development bureau
Semiconductor lasers

System division
Imaging systems

Electron tube division
Photo-multipliers

Solid state division
Photo-sensors
Why does HAMAMATSU PHOTONICS K.K. have working on inertial fusion research?

Chairman of HAMAMATSU PHOTONICS K.K.

Target
- Materials
- Fabrication
- Injection
- Tracking
...

Laser
- Laser diode
- Amplifier
- Optics
- Laser system
...

Plasma Diagnosis
- Ion, Electron
- Neutron
- X-ray camera
- X-ray source
...

HAMAMATSU PHOTONICS will play an important role in the IFE community with the technologies on targets, lasers and plasma diagnosis.

Low cost Energy ¥3.5/kWh
High power laser systems of our section

**MATSU-1**
Diode-Pumped High Intensity Laser
- Wavelength: 800 nm
- Output energy: 2 J
- Pulse-width: 50 fs
- Peak power: 40 TW
- Shot cycle: 10 Hz

**KURE-1**
Diode-Pumped High Energy Laser
- Wavelength: 527 nm
- Output energy: 12 J
- Pulse-width: 10 ns
- Shot cycle: 10 Hz

Because high energy, high efficiency and high repetition are required to laser driver, the semiconductor laser module is a key device to achieve.
High response neutron detector using $^6$Li scintillator

Detector module view
72mm (Dia.) 200mm (L)

Li-6 density: 8 wt%
Contents

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3. Civilian Project for Fusion research

4. Summary and conclusion
Target technologies for laser fusion demonstration

**Target Factory**
- Microencapsulation
- Laser machining
- Coating
- **Metrology**
  - Interferometry
  - X-ray imaging
- **Assembly**

**Ignition Facility**
- Laser driver
- Target chamber
- **Target Injection**
- Cryogenic cooling
- Tritium handling
Our fabricated shells and beads

Our plastic shells are made by microencapsulation. W/O emulsions are made using droplet generator. These are cured and organic solvent is lost, then core water in the shells dries out.
Optical non-contact measurement without damage

Measurement thickness: 0.020–50µm
Repeatability: 0.02nm
Measurement spot size: Φ8–80µm
Number of measurement layers: 10
Analysis: FFT or Curve fitting
Principle of acquiring a wall thickness

Fast Fourier Transform

**Thickness**
Diameter and wall thickness of PAMS shell were measured after we picked up 10 shells randomly.

<table>
<thead>
<tr>
<th>No.</th>
<th>Diameter [µm]</th>
<th>Wall thickness [µm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.1</td>
<td>2251.3±7.4</td>
<td>27.63±1.23</td>
</tr>
<tr>
<td>No.2</td>
<td>2239.2±6.3</td>
<td>27.56±1.21</td>
</tr>
<tr>
<td>No.3</td>
<td>2252.4±7.5</td>
<td>27.71±1.24</td>
</tr>
<tr>
<td>No.4</td>
<td>2249.3±7.3</td>
<td>27.68±1.22</td>
</tr>
<tr>
<td>No.5</td>
<td>2251.1±7.4</td>
<td>27.67±1.23</td>
</tr>
<tr>
<td>No.6</td>
<td>2250.2±7.5</td>
<td>27.69±1.23</td>
</tr>
<tr>
<td>No.7</td>
<td>2248.5±7.2</td>
<td>27.66±1.22</td>
</tr>
<tr>
<td>No.8</td>
<td>2250.9±7.4</td>
<td>27.68±1.23</td>
</tr>
<tr>
<td>No.9</td>
<td>2253.7±7.6</td>
<td>27.70±1.24</td>
</tr>
<tr>
<td>No.10</td>
<td>2251.5±7.5</td>
<td>27.69±1.23</td>
</tr>
</tbody>
</table>
Many sub micron sized dents and vacuoles are found in a shell wall using usual method.

**Microscope image**

**SEM image**

Dent : Clear circle
Vacuole : Fuzzy circle

Dent only
Dents and vacuoles are fairly decreased using improved method.

**Microscope image**

**SEM image**

Dent : Clear circle
Vacuole : Fuzzy circle

Dent only
Our roadmap of target development

1st term
- Microencapsulation
- Laser Machining
- Measurement
- Interferometry
- Micro X-CT
- Assembly

2nd term
- Coating

3rd term
- Target Injection
- Tritium handling
- Cryogenic cooling

Target Business
For your request

Demonstration
For development

Now
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Civilian project for inertial fusion energy

Electricity cost reduction to 3.5 yen/kWh

Inertial Fusion Energy

Creation of photonics industries
Fusion physics, Nuclear science

Sustainable energy
Clean energy, Zero emission

Mr. Komeda presents P-04 poster at tomorrow afternoon.
New fusion ignition concept of this collaboration
Target view by microscope

We fabricated and assembled the above target. These targets will be irradiated using our laser driver or that of ILE, Osaka university.
13TW Laser driver for Inertial Fusion Research

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak intensity</td>
<td>13 TW</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>1.25 Hz</td>
</tr>
<tr>
<td>On target energy</td>
<td>2 J</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>148 fs</td>
</tr>
</tbody>
</table>

- **Seed laser**: Ti:sapphire laser 1J x 10Hz
- **Main amplifier**: Ti:sapphire amplifier 3.8J x 1.25Hz
- **Pump DPSSL**: Nd:glass laser 10J x 10Hz at 527nm
Disk Target in chamber and some measurement systems

- Neutron detector #1
- Neutron detector #2
- Neutron detector #3
- Laser driver
- X-ray Streak Camera C4575–03
- Target on a rotate disk
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Summary and conclusion

1. We have been developing the key technologies, such as target and laser driver, for commercial power generation using inertial fusion reactor in future. In target technology, we are advancing for business and IFE research according to our roadmap.

2. We have started to fabricate more kind of plastic shells. The merits of our shells are high sphericity and uniformity of wall thickness, and there are not almost dents and vacuoles. Our high quality shells will be great importance in the implosion experiment for high gain.

3. We have promoted a small civilian project toward the IFE development with TOYOTA group and GPI, since 2008. We hope to progress larger project of IFE research.
Acknowledgements

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R. Yoshimura (Hamamatsu Photonics K.K.)
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N. Nakamura, T. Kondo, M. Fujine (TOYOTA Motor Corporation)
H. Azuma, H. Motohiro, T. Hioki (TOYOTA Central R&D Lab. Inc.)

Neutron Detector Development
Y. Arikawa, N. Sarukura, H. Azechi (ILE, Osaka Univ.)
T. Murata (Kumamoto Uiv.) et al.
Thank you for your attention.