Present status of laser-produced plasma EUV light source

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1-Komatsu / EUVA (Extreme Ultraviolet Lithography System Development Association)  
2- Gigaphoton / EUVA,  3- Gigaphoton Inc.

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Summary

➤ Product roadmap
  ✓ Target specification and schedule of Gigaphoton LPP source product is updated.
    • 75W average power will be available in 2011/2Q.

➤ ETS (1st generation integrated setup LPP source)
  ✓ First performance data is reported.
    • Average power: 2.5W (@/F, calculation)
    • Brightness: 25W (@/F, calculation)
    • Duty cycle: 10%
# EUV Light Source Roadmap

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>&gt;400W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GL400E</td>
</tr>
<tr>
<td>&gt;200W</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>GL200E</td>
</tr>
<tr>
<td>&gt;100W</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>GL100E</td>
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<tr>
<td>100W</td>
<td></td>
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<td>ETS</td>
</tr>
</tbody>
</table>

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# EUV Light Source Major Specifications

<table>
<thead>
<tr>
<th>EUV model</th>
<th>ETS</th>
<th>GL100E proto</th>
<th>GL200E</th>
<th>GL400E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>W</td>
<td>100</td>
<td>&gt;100</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Pulse energy</td>
<td>mJ</td>
<td>1</td>
<td>&gt;1</td>
<td>&gt;2</td>
</tr>
<tr>
<td>Max rep rate</td>
<td>kHz</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Max Duty Cycle</td>
<td>%</td>
<td>75</td>
<td>&gt;75</td>
<td>&gt;75</td>
</tr>
</tbody>
</table>

## Sub systems

<table>
<thead>
<tr>
<th>Sub systems</th>
<th>ETS</th>
<th>GL100E proto</th>
<th>GL200E</th>
<th>GL400E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Material and Shape</td>
<td>Sn droplet</td>
<td>Sn droplet</td>
<td>Sn droplet</td>
<td>Sn droplet</td>
</tr>
<tr>
<td>Droplet Diameter</td>
<td>micro meter</td>
<td>60</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Debris Mitigation</td>
<td>Magnet and cleaning</td>
<td>Magnet and cleaning</td>
<td>Magnet and cleaning</td>
<td>Magnet and cleaning</td>
</tr>
<tr>
<td>Collector Mirror Lifetime</td>
<td>Bpl</td>
<td>11</td>
<td>&gt;200</td>
<td>&gt;1250</td>
</tr>
<tr>
<td>Tool Interface</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Average Power Improvement Chart (scheduled)

Climbing up the average power cliff very rapidly

present
Concept of Gigaphoton LPP Source

**Requirement for EUV source for HVM**
- High EUV power >115 W
- EUV Stability
- Collector mirror lifetime
- Low CoG / CoO

Original technologies
1. CO₂ laser and Sn LPP source
2. Magnetic field plasma guiding
3. High power pulsed CO₂ laser

![Diagram of EUV source](image)
ETS System Configuration

System layout

Laser System

- Oscillator
  - Wave length: 10.6μm
  - Rep. rate: 100kHz
  - Pulse width: 20 ns (FWHM)

- Pre-Amplifier
  - RF-excited CO2 laser

- Main Amplifier
  - RF-excited CO2 laser

Laser Power: 13 kW
Pulse Width: 20 ns
Repetition Rate: 100 kHz
Pulse energy stability: 2% (3s, 500 pulses)

EUV chamber

Laser beam profile

13 kW
100 W at I/F equivalent

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ETS EUV Chamber Configuration
**Droplet Generator**

**Droplet for ETS**
- Diameter: 60um
- Stability: ±13um
- Velocity: 60mss/s
- Frequency: 400kHz

**Droplet experimental chamber**

**Graphs**
- X-Position [um] vs. Time [min]
- Z-Position [um] vs. Time [min]

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Mitigation Experiment

- **Ion**
  - Faraday cup: 1000 pls (10 ms) @ 100 kHz

- **Mirror life**: Mo/Si
  - Sample mirror: surface measurement

- **Condition**
  - Magnetic field applied
  - Laser: 50 mJ, 100 kHz, 2.4% duty (25 ms on + 1 s off)
  - Droplet: φ 60 um
Ion Shielding by Magnetic Field – Faraday Cup signal

- Under application of Magnetic field, off-axis (related to B-field) ion signal is below the detection limit.

![Graph showing ion signal comparison with and without B-field](image)

- FC position: H52.5deg, V30deg
- CO2 Laser energy: 50mJ
- 100 pulse average
ETS Experiment

➢ 1st generation integrated LPP system

➢ Demonstration of 100W (av.75W) operation
  ✓ Prove system concept with real data with integrated system
    ● Pre-pulse target heating
    ● Mass limited target
    ● Magnetic mitigation
    ● Mirror cleaning

➢ Clarify the engineering issues of component and find solution
  ✓ CO2 laser
  ✓ EUV chamber (mirror, droplet gen., etc.)

➢ Feedback engineering data to GL100E
EUV Plasma Light

- CO₂ Laser power 5kW
- Duty 10%
  - Burst ON 20msec
  - Burst OFF 180msec
- w/ Droplet position control
- w/o Droplet timing control
- w/o Energy control
EUV Energy w/o pre-pulse

1msec average/point

- Average power (@I/F, calculation): 2.5W
- Brightness (@I/F, calculation): 25W
- Duty cycle: 10%
- Max. non stop operation time: 3 hr
- Experiment time: 10 hr
- Average CE: 1.5%

- w/ Droplet position control
- w/o Droplet timing control
- w/o Energy control

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EUV Energy w/o pre-pulse

Long term operation

✓ w/ Droplet position control
✓ w/o Droplet timing control
✓ w/o Energy control
EUV Energy w/o pre-pulse

- Burst mode stability

50-burst

4 msec moving average/point

Number of pulses [x2]

- w/ Droplet position control
- w/o Droplet timing control
- w/o Energy control
YAG laser is being prepared.
3% of CE with pre-pulse is expected.
# Status Summary of ETS Experiment

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Type</th>
<th>Performance at Plasma</th>
<th>Integrated Performance</th>
<th>Performance Projections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigaphoton Komatsu EUVA</td>
<td>Sn LPP</td>
<td>Demonstrated operating time</td>
<td>Average EUV power in $2\pi$ at plasma (measured)</td>
<td>Demonstrate d operating time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 hours @ 10% duty cycle</td>
<td>7.5W @ 10% duty cycle</td>
<td>3 hours @ 10% duty cycle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>With droplets No integrated Source</td>
</tr>
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## Acknowledgments

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