LONG COLLECTOR MIRROR LIFETIME DEMONSTRATION AROUND 100W AVERAGE LPP-EUV SOURCE FOR SEMICONDUCTOR HIGH VOLUME MANUFACTURING

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Agenda

- Introduction

- HVM Ready System Performance
  - EUV Source System
  - Availability Status

- Key Component Technology update
  - Pre-pulse technology
  - Droplet generator
  - CO2 laser
  - Collector Mirror Life Extension

- Summary
INTRODUCTION
2017 Business Highlights

DUV Business
- We foresee 94-unit shipment as the projection for 2017
- Announced a new GT65A product with cutting-edge lithography light source technology and new eco-friendly solutions

EUV Business
- 0.4% per Giga-pulse of Collector mirror reflectance demonstrated
- Further scalability scenario toward 300/500W EUV power realized
- Achieved major milestone toward >80% availability on Pilot light source

FPD Business
- Selective Laser Annealing system with GT600K-Integrated Released into the China market in Oct 2017
- High availability > 99.7% through Lithography experience
- Advanced maintainability, No window cleaning required
- Minimum gas usage by Gas recycling system
HVM READY SYSTEM PERFORMANCE
Gigaphoton LPP Source Concept

1. High ionization rate and CE EUV tin (Sn) plasma generated by dual-wavelength shooting via CO₂ and pre-pulse solid-state lasers
2. Hybrid CO₂ laser system with short pulse high repetition rate oscillator and commercial cw-amplifiers
3. Tin debris mitigation with a superconductive magnetic field
4. Accurate shooting control with droplet and laser beam control
5. Highly efficient out-of-band light reduction with grating structured C1 mirror
## Target System Specification

<table>
<thead>
<tr>
<th>Target Performance</th>
<th>Proto#1 Proof of Concept</th>
<th>Proto#2 Key Technology</th>
<th>Pilot#1 HVM Ready</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EUV Power</strong></td>
<td>25W</td>
<td>&gt;100W</td>
<td>250W</td>
</tr>
<tr>
<td><strong>CE</strong></td>
<td>3%</td>
<td>&gt; 4%</td>
<td>&gt; 5%</td>
</tr>
<tr>
<td><strong>Pulse Rate</strong></td>
<td>100kHz</td>
<td>100kHz</td>
<td>100kHz</td>
</tr>
<tr>
<td><strong>Output Angle</strong></td>
<td>Horizontal</td>
<td>62° upper</td>
<td>62° upper</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>~1 week</td>
<td>~1 week</td>
<td>&gt;80%</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Droplet Generator</strong></td>
<td>20 - 25μm</td>
<td>&lt; 20μm</td>
<td>&lt; 20μm</td>
</tr>
<tr>
<td><strong>CO₂ Laser</strong></td>
<td>5kW</td>
<td>20kW</td>
<td>27kW</td>
</tr>
<tr>
<td><strong>Pre-pulse Laser</strong></td>
<td>picosecond</td>
<td>picosecond</td>
<td>picosecond</td>
</tr>
<tr>
<td><strong>Collector Mirror Lifetime</strong></td>
<td>Used as development</td>
<td>10 days</td>
<td>&gt; 3 months</td>
</tr>
<tr>
<td></td>
<td>platform</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
First HVM EUV Source

- 250W EUV source

<table>
<thead>
<tr>
<th>Specification</th>
<th>Target Specification</th>
<th>HVM Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>EUV Power</td>
<td>&gt; 250W</td>
</tr>
<tr>
<td></td>
<td>CE</td>
<td>&gt; 4.0 %</td>
</tr>
<tr>
<td></td>
<td>Pulse rate</td>
<td>100kHz</td>
</tr>
<tr>
<td></td>
<td>Availability</td>
<td>&gt; 80 %</td>
</tr>
<tr>
<td>Technology</td>
<td>Droplet generator</td>
<td>&lt; 20mm</td>
</tr>
<tr>
<td></td>
<td>Droplet size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CO2 laser</td>
<td>&gt; 20kW</td>
</tr>
<tr>
<td></td>
<td>Power</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-pulse laser</td>
<td>Pulse duration psec</td>
</tr>
<tr>
<td></td>
<td>Debris mitigation</td>
<td>Magnet, Etching</td>
</tr>
</tbody>
</table>

EUV Exposure Tool
Pilot System EUV Chamber
### System Performance: 125W Operation Data

<table>
<thead>
<tr>
<th>Performance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average power at IF</td>
<td><strong>125W</strong></td>
</tr>
<tr>
<td>Dose error (3 sigma) *1</td>
<td><strong>0.09%</strong></td>
</tr>
<tr>
<td>Die yield (&lt;0.16%)*2</td>
<td><strong>96.9%</strong></td>
</tr>
<tr>
<td>Operation time</td>
<td><strong>28h</strong></td>
</tr>
<tr>
<td>Pulse Number</td>
<td><strong>10BpLs</strong></td>
</tr>
<tr>
<td>Duty cycle</td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td>In-band power</td>
<td><strong>125W</strong></td>
</tr>
<tr>
<td>Dose margin</td>
<td><strong>30%</strong></td>
</tr>
<tr>
<td>Collector lifetime *3</td>
<td><strong>--</strong></td>
</tr>
<tr>
<td>Repetition rate</td>
<td><strong>100kHz</strong></td>
</tr>
</tbody>
</table>

**Note**
- *1: Dose error is defined by 800 pulse (8 ms) moving window
- *2: Dose performance failure is mainly due to droplet combination failure
- *3: Dummy mirror was used for investigation.
4-8. System Performance: Pulse to Pulse Operation Data

**EUV Energy**

**Dose error**

800 pulse (8ms) moving window

**CO2 Energy**
Availability potential test

- 2 week availability potential test was done. Availability was 64% and idle time was 25%. Availability is potentially achievable at 89%.

### System stop event table

<table>
<thead>
<tr>
<th>Day</th>
<th>Event</th>
<th>Repair time</th>
<th>Root cause</th>
<th>Countermeasure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Dose Error</td>
<td>1.25h</td>
<td>25% dose margin is not sufficient</td>
<td>Dose margin 25% -&gt; 28% New shooting control will be applied at Jun.</td>
</tr>
<tr>
<td>3</td>
<td>Sensor Error</td>
<td>3h</td>
<td>Sensor reliability</td>
<td>New sensor will be applied (TBD).</td>
</tr>
<tr>
<td>5</td>
<td>Dose Error</td>
<td>-</td>
<td>Droplet combination failure</td>
<td>Countermeasures will be applied at Jul.</td>
</tr>
<tr>
<td>6</td>
<td>Dose Error</td>
<td>1.25h</td>
<td>Shooting control algorithm</td>
<td>Same as Day 2 countermeasure</td>
</tr>
<tr>
<td>8</td>
<td>Dose Error</td>
<td>0.25h</td>
<td>28% dose margin is not sufficient</td>
<td>Dose margin 28-&gt;35% Same as Day 2 countermeasure.</td>
</tr>
<tr>
<td>10</td>
<td>Dose Error</td>
<td>3.75h</td>
<td>Droplet position instability due to particle issues.</td>
<td>Countermeasures are going on.</td>
</tr>
<tr>
<td>13</td>
<td>Dose Error</td>
<td>4.25h</td>
<td>Mirror damage in BTS(beam transfer system) for new mirror evaluation.</td>
<td>Replacement to conventional mirror</td>
</tr>
<tr>
<td>14</td>
<td>Dose Error</td>
<td>11.25h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dose error: System stopped at > 2% Dose error (3 sigma) /10kpl's slit and error was not recovered by automatic function

Idle time: Time for waiting operator.

24 hour x 7 days definition
Unmanned operation between 9pm thru 8am

MTTR: 2.8h
Availability Trends

- Availability improvement has been made and the challenges are classified by modules.

- Idle time: Time for waiting operator or service.

- Downtime breakdown:
  - Beam steering system: 0%
  - Others: 16%
  - Droplet generator: 22%
  - CO2 laser: 29%
  - Vessel: 28%
  - Pre-pulse laser: 5%

- Time for gas replacement in CO2 pre-amplifier.

- Availability breakdown:
  - Time ON: 53%
  - Idle time: 29%
  - Scheduled down: 13%
  - Unscheduled down: 5%

- Graph showing availability trends from 2015 to 2018:
  - 2015: 15%
  - 2016: 17%
  - 2017: 53%
  - 2018: 44%
KEY COMPONENT TECHNOLOGY UPDATE
Gigaphoton EUV Technology

1. Debris Mitigation by Magnet

2. Droplet Generator

3. Pre-pulse laser

4. CO2 laser system

- Collector Mirror
- pre-pulse laser
- CO2 laser
- Chamber
- CO2 Laser Amplifier
- CO2 Laser Pre-amplifier
- CO2 Laser Oscillator
- Heat Exchanger
Gigaphoton EUV Technology for Lower CoO

1. Droplet Generator
   - CO2 laser
   - Chamber

2. Pre-pulse laser
   - CO2 Laser Amplifier

3. CO2 laser system
   - CO2 Laser Pre-amplifier
   - CO2 Laser Oscillator
   - Heat Exchanger

4. Debris Mitigation by Magnet

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Gigaphoton EUV Technology for Lower CoO

1. Droplet Generator
   - 100kHz (2x) rep rate
   - 90m/sec DL speed
   - 900um droplet distance
   - 20um small droplet
     => less contamination
     => longer DLG life

2. Pre-pulse laser
3. CO2 laser system
4. Debris Mitigation by Magnet

- CO2 Laser Amplifier
- CO2 Laser Pre-amplifier
- CO2 Laser Oscillator
- Heat Exchanger

100kHz (2x) rep rate
90m/sec DL speed
900um droplet distance
20um small droplet
=> less contamination
=> longer DLG life

- Slide 18
- EUVL – WS 2018
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1-1. Gigaphoton EUV Technology: Droplet Generator

- **Benefit:** Small sized high speed droplets
  - Less debris and 3x tin reservoir lifetime due to 1/3 volume against conventional droplets
  - High speed droplets to support up to 100kHz operation, doubling the today’s source

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>GPI</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Droplet speed</strong></td>
<td>(60m/s)</td>
<td>90m/sec</td>
<td>Influence from plasma is ½ vs conventional technology because the distance of 2 droplet is 1.5x</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>50kHz</td>
<td>100kHz</td>
<td>High frequency enables to reduce one plasma energy by half to reduce Sn contamination</td>
</tr>
<tr>
<td><strong>Droplet size</strong></td>
<td>30 micron</td>
<td>20 micron</td>
<td>1/3 in Sn volume. Less contamination on the corrector mirror</td>
</tr>
</tbody>
</table>
1-2. Droplet Generator

- Ar pressurized up to 400 atmosphere pressure
- High-pressure Sn tank
- Nozzle
- Heater
- Tank
- Piezo Actuator
- Droplet

Particle management

20um droplet generation technology

100kHz ejection technology

Diameter 20um position stability +/- 5um

- 20MPa–DLG 60m/s
- 40MPa–DLG 90m/s
- 90m/s

Freq. =100kHz
Freq. =100kHz
Freq. =50kHz

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Droplet Status

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Gigaphoton EUV Technology for Lower CoO

1. Droplet Generator

2. Pre-pulse laser
   - Pico sec 1um pre-pulse
   - Ideal dome mist
   - >5% EUV CE

3. CO2 laser system

4. Debris Mitigation by Magnet

- CO2 Laser Pre-amplifier
- CO2 Laser Oscillator
- Heat Exchanger

- Collector
- Mirror
- Chamber
- Pre-pulse laser
### Benefit
- **Highest CE (Conversion Efficiency) at 5%** demonstrated
- Supports growing demand for **high power >500W**
- Run with less resources such as electricity/water/gas

### Table

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<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulse duration</strong></td>
<td>(Nano sec)</td>
<td>Pico sec</td>
<td>High EUV CE &gt;5%</td>
</tr>
<tr>
<td><strong>WL of pre-pulse</strong></td>
<td>10.6um</td>
<td>1um</td>
<td>Separate pre-pulse unit provide flexibility for the optimization for long term operation</td>
</tr>
<tr>
<td><strong>Optical path</strong></td>
<td>2 optical path</td>
<td>Coaxial</td>
<td>Pre-pulse beam with the same optical path as main CO2 beam. Shorter beam axis alignment time.</td>
</tr>
</tbody>
</table>

### Graph
- CE at 37 deg: 5.5%
- PPL - CO₂ delay
2-2. Pre-pulse technology

- Advantage of pico-second pre-pulse over nano-second

Pre-pulse (nano-second)

‘Disk’ like target

Shadow graph

Pre-pulse (pico-second)

‘Dome’ like target

Ideal

Very short pulse duration with 1um wavelength laser

Same optical path between pre-pulse and main

X-ray CCD

400 um

400 um
Gigaphoton EUV Technology for Lower CoO

1. Droplet Generator
   - CO2 laser
   - Debris Mitigation by Magnet

2. Pre-pulse laser
   - CO2 Laser Amplifier
   - Heat Exchanger
   - CO2 Laser Pre-amplifier

3. CO2 laser system
   - Uniform beam profile
   - Auto beam adjustment
   - 30% less electricity
   - High CO2 CE
   - High availability

4. Debris Mitigation
   - Droplet Generator
   - Pre-pulse laser
   - CO2 laser system
   - CO2 Laser Ampifier

✓ 30% less electricity
✓ Uniform beam profile
=> High CO2 CE
=> less electricity usage
✓ Auto beam adjustment
=> High availability

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### 3-1. Gigaphoton EUV Technology: CO₂ Lasers

**Benefit**

- **Excellent beam uniformity** enables efficient EUV creation
- **Short maintenance down time**
  - Separated optical binding module design
  - Auto beam adjustment
- **Efficient CO₂ Laser** and eco-friendly

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>GPI</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam profile uniformity</td>
<td>Not uniform</td>
<td>Uniform</td>
<td>Uniform beam profile leads higher CE.</td>
</tr>
<tr>
<td>Separate Optical Binding module</td>
<td>N/A</td>
<td>Yes</td>
<td>Minimize chamber replace time</td>
</tr>
<tr>
<td>Auto Beam adjustment</td>
<td>N/A</td>
<td>Yes</td>
<td>Keep uniform beam profile without interruption for adjustment</td>
</tr>
<tr>
<td>Power requirement</td>
<td>&gt;1,200kVA</td>
<td>880kVA</td>
<td>30% less electricity</td>
</tr>
</tbody>
</table>

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3-2. CO₂ Lasers: Higher EUV CE with Uniform Beam Profile

- >5% CE was achieved due to the greatly improved CO₂ beam profile

Greatly improved evenness in beam profile allows for more uniform and efficient ionization of droplets – thus resulting in higher CE

Previous CO₂ beam profile was very uneven and hence less efficient by comparison
3-3. CO2 Lasers : Separate Optical Biding Module

- Optical Binding Module is isolated from the CO$_2$ Lase Chamber and Power Supply

- Chamber replacements without axis realignment
3-4. CO₂ Lasers : Auto Beam Adjustment

- Monitor modules and beam steering modules support easy maintenance.

**Monitor module**
- Beam profile camera
- Beam divergence camera
- Pulse energy sensor
- Pulse timing sensor (Oscillator only)

**Beam steering module**
- XY steering mirror
- Z beam expander

**Easy & Stable beam axis adjustment**

**To source chamber**
Beam transfer system

- CO₂ laser
- Pre-Pulse laser (PPL)

**Monitor module**
- Beam profile camera
- Beam divergence camera
- Pulse energy sensor
- Pulse timing sensor (Oscillator only)

**Beam steering module**
- XY steering mirror
- Z beam expander

**Back reflection monitor**
- Power meter
Gigaphoton EUV Technology for Lower CoO

1. Droplet Generator
2. Pre-pulse laser
3. CO2 laser system
4. Debris Mitigation by Magnet

- Magnetic field, 20μm small droplet, 98% Sn ionization lead less contamination
- 0.4%/G pulse @30W was achieved
- 125W mitigation test is ongoing

- CO2 Laser Amplifier
- CO2 Laser Pre-amplifier
- CO2 Laser Oscilator
- Heat Exchanger

Magnetic field, 20μm small droplet, 98% Sn ionization lead less contamination
0.4%/G pulse @30W was achieved
125W mitigation test is ongoing

- Pre-pulse laser
- CO2 laser system
- Chamber
- Collector
- Mirror
4-1. Gigaphoton EUV Technology : Debris Mitigation

**Benefit:**
- High uptime and low CoO by long collector mirror lifetime
- **Magnetic mitigation** to protect the collector mirror surface from tin
- Long lifetime to minimized downtime for collector swap

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>GPI</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic field mitigation technology</td>
<td>N/A</td>
<td>1/100 # of Tin atom</td>
<td>Reduces # of Sn ion which reaches collector mirror.</td>
</tr>
<tr>
<td>Smaller Sn droplet</td>
<td>30 micron dia.</td>
<td>20 micron dia. 1/3 in volume</td>
<td>Less unusable Sn for EUV emission to reduce contamination.</td>
</tr>
<tr>
<td>Hi ionization ratio of Sn 20um droplet</td>
<td>60%</td>
<td>98%</td>
<td>Less contamination on collector mirror and also less contamination inside chamber.</td>
</tr>
<tr>
<td>&gt;125W Mitigation</td>
<td>Practical performance at customer site</td>
<td>GPI internal test is on going</td>
<td>0.4% / G pulse at 30w average power was confirmed. Mitigation test with more than 125W is ongoing.</td>
</tr>
</tbody>
</table>
4-2. Short-term: Etching and Dissociation Sn balance on the Mirror Surface

Chemical Equilibrium on the Mirror Surface

- Tin ionization & magnetic guiding
  - Tin is ionized effectively by double pulse irradiation
  - Tin ions are confined with magnetic field
  - Confined tin ions are guided and discharged from exhaust ports

- Protection & cleaning of collector with H₂ gas
  - High energy tin neutrals are decelerated by H₂ gas in order to prevent the sputtering of the coating of collector.
  - Deposited tin on the collector is etched by H radical gas.*
  - Gas flow and cooling systems for preventing decomposition of etched tin (SnH₄)

*H₂ molecules are dissociated to H radical by EUV-UV radiation from plasma.

SnH₄ → Sn + 4H

Photo Chemical Etching
Sn + 2H₂ + hv → SnH₄

Radical Etching
Sn + 4H* → SnH₄

Dissociation
SnH₄ → Sn + 2H₂

Dissociation Speed

\[ k = A \cdot \exp\left(-\frac{E_a}{RT}\right) \]
4-3. Collector Mirror: Lifetime Status

- Power level of EUV: 95W in Burst, (= 1.9mJ x 50kHz), 33% duty cycle, 31W in average.
- Collector lifetime was improved to -0.4%/Bpls by magnetic debris mitigation technology optimization.

![Graph showing reflectivity over pulse number for different conditions: Proto#2 31W low heat load with condition A, Pilot#1 85W high heat load with condition B, and Proto#2 31W low heat load with condition C.]

Far field pattern in test condition B and C.

- Back flow to collector with Tin
- Tin sputtering

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4-4. Long-term: Capping Layer and Multi-Layer Durability

- **Cross-section of Cap layer after long-term testing**
  - Thickness changes at capping layer due to sputtering.
  - First Si layer become thicker and reflectance down around 30% due to oxidization.
4-5. Dummy Mirror Observation at 75W/125W av.

- Sputtering rate increases in high power operation.
- Tin deposition started after capping layer disappearance because Tin etching performance depend on capping layer.

**75W, 1Bpls**
Sputtering rate < 0.1nm/Bpls

**125W, 1Bpls**
Sputtering rate 8.4nm/Bpls

**125W, 10Bpls**
Capping disappearance and Tin deposition
4.6. Sputtering Effect Increase by Higher Operation Power

- Sputtering rate enhancement occurred by gas heating at higher output power.

**<Mechanism>**

- Higher power
- Gas heating
- Gas density decrease
- Gas stopping decrease

*Preliminary Result*

- Sputtering rate enhancement occurred by gas heating at higher output power.

*EUV plasma cooling is key point of mirror lifetime extension at higher power operation.*
4-7. Mitigation Test Achievement and Next step

- **Criteria**: 0.2%/Gpl at 1B pulses
- **Achievement**: Proof of concept coupon test with 75W succeeded. Ongoing with 125W, Flow improvement, New cap. Layer
- **Next step**: With real mirror, 125W degradation test for 0.2%/Gpl

<table>
<thead>
<tr>
<th>Run #</th>
<th>180314 PRT2</th>
<th>180404 PRT2</th>
<th>1807XX PRT2</th>
<th>1808XX PRT2</th>
<th>1812XX PRT2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power [W]</strong></td>
<td>38</td>
<td>75</td>
<td>125</td>
<td>125</td>
<td>250</td>
</tr>
<tr>
<td><strong>Mirror Contamination test coupon yield @1Bpls</strong></td>
<td>OK</td>
<td>OK</td>
<td>On going</td>
<td>Plan Real mirror</td>
<td>Plan Real mirror</td>
</tr>
<tr>
<td><strong>Sn in Chamber [a.u.]</strong></td>
<td>5.68E-11</td>
<td>1.11E-10</td>
<td>2.21E-10</td>
<td>2.21E-10</td>
<td>2.21E-10</td>
</tr>
<tr>
<td><strong>Sn on Mirror [a.u.]</strong></td>
<td>8.64E-12</td>
<td>1.68E-11</td>
<td>3.36E-11</td>
<td>3.36E-11</td>
<td>3.36E-11</td>
</tr>
<tr>
<td><strong>Duty [%]</strong></td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Repetition [kHz]</strong></td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>IF EUV [mJ]</strong></td>
<td>1.5</td>
<td>1.5</td>
<td>1.25</td>
<td>1.25</td>
<td>2.50</td>
</tr>
<tr>
<td><strong>Flow optimization</strong></td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Flow improvement</strong></td>
<td>-</td>
<td>-</td>
<td>1st Step</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>New Cap. layer</strong></td>
<td>-</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Summary

- Pilot#1 is up running and its demonstrates HVM capability;
  - High conversion efficiency 5% is realized with Pre-pulse technology.
  - High speed (>90m/s) & small (20micron) droplet is realized.
  - High power CO2 laser technology is one of the important technology for HVM.
  - Output power 250W in-burst power @50% duty (125W ave.) several min.
  - Output power 113W in-burst power @75% duty (85W ave.) 143hrs.
  - Pilot#1 system achieved potential of 89% Availability (2weeks average).

- **Recent achievement for most critical challenges mirror life**
  - -0.2%/Gpls with 125W ave. was demonstrated at short term dummy mirror test

- **Next Step**
  - -0.2%/Gpls with 125W ave. with full size mirror
  - >90% availability challenge with operation software enhancement
  - 250W ave. with -0.2%/Gpls, >90% availability proof test in 2020 target
# Key Performance Status and its target

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2018 Current</th>
<th>2018 End</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In-band power</strong> (Average Power)</td>
<td>87W (83W)</td>
<td>113W (111W)</td>
<td><strong>125W (125W)</strong></td>
<td>250W</td>
</tr>
<tr>
<td><strong>Collector lifetime</strong></td>
<td>No data</td>
<td>-10%/Bpl s *3</td>
<td><strong>-0.2%/Bpl s</strong></td>
<td>-0.2%/Bpl s</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>15%</td>
<td>44%</td>
<td><strong>(53%)</strong></td>
<td>&gt; 80%</td>
</tr>
</tbody>
</table>

**Proto #2**

**Pilot #1**

*1, Collector lifetime estimation has been started from 2017
*2, Max availability in 4 week operation.
*3, Main issue was capping layer performance.
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