HIGH POWER LPP-EUV SOURCE WITH LONG COLLECTOR MIRROR LIFETIME FOR HIGH VOLUME SEMICONDUCTOR MANUFACTURING

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Gigaphoton Inc. Hiratsuka facility: 3-25-1 Shinomiya Hiratsuka Kanagawa, 254-8567, JAPAN
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 CO$_2$ and pre-pulse solid-state lasers

2. Hybrid CO$_2$ laser system with short pulse high repetition rate oscillator and commercial cw-amplifiers

3. Tin debris mitigation with a super conductive 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>EUV Power</td>
<td>25W</td>
<td>&gt;100W</td>
<td>250W</td>
</tr>
<tr>
<td>CE</td>
<td>3%</td>
<td>&gt; 4%</td>
<td>&gt; 5%</td>
</tr>
<tr>
<td>Pulse Rate</td>
<td>100kHz</td>
<td>100kHz</td>
<td>100kHz</td>
</tr>
<tr>
<td>Output Angle</td>
<td>Horizontal</td>
<td>62° upper</td>
<td>62° upper</td>
</tr>
<tr>
<td>Availability</td>
<td>~1 week</td>
<td>~1 week</td>
<td>&gt;80%</td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Droplet Generator</td>
<td>20 - 25µm</td>
<td>&lt; 20µm</td>
<td>&lt; 20µm</td>
</tr>
<tr>
<td>CO₂ Laser</td>
<td>5kW</td>
<td>20kW</td>
<td>27kW</td>
</tr>
<tr>
<td>Pre-pulse Laser</td>
<td>picosecond</td>
<td>picosecond</td>
<td>picosecond</td>
</tr>
<tr>
<td>Collector Mirror Lifetime</td>
<td>Used as development platform</td>
<td>10 days</td>
<td>&gt; 3 months</td>
</tr>
</tbody>
</table>
## Layout of 250W EUV Light Source Pilot #1

### First HVM EUV Source

- 250W EUV source

<table>
<thead>
<tr>
<th>Operational specification (Target)</th>
<th>HVM Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance</strong></td>
<td></td>
</tr>
<tr>
<td>EUV Power</td>
<td>&gt; 250W</td>
</tr>
<tr>
<td>CE</td>
<td>&gt; 4.0 %</td>
</tr>
<tr>
<td>Pulse rate</td>
<td>100kHz</td>
</tr>
<tr>
<td>Availability</td>
<td>&gt; 80 %</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td></td>
</tr>
<tr>
<td>Droplet generator</td>
<td>Droplet size &lt; 20mm</td>
</tr>
<tr>
<td>CO2 laser</td>
<td>Power &gt; 20kW</td>
</tr>
<tr>
<td>Pre-pulse laser</td>
<td>Pulse duration psec</td>
</tr>
<tr>
<td>Debris mitigation</td>
<td>Magnet, Etching &gt; 15 days (&gt;1500Mpls)</td>
</tr>
</tbody>
</table>

EUV Exposure Tool

- EUVL – WS 2018
Pilot System EUV Chamber
4-7. System Performance: 125W Operation Data

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

Preliminary Result
AVAILABILITY STATUS
Availability potential test

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

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

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

### Availability Breakdown

- **Idle time**: Time for waiting operator or service
- **Time ON**: 53%
- **Idle time**: 29%
- **Scheduled down**: 13%
- **Unscheduled down**: 5%

### Downtime Breakdown

- **Beam Steering System**: 9%
- **Others**: 16%
- **Droplet generator**: 22%
- **CO2 Laser**: 29%
- **Vessel**: 28%
- **Pre-pulse Laser**: 5%

### Availability Trend Chart

<table>
<thead>
<tr>
<th>Year</th>
<th>Max Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>15%</td>
</tr>
<tr>
<td>2016</td>
<td>44%</td>
</tr>
<tr>
<td>2017</td>
<td>44%</td>
</tr>
<tr>
<td>2018</td>
<td>53%</td>
</tr>
</tbody>
</table>

Time for gas replacement in CO2 pre-amplifier

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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

Heat Exchanger

CO2 Laser Amplifier
CO2 Laser Pre-amplifier
CO2 Laser Oscillator
Gigaphoton EUV Technology for Lower CoO

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

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

Chamber
Collector
Mirror

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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

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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>Droplet speed</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>Frequency</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>Droplet size</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

Droplet Generator

Particle management

20um droplet generation technology

High-pressure Sn tank

100kHz ejection technology

Nozzle

Heater

Tank

Piezo Actuator

Droplet

Ar pressurized up to 400 atmosphere pressure

Diameter 20um  position stability <+- 5um

20MPa-DLG

60m/s

40MPa-DLG

90m/s

90m/s

Freq. =100kHz

Freq. =100kHz

Freq. =50kHz

High-pressure Sn tank
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

Chamber

Pre-pulse laser

Collector
Mirror

Pico sec 1um pre-pulse
Ideal dome mist
>5% EUV CE
2-1. Gigaphoton EUV Technology : Pre-pulse technology

**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>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>GPI</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse duration</td>
<td>(Nano sec)</td>
<td>Pico sec</td>
<td>High EUV CE &gt;5%</td>
</tr>
<tr>
<td>WL of pre-pulse</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>Optical path</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>
2-2. Pre-pulse technology

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

- Pre-pulse (nano-second) vs. Pre-pulse (pico-second)
  - 'Disk' like target vs. Ideal 'Dome' like target
  - Very short pulse duration with 1um wavelength laser
  - Same optical path between pre-pulse and main

Shadow graph

X-ray CCD

400 μm

400 μm

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Gigaphoton EUV Technology for Lower CoO

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

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

Heat Exchanger
CO2 Laser Pre-amplifier
CO2 Laser Amplifier

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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>
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.

![Graph showing CE performance vs. CO2 pulse energy](image-url)
3-3. CO2 Lasers : Separate Optical Biding Module

- Optical Binding Module is isolated from the CO$_2$ Laser 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.

![Diagram of CO₂ laser system]

- Easy & Stable beam axis adjustment

- Monitor modules:
  - 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

CO₂ Laser

Pre-Pulse laser (PPL)

To source chamber

Beam transfer system
Gigaphoton EUV Technology for Lower CoO

4. Debris Mitigation by Magnet
- Magnetic field, 20um small droplet, 98% Sn ionization lead less contamination
- 0.4%/G pulse @30W was achieved
- 125W mitigation test is ongoing

2. Pre-pulse laser
- CO2 Laser Amplifier
- Pre-amplifier
- CO2 Laser Oscillator

1. Droplet Generator
- CO2 laser
- Chamber

3. CO2 laser system
- Heat Exchanger

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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

- 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.

- 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

- Tin ionization

- Removal of tin

- Dissociation Speed

spender. Emission of tin by tin ionization

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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](image)

- Prototype #2: 31W low heat load with condition A
- Pilot #1: 85W high heat load with condition B
- Proto #2: 31W Low heat load with condition C

Far field pattern in test condition B and C

- Tin sputtering
- Backflow to collector with Tin
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.

**Preliminary Result**

<table>
<thead>
<tr>
<th>Sputtering rate</th>
<th>Capping layer disappearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>75W, 1Bpls</td>
<td>No Tin deposition</td>
</tr>
<tr>
<td>Sputtering rate</td>
<td>&lt; 0.1nm/Bpls</td>
</tr>
<tr>
<td>125W, 1Bpls</td>
<td>Tin deposition</td>
</tr>
<tr>
<td>Sputtering rate</td>
<td>8.4nm/Bpls</td>
</tr>
<tr>
<td>125W, 10Bpls</td>
<td>Capping disappearance</td>
</tr>
<tr>
<td></td>
<td>and Tin deposition</td>
</tr>
<tr>
<td>Capping layer</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>No Capping</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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4-6. Sputtering Effect Increase by Higher Operation Power

Preliminary Result

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

**<Mechanism>**

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

![Graph showing sputtering rate in current set-up](image1)

**Sputtering rate in current set-up**

- 125W
- 38W

![Graph showing calculated line by SRIM](image2)

**Calculated line by SRIM**

- Tin atoms on mirror surface
- Temperature

**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</th>
<th>180404</th>
<th>1807XX</th>
<th>1808XX</th>
<th>1812XX</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 @1Bpl</strong></td>
<td>OK</td>
<td>OK</td>
<td>On going</td>
<td>Plan</td>
<td>Plan</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
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></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Average Power)</td>
<td>87W (83W)</td>
<td>113W (111W)</td>
<td>125W (125W)</td>
<td>250W</td>
</tr>
<tr>
<td><strong>Collector lifetime</strong></td>
<td>No data</td>
<td>-10%/Bpls *3</td>
<td>-0.2%/Bpls</td>
<td>-0.2%/Bpls</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>15%</td>
<td>44%</td>
<td>(53%)</td>
<td>&gt; 80%</td>
</tr>
</tbody>
</table>

**Proto #2**

**Pilot #1**

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*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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