# Cymer's Light Source Development for EUV Lithography

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# Outline

- **Introduction**
  - EUVL critical issues
  - EUV sources
- **Cymer Source Development**
  - Overview
  - Power scaling
- **Technology Outlook**

# Critical Issues Facing EUV Lithography

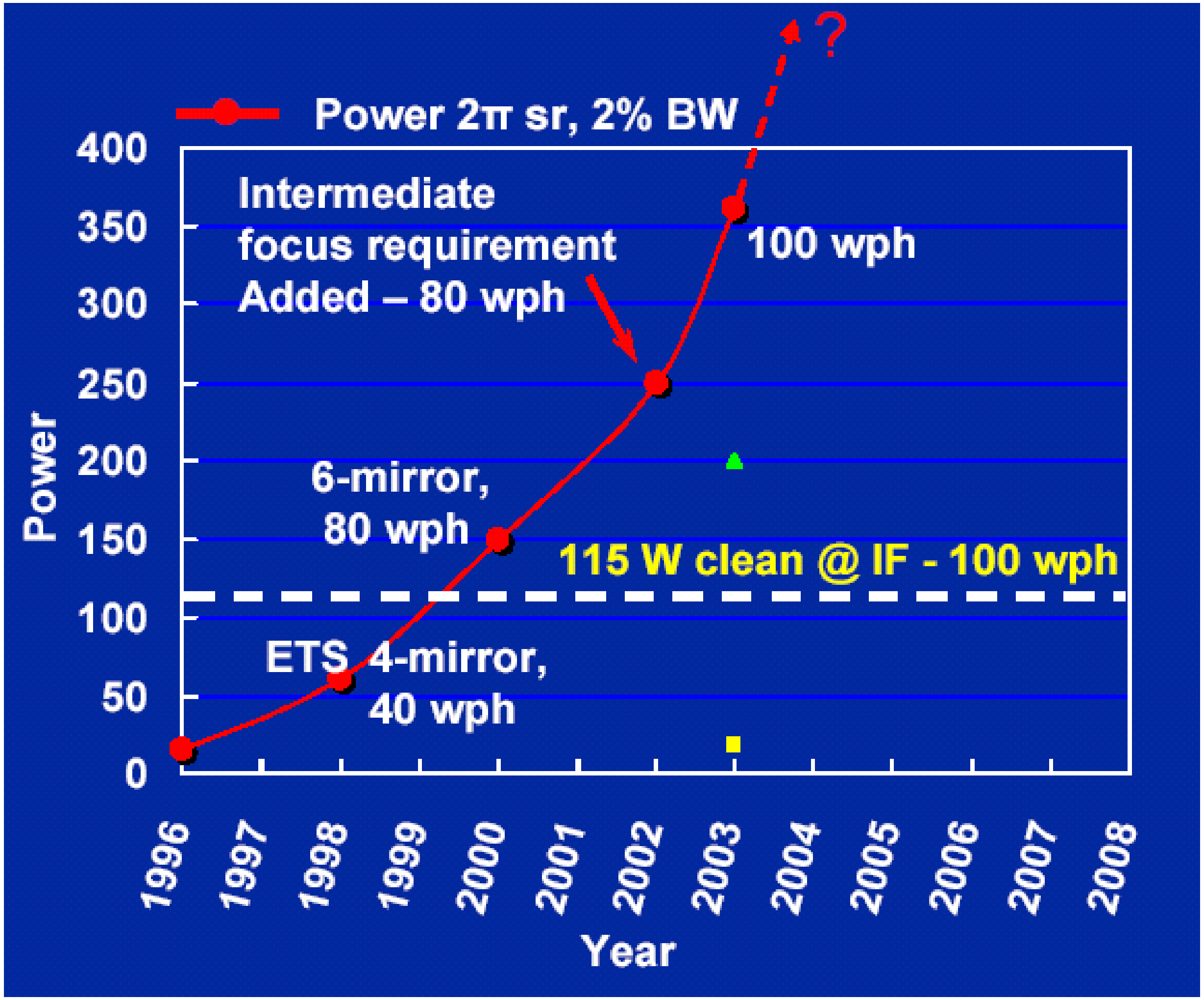
## *Industry Risk Perspective*

- Source output power and lifetime, including condenser optics lifetime (1,3)
- Availability of defect-free masks (2,5)
- Reticle protection during storage, handling and use (6)
- Projection and illuminator optics lifetime (7)
- Resist resolution, sensitivity and line width reduction (LWR) (10)
- Optics quality for the 32 nm node (8)

* 2002 ranking in brackets

**Source: 2nd International EUVL Symposium Steering Committee, October 2003**

# Source Power Requirements Over Time



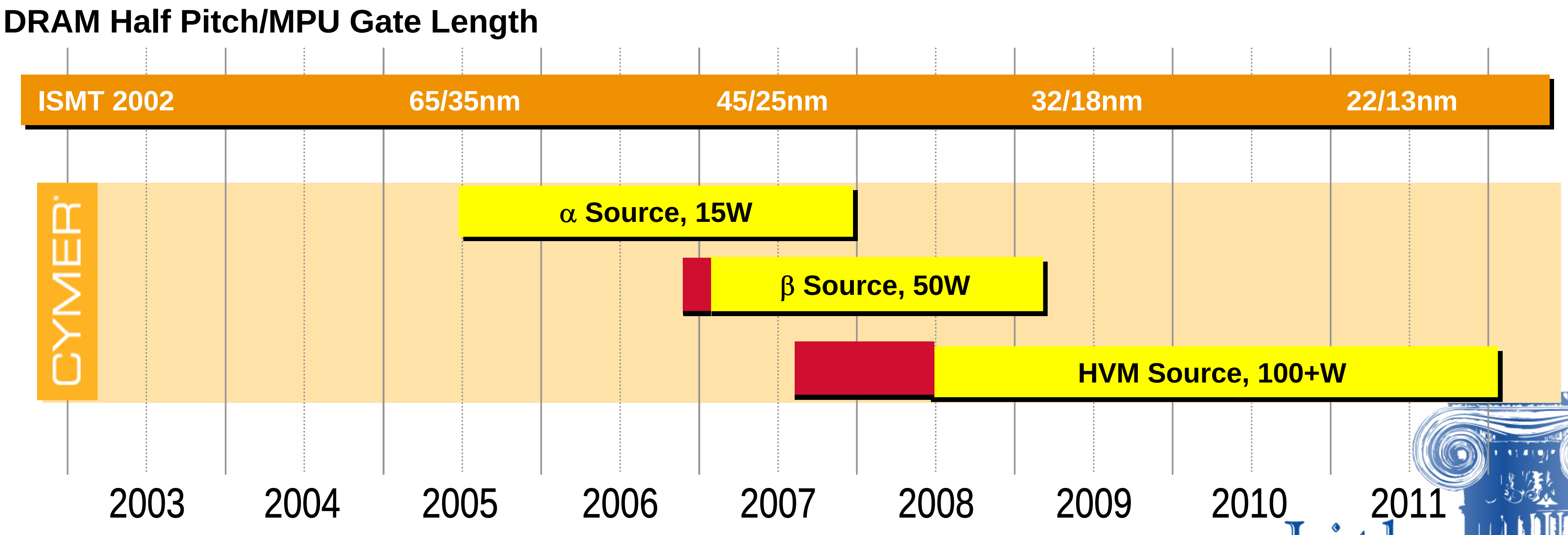
Source: C.Gwyn, 2nd Intl. EUVL Symposium, Oct. 2003

# Industry and Tool Roadmap for EUVL

**January 26, 2004 Press Release:**

Subject: Development agreement between Intel and Cymer
Purpose: Accelerated development of production-worthy EUV source
Amount: $20M
Period: 3 Years

**At this forum**, Cymer makes the first public announcement of pursuing both DPP **and** LPP EUV light source technology.



DRAM Half Pitch/MPU Gate Length

# Choices for EUV Source Technology

**The choice of EUV source technology can be broken into two major decisions:**

**1) Method of plasma excitation**

Discharge Produced Plasma (DPP) or Laser Produced Plasma (LPP)

**2) Source element**

Xe, Sn, In, Li…

# Problems to be Solved

**The most significant problems that must be solved for any choice of EUV source technology:**

- EUV power scaling: 100+W (in-band) at the intermediate focus
- Collector lifetime: 100 G shots
  (A shorter collector lifetime can be tolerated if its cost is low and replacement time is short)
- System Affordability:

  DPP: collector lifetime, electrode lifetime, debris shield lifetime

  LPP: system price, collector lifetime, laser component lifetime

# EUV Power Scaling: Source Element Choice

- Though xenon will remain a convenient source element during development, it will not likely be the High Volume Manufacturing (HVM) source element due to low conversion efficiency.

- The remaining candidates (with potentially higher CE) are condensable materials at room temperature.
  - Thus, improved CE comes with the new challenge of collector protection/cleaning of low vapor pressure source elements.

# EUV Power Scaling: Source Multiplexing

- Since the DPP source etendue is equal to the allowed upper limit, combining multiple DPP sources requires temporal multiplexing with moving mirrors or sources.

- The LPP source etendue is much smaller than the allowed upper limit, thus multiple LPP sources can be combined optically.
  - EUV power scaling for LPP can be achieved by adding identical systems (for example: a 100W source can be made up of 2 X 50W sources).
  - Only the technology problems of a smaller power source must be solved for LPP (50W instead of full 100W).

# EUV Power Scaling: Thermal Engineering

- **Electrode cooling is the greatest thermal challenge for DPP**
  - The technical path to provide the required thermal extraction to achieve 100+W at intermediate focus is very challenging.
- **Jet nozzle cooling was greatest thermal challenge for LPP**
  - With the development of liquid jet and droplet source delivery at large distances, nozzle cooling no longer an issue.
  - Thermal engineering challenge of LPP has “moved upstream” to the laser head – a more tractable challenge.

# Primary Collector Lifetime: Debris

- **DPP systems can produce the following types of debris:**
  - Fast source element ions
  - Fast source element neutrals
  - Source element particles
  - Fast electrode material ions
  - Fast electrode material neutrals
  - Electrode material particles
  - Insulator material

- **LPP systems can produce the following types of debris (assuming long distance source element delivery):**
  - Fast source element ions
  - Fast source element neutrals
  - Source element particles

# Primary Collector Lifetime: Debris

- The primary difference between debris from DPP and LPP is the existence of DPP electrode and insulator material.
- DPP erosion tests show that tungsten is the best electrode material.
- Tungsten has a higher atomic mass than any proposed source element.
- Thus, regardless of source element choice the DPP must contend with high atomic mass debris.

# System Affordability

## Major components of EUV source system cost:

| **DPP** | **LPP** |
|---|---|
| Grazing incidence collector (multi shell) | Multi-layer mirror collector (single “element”) |
| Source vacuum vessel system | Source vacuum vessel system |
| Electrodes with cooling | Beam delivery |
| Source element delivery | Source element delivery |
| SSPPM | Laser source |
| **Consumables** | |
| Collector | Collector |
| Electrodes | Pump diodes / Laser chamber |
| Debris trap | Laser optics |

# Why is Our Current Assessment Different than That Previous?

## DPP

- Goal was 30-40W source at plasma point.  Now goal is 100+W at intermediate focus.  Thermal engineering supported 30-40W at plasma point, but questionable if it can support 100+W at intermediate focus.
- DPF produced small source size, but at low efficiency.  As efficiency increased, so did source size.
- Efforts to reduce electrode erosion are yielding, but not quickly, and with a drop in optical efficiency.

## LPP

- Long distance nozzles did not exist.  Nozzle erosion was considered insurmountable.
- Diode laser prices and lifetimes needed much improvement.
- MOPA excimer did not exist.  We had no practical path towards high power, high repetition rate excimer for LPP.

# Cymer EUV Source Outlook

**DPP**

- DPF development ongoing

**LPP**

- Experiments with Nd:YAG laser at 1064, 532, 355, 266 nm
- Test standard pulse duration and shortened pulse duration 248 nm
- Improve laser beam quality (reduce spot size)
- Compare different targets: jet, droplet, pellet
- Target position control
- Quantify major mirror erosion mechanisms

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