powerlase

EUV

powerlase

powerlase EUV

High Power, Short Pulse and Cost Effective Laser Modules for LPP EUV Source

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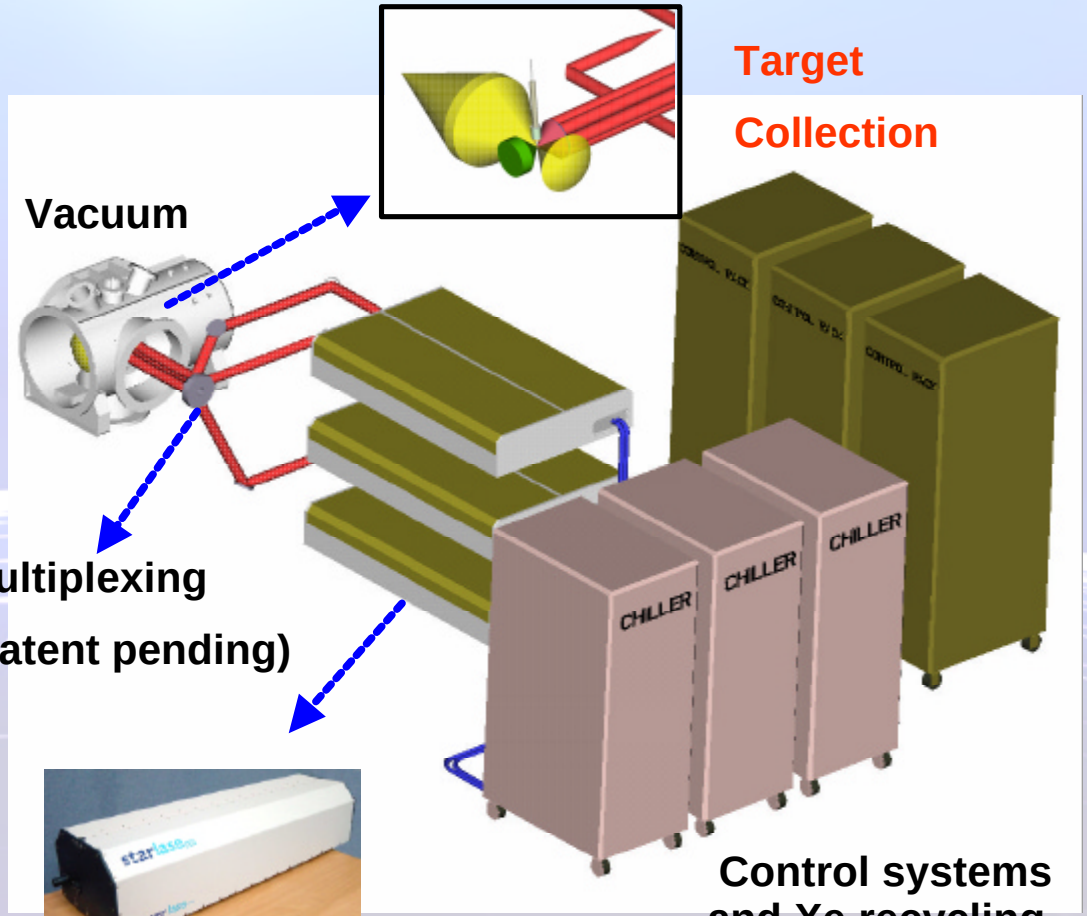
Presentation outline

- **Current Powerlase activities**
- **High power laser performance**
  - Parameters and efficiency
  - Reliability and diode lifetime
- **EUV target approaches**
  - Xe target
  - Sn target
- **Roadmap and cost of ownership**
- **Summary**

Powerlase LPP EUV source for 2005

- 3 x multiplexed lasers
  - 3.6 kW, 2005
- Construction near completion
  - **10-20 W EUV at IF**
- Scalable



1.2 kW laser module (patent pending)

Control systems and Xe recycling (patent pending)

High Power Lasers and Multiplexing

Starlase Acousto Optic (AO) and Electro Optic (EO) systems

Advanced performance…

…industry proven

Powerlase High Average Power gain modules

Core technology for all Starlase lasers

Unified, efficient laser cavity (18%), industrially proven design

Range of pump powers available

AO - Proven performance in the field

Market availability up to 800 W

Scalability beyond 1 kW

Pulse duration >40 ns

Rep rate >10 kHz

EO - Advanced switching technology

Pulse duration <10 ns

Rep rate 10 kHz (per laser module)

1 kW demonstrated

1.2 kW systems under construction

Laser module service life

EUV laser modules based on industrially proven range of Starlase lasers

Reliable, stable and serviceable

Proven in the semiconductor industry

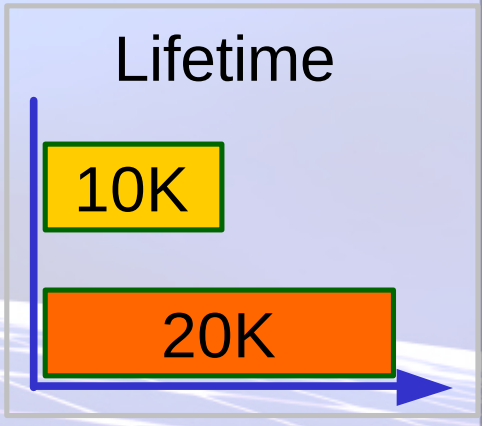
Industrially driven development

Reliable pump laser diodes at heart of every Starlase laser

All new industrial laser technologies powered by laser diodes

Industry moving to: **10,000 hours** and higher power

Higher power diodes in existing laser designs: **upto 20,000 hours**



Driven by

Increasing competition between diode suppliers and increasing demands of users

Enabled by

Developments in manufacturing technology, improved cavity designs, better packaging and improved process control

Upside

Diode manufacturers roadmap for increased diode power output

Laser module service life

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Reliable,
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Diode manufacturers roadmap for increased diode power output

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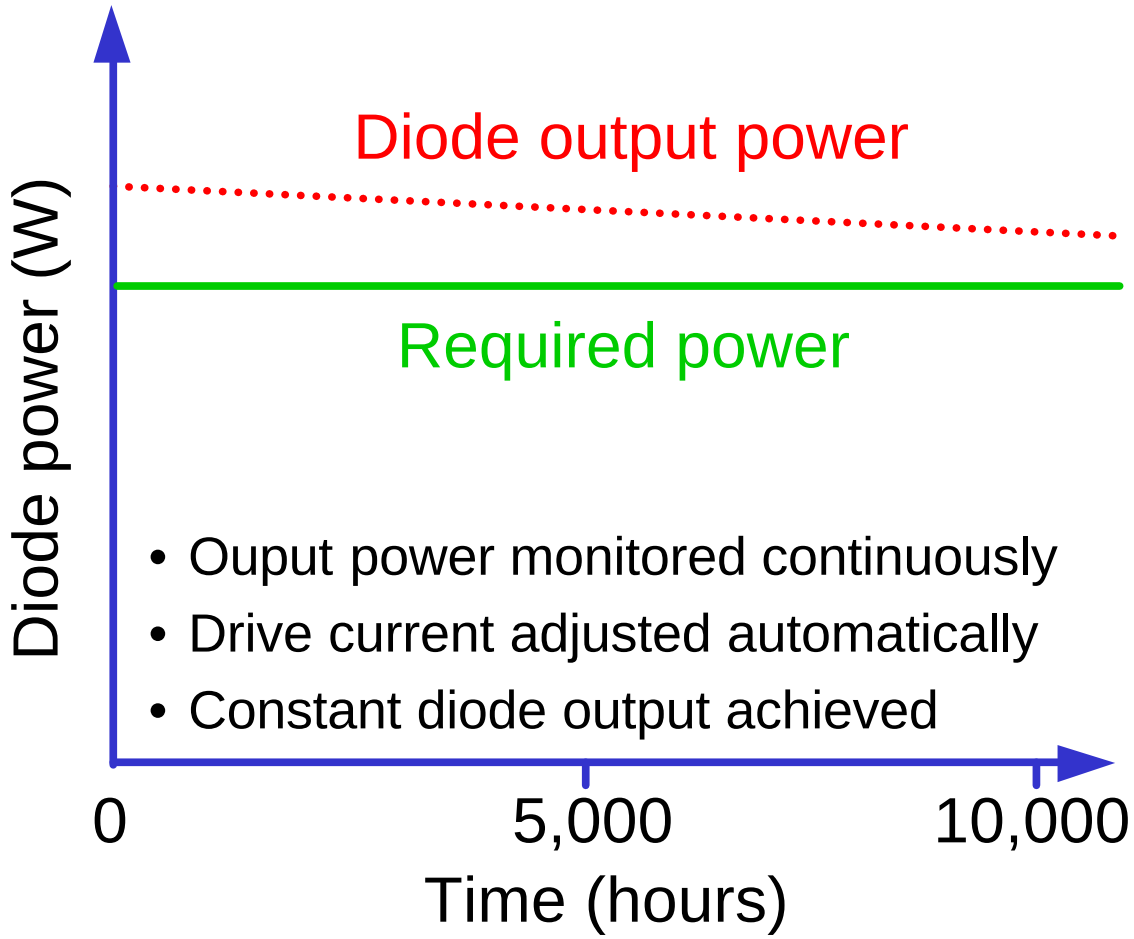
Typical diode performance data



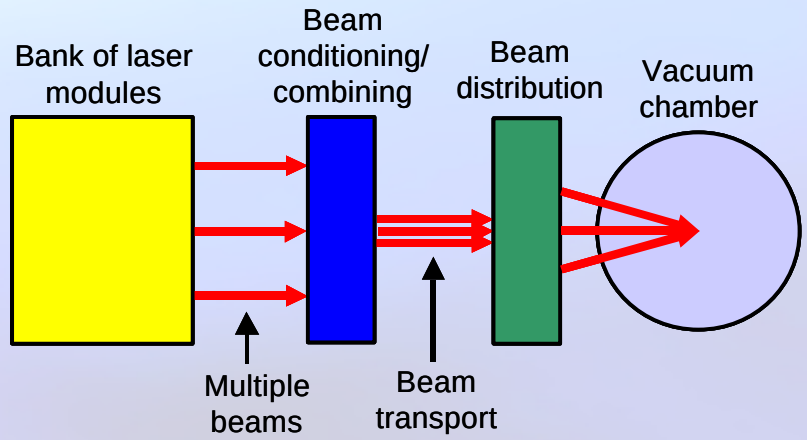
- Ouput power monitored continuously
- Drive current adjusted automatically
- Constant diode output achieved

Spatial and temporal multiplexing

Key Features

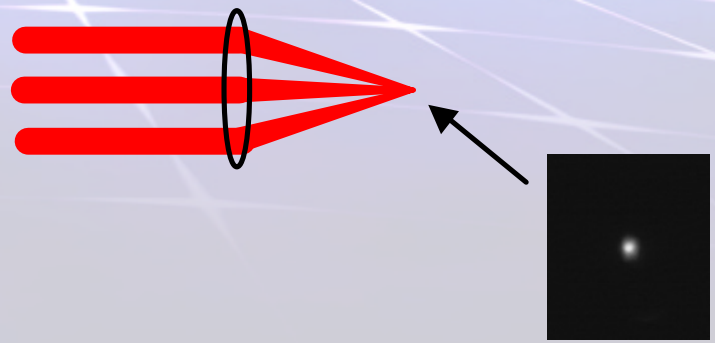
- Enables flexible scale-up route to production power levels using laser modules
- Temporal multiplexing can be readily employed to scale up by repetition rate
- Laser power requirements shared over multiple simple laser modules
- EUV system continues to function should a laser module require maintenance
- Designed to accommodate EUV collection optics
- Straightforward to align
- Alignment is stable and continuously monitored

Laser Beam Multiplexing Schematic



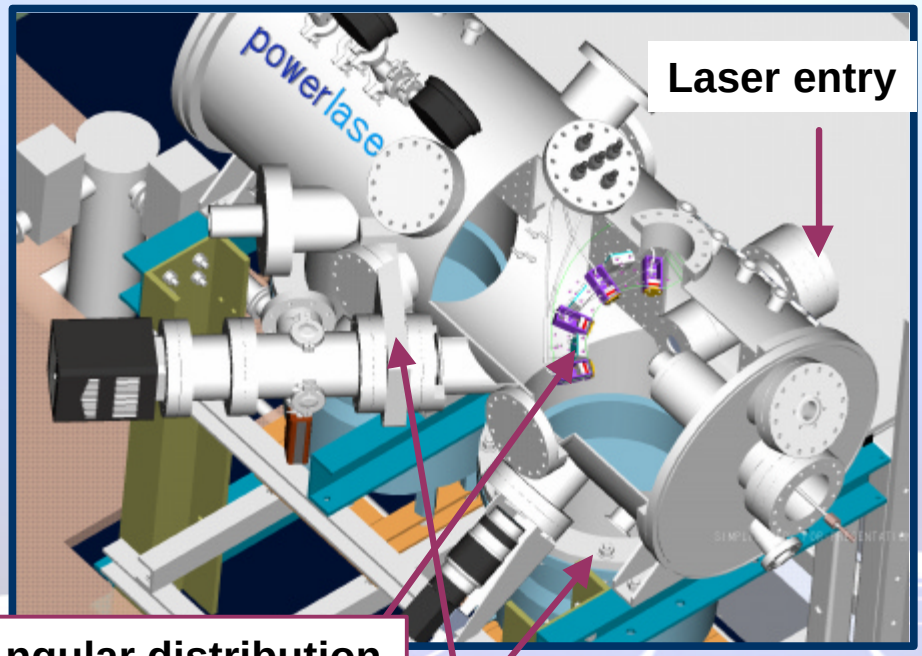
Multiplexing options (already demonstrated)

- Use of single lens to combine three beams



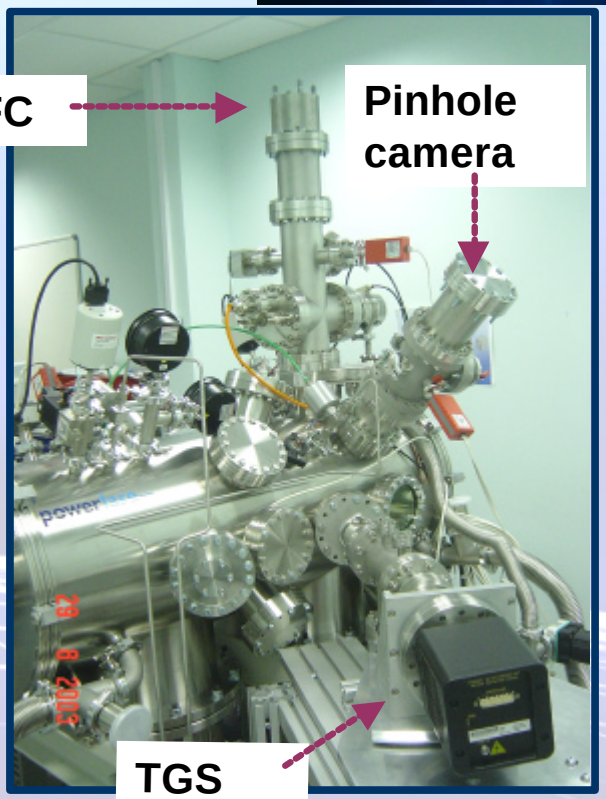
EUV Targets and Source Performance

Interaction chamber and diagnostics



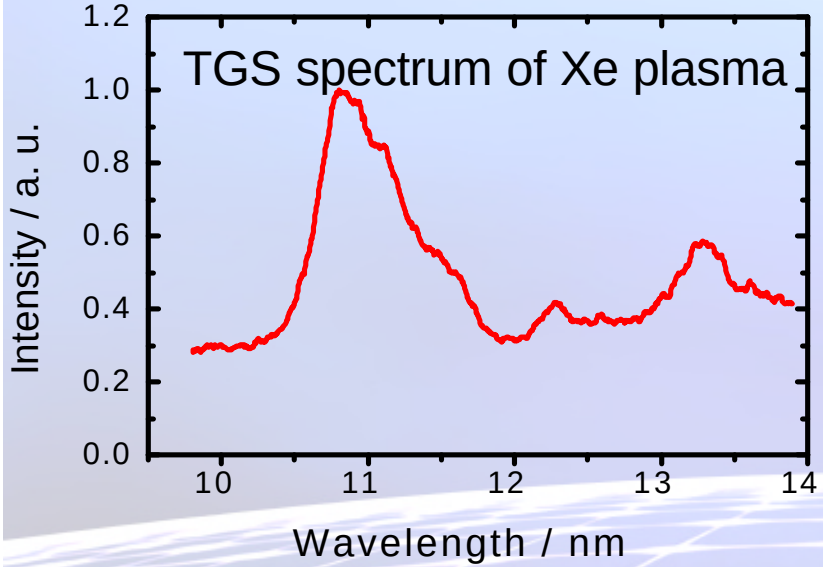
- Angular distribution
- Out-band
- Sample holder

TMP's



- Next generation system near completion to accommodate:
  - New spatial multiplexing optics
  - Larger collection optics
  - Mitigation and diagnostics systems

Xe target - recycling and contamination control

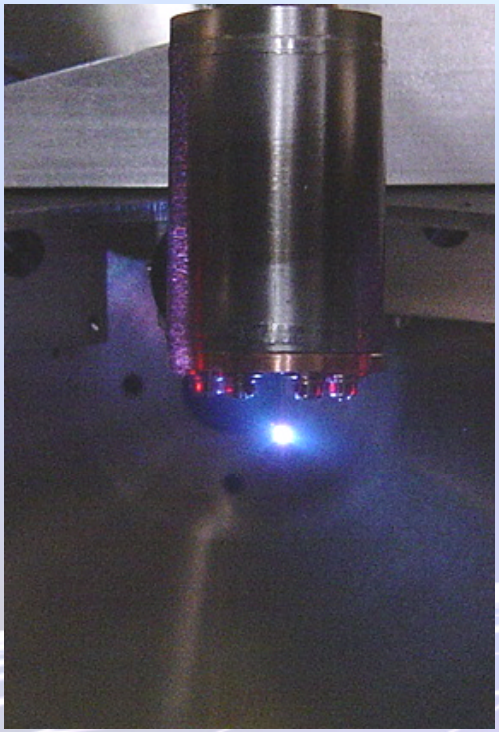


- The Xe gas is compressed up to 50 bar, recycled and purified continuously
- Extremely low Xe consumption

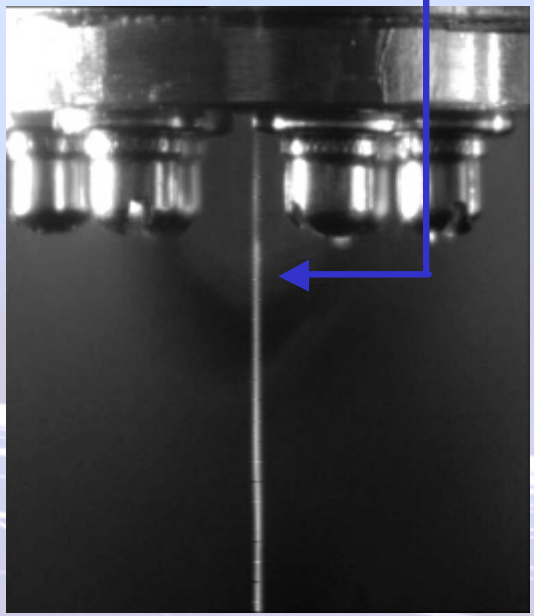
RGA is monitoring the presence of hydrocarbons and water vapour which have detrimental effect on the MLM :

- Water level (peak 18) ~10^{-9} mbar
- Hydrocarbon level was measured using RGA: $\Sigma 45..200 \leq 5\times10^{-10}$ mbar

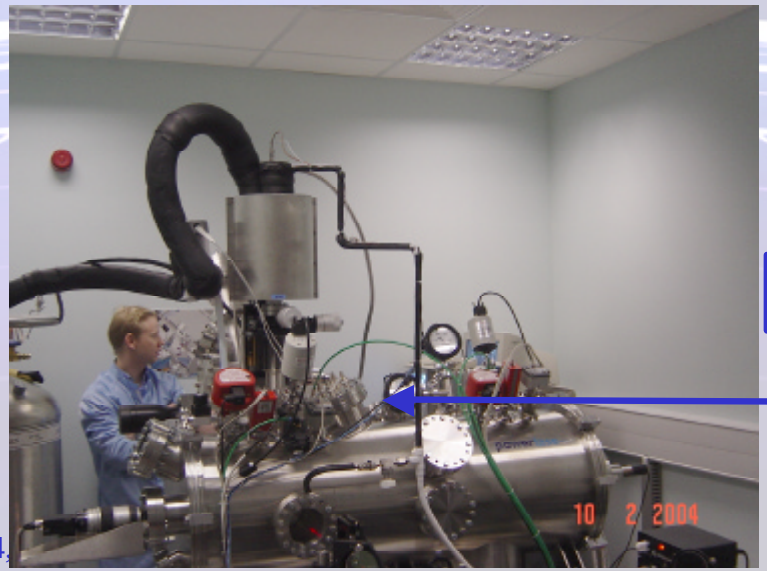
Solid Xe filaments



- Jet size ~50um
- Low Xe background ~10^{-4} mbar

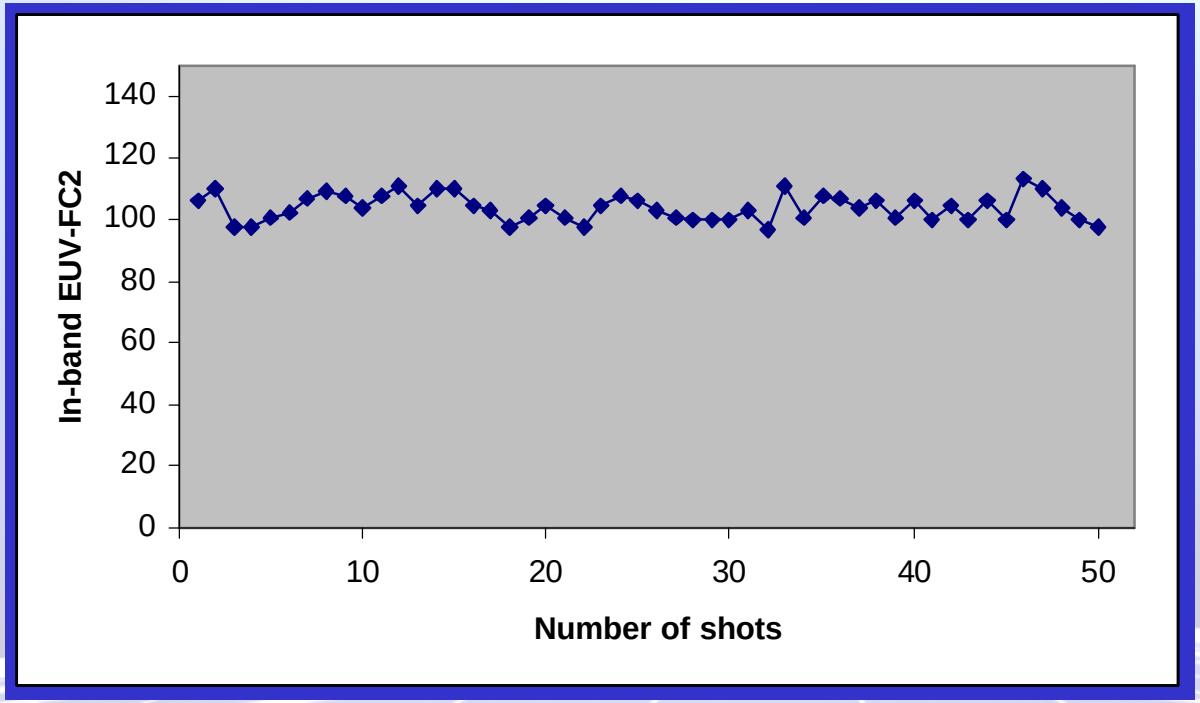


Xe Filaments



Xe Lance

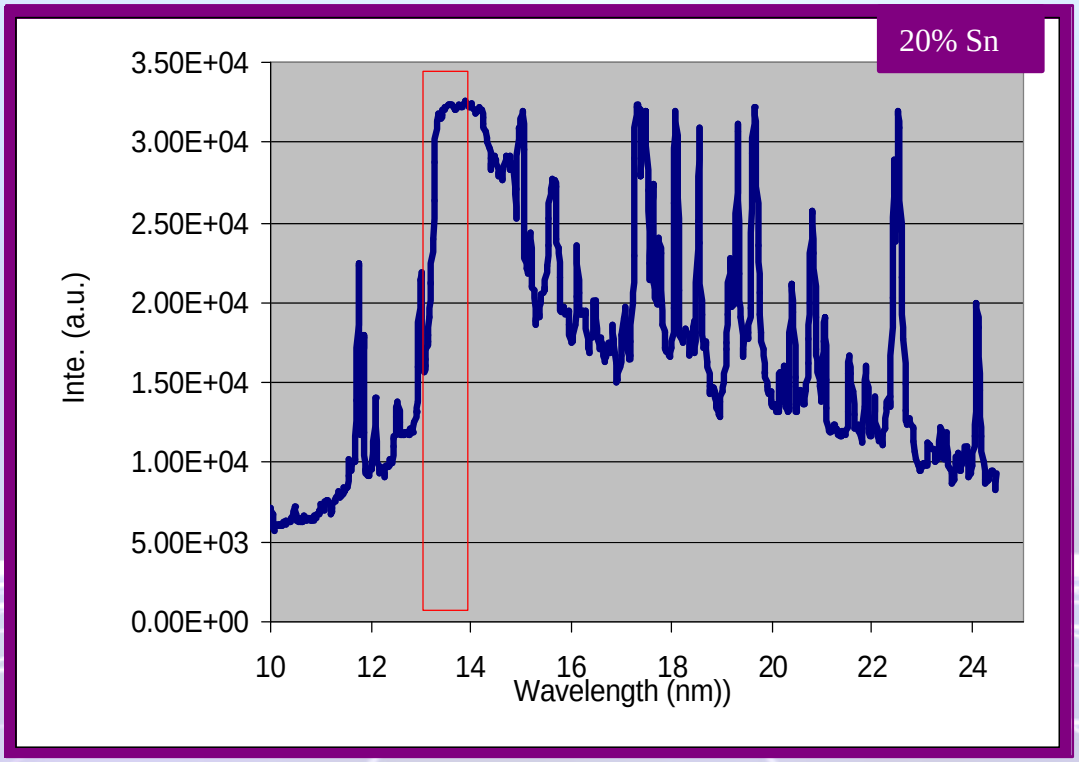
Current Xe data



- This was taken at CE of 0.4%
- 3 sigma =±1% at 60mm from nozzle
- Laser energy 200mJ
- Pulse duration 9ns

- Highest CE was achieved using 0.7%

Tin data: Powerlase result Oct. 2004



- **Highest CE of 2% was achieved using low rep rate laser with similar pulse parameters to those of our high rep rate laser.**
- **Plenty of scope for further optimisation**

Powerlase source roadmap and projected Cost of Ownership (CoO)

Scale up strategy

- **1 kW laser power demonstrated** — **Q4 2003** ✓
- **Xenon 10W demonstrator tool**
  - 3 x 1.2 kW laser modules under construction
    - Total laser power 3.6 kW — **Q1 2005** ✓
  - 0.7% CE demonstrated in LPP xenon
  - Assume 40% collection efficiency including mitigation
  - Gives ~25 W into 2π and **~10 W at IF** — **Q1 2005**

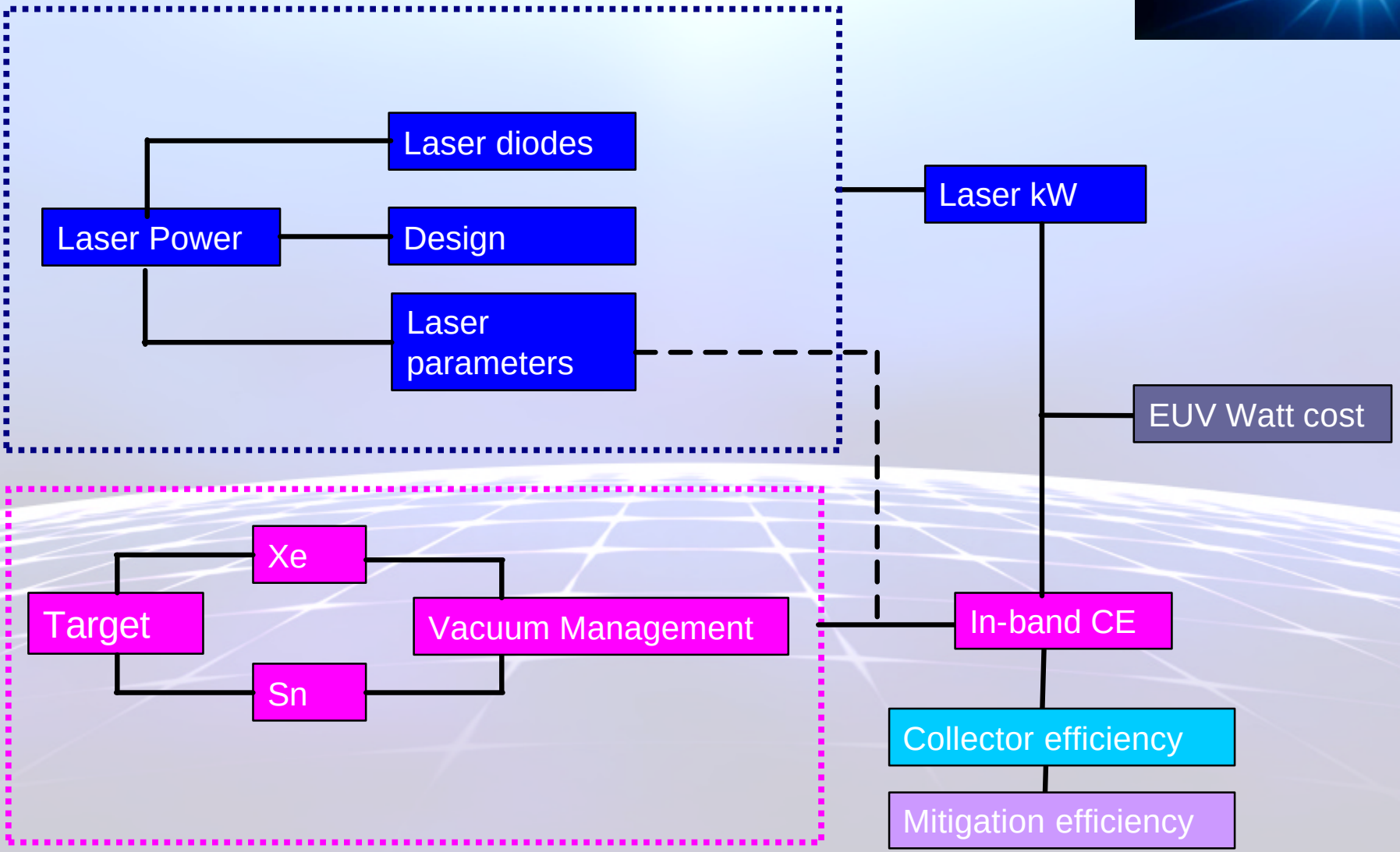
- **10 x 1.2 kW lasers can be multiplexed to 50 mm spot**
  - Total laser power 12 kW
  - 2% CE demonstrated from LPP tin target
  - Assume 40% collection efficiency including mitigation
  - Gives ~240 W into 2π and **~100 W at IF**
- **Powerlase and a partner can deliver this power in 2005/6**

Powerlase LPP source can meet industry requirements

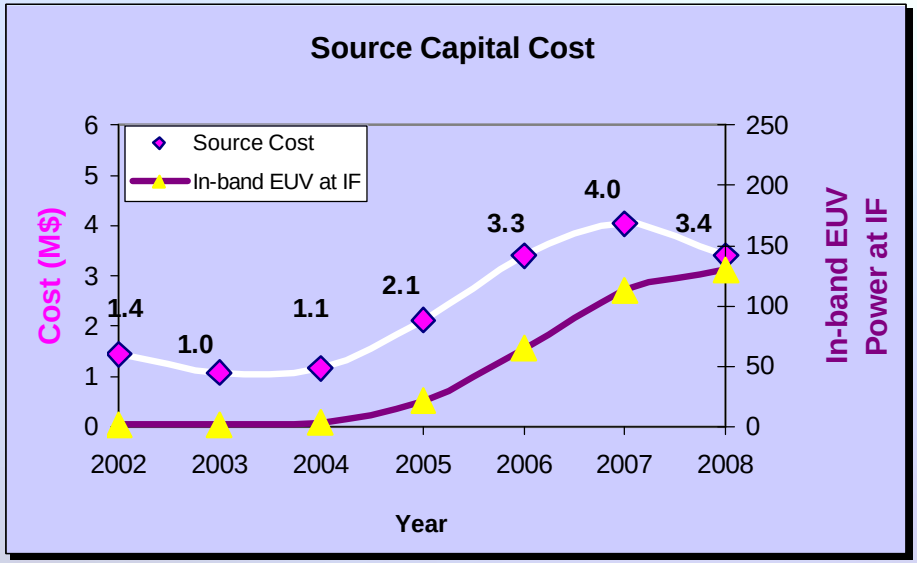
	Xenon technology							Tin technology			
	2002	Today	Q1 05	Q3 05	2006	2007	2008	Q3 05	2006	2007	2008
Solid state laser driver (kW)	0.45	1	3.6	3.9	9	25	27	3.9	9	15	16
Net CE(%)	0.5	0.7	0.8	0.9	1	1.1	1.2	1.5	2	2.2	2.5
EUV Power (w/2π)	2.25	7	29	35	90	275	325	60	180	330	400
Collection angle (sr)	5	5	5	5	5	5	5	5	5	5	5
Collection efficiency + mitigation (%)	40	40	45	45	45	45	45	45	45	45	45
EUV at IF (W)	1	2.5	10	12	32	100	120	20	65	120	140

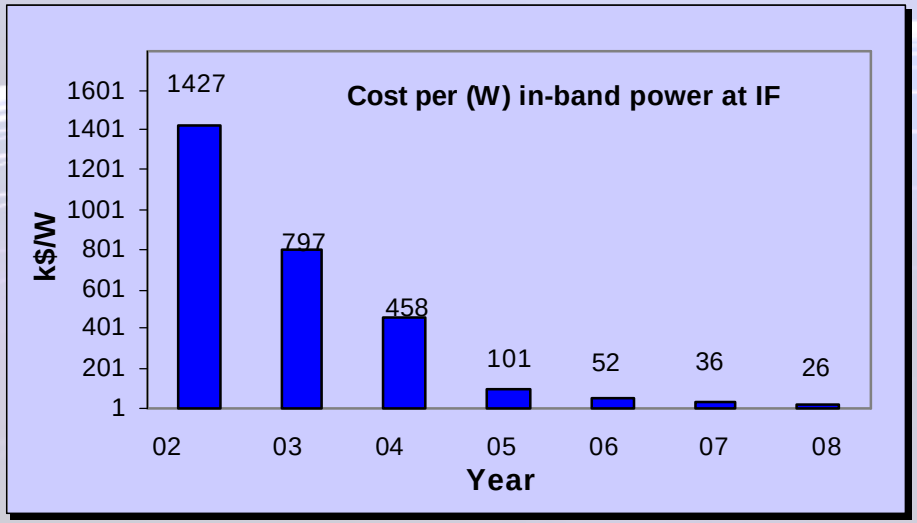
- High power laser improvements
- Xe and Sn target improvements

Projected cost of ownership model



EUV source cost projections





Cost influences

- Laser diode cost
- Laser efficiency
- Number of laser modules
- Target technology
- Collector efficiency

Summary

- Improvements in efficiencies of high power lasers for LPP sources have been made
- Alternative targets have been evaluated
- Clear and cost effective source roadmap to production level EUV source

Acknowledgements

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