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Changes for the Better

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Gain enhancements of CO_2 laser amplifiers by using transverse-gas-flow configuration to boost up driving powers for EUV generations

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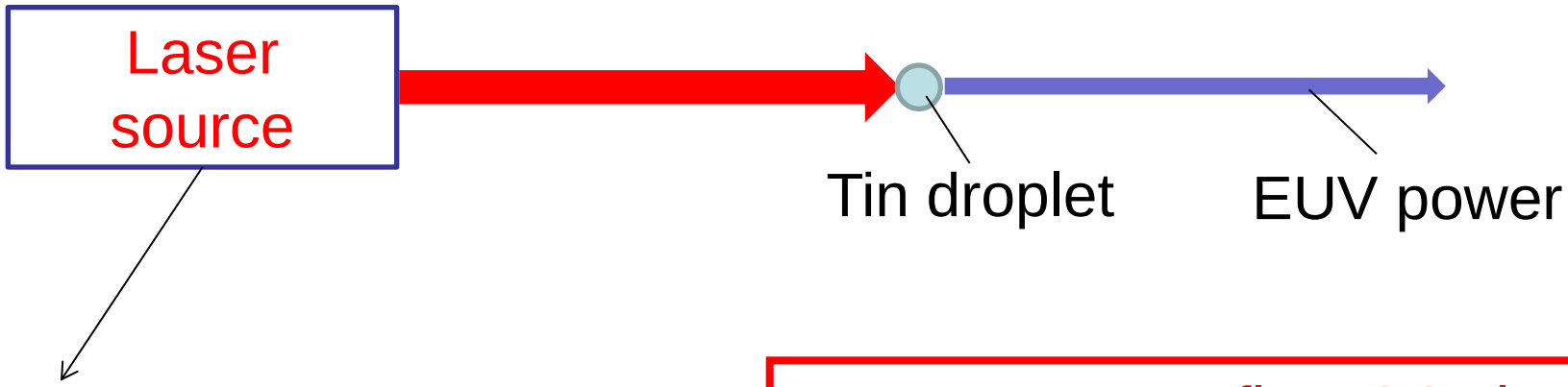
Target issues

- EUV lithography fields -

1. Not enough EUV powers achieved so far.

2. Stable EUV apparatus required for real business.
   (1)Physical stability
   (2)Business capability

Our solution proposal



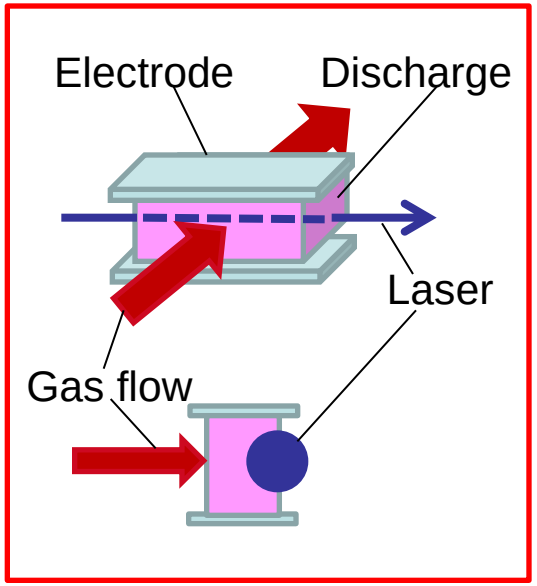
Transverse-gas-flow CO_2 lasers

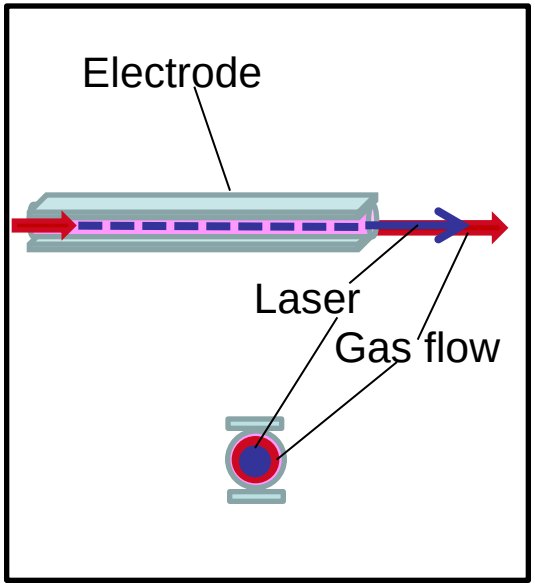
Requirements

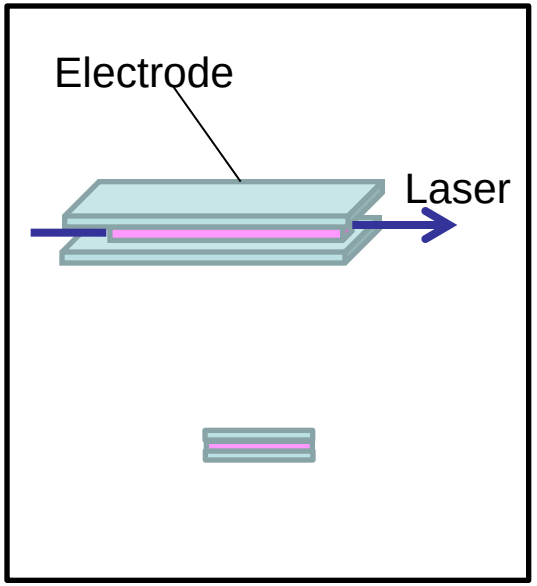
1. Enough driving powers ⇦ Higher amplifier gains
2. Physical stability ⇦ Lower gas-flow speed
3. Business capability ⇦ Cutting capability

Ⅰ. Introduction (1/2)

Transverse-gas-flow CO_2 lasers vs. other CO_2 lasers







1. Transvers-gas-flow

Low flow
+Short length
⇒Stable operation

Higher gain
⇒Higher power

2. Fast-axial-flow

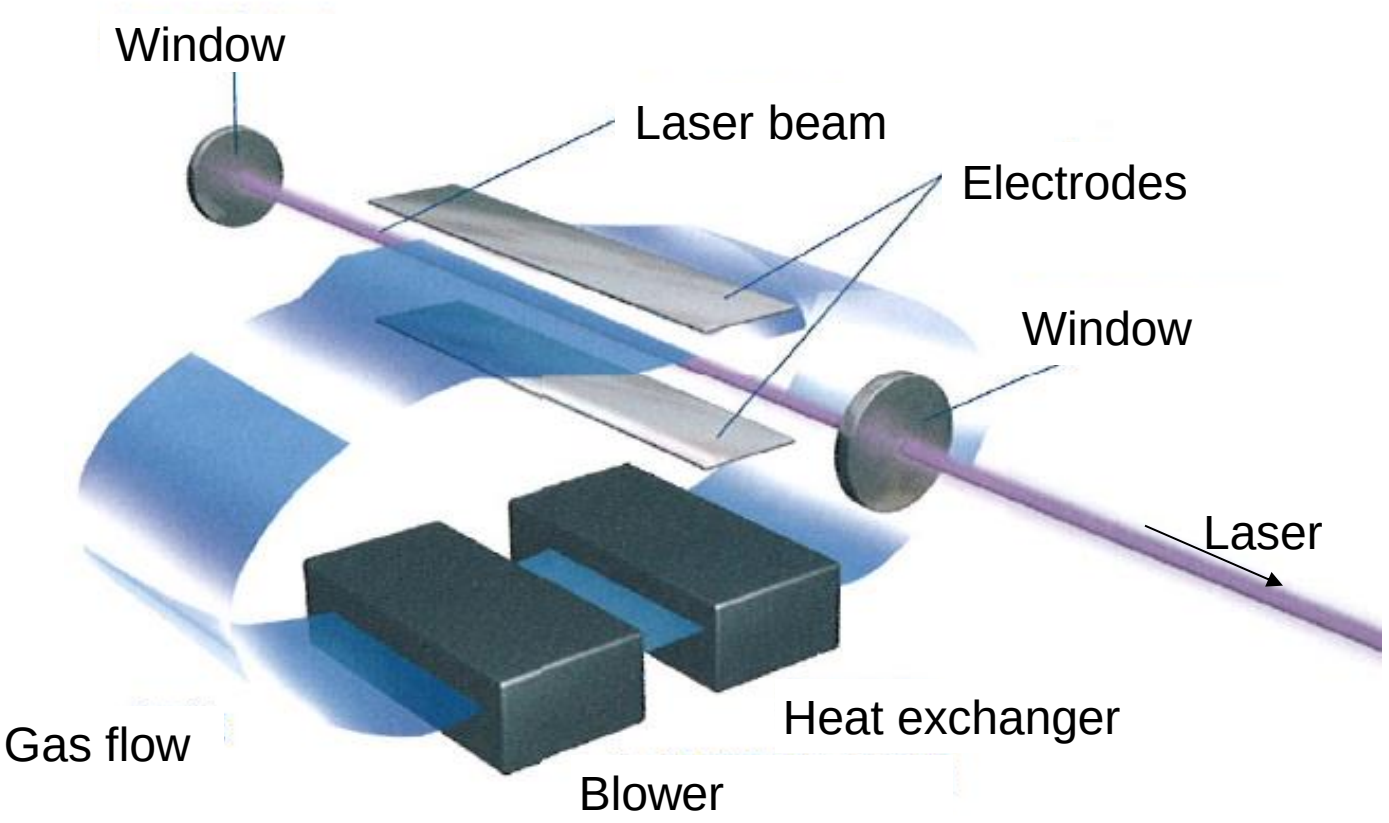
Fast flow
Long length

3. No flow

No flow
Wide area

Transverse-gas-flow CO_2 laser

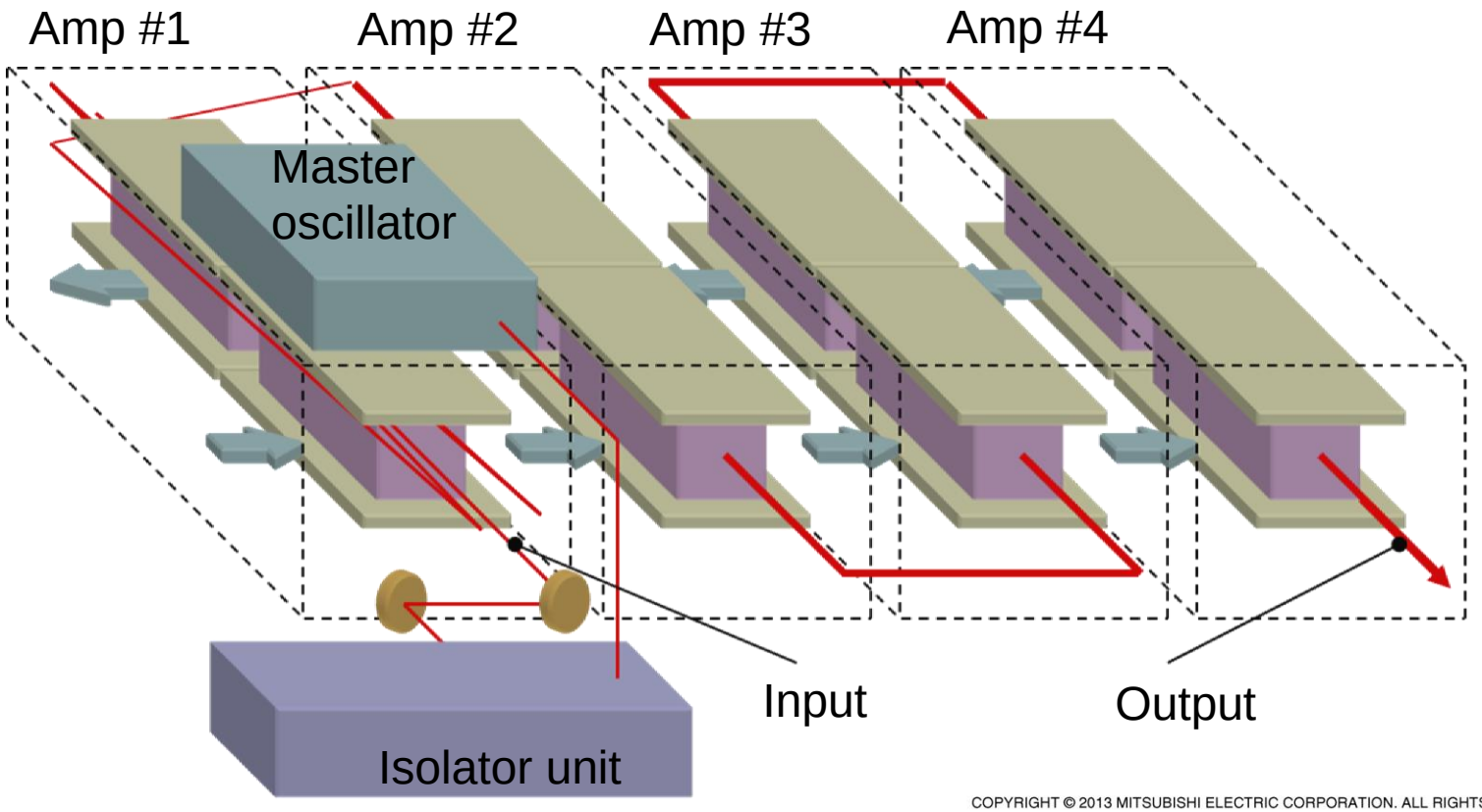
- Gas flow is flowing transversely to the laser beams



Ⅱ. Experimental apparatus (1/3)

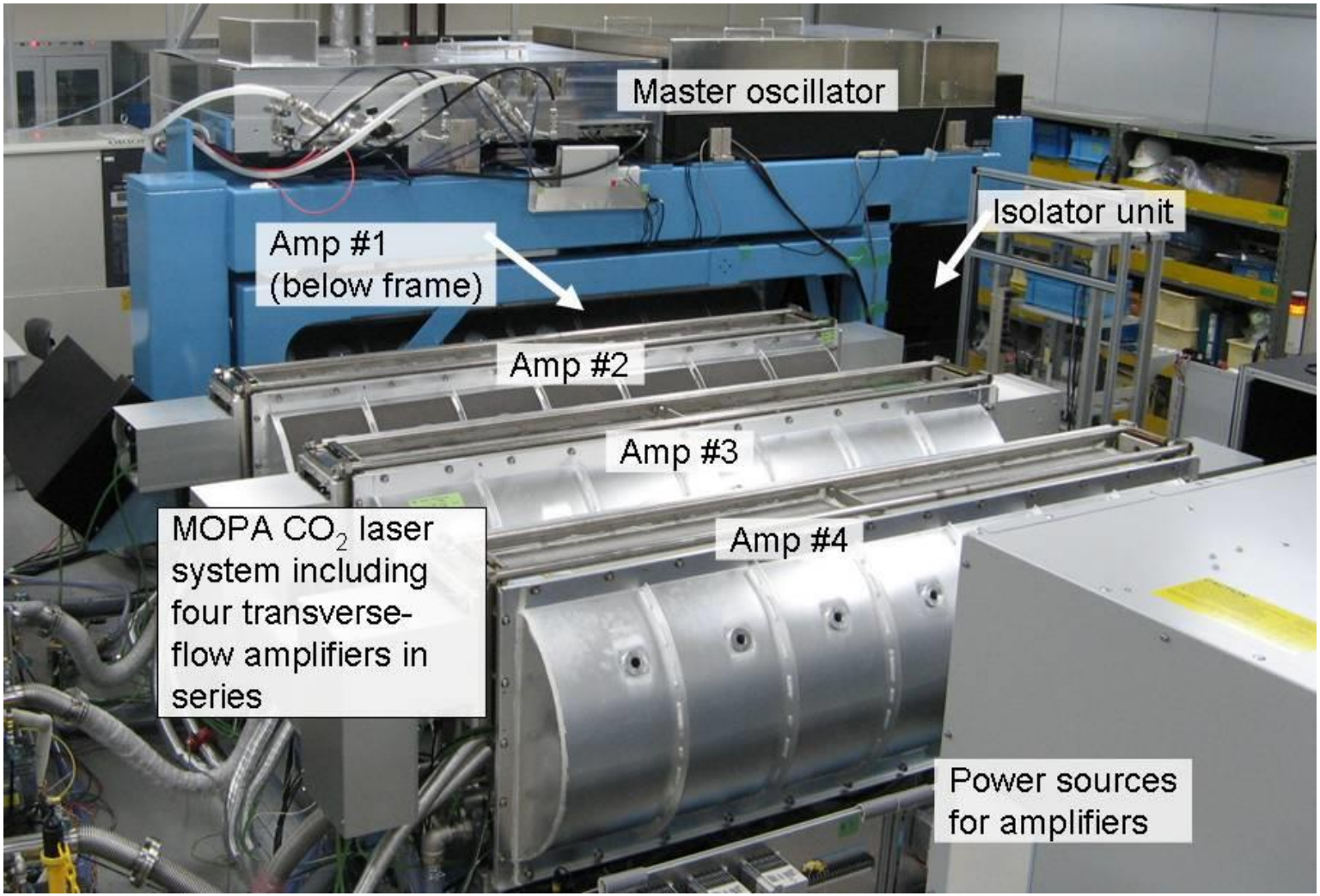
Over view

- Four transverse-gas-flow amplifiers
  - Five-folded optical path in amp #1
  - Straight paths in amp #2,#3,#4



Ⅱ. Experimental apparatus (2/3)

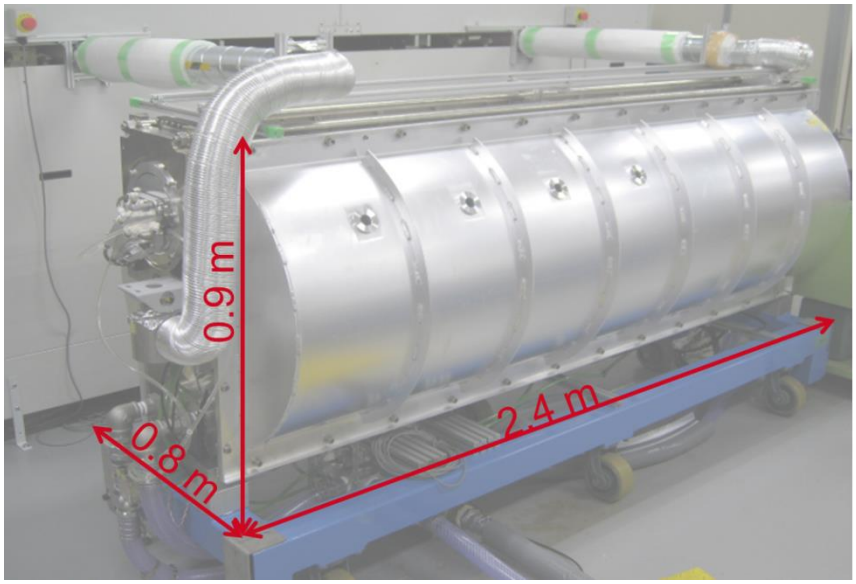
Over view



Ⅱ. Experimental apparatus (3/3)

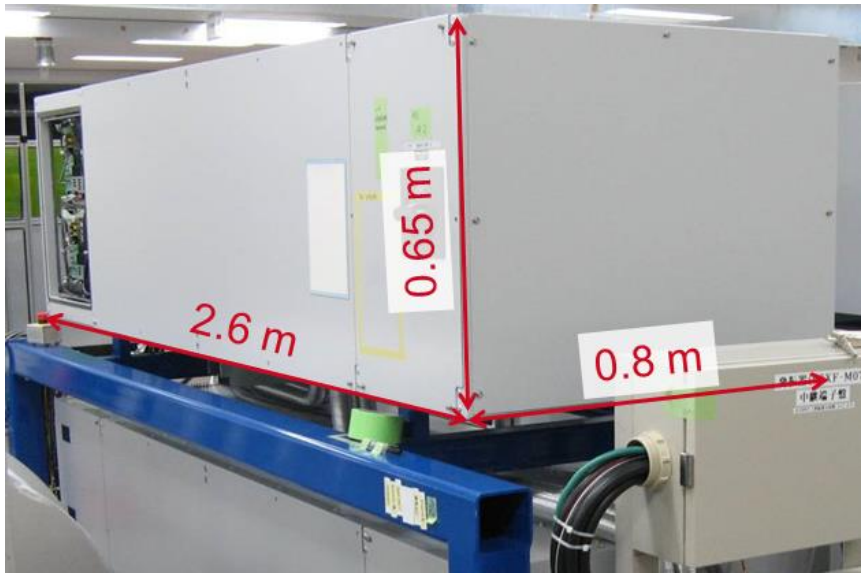
Amplifier

L2.4m H 0.9m W 0.8m



Power source

L2.6m H 0.65m W 0.8m



Ⅲ. Experimental results (1/6)

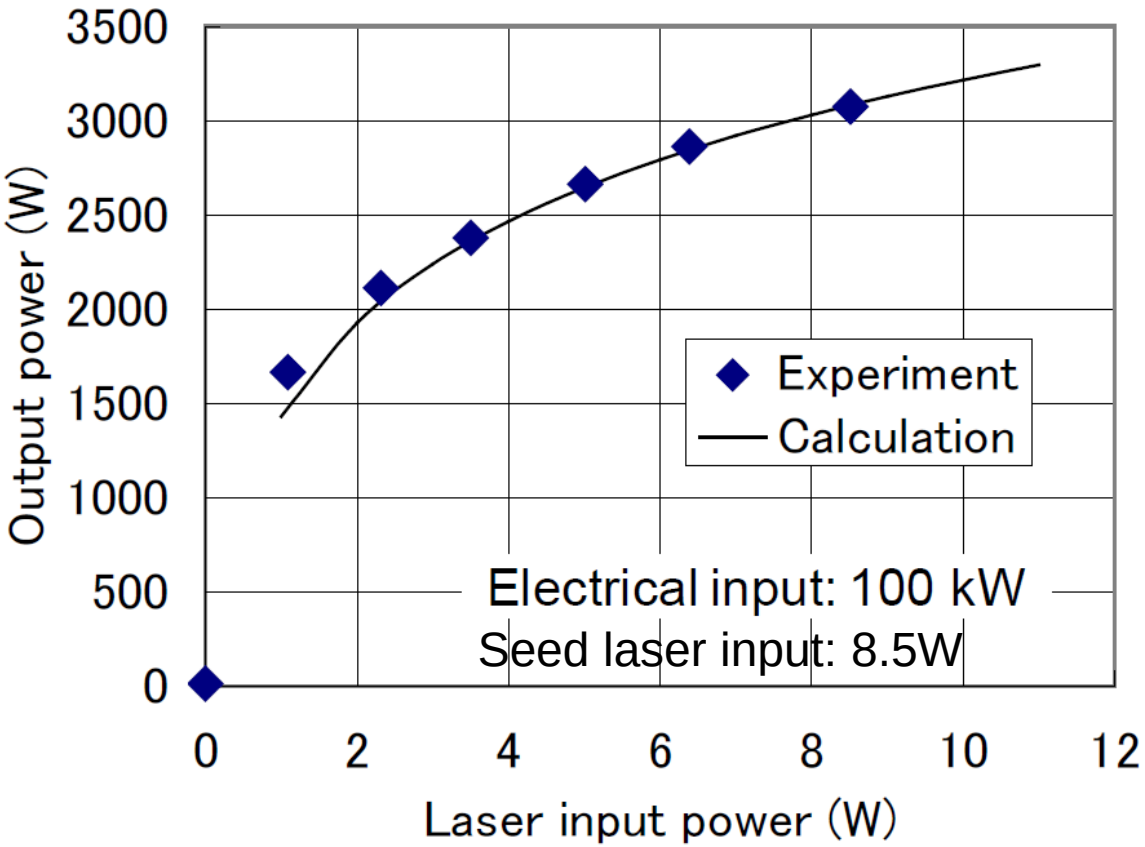
Operating conditions

- Electrical input powers for discharge: 100 kW x4, duty 33%
- Laser input: 15 ns, 100 kHz

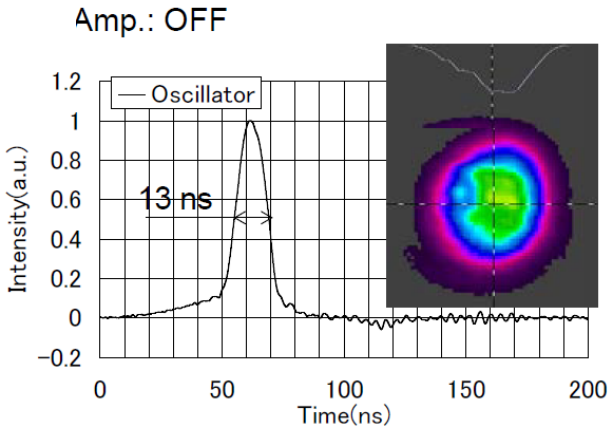
Master Oscillator	
Wavelength	10.6 um P(20,22)
Repetition frequency	100 kHz
Pulse duration	15 ns
Amplifiers	
Laser input	22 W max
Beam radius($1/e^2$)	6 mm@amp#1 , 15 mm@amp#2-4
Electrical input	100 kW max x4
Discharge duty	33%
Discharge volume	5x4x188 cm^3 x4
Gas pressure	7.0 kPa

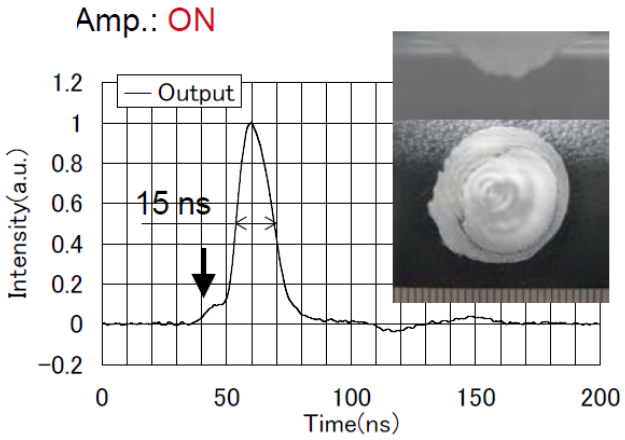
Ⅲ. Experimental results (2/6)

Single amplifier performance



Amp #1
Waveform and Beam pattern

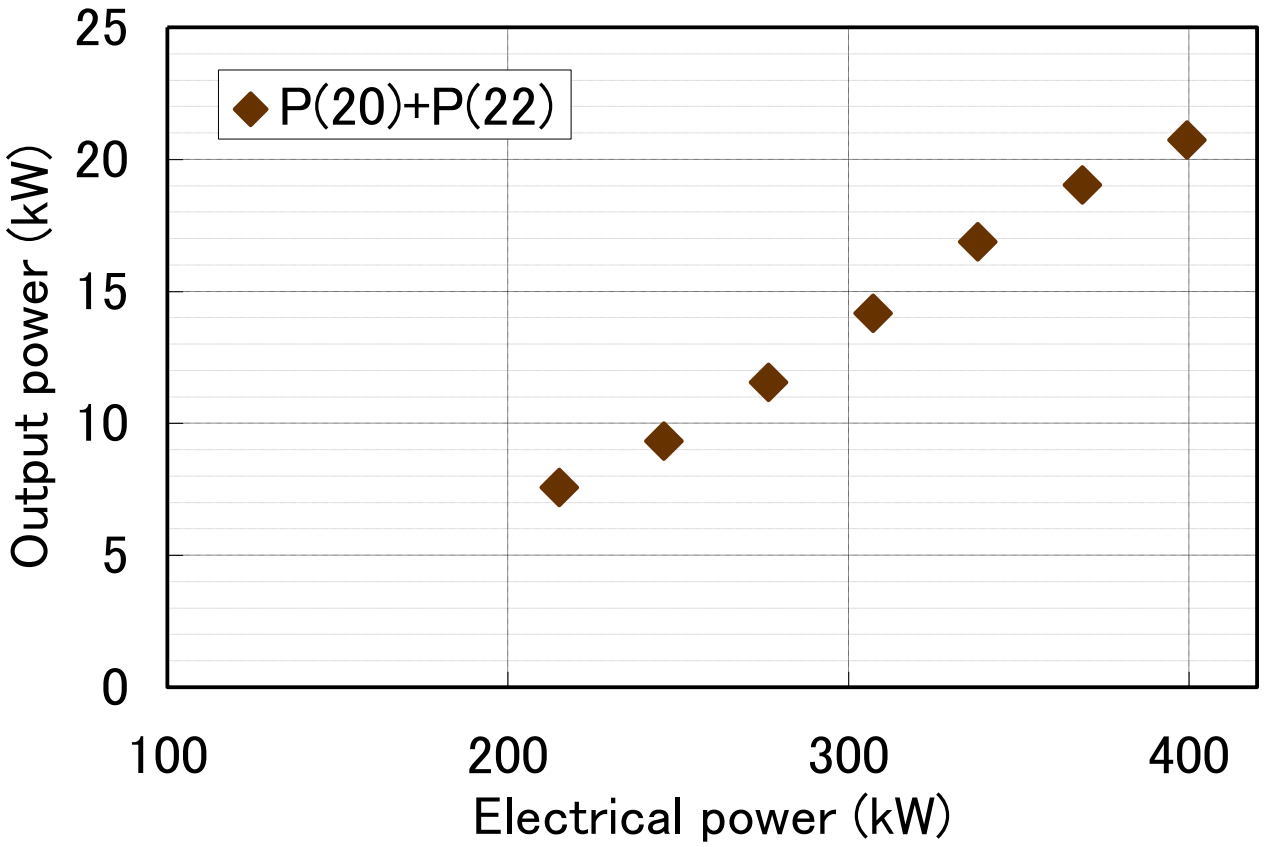




Ⅲ. Experimental results (3/6)

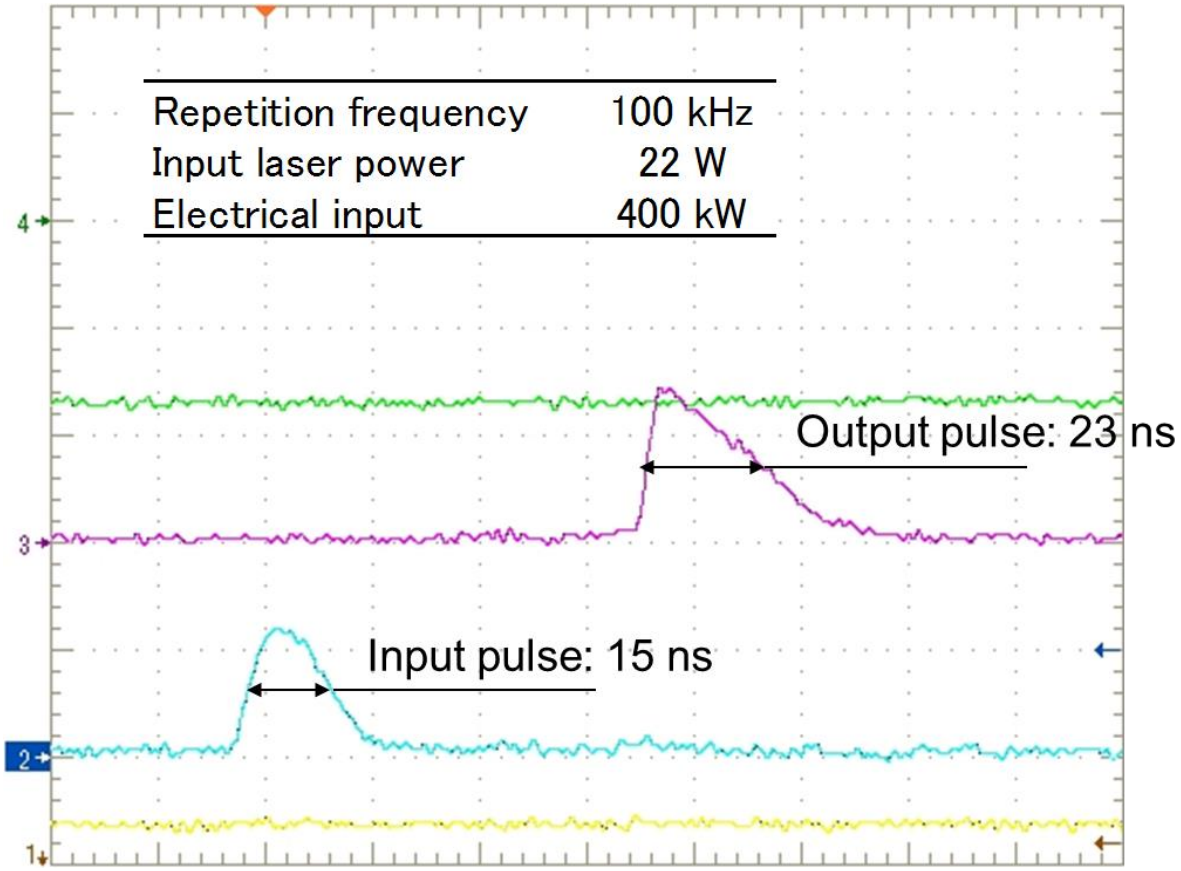
Four amplifiers driven by two-line oscillator

- Output power 21 kW was demonstrated（duty 33%）



Ⅲ. Experimental results (4/6)

Pulse shape example



- Output pulse duration: 23 ns
- Expected pulse stretch

Ⅲ. Experimental results (5/6)

Experimental results summary

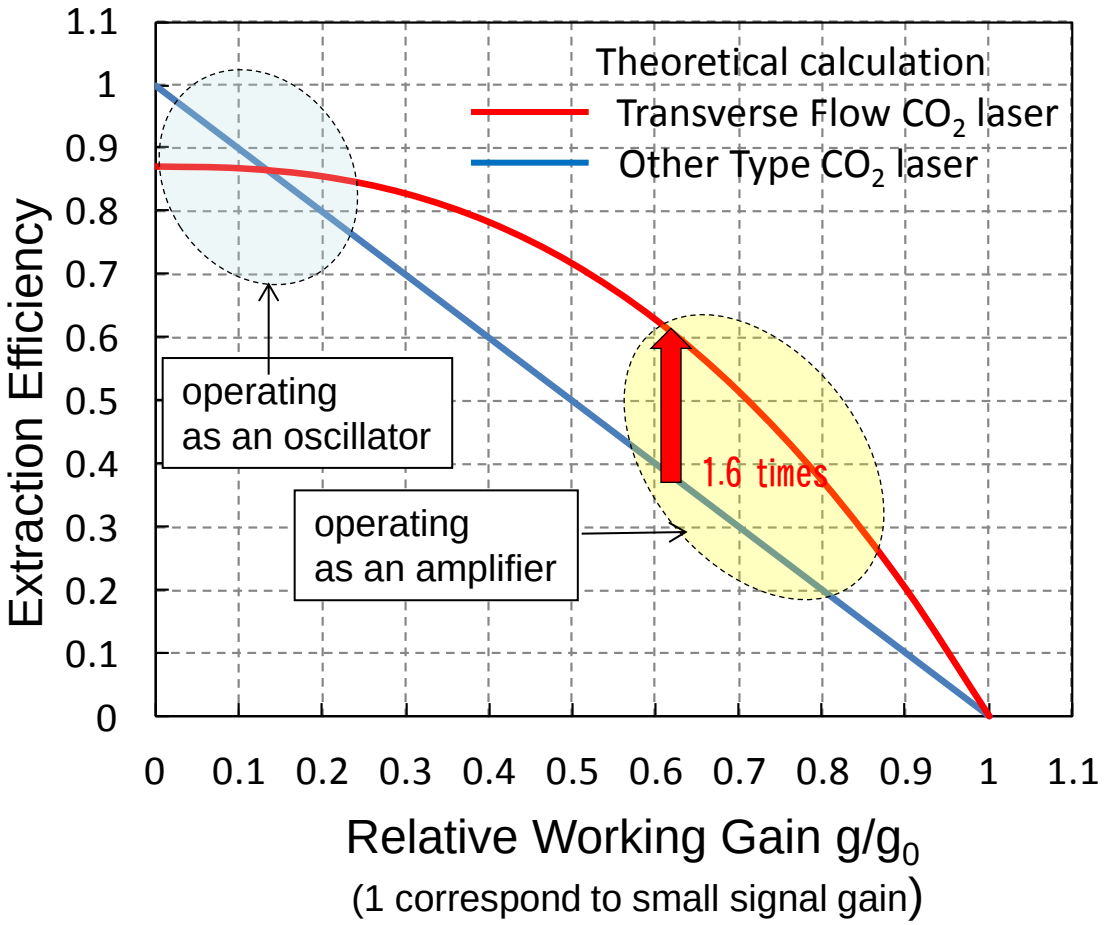
1. CO_2 laser power of 21 kW was achieved.

2. Higher power (approximately, 1.6times) was achieved compared with axial-flow CO_2 lasers at the same electrical input of 400kW.

3. Electrical-to-optical efficiency was 5.3%

Ⅲ. Experimental results (6/6)

Theoretical calculations



Ⅳ. Future prospects (1/2)

EUV generation by using transverse-gas-flow CO_2 lasers

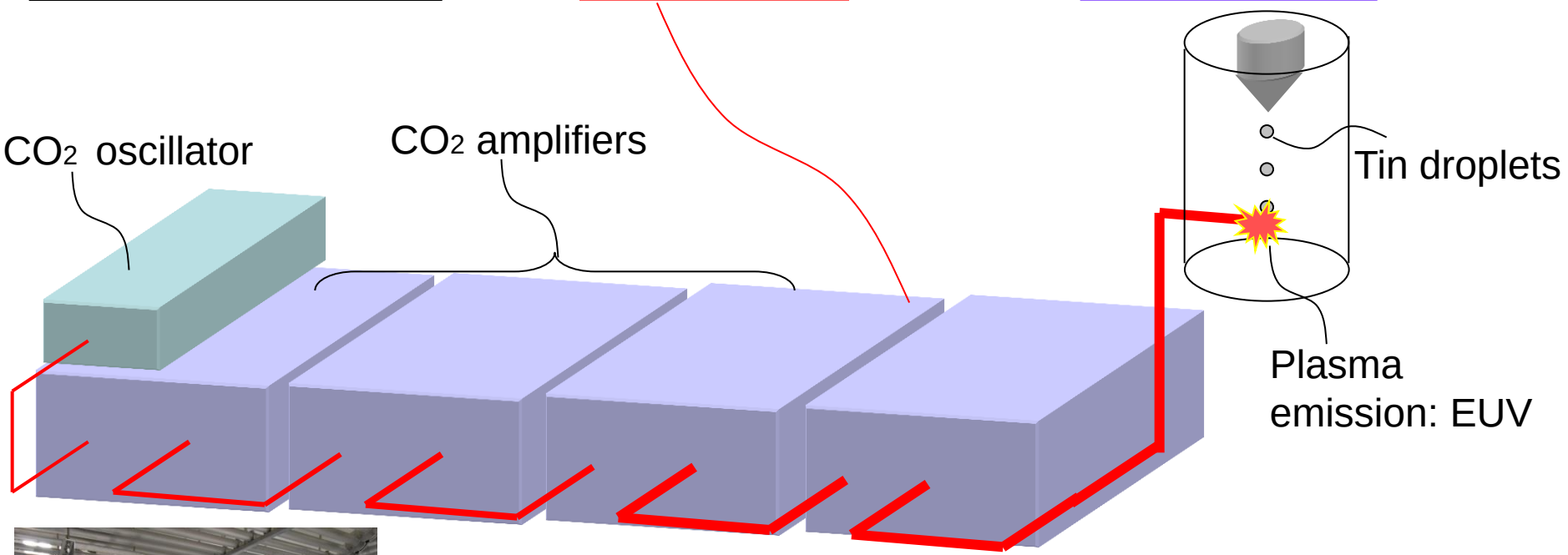
Electrical power
0.5-1 MW

→

CO_2 laser
> 20kW

→

EUV
250-500 W



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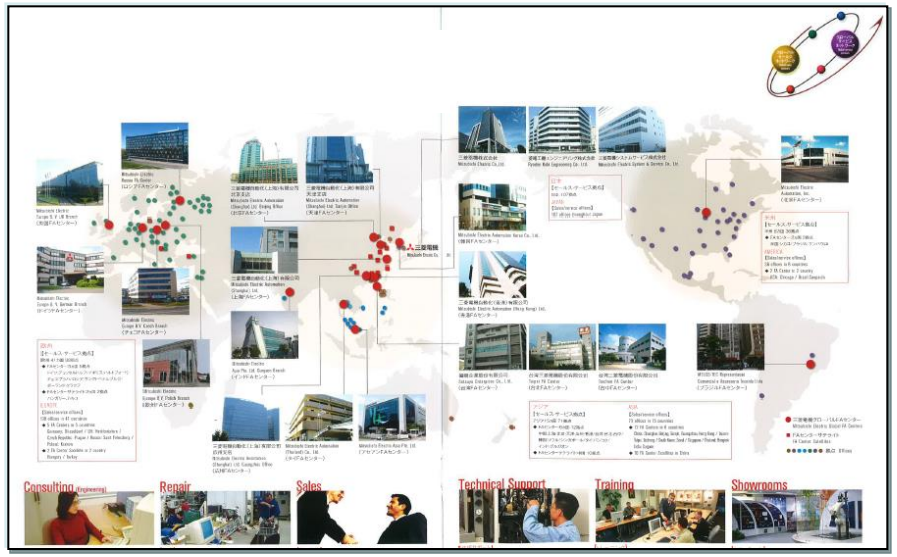
Ⅳ. Future prospects (2/2)

By applying our solution: transverse-gas-flow CO_2 lasers,

1. Driver power saturation problems could be solved.

2. Physical stability of EUV powers could be improved.

3. Reliable supply could be guaranteed backed up healthy growing material processing markets.



Acknowledgements (1/2)

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Acknowledgements (2/2)

Thank you very much for your attention.

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