High Power Laser Feasibility
-
High-Power Pulsed CO_2 Lasers

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Statements

- Our Strategy

  - We use Xenon as plasma source because - at present - we still do not have a solution for efficient Sn mitigation.
  - Sn mitigation development is very important and parallel development to Xe is necessary.
  - With established Sn mitigation technology, a Sn plasma source is possible.
  - Only CO2 laser technology can provide 60kW average laser power at the present state of laser technology (neither Nd:YAG nor Excimer nor others).

Statements

- Merits of CO2 laser technology
  - Established laser technology with high average power;
    currently > 20kW cw-CO2 lasers are available on the market (e.g. cutting, welding) ⇔ different situation as compared to Nd:YAG and Excimer lasers
  - High beam quality ⇔ Nd:YAG laser wavefront distortion
  - High wall-plug efficiency of 20%, as cw-Nd:YAG lasers
  - Low cost per kW ⇔ 1/5 - 1/10 of Nd:YAG and Excimer laser

- Required technology for a EUVL application
  - A laser pulse length of 10ns.
  - A short pulse CO2 oscillator with amplifier stages.

LPP EUV Source Roadmap

Item	1st Mid term 2004/9	2nd Mid term 2006/3	EUVA Final 2008/3	HVM Source (2009)
EUV Power (IF)	5.7W	10W	50W	115W
Stability	---	σ<±10%	σ <±5%	3 σ <±0.3%
Laser	YAG:1.5kW	CO_2*:7kW	CO_2*: 30kW	CO_2*: 60kW
Laser freq.	10kHz	100kHz	100kHz	100kHz
CE (source)	0.9%	0.5%	0.6%	0.7%
Target	Xe-Jet	Xe-Droplet	Xe-Droplet	Xe-Droplet

***with Pre-Pulse YAG Laser**

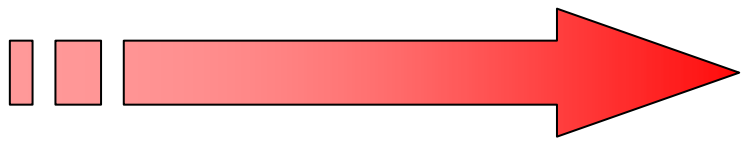
Technology for 10W

Nd:YAG Laser, Liquid Xe jet

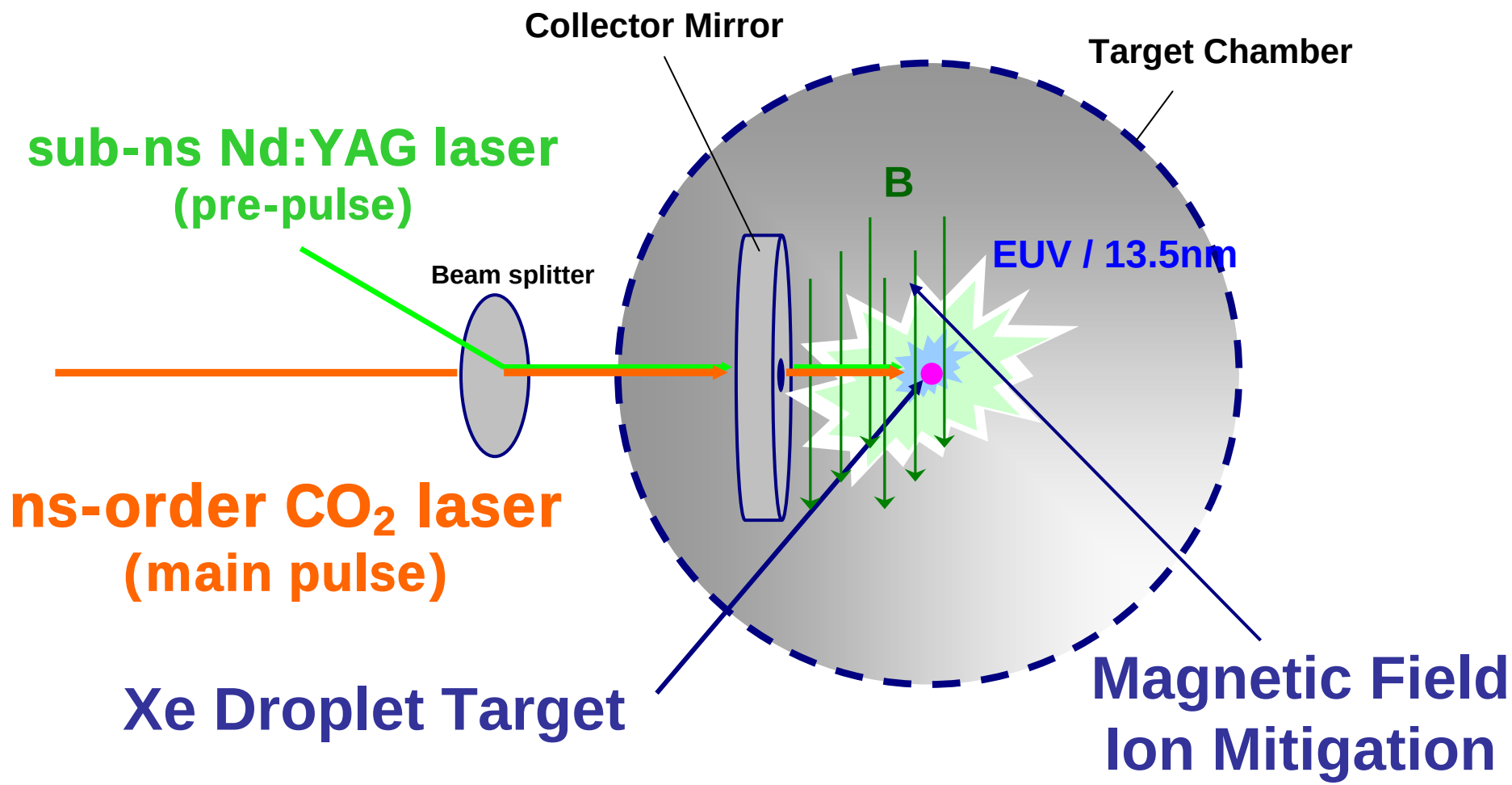
Technology for 115W

CO_2 Laser, droplet target

Magnetic field mitigation



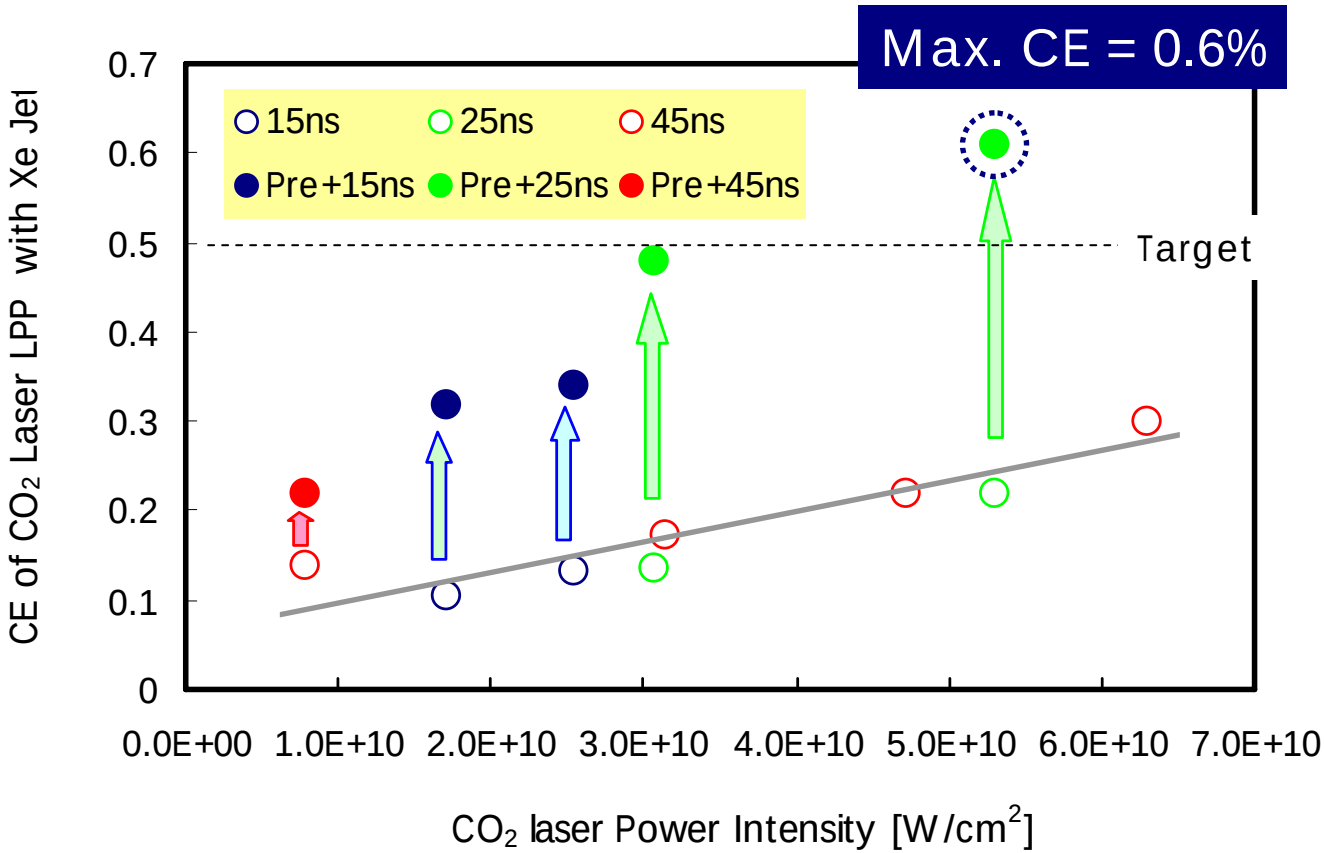
New LPP Light Source Concept



Conversion Efficiency (CE) of 0.6 % has been achieved (Xe Jet)

Conversion Efficiency of pre-pulsed CO2 laser Plasma

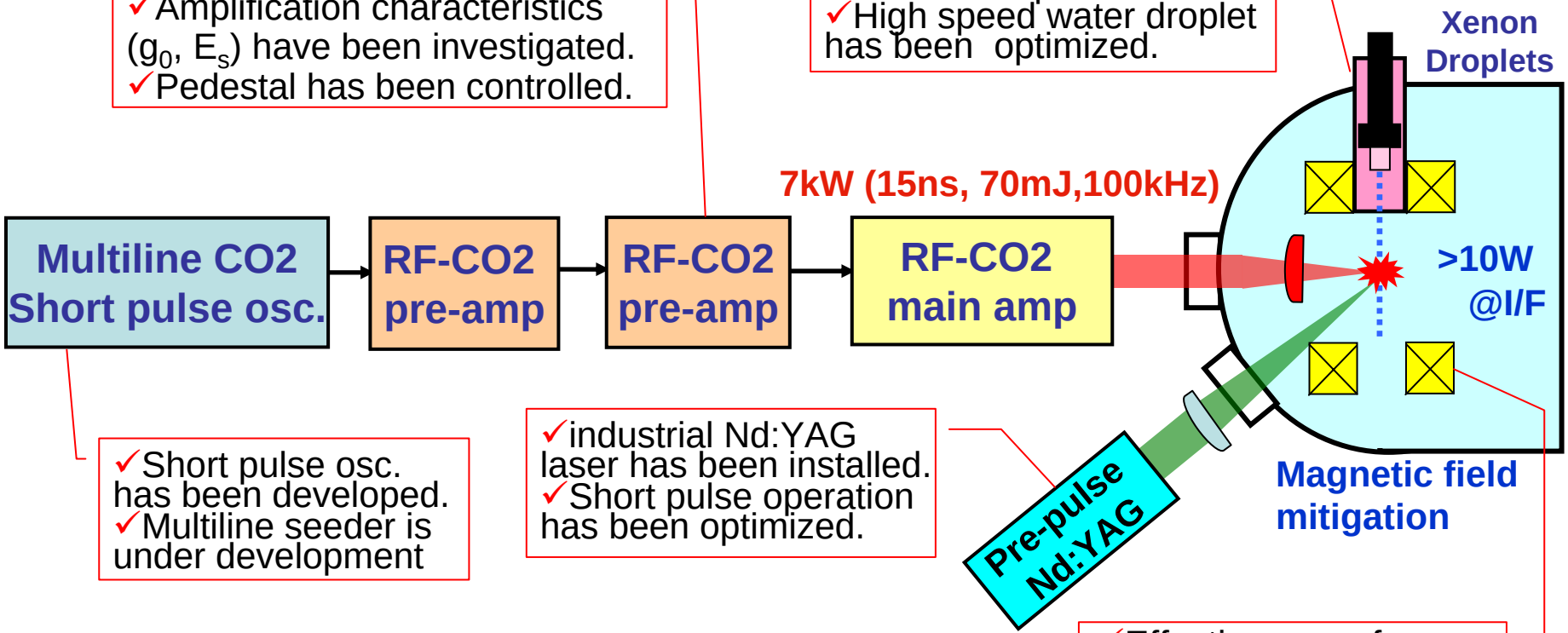
Pre-pulse laser increases CE significantly:



CO_2 laser based 10W-EUV system

✓Industrial RF-CO2 lasers have been installed.
✓Amplification characteristics (g_0, E_s) have been investigated.
✓Pedestal has been controlled.

✓High speed Xe droplet is under development.
✓High speed water droplet has been optimized.



✓Short pulse osc. has been developed.
✓Multiline seeder is under development

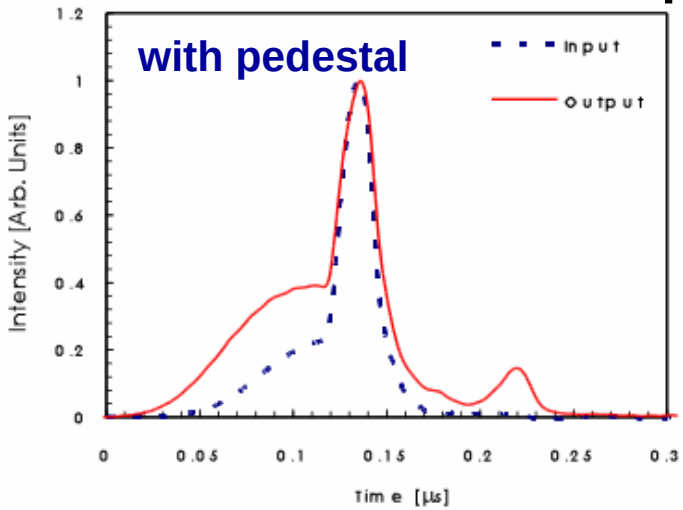
✓industrial Nd:YAG laser has been installed.
✓Short pulse operation has been optimized.

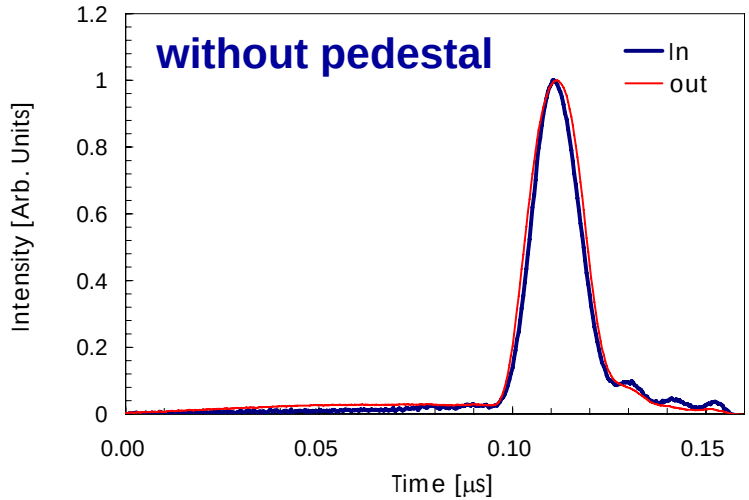
✓Effectiveness of magnetic field mitigation has been confirmed for pre-pulsed CO2.

System operation : 1Q/2006

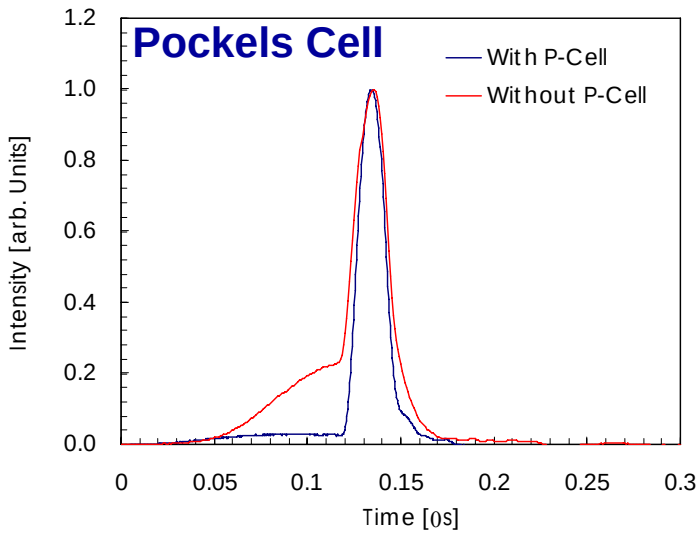
Pedestal control

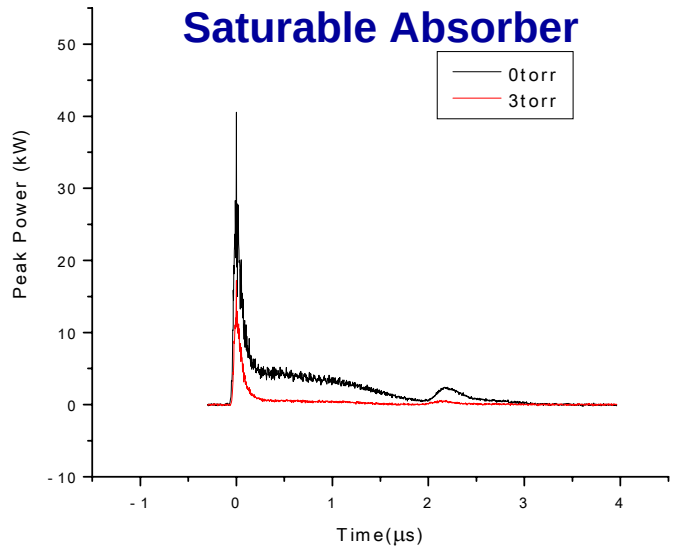
- **Amplification with and without a pedestal**



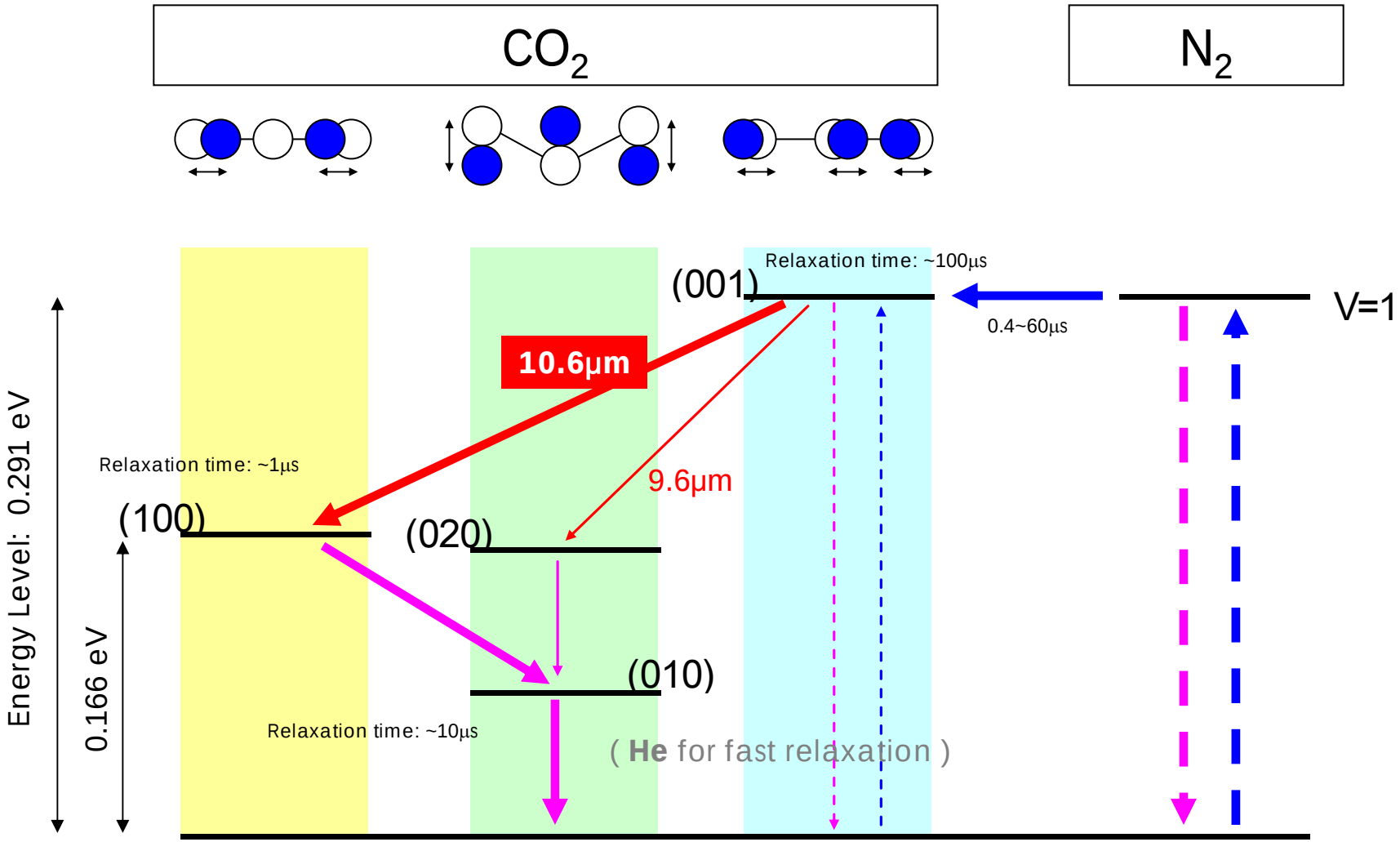


- **Pedestal control by pockels cell and saturable absorber**



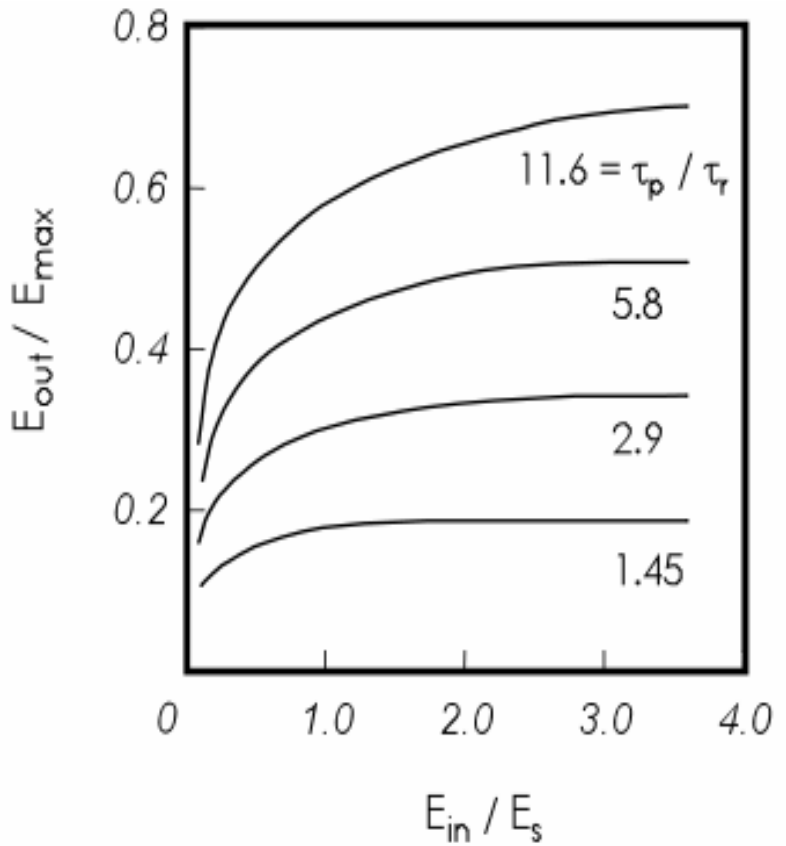


Energy Levels of CO_2 Laser (vibration)



Quantum efficiency: (0.291eV-0.166eV)/0.291eVx100=43%

Extraction Efficiency



Transition from cw to pulsed operation

Es : saturation fluence [J/cm^2]
Emax :maximum output fluence
Ein : input fluence
Eout : output fluence

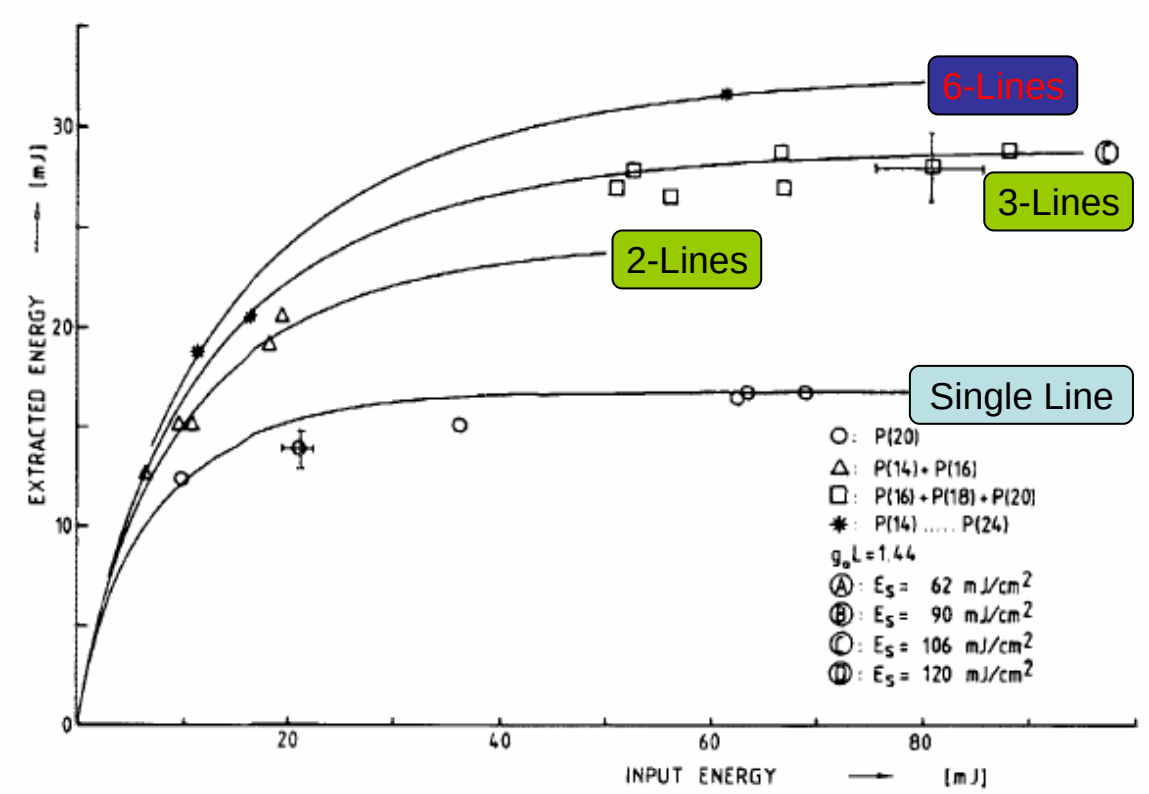
Tp : laser pulse width

Tr **:** rotational relaxation time, 1.5ns

Target wall-plug efficiency for pulsed CO_2: 10% (multiline-RF-CO_2)

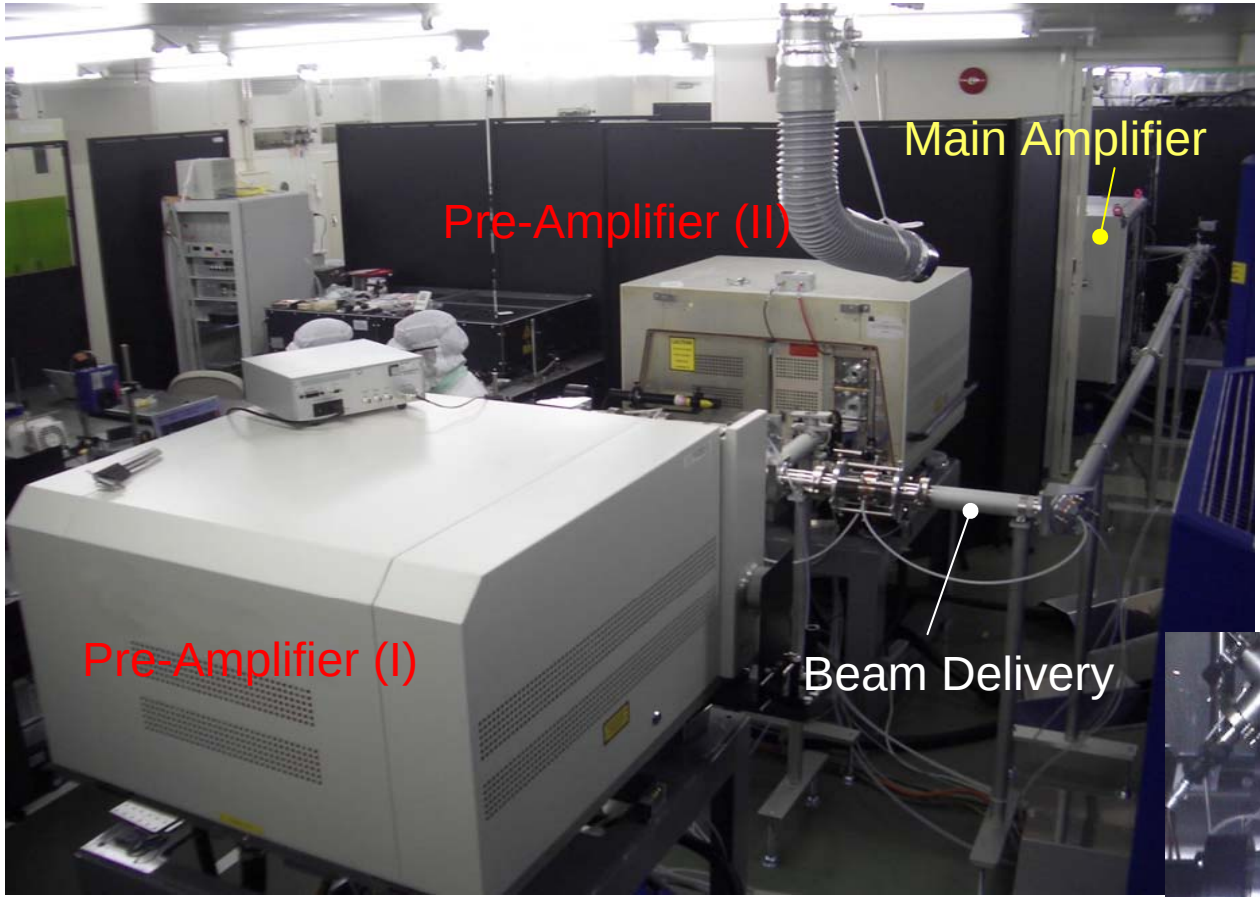
Multi-line amplified CO_2 laser concept

About twice the laser energy was extracted using 6-line amplification.

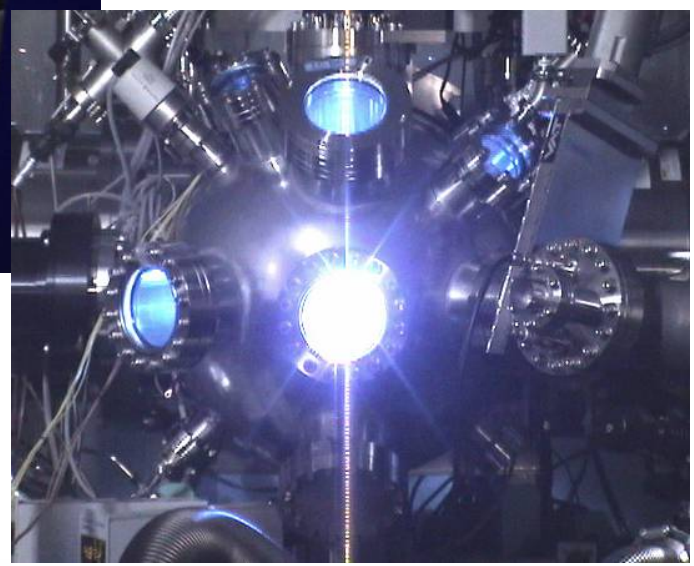


Rooth et. al., J. Appl. Phys., 58, pp. 1120, (1985).

RF-CO2 laser based 10-W LPP system



Target Chamber



Summary

Laser Technology	Average Power (kW)	Pulse Width (ns)	Op Freq. (k Hz)	CE -Wall Plug to Laser light (%)	Capital cost ($M)	Operation Cost /year ($M)	Investment Required to meet HVM Technical Requirements ($M)	Expected Date to meet HVM Goal	Main Risk 1	Main Risk 2	Main Risk 3
Pulsed CO_2 Lasers											
EUVA										EUV system	EUV system
Today (10W)	*(7)*	*15*	*100*	*5*			*20*		*capital*	*(power)*	
Limit	*100*	*1*	*150*	*15*				*2009*	*capital*	*collector mirror lifetime*	*thermal management*
HVM Goal	**10-20 kW**	**10-110**	**> 10**	**TBD**	**TBD**	**TBD**	**TBD**	**2009**			

thank you for your attention !