Scaling of short pulse CO_2 laser into multi 10kW output power

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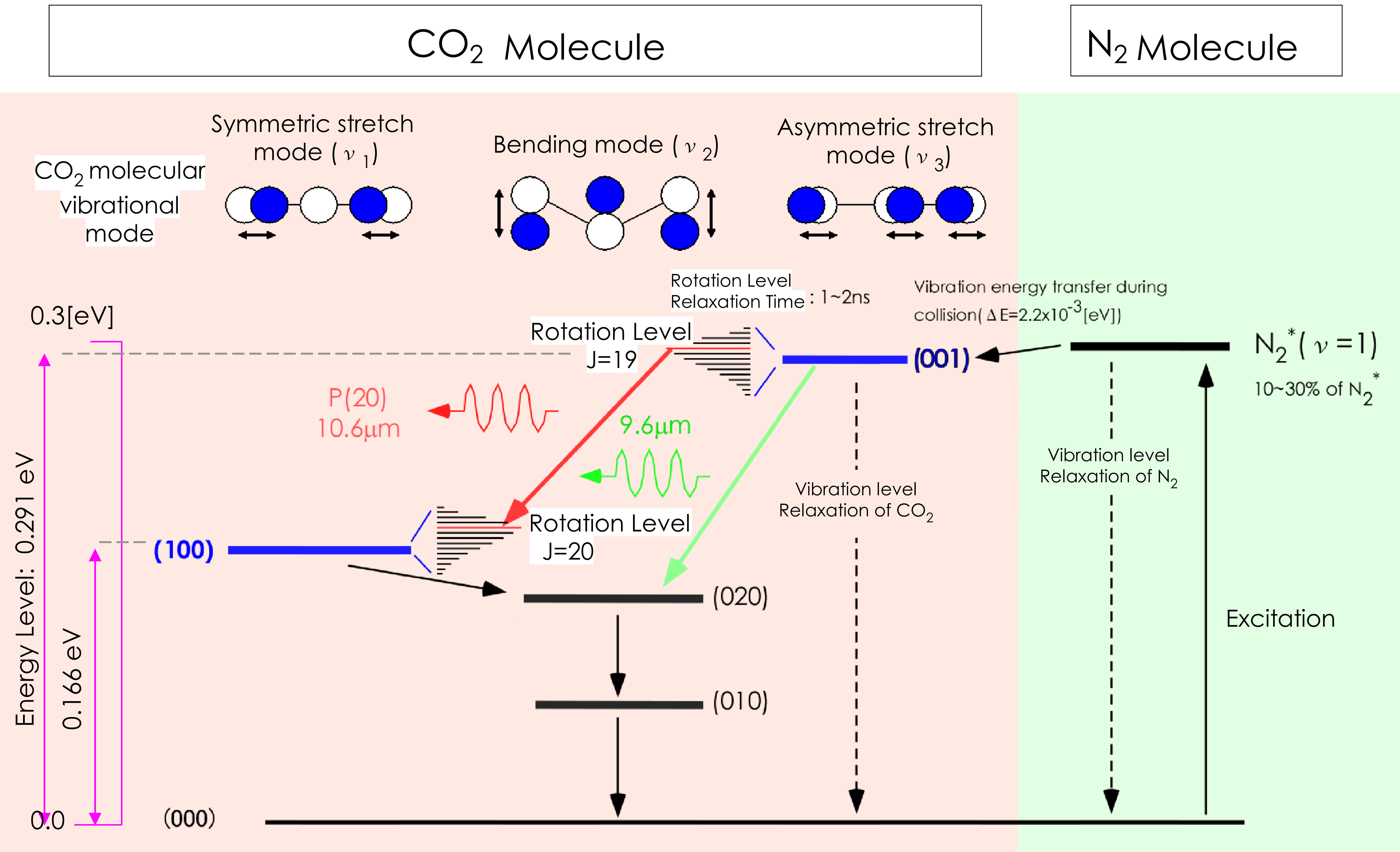
Abstract
Scaling of a short pulse CO_2 laser to multi 10kW output power is done based on recent amplification experiments with a RF-pumped gain module of sub 10kW level. The limitation of the scaling is the damage of optical components, which is close to the cw damage limit, and not wavefront aberration as for solid state laser. Especially, the CO_2 laser cost ($/kW) decreases with increasing output power.

§ Vibrational - Rotational CO_2-N_2 Laser Energy Level Diagram



§ Rotational relaxation time (RF-excited CO_2 laser)

$$\tau_r = [7.58(\phi_{CO_2} + 0.73\cdot\phi_{N_2} + 0.64\cdot\phi_{He})\cdot P\cdot\sqrt{\frac{300}{T}}.10^6]^{-1}$$

Φ: partial ratio
P: Pressure [torr]
T: Temperature [K]

"Broadening coefficients for the P(20) CO_2 laser transition", R.L.Abrams, Appl. Phys. Lett. 25, pp.609, 1974

τ_r = 2.3 ns

Typical Gas Parameter
- CO_2:N_2:He=1:1:8
- Pressure: 100[torr]
- Temperature: 450[K]

§ Short Pulse Amplification

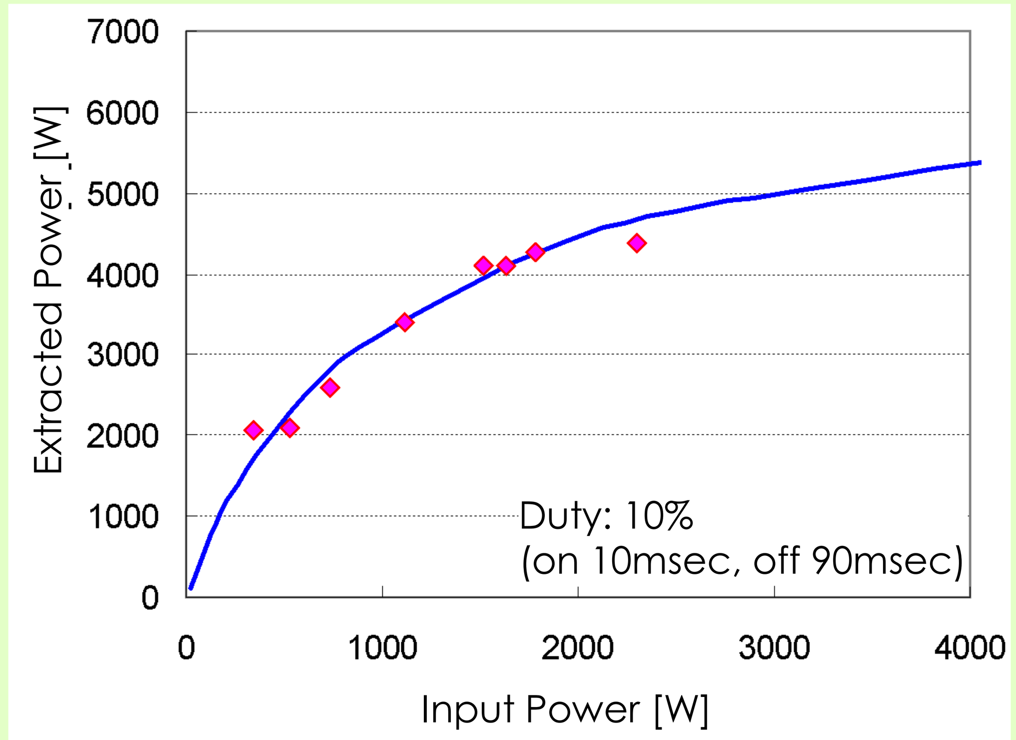
- τ_r is finite within pulse duration (~50 ns)
- Extracted power is decreased compared to the case of CW amplification

§ Estimated amplification with RF-excited CO_2 laser

★ Frantz - Nodvik Equation $E_{out} = E_s \cdot \ln[(1+\exp(g_0\cdot L)[\exp(\frac{E_{in}}{E_s})-1]]$

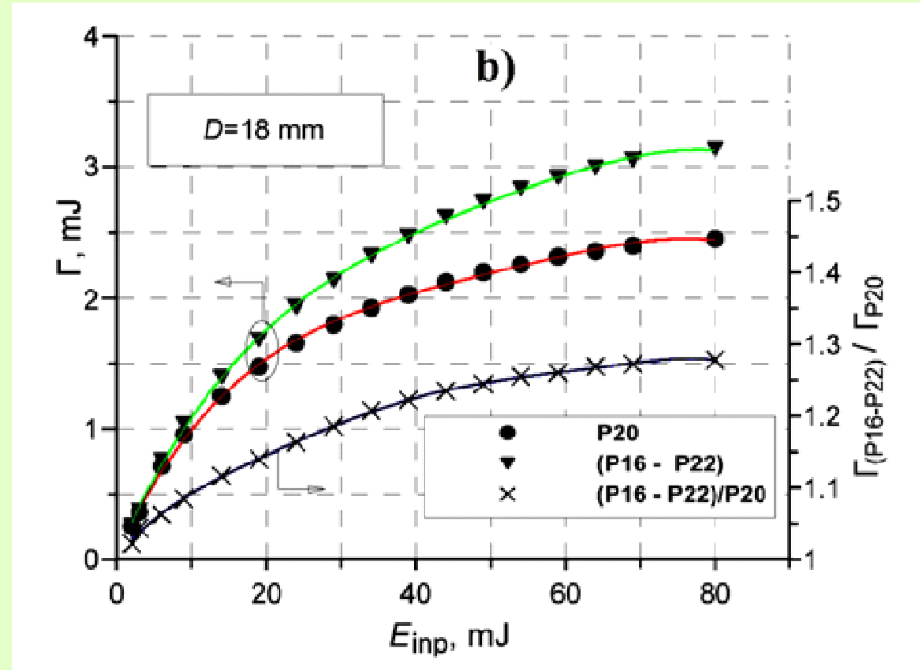
Ein : input fluence [J/cm^2]
Eout : output fluence [J/cm^2]
g_0 : gain [%/cm]
Es : saturation fluence [J/cm^2]
l : gain length [cm]

Experimental result of Extracted Power with Single-Line Oscillator and 15 kW amplifier module at 100 kHz



- ◆ - is the extracted power of amplification result.
Extracted power estimation is over 5 kW.
Extracted efficiency is over 5.5% from pumping power

Numerical Calculation Result of Amplification with Multi-Line Oscillator



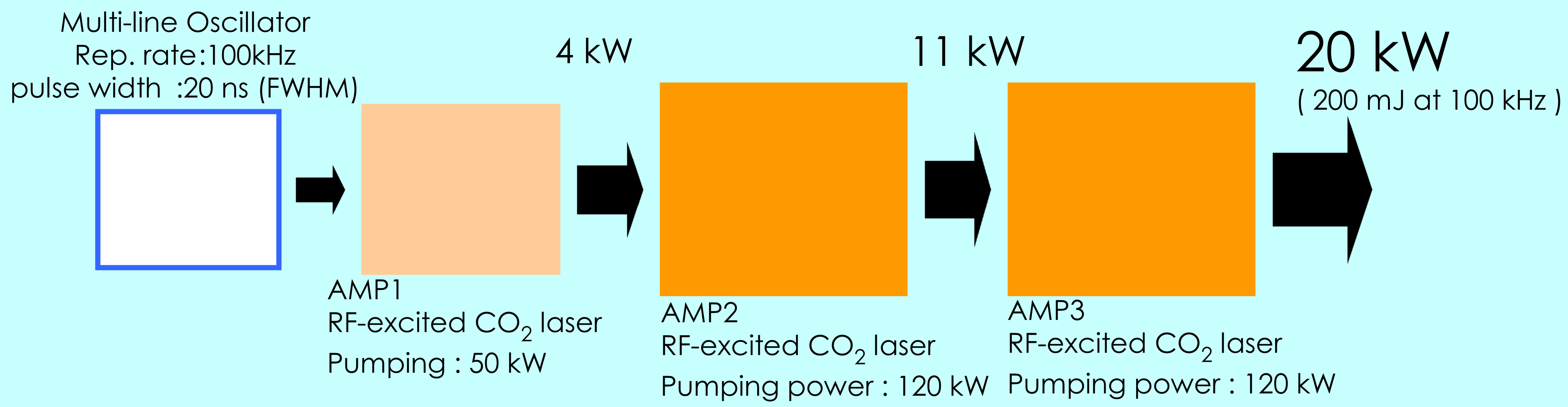
-X- is the amplification ratio between the (P16-P22) spectrum and the P20 line

This work was performed by Research Institute for Laser Physics, St. Petersburg, Russia [V.E. Sherstobitov]

Estimated extracted power of 15 kW amplifier module in case of input power with 3 kW
Multi-line : > 6.5 kW (5 kW×1.3)
Single-line : > 5 kW

Extracted efficiency from pumping power is estimated
Multi-line : > 7.2 %
single-line : > 5.5 %

§ Block diagram of 20kW Short Pulse CO_2 laser MOPA system



One beam, 20 kW is reasonable estimate !!

Power Limitation
- Damage of Optics ⇒ Short pulse damage threshold lower than CW threshold
(copper mirror:10J/cm^2, ZnSe window:1J/cm^2 ⇒ Pulse energy with low rep. rate is OK, but high rep. rate with 100kHz is unknown)
- Filling Factor ⇒ Laser beam diffraction
(The tube diameter (Φ18 mm) and input beam diameter(Φ12 mm) is OK)
- Saturation ⇒ Re-absorption from lower laser level (?)

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NEDO