Gaseous-Discharge Lasers

Helium-Neon Laser

"red" laser line at 6328Å

$$3S_2 \rightarrow 2P_4$$

(…) – A coefficients

- a glass tube ~10 – 100 cm long
- 2 – 8 mm in diameter
- He:Ne 5:1 to 20:1
- typical currents through the discharge tube: 5 – 100 mA

(1)

$$e(K.E.) + He(1\not{S}) \rightarrow He(2\not{S}) + e(K.E. - 20.6\ eV)$$

(2)

$$He(2\not{S}) + Ne(ground) + 387cm^{-1} \rightarrow He(1\not{S}) + Ne(3S_2)$$

from K.E. of colliding atoms

The lower $2P_4$ has a much shorter radiative lifetime than the upper $3S_2$

$\Rightarrow$ easier population inversion

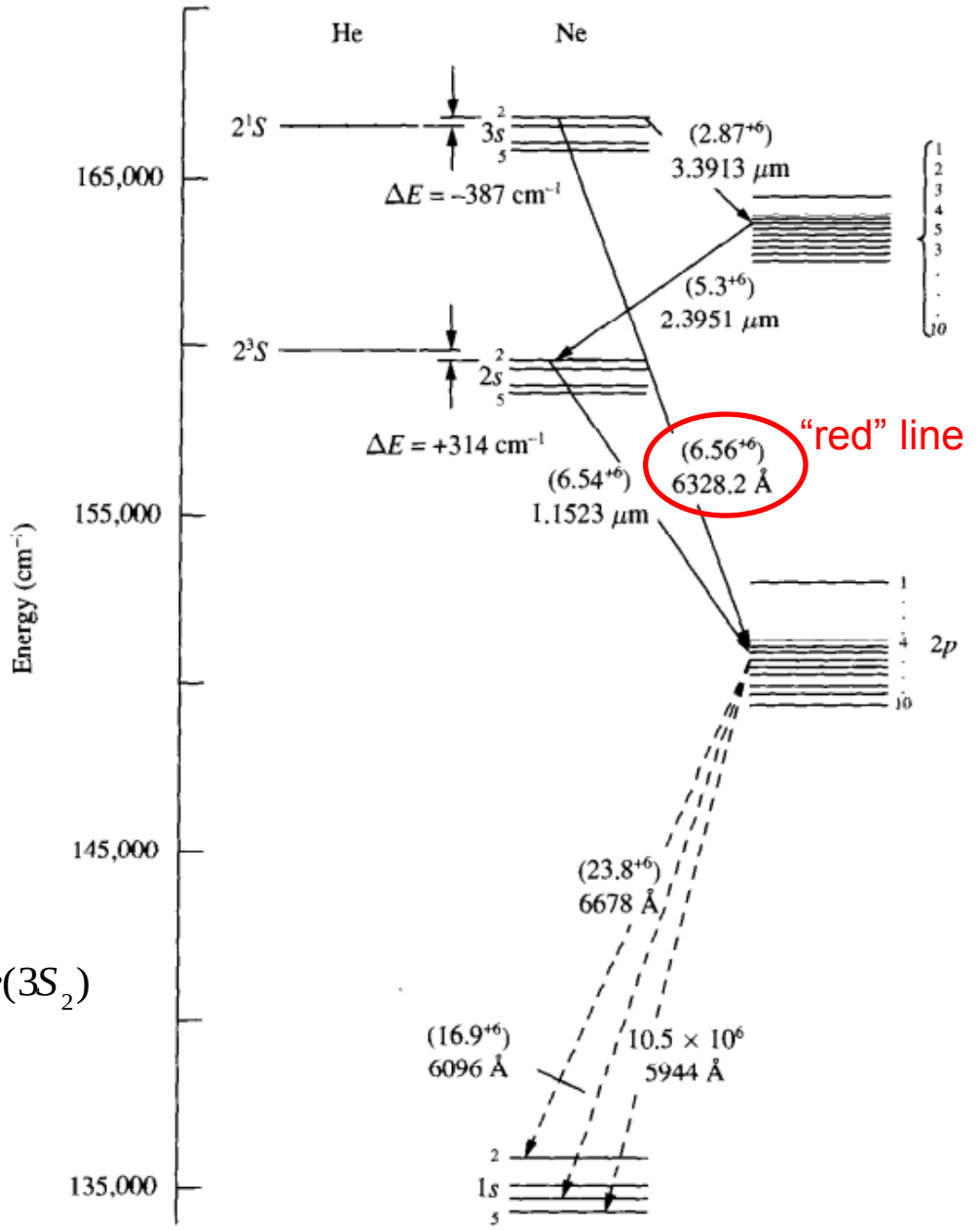

FIGURE 10.28. Energy level diagram for the helium-neon laser. The solid line represents the common laser line; the dashed lines are spontaneous. The numbers in parentheses are the *A* coefficients.

Ar^+ Laser

Selection rules:

$$\Delta J = \pm 1, 0\ ,\quad \Delta L = \pm 1, 0\ ,\quad \Delta S = 0$$

(first to 'brake', e.g. 5145 Å)

To reach the upper laser level of the 4880 Å line at 35.4 eV (158,731cm^{-1}) we need to provide 15.75 eV of ionization + additional 19.68 eV

Because the high-energy tail of the electron distribution drops as $\exp\left[-\frac{t}{kT}\right]$ there are many more electrons capable of first ionizing the atom (15.75 eV) and then another electron exciting the ion (19.68 eV), than have the energy (35.43 eV) to excite $4p^2D^0_{5/2}$ state directly from the natural argon ground state.

$\Rightarrow$ 2-step excitation!

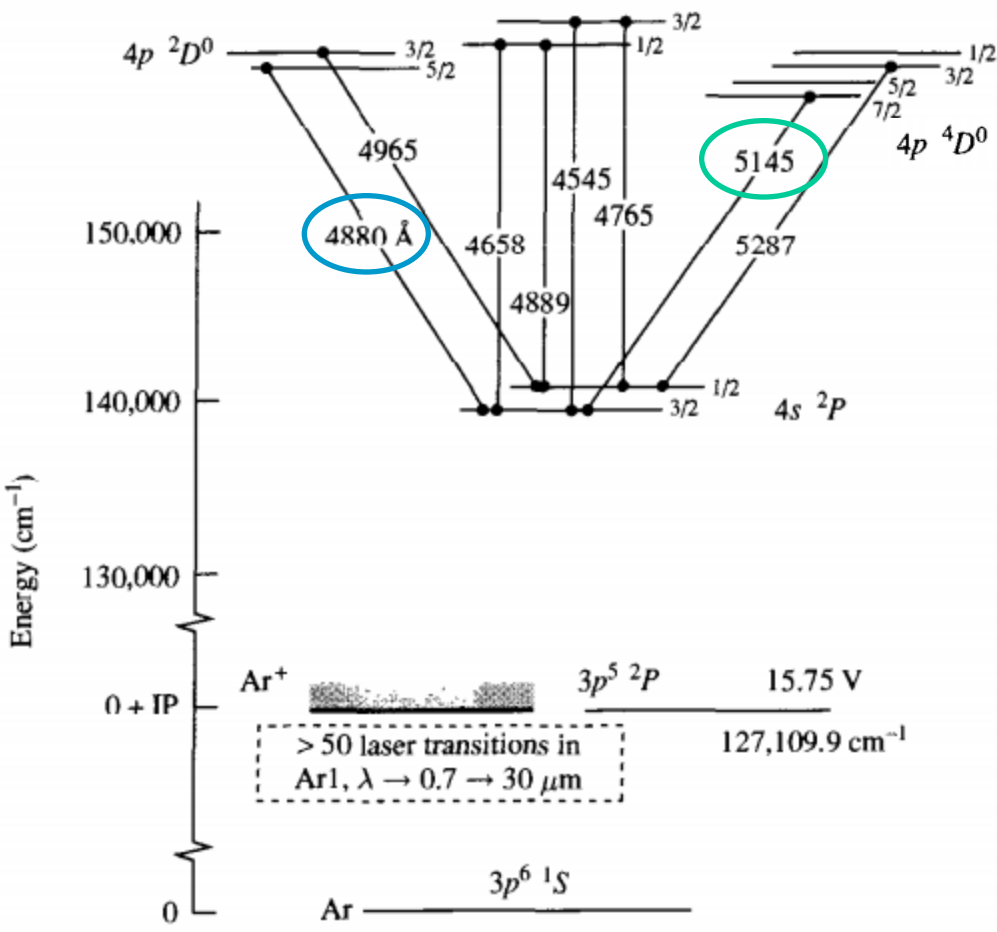

FIGURE 10.30. Energy-level diagram for the argon-ion laser.

- discharge is intense (requires watercooling)

- efficiencies:
  for 5W output
  12 kW power supply from a 3-phase 460 V, 60 Hz plug is needed

CO_2 Laser

- Most efficient ("wall-plug" efficiency ~30% !).
- Industrial applications [pattern cutting (e.g. steel), welding, weaponry, laser fusion, …]
- Generation in mid-IR

(1) For the upper state:

$$e + N_2(u = 0) \rightarrow N_2(u = n \leq 8) + (e - K.E.)$$

followed by:

$$N_2(u = n) + CO_2(000) \rightarrow N_2(u = n - 1) + CO_2(001)$$

or:

$$e + CO_2(000) \rightarrow CO_2(001) + (e - K.E.)$$

(2) For the lower state:

$$e + CO_2(000) \rightarrow CO_2(001) \rightarrow CO_2(020) \rightarrow CO_2(100) + (e - K.E.)$$

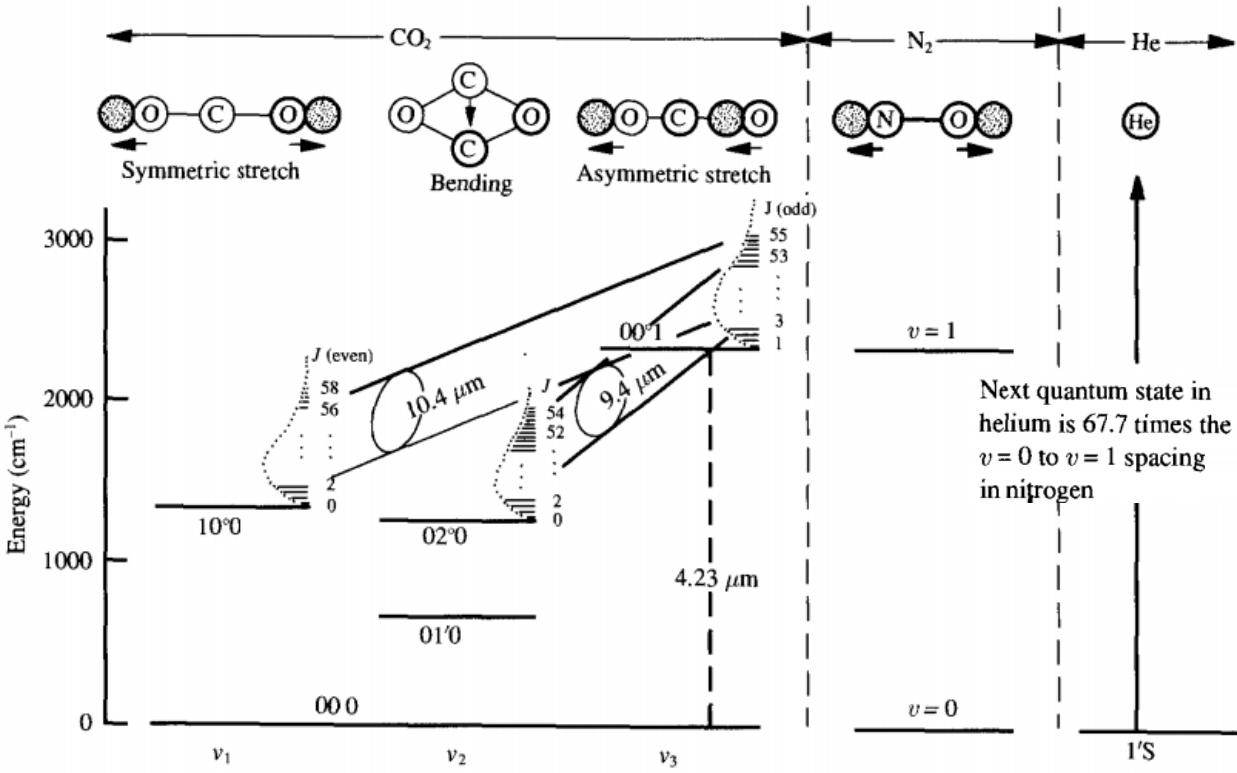

FIGURE 10.31. Energy-level diagram of the CO_2-N_2-He laser.

Although ionization is essential to maintain an active discharge, the fraction of electrical power used to do so is usually insignificant in discharges in molecular gases. 60% of the electrical power can be turned into pumping the upper level!

Excimer Lasers

The rare gases (He, Ne, Ar, Kr, Xe) are chemically inert. When one of the electrons is excited to the next "shell", the inert atoms acts as an alkali atom. Therefore, similar say to:

$K + F_2 \rightarrow (K^+F^-) + F$ we have, for example: $Ar^* + F_2 \rightarrow (Ar^+F^-)^* + F$

rare gas-halide "salt"

Excimer: Molecule which exists in excited state only. (Dissociates upon relaxation)

(1) high power
(2) UV operation
(3) pulsed

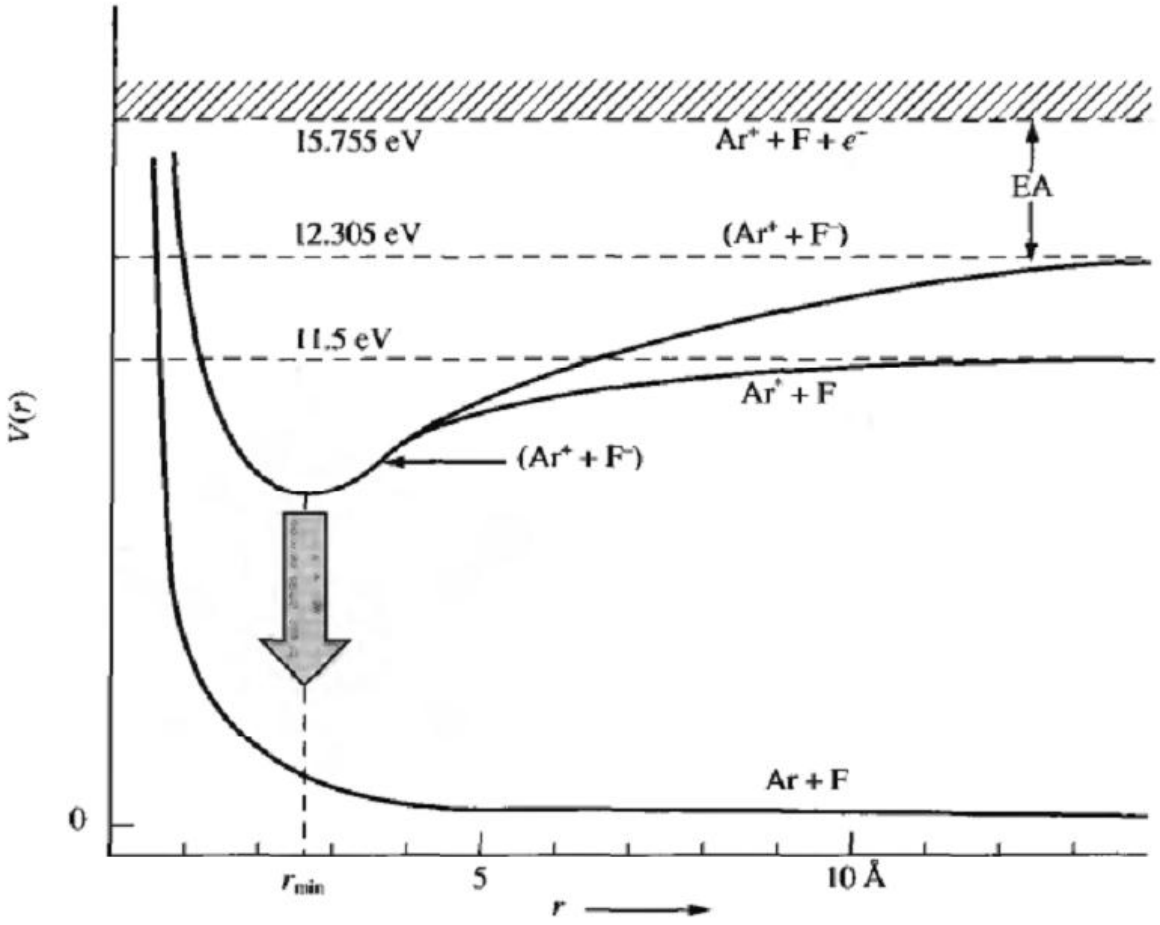

FIGURE 10.33. Energy-level diagram associated with the formation of the (Ar^+F^-) excimer.