Ministry of Higher Education and Scientific Research
Al-Mustaqbal University
College of Medical and Health Technologies
Aesthetic and Laser techniques Department

Laser Physics

Types Lasers and applications

First stage

Lecture5

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Types Lasers and applications

Gas Lasers

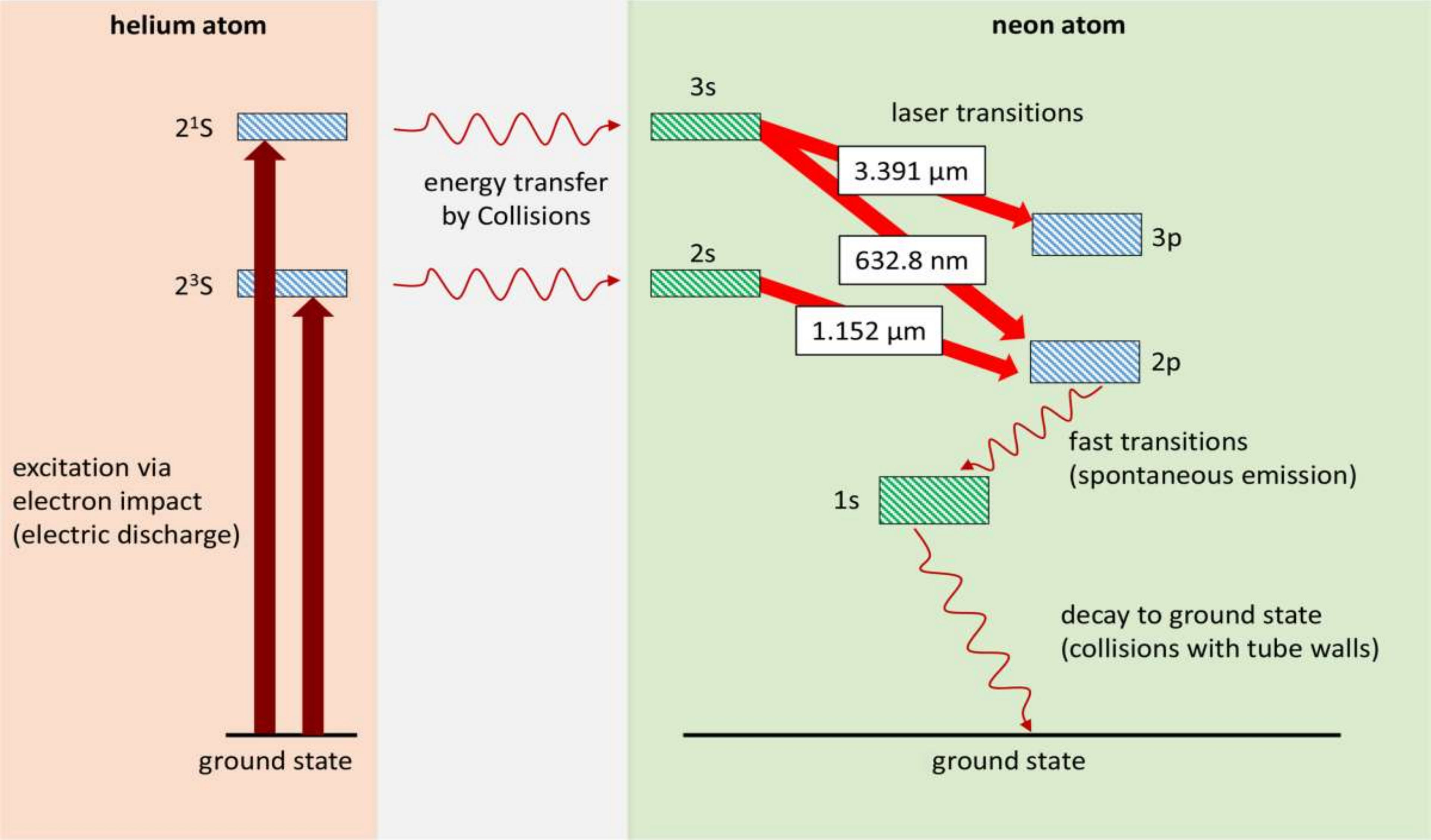
1. Atomic Gas Laser; *He: Ne* Laser

The helium neon (**He-Ne**) laser was the first **continuous** wave laser ever and is one of the most important laser sources in modern measurement technology

For laser operation, the actual laser **active gain medium is neon whereas helium is added in order to support the excitation process** (comparable to the function of helium in carbon dioxide lasers).

The electrons generated in this way cause the excitation of helium atoms to different higher excited states, finally accumulating in the comparatively longlasting metastable states 23S and 21S, as shown in figure

energy levels of helium and neon including the dominant transitions



Properties, parameters and characteristics

- Laser active gain medium: gaseous neon.
- Gas mixture (typical): He : Ne – 10:1.
- Emission wavelengths : 543.3 nm (green), 594.1 nm (yellow), 611.8 nm (orange), 632.8 nm (red), 1152.3 nm (infrared), 1523.1 nm (infrared), and 3391.3 nm (infrared).
- Efficiency factor: < 1%.
- Laser power: typically 1–5 m W , up to 100 m W possible.
- Beam guidance by fibres possible

Application of low power lasers(below 10 mW)

-Laser as a telecom transmitter;

-Laser as a spectroscopic sensor;

-laser a medical diagnostic tool:

Applications in medicine

- Classical targeting or pilot laser.
- Light source for spectroscopy in diagnostic.
- Light source for therapeutic applications

-Laser as write-read tool;

-laser as bar code reader,etc.

Application of High power lasers(> 10 KW)

-laser as a industry tool;

-laser as a surgery instrument;

-laser as a weapon;

-laser as a free space transmitter , etc.

II. Ionized Gas Laser

The most common ionized gas lasers are from the noble gases Argon (Ar^+) and Krypton (Kr^+)

Ion lasers

Krypton gas may be used in an ion laser as well with various wavelengths, covering the entire visible spectrum from violet to red.

Active medium: krypton-ion (Kr^+) laser.

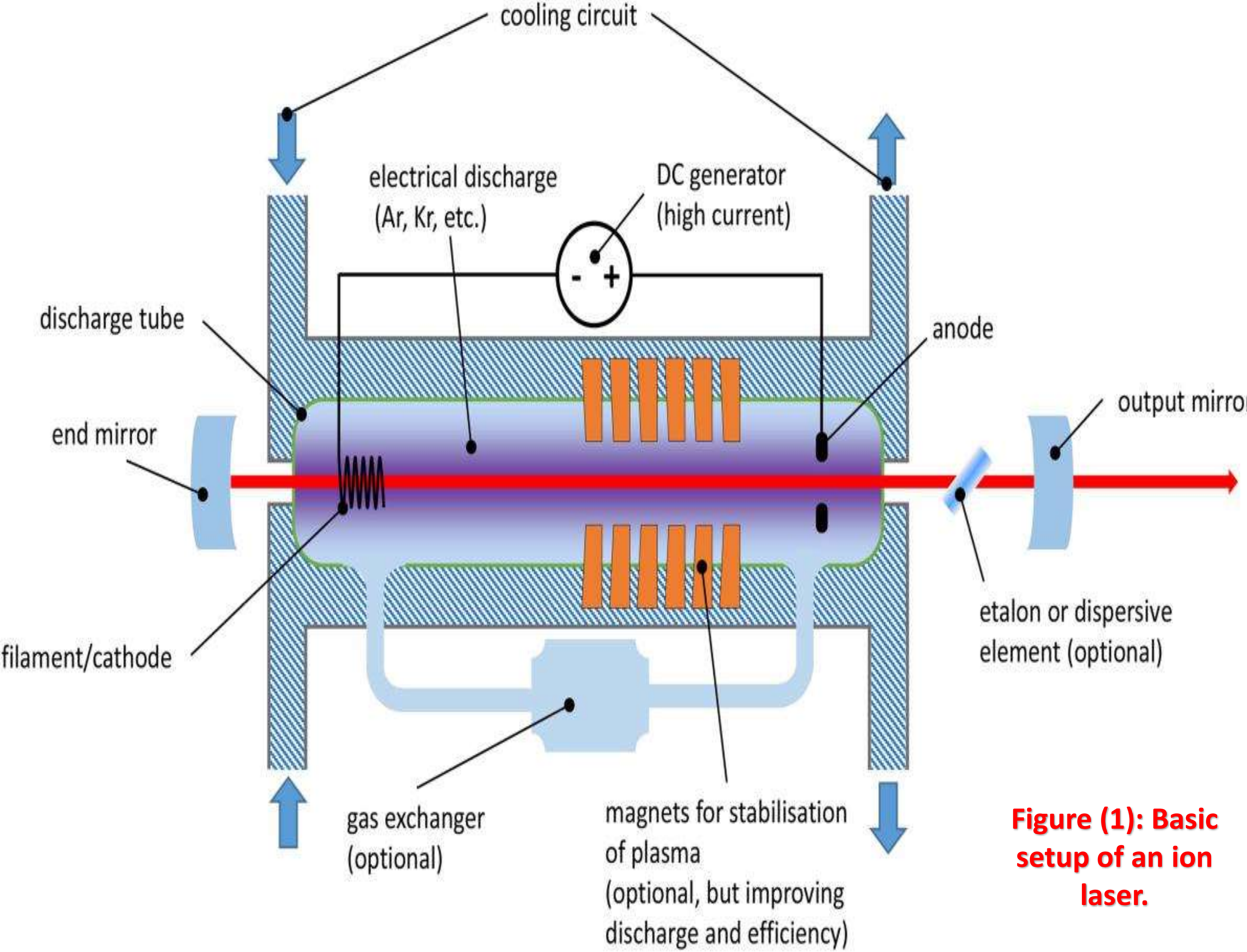


Figure (1): Basic setup of an ion laser.

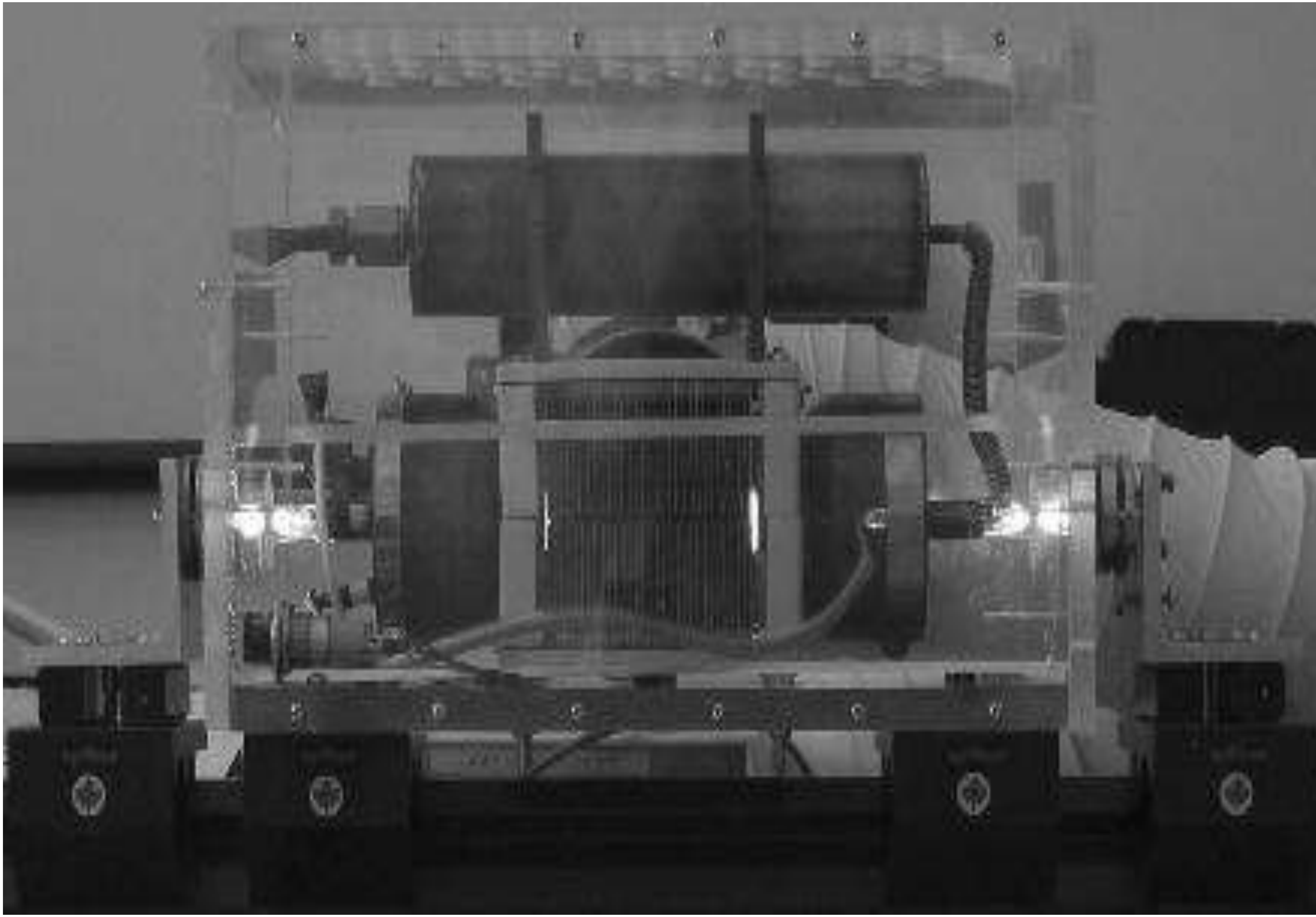


Figure :Small krypton-ion laser

Properties, parameters and characteristics

• Laser active gain medium: ions of inert gases, e.g. argon or krypton.

• Emission wavelengths: 350–800 nm, depending on the inert gas used.
• Efficiency factor: < 1%.
• Pulsed or continuous wave (c w) operation possible.
• Typical pulse duration in pulsed operation: a number of picoseconds.
• Guidance by fibres possible.
• Water cooling necessary.
• Output power up to 30 W (argon-ion laser) and 10 W (krypton-ion laser),

Applications in medicine

- Treatment of vascular diseases.
- Removal of pigments.
- Laser-based diagnostics, e.g. multi fluorescence microscopy or flow cytometry.

Uses

- Krypton: used as a better filler gas for high-quality light bulbs, also in halogen lamps
- Xenon: gas-discharge lamps, are used as filler gases for lamps, sometimes as constituents of gas mixtures
- High-purity gases are required for these applications.

MEDICAL USES

Liquid argon can be used to destroy cancer cells, while blue argon lasers are used to repair arteries, destroy tumors, and correct defects in the eye .

Molecular Laser

1- Carbon Dioxide (CO_2) Laser

Carbon dioxide is the most efficient molecular gas laser material that exhibits for a **high power** and **high efficiency gas laser** at **infrared wavelength**.

Construction

The **gas** used for this **special type of gas laser** is a mixture of **helium (82%),Nitrogen (13.5%),** and carbon dioxide (4.5%) which fills an **arc discharge tube** as shown in **figure**

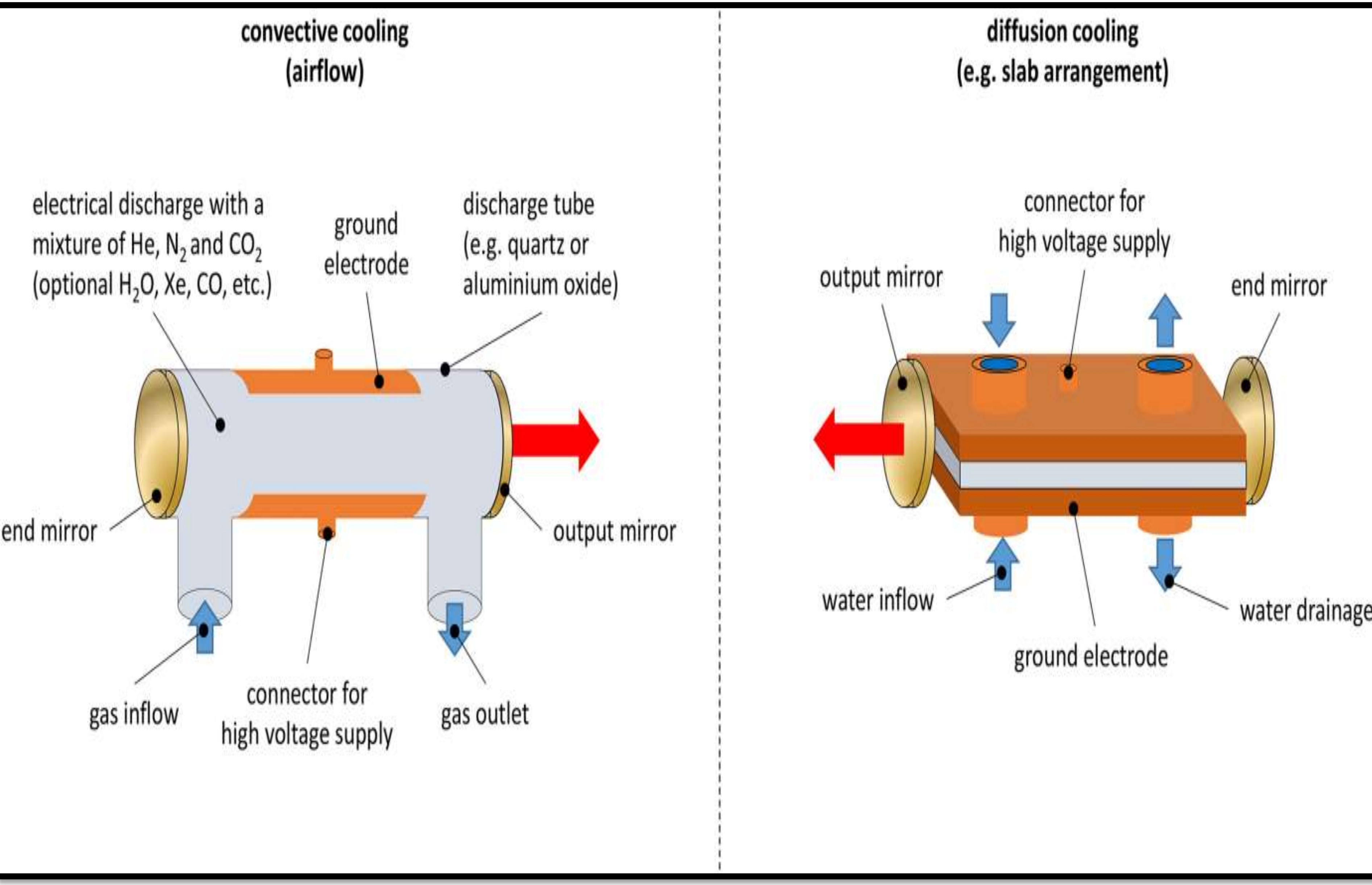
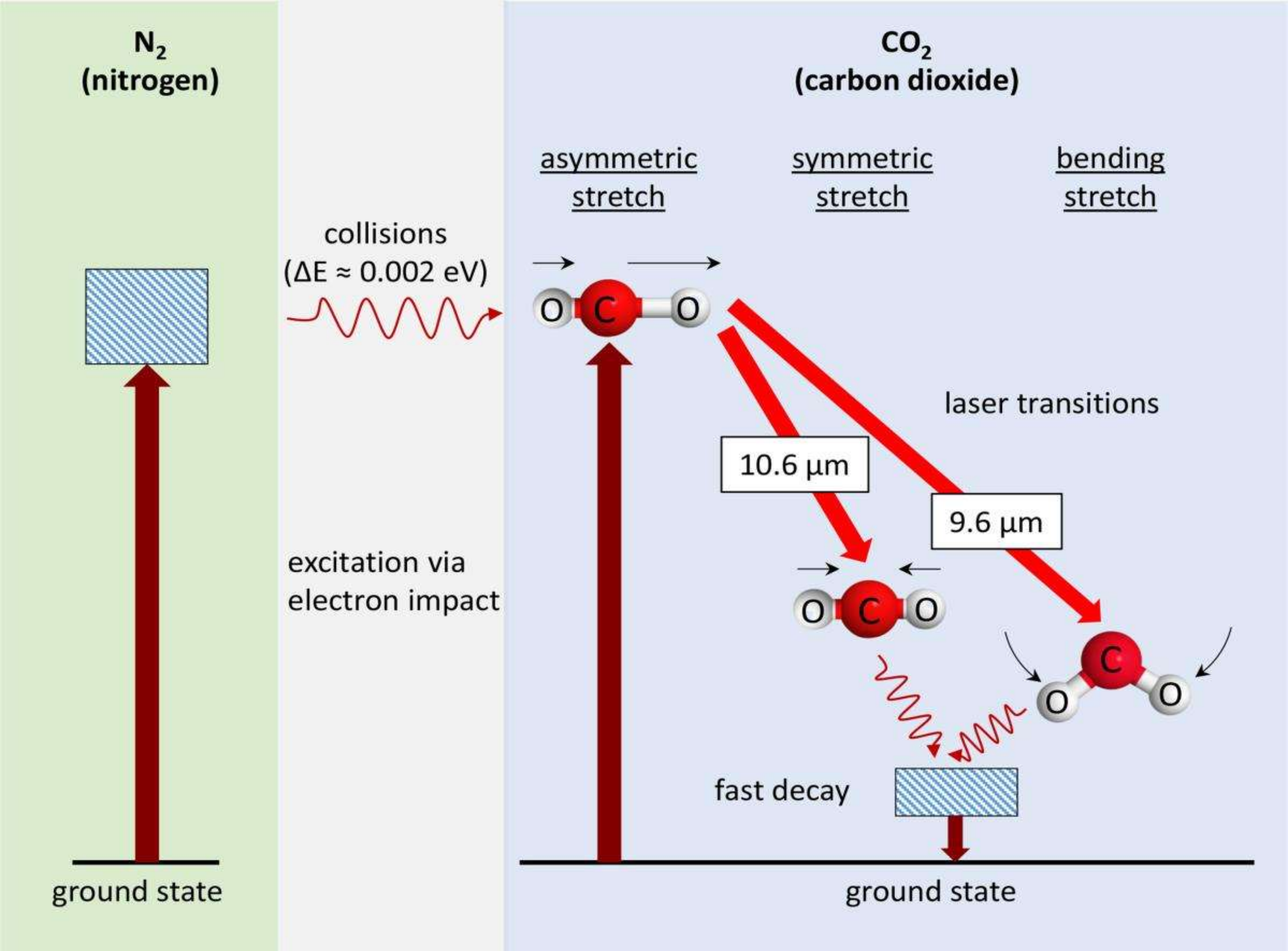


Figure: Basic setup of a CO2 laser.

Properties, parameters and characteristics

- Laser **active gain medium**: **gaseous** carbon dioxide.
- Gas mixture (typical): **CO_2:N_2:He – 1:1:8**.
- Emission wavelengths: **10.6 µm and 9.6 µm**.
- **Efficiency factor**: up to **30%**.
- **Pulsed** or **continuous wave** (**cw**) operation possible.
- Simple and robust setup without any hazardous gases.
- Laser power: up to a number of **megawatts** in cw operation.
- **Beam guidance** by **mirror systems**.
- **Penetration depth into tissue: some tens of microns (typically 10–30 µm).**



N2
(nitrogen)
CO2
(carbon dioxide)
asymmetric stretch
symmetric stretch
bending stretch
collisions
(ΔE ≈ 0.002 eV)
O C O
laser transitions
10.6 µm
9.6 µm
excitation via
electron impact
O C O
C
O O
fast decay
ground state
ground state

Application

1- <u>industrial</u> applications including cutting, drilling, welding, and so on. It is widely used in the laser pyrolysis method of nanomaterials processing.

2- Laser surgery

For cutting materials , It is also used in surgical applications since the wavelength is readily absorbed by flesh vaporizing it; the heat also serves to cauterize the cut, thus reducing bleeding

Excimer Laser

What Is Excimer Laser ➔ **The term** "**excimer**" stands for **excited dimer**. ➔ An excimer laser is an ultraviolet (UV) laser that uses a compound of **noble gases** And **halogen**

emits laser irradiation in the ultraviolet wavelength range from 126 to 351 nm

such as argon (Ar2) or xenon (Xe2) or noble gas halide bonds, e.g. ***argon fluoride (ArF)*** **or** ***xenon chloride (XeCl)***.

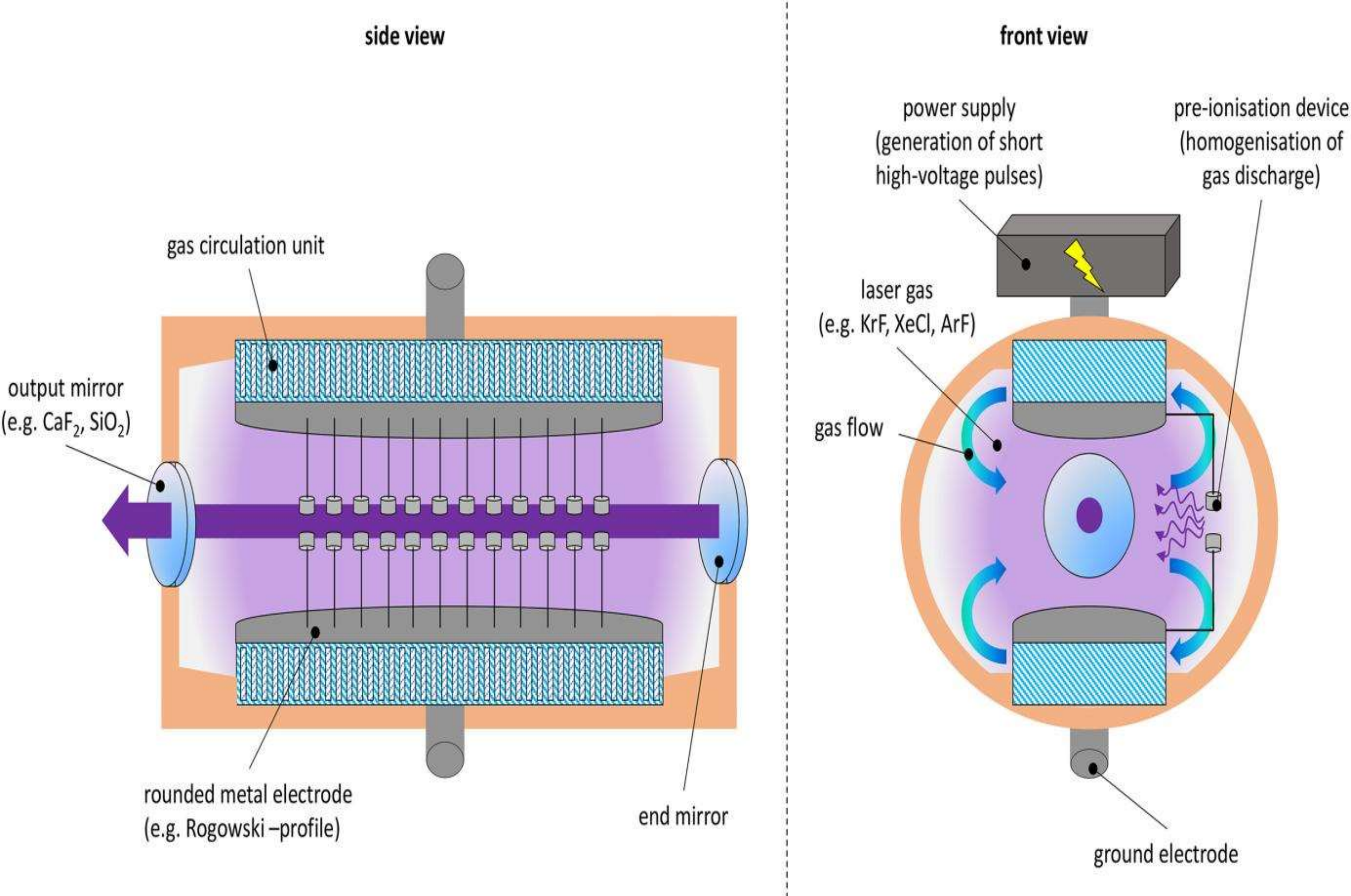


Figure :Basic setup of an excimer laser

Properties, parameters and characteristics

- ***Laser active gain medium*: excited dimers.**
- **Emission wavelengths: 126–351 nm.**

as its gain medium ➔ Typical examples being Ar F excimer lasers (wavelength of 193 nm), ➔ Kr F excimer lasers (wavelength of 248 nm), ➔ Xe Cl excimer lasers (wavelength of 308 nm), ➔ and Xe F excimer lasers (wavelength of 351 nm).

- **Efficiency factor: 2–4%.**

high efficiency for lasers in the ultraviolet range

- **Laser power: typically 200 W.**
- **Exclusively pulsed operation possible.**
- **Water cooling required.**

❑ **Safety** is an **important** topic when discussing excimer lasers due to their **high power** ratings **within the UV spectrum**.

eye damage*; *excimer lasers, which are capable of power levels of several hundred watts, are easily capable of considerable damage to an operator's eyes or skin.

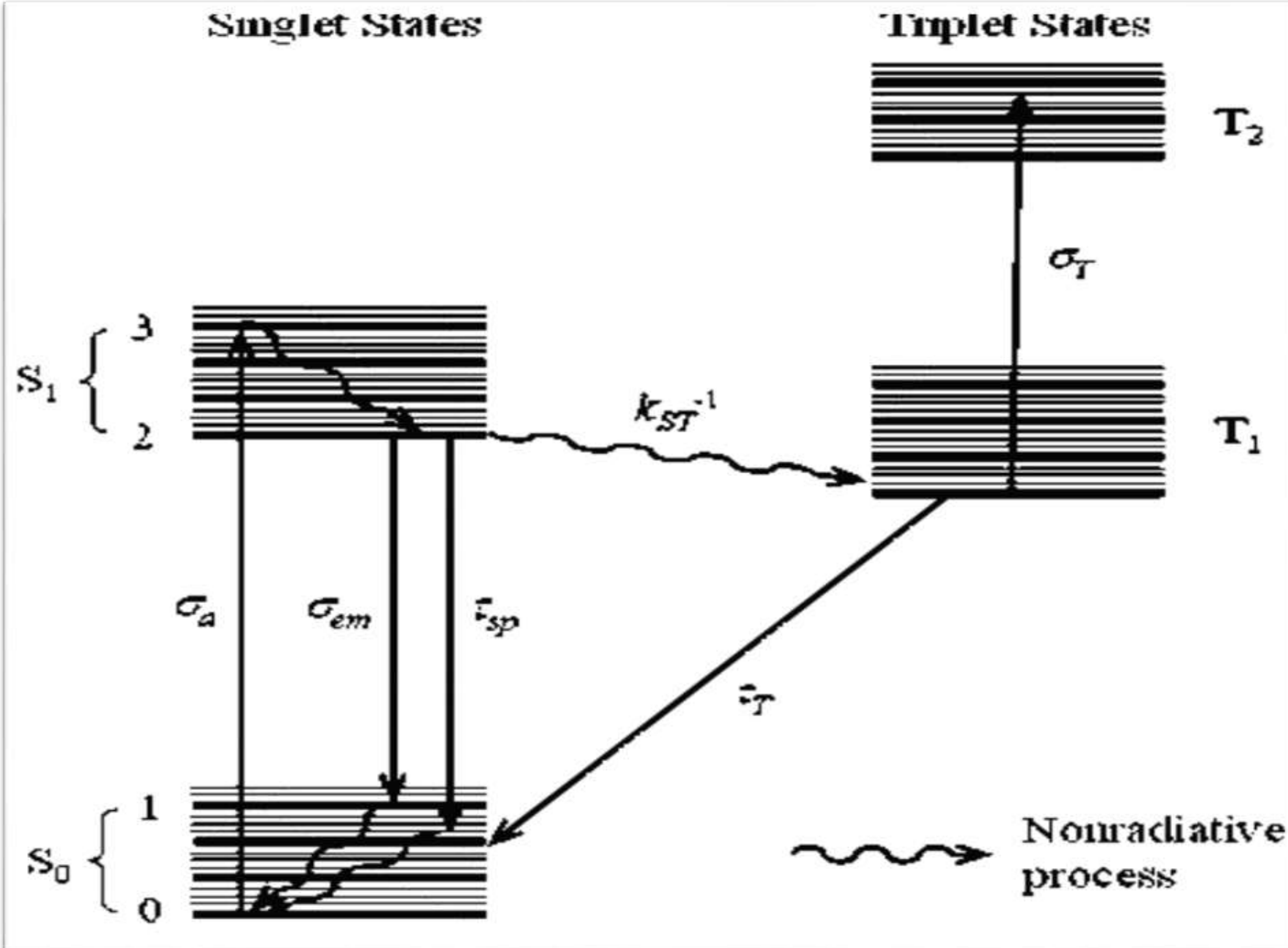
Applications in medicine in ophthalmology

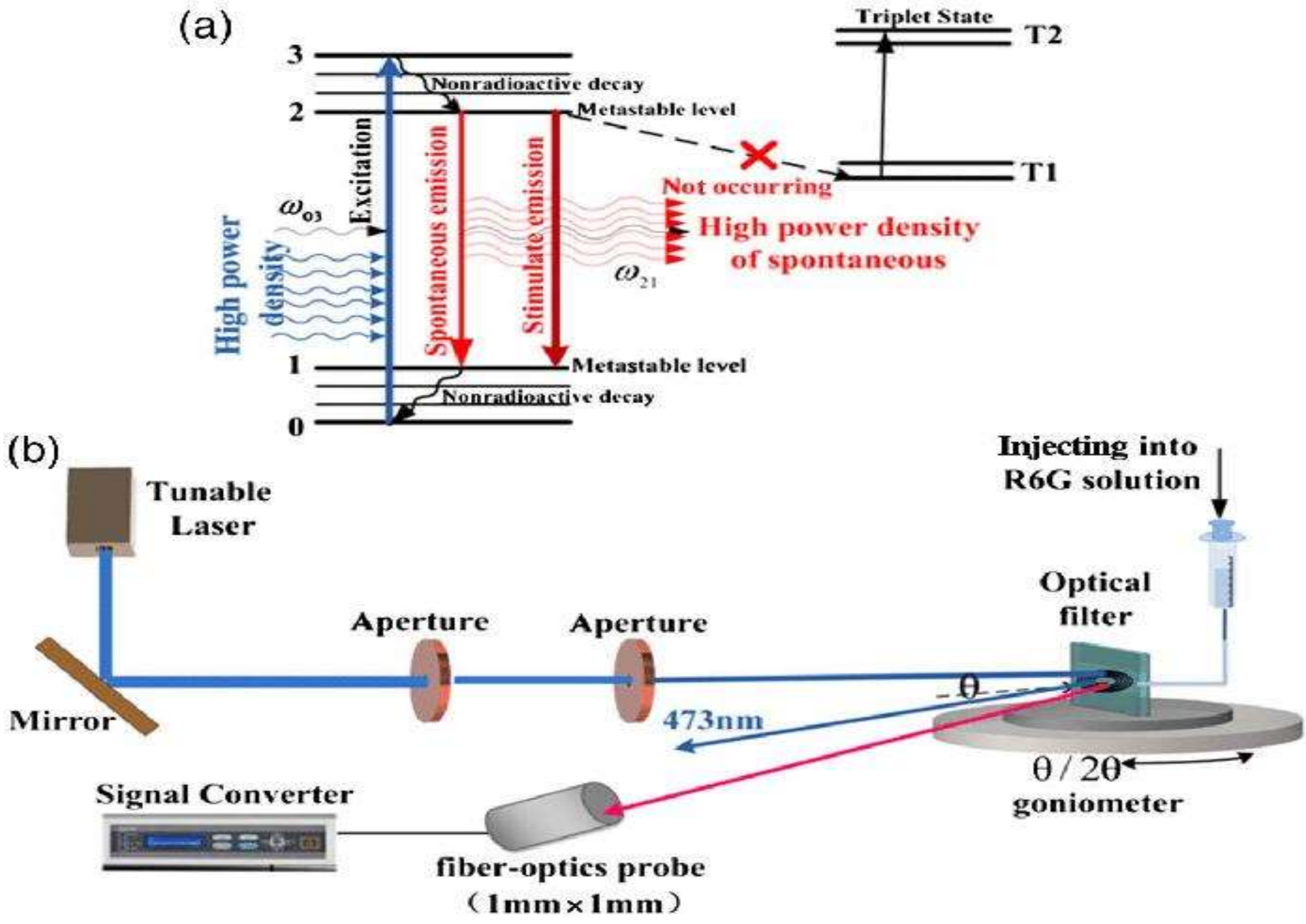
1. . Laser Power and Safety have applied in a variety of fields such as industry and medicine (vision correction surgery such as LASIK.

- ❑ The principal advantage of excimer lasers is that they are capable of producing **a very small**, precise **spot** at **a very low (UV) wavelength**.
- ❑ Excimer lasers are **excellent** for **removing excess material** through laser ***ablation*** due to the fact that they are able to precisely destroy material with
little to no thermal buildup. f'' material during **ablation**.
- ❑ **Photolithography**, **especially** in **semiconductor manufacturing**

Dye lasers

Dye lasers could also be referred to as **liquid lasers** since the laser **active medium** is a **radiant dye**, dissolved in a carrier liquid. In contrast to most other **laser sources**, dye lasers can be tuned within a broad **range of laser wavelengths**. For a single dye, the **range amounts to 50–100 nm** and the availability of a number of different dyes, see **figure** , allows the generation of **laser irradiation in the visible and near infrared wavelength range from 400 to 900 nm**


Singlet States
Triplet States
T2
σT
S1
3
2
kST-1
T1
σa
σem
τsp
τT
1
S0
0
Nonradiative process



(a)
Triplet State
T2
3
Nonradioactive decay
2
Metastable level
Excitation
Spontaneous emission
Stimulate emission
Not occurring
T1
ω_{03}
High power density
High power density
of spontaneous
ω_{21}
1
Metastable level
Nonradioactive decay
0
(b)
Tunable Laser
Injecting into R6G solution
Optical filter
Aperture
Aperture
Mirror
θ
473nm
θ / 2θ goniometer
Signal Converter
fiber-optics probe
（1mm×1mm）

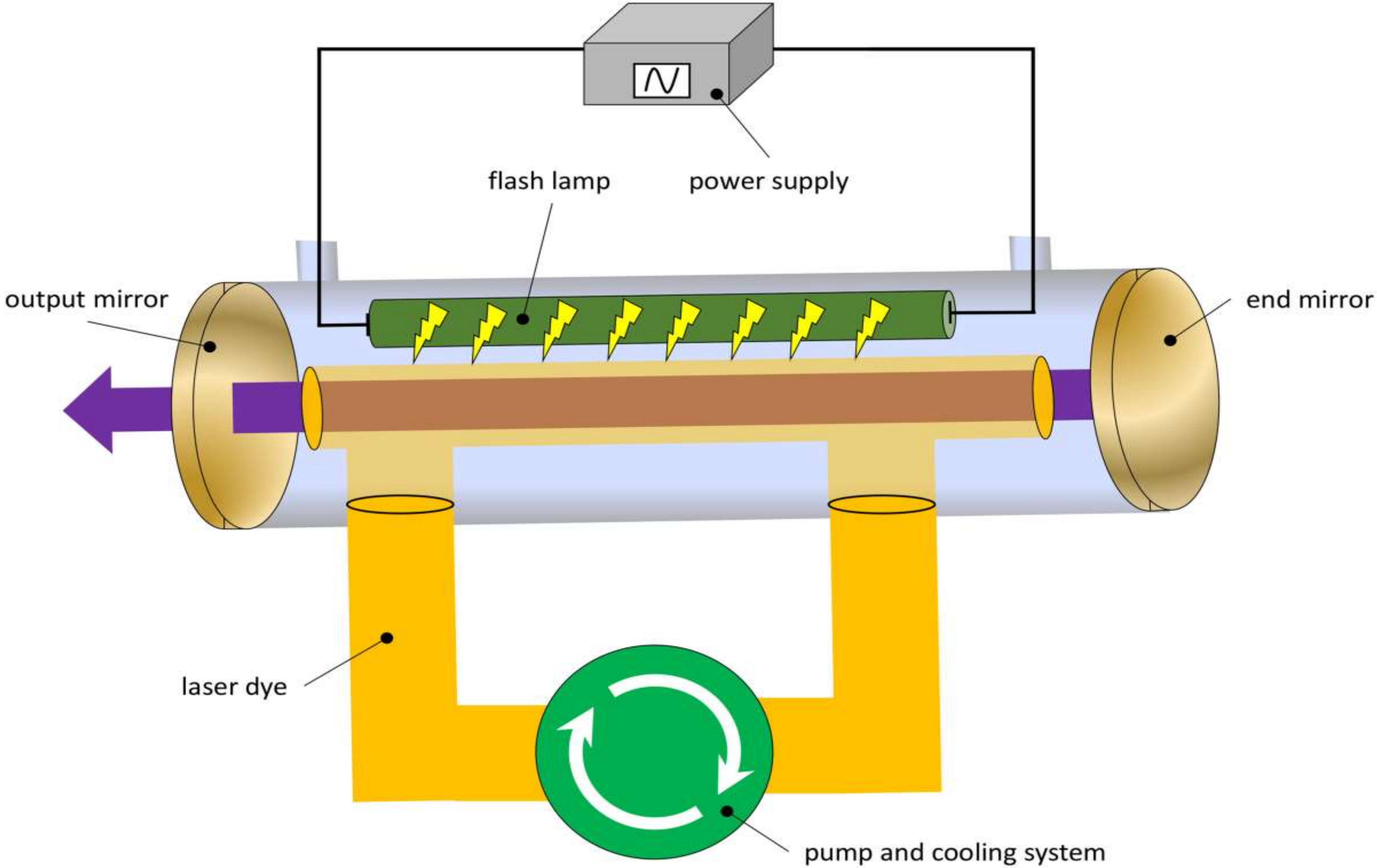


Figure : Setup of a flash lamp-pumped dye laser

Properties, parameters and characteristics

- **Laser active gain medium**: ***fluorescent, radiant dyes***.
- Emission wavelengths: **400–900 nm**.
- Spectral bandwidth of single dye: **50–100 nm**.
- Efficiency factor: approximately **0.5%**.
- *Pulsed* or **continuous** wave (**cw**) operation **possible**.

Advantages

 Low cost Tuning possible with multiple means

 No degradation of the optical properties of the organic dye.

 More robust (professional) and compact systems.

Disadvantages

 Limited lifetime.

 Limited output power

Applications in medicine

1• Treatment of vascular malformation (dysplasia) in dermatology

2• Light source for spectroscopy for the examination of tissue

3• Light source for Laser Scanning Microscopy (LSM) in diagnostic

.

2- Solid State Lasers:

Main components of solid state lasers

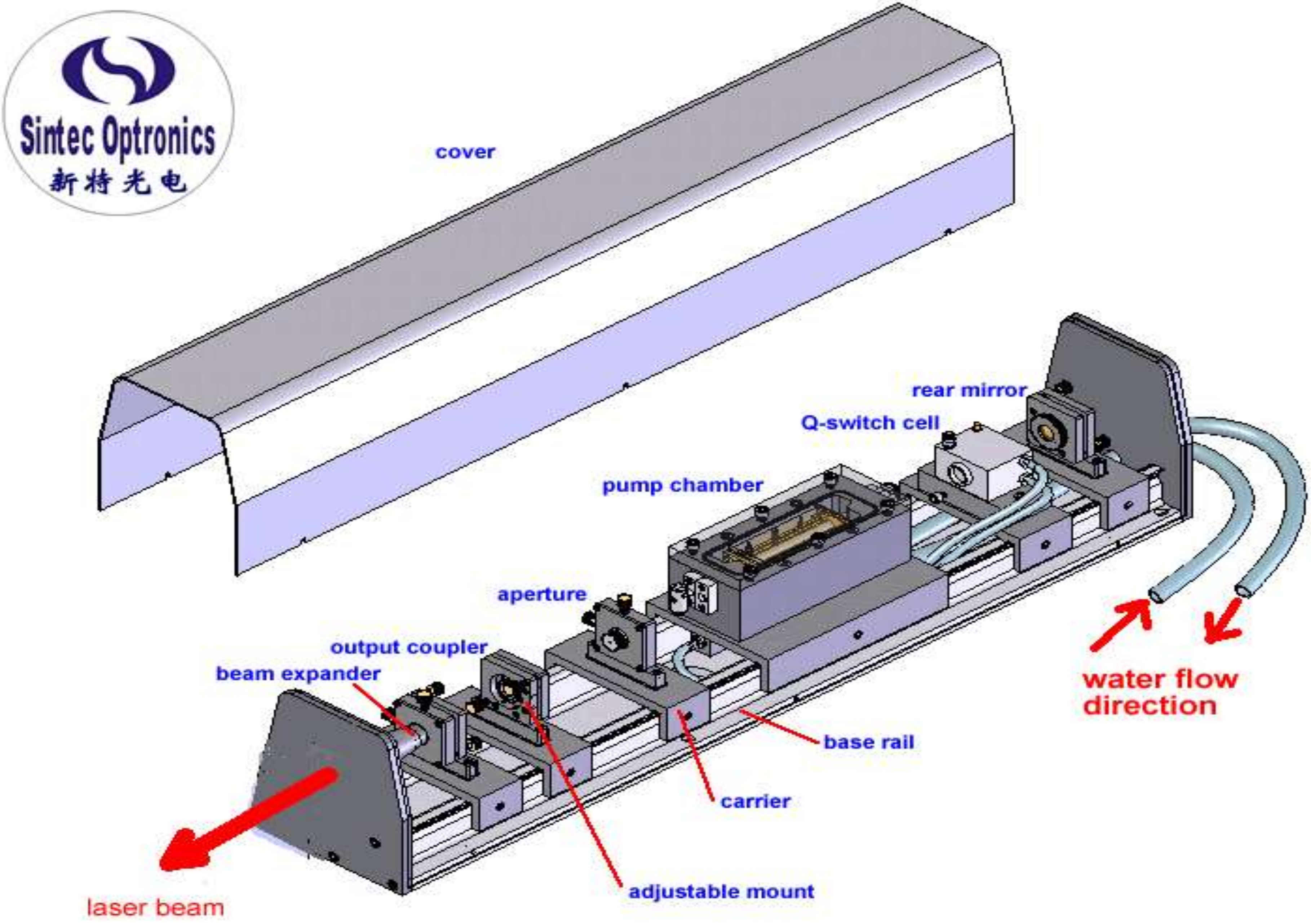
***In spite of the difference in the sizes and types of laser devices, they consist of three common elements; they are Active medium, Energy sources & resonant cavity*.**

Solid state lasers have active media obtained by embedding transition , Metals (Ti^{+3}, Cr^{+3}, , Co^{+2}, Ni^{+2}, Fe^{+2}, etc.), rare earth ions (Ce^{+3}, Pr^{+3}, Nd^{+3}, Pm^{+3}, , Ho^{+3}, Er^{+3}, Yb^{+3}, etc.), and actinides only responsible for lasing actions, while physical properties such as thermal conductivity and thermal

.

expansivity of the **host material** are important in determining the efficiency of the laser operation Arrangement of host atoms around the **doped ion** modifies its energy levels. Different lasing wavelength in the active media is obtained by **doping of different host materials** with same active ion.

$Y_3Al_5O_{12}$, $YAlO_3$, $Y_3Ga_5O_{12}$, $Y_3Fe_5O_{12}$, $YLiF_4$, Y_2SiO_5, $Y_3Sc_2Al_3O_{12}$,
$Y_3Sc_2Ga_3O_{12}$,$Ti:Al_2O_3$, $MgAl_2O_4$ (spinel) etc……. (Alexandrite), and so on, are some of the important hosts



Main components of a laser

A STABILITY CRITERION

A stable resonator is one in which rays can be trapped by the curvature of the mirrors—they will bounce back and forth between the mirrors forever

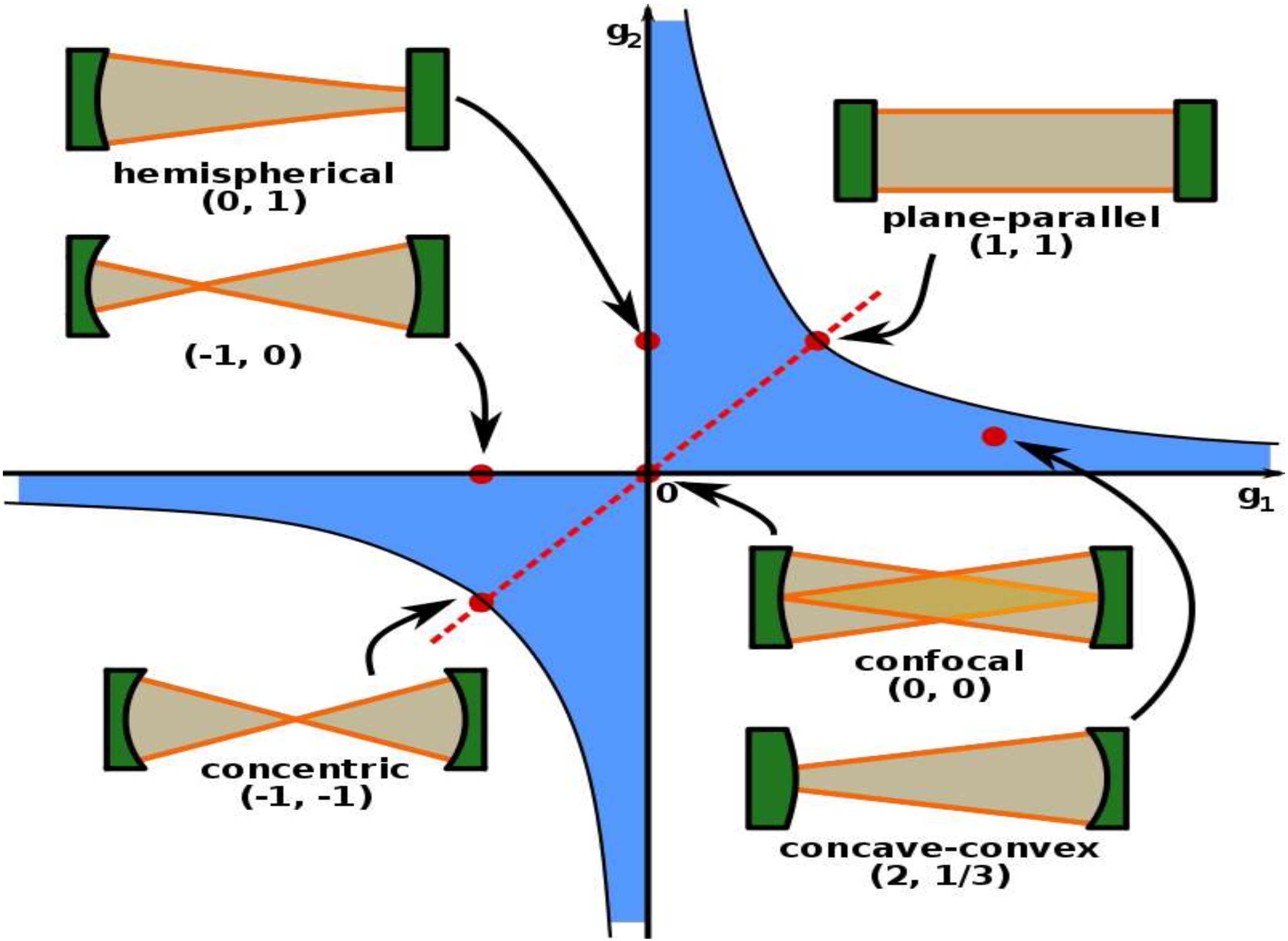
? The condition for stability is

$$0 < g_1 g_2 < 1$$

In which g1 and g2 are the so-called g-parameters

$$g_1 = 1 - L/R_1$$
$$g_2 = 1 - L/R_2$$

The curvatures of the two mirrors are r1 and r2, and the spacing between them is L



g2
g1
0
hemispherical
(0, 1)
(-1, 0)
plane-parallel
(1, 1)
confocal
(0, 0)
concentric
(-1, -1)
concave-convex
(2, 1/3)

gain coefficient

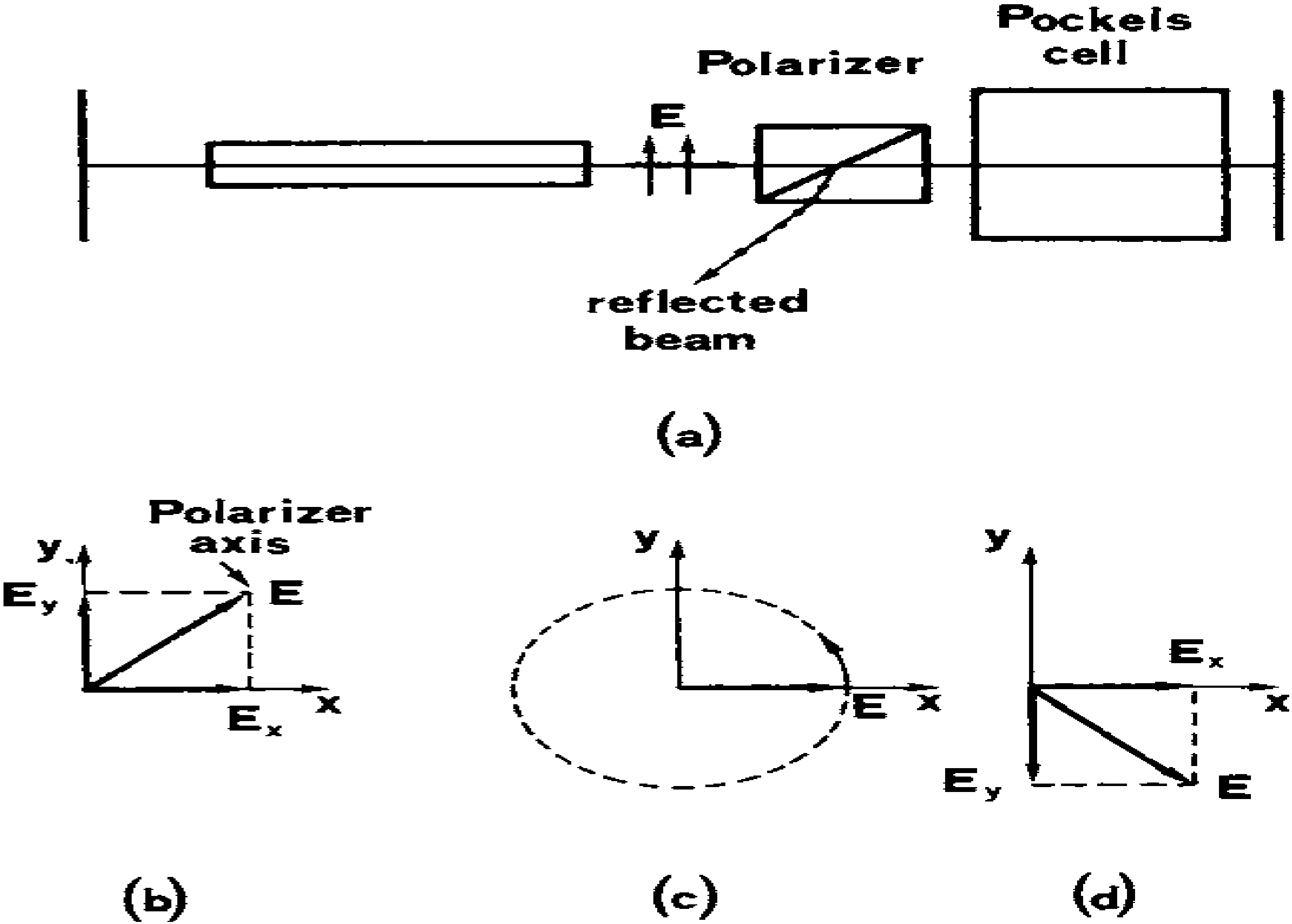
$$g = \frac{g_0}{1 + (I/I_s)}$$

$$I_s = h\nu/\sigma\tau$$

I_s : Saturation intensity

Methods of Q-Switching.

There are several methods that have been developed to achieve switching of the cavity Q and, in this section, we will limit ourselves to a discussion of the most commonly used, namely: (i) Electro-optical shutters. (ii) Rotating prisms. (iii) Acousto-optical switches. (iv) Saturable absorbers.


Pockels
cell
Polarizer
E
reflected
beam
(a)
Polarizer
axis
y
E_y
E
x
E_x
(b)
y
E
x
(c)
y
E_x
x
E_y
E
(d)

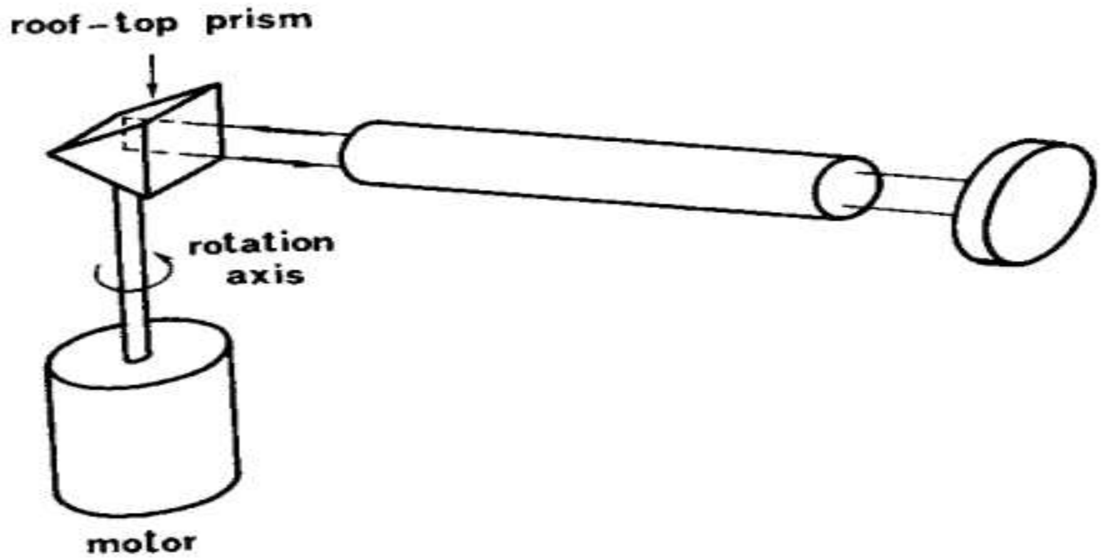


FIG. 8.6. Mechanical Q-switching system using a rotating 90° roof-top prism.

THANK YOU ALL