

The Hows and Whats of Lasers

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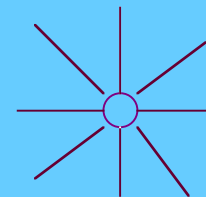
L ight

A mplification by

S timulated

E mission of

R adiation



**WARNING : Dangerous radiation is
emitted from this aperture**

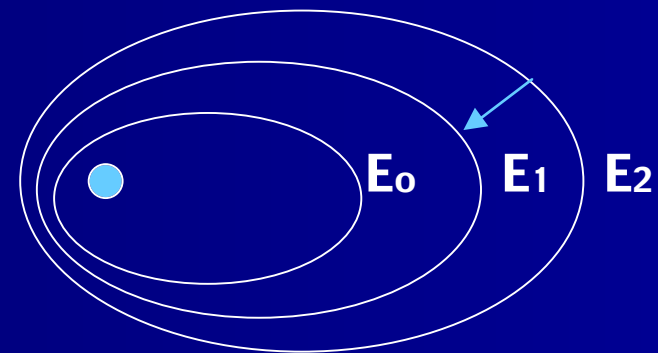
Why care about Lasers?

- Lasers are found in a wide variety of commercial and defense applications
- Lasers are the foundation of high-speed fiber optic communications systems
- Laser beams have unique characteristics: very little beam spread, the ability to focus a great deal of energy very precisely, and they come in many different frequencies (colors); each of these attributes can be exploited for specific applications
- Lasers come in many varieties, and can often be tailored to the specific application
- Certain lasers can be made very small – a plus for communications and certain medical applications
- Lasers use energy fairly efficiently

The Basic Physics of Lasers I

Light is the result of transitions between energy states, represented by different electron orbitals.

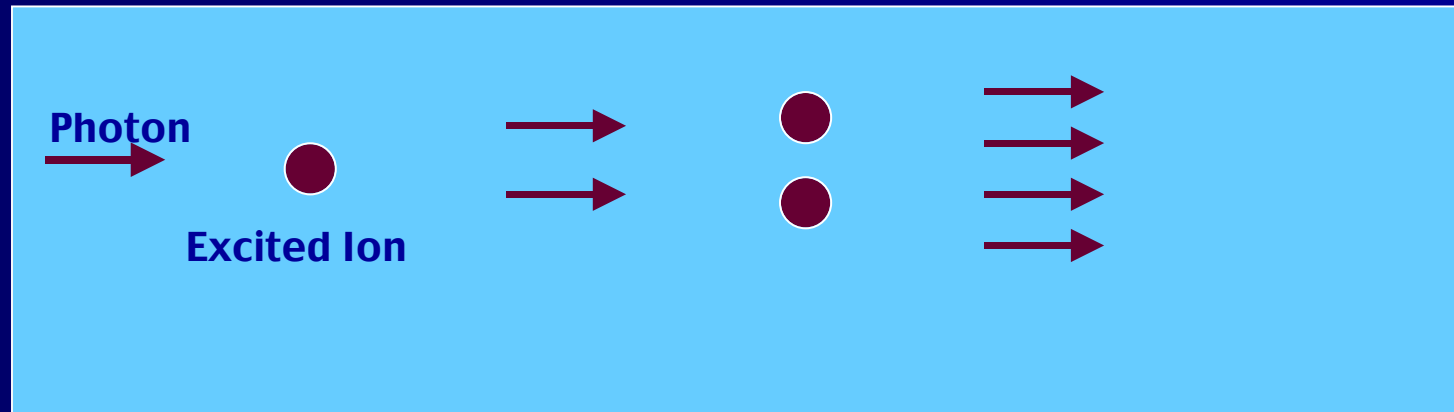
When this transition occurs the energy is emitted as a photon, a “particle” of radiation, often visible light.



A diagram of an excited laser material ion

The Basic Physics of Lasers II

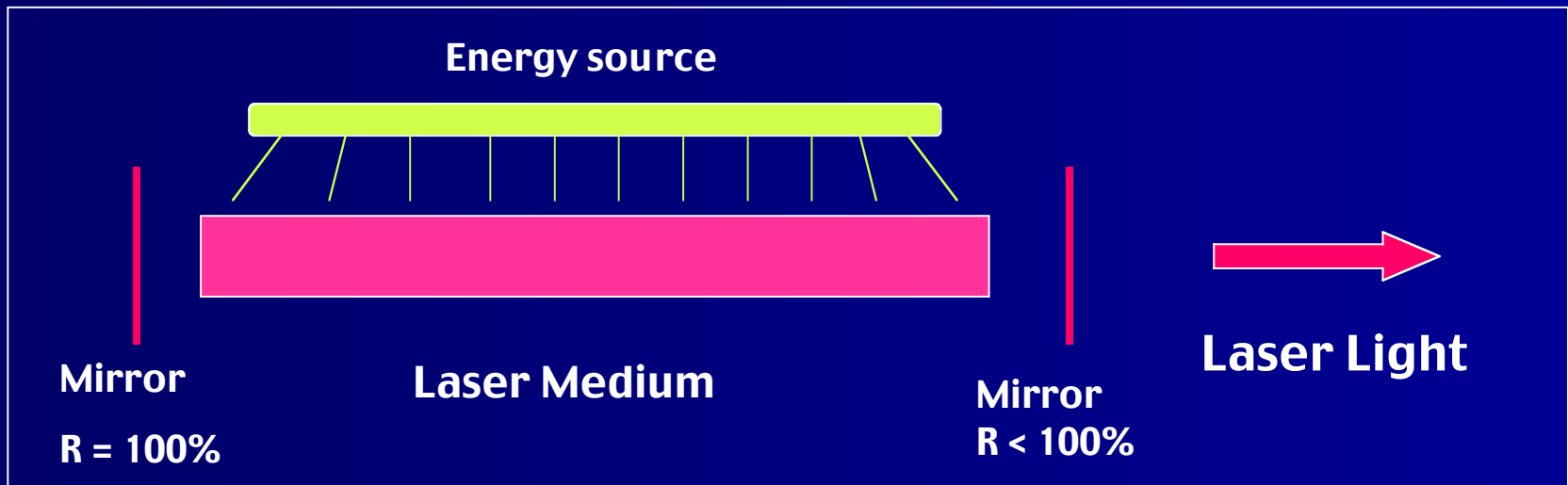
Stimulated Emission



A spontaneously emitted photon interacts with excited ions in the laser medium. The electric field of one photon induces another excited ion to emit another photon. This new photon will be at the same frequency (color) as the original photon, will be traveling in the same direction, and will be in phase with it.

A typical laser

Laser diagram



When excited by the energy source, the ions in the Laser Medium emit photons in all directions. But only the light emitted along the straight line between the mirrors is significantly amplified. The other light just goes off “sideways” and is lost. As the remaining light bounces back and forth between the mirrors, it gets brighter and brighter. And each time the light bounces off the front mirror, a small fraction of the light goes through. This is the laser light we see

The parts

Depending on the type of laser, its energy can come
straight from wall voltage or a battery,
from light source such as a flashlamp or another laser,
from a chemical reaction
from a nuclear reaction

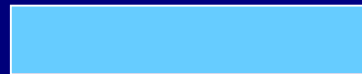
The laser medium can be
glass,
a crystal,
a semiconductor,
or even a beam of electrons

The mirrors can be supplied by
glass, or metal, or the facets of a crystal, or even magnetic
fields

Why is laser light special?

Laser beams are coherent

Flashlight



Laser



Coherence allows laser light to be tightly focused and to travel long distances with negligible beam divergence (spreading)

Why is laser light special?

Laser light is monochromatic (single color)

Laser light is usually polarized (this affects the way it interacts with materials, including how it reflects off surfaces and transmits through materials)

Laser light can often be produced either in a continuous stream or in pulses

Lasers have a wide range of applications

In Communications (primarily by optical fiber)

In Medicine (cutting, cauterizing, angioplasty, tissue welding, cancer treatment, lithotripsy, for cosmetic uses, dentistry, diagnostics, ...)

In Manufacturing (cutting, welding, machining, diagnostics, ...)

In Defense (communications, disabling electronics, disabling troops, destroying, ...)

Different types of lasers

- **Gas lasers (Argon ion, Helium Neon, ...)**
- **Solid State Lasers (Ruby, Neodymium YAG, Titanium Sapphire, Erbium YAG,...)**
- **Diode Lasers (Semiconductor lasers)**
- **Chemical Lasers (Hydrogen Fluoride, Iodine Oxygen, ...)**

Choosing the right laser

The choice of laser for any application depends upon the specific needs:

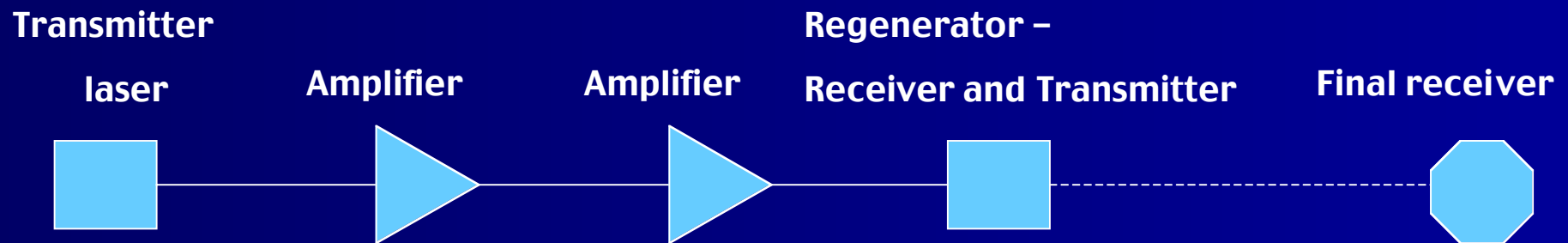
- Power
- Wavelength (color) – and possible need for wavelength tunability
- Continuous beam or pulses
- Beam quality
- Reliability
- Ruggedness

A word about Chemical Lasers

Chemical lasers are different from other lasers in that the materials that are the laser medium also supply energy for the laser. These lasers essentially supply their own power. When the chemicals are mixed, they produce an exothermic (energy releasing) chemical reaction.

However, if the chemicals are not replenished, the process “runs out”, and the laser quits. In the laboratory, the chemicals are kept flowing through the system constantly at just the right rate.

Fiber Optic Communications



Maximum distance
between
amplifiers is 30-
100 miles

Fiber optic communications systems are very straightforward. They consist of an initial transmitter, which encodes audio (and now video) signals as light pulses. These signals are sent down a fiber optic cable. Every so often there is an amplifier, to counteract the loss within the cable. Occasionally there is a regenerator, which receives the incoming signal, reprocesses it to remove noise, and then retransmits it. This series of steps continues until the signal reaches the final receiver, which translates the optical signal back into audio and video.

Free Space Laser Communication

Like fiber optic communication, a transmitter encodes an audio or video signal as laser pulses. But the laser light is transmitted through free space. This requires a clear line of sight between the transmitter and the receiver.

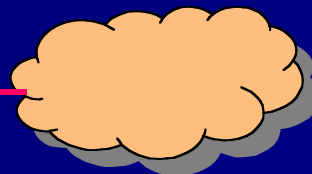
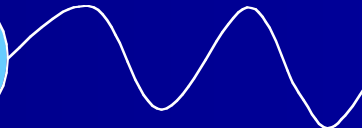
Transmitter Laser



Receiver



Signal



No Signal

Free Space Laser Communication requires precise aim. Unlike radio signals which spread broadly, laser beams stay tightly focused, and can potentially miss a receiver, particularly if one or both of the transmitter and receiver are moving

