Announcements:

Exam 2 is next week (Tue., 7:30-9:00pm) in G1B30 (next to our classroom)
Topics: TZD, Chapters 3-5, 11.9, 11.10

No written HW due for next week but reading assignments are due as usual.

What’s so special about LASER light?

Remember the word 'coherence'? (We used it occasionally in context with interferometers, diffraction and with photons.)

There are two types of coherence:
- Spatial coherence
- Temporal coherence

LASERs produce light with excellent spatial and temporal coherence.

Spatial coherence

Collimating lens
Flashlight (incoherent)
Laserpointer (coherent)

Temporal coherence

Flashlight (incoherent)
'Lach-Zehnder' interferometer
Laser (coherent)

For very stable lasers: \((\tau_1 - \tau_2)_{\text{max}} \approx 1 \text{ second.}\)
(This corresponds to 300'000 km path difference!)

Remember this one (from class 3):

E-field (for a single color):
\[ E(x,t) = A_0 \sin(\omega t + \frac{\lambda x}{c} + \phi) \]
\( \omega = 2\pi f \)

Temporal coherence: \(\omega\) and \(\phi\) are very well defined constants (i.e. time independent).

Let's make a coherent light pulp!

Bad: Throw away most of the light and individual photons still have random phases \(\phi\)

Color filter (passes only certain colors, \(\omega\))

Aperture

Remember: Coherent light requires that \(\omega\) and \(\phi\) are constants.
How light interacts with atoms

Spontaneous emission of light: Excited atom emits one photon.

Absorption of light: Atom absorbs one photon.

Stimulated emission: clone the photon — A. Einstein


Laser: Stimulated emission to clone photon many times (~10^{20}/s)
Light Amplification by Stimulated Emission of Radiation

Stimulated emission

Identical phase
Identical energy
Identical momentum

Legend:
Photon Atom in ground state Atom in excited state

Stimulated emission

To increase the number of photons when going through the atoms, more atoms need to be in the upper energy level than in the lower.
Need a “Population inversion”
(This is the hard part of making laser, b/c atoms jump down so quickly.)

Legend:
Photon Atom in ground state Atom in excited state

Optical resonator

Some fraction of the photons are ‘recycled’ through the amplifier (feedback!). The rest is used as the laser’s output.
This is done with an ‘optical resonator/cavity’

Continuous supply energy to the atoms to maintain population inversion.
Semiconductor lasers are tiny!

But others can be fairly ‘involved’

...or very involved...

All the energy of this laser is focused into this! (Trigger Nuclear fusion.)

No population inversion in 2 level atom!

Population inversion means: More atoms are in the excited state than in the ground state. As soon as we have the same number of atoms in the excited state as in the ground state, the probability of creating an excited atom is same (or smaller, when considering spontaneous emission) as the probability of having stimulated emission!

→ Can never reach population inversion in 2-level atom!

Need at least 3 energy levels!

→ Use a second color of light to create population inversion

Let’s play!

http://phet.colorado.edu/simulations/lasers/lasers.jnlp
LASERs need:
• Population inversion → Gain
• Optical feedback (optical resonator) → Coherent light

Various 'flavors' of Lasers
- Gas lasers
- Dye lasers (liquid)
- Chemical lasers
- Solid state lasers
- Fiber lasers
- Diode lasers
- Gas dynamic lasers

Practically unlimited numbers of applications for lasers

Just to name a few:
Medicine: Surgery (no bleeding, noncontact → eye)
          Diagnostics (TP-Microscopy, tomography)
Machining: Tight focus allows very high intensity.
          (100 W cut through hardened steel like butter)
Science: Huge variety of applications
          (Ultra precise spectroscopy / light matter interaction...)
Commercial: DVD/CD, range finding, leveling
            telecommunication…