RADLEY

Lasers

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Radley College

Today we shall

1. understand stimulated emission
2. know how a laser works
3. use our knowledge about energy levels from previous lessons

Textbook p. 183 [APFY]

Specification Requirement

4.5 – Lasers

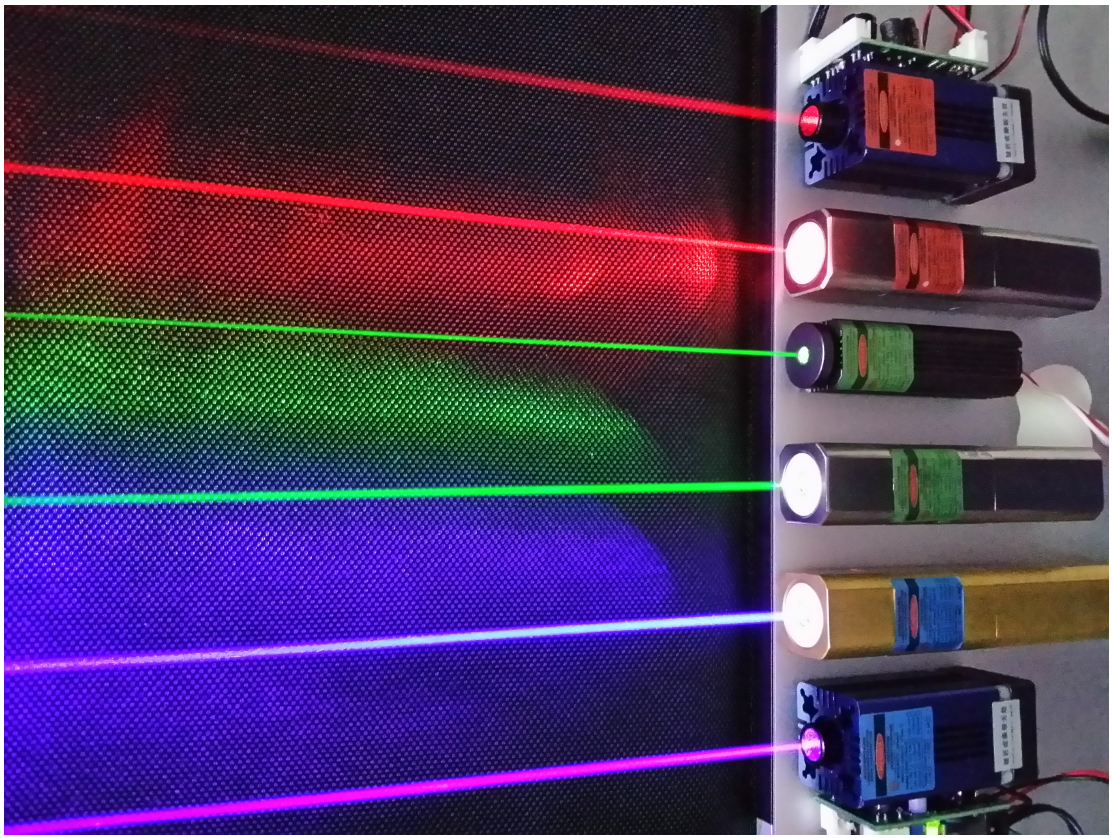
the process of stimulated emission and how this process leads to light emission that is coherent

the idea that a population inversion ($N2 > N1$) is necessary for a laser to operate

the idea that a population inversion is not (usually) possible with a 2-level energy system

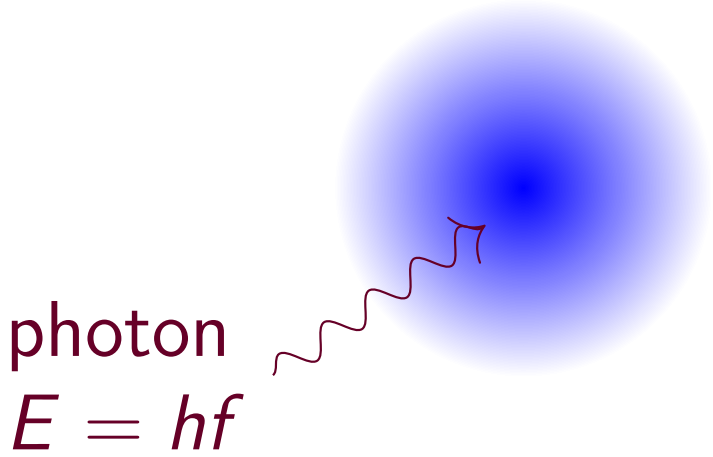
[Eduqas A Level Physics Specification, teaching from 2015]

Seeing a laser beam



[Image credit: Wikimedia / (CC-BY)]

Absorption: an atom absorbs energy (an electron jumps to an excited state)



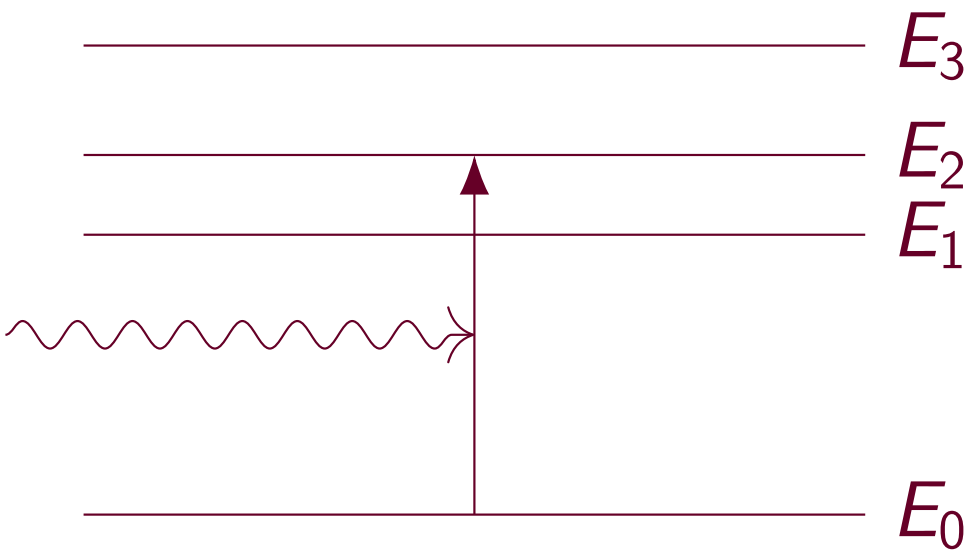
A photon of adequate energy imparts its energy to the atom

Absorption: an atom absorbs energy (an electron jumps to an excited state)

A photon of adequate energy imparts its energy to the atom, causing the electron cloud to take on a new configuration.

Absorption: an atom absorbs energy (an electron jumps to an excited state)

photon
$E = hf = E_2 - E_0$

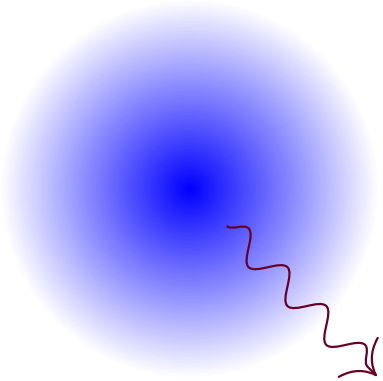


An electron jumps into a higher-energy excited state, and the photon has ceased to exist.

Spontaneous emission is when an atom emits its overload of energy as a photon

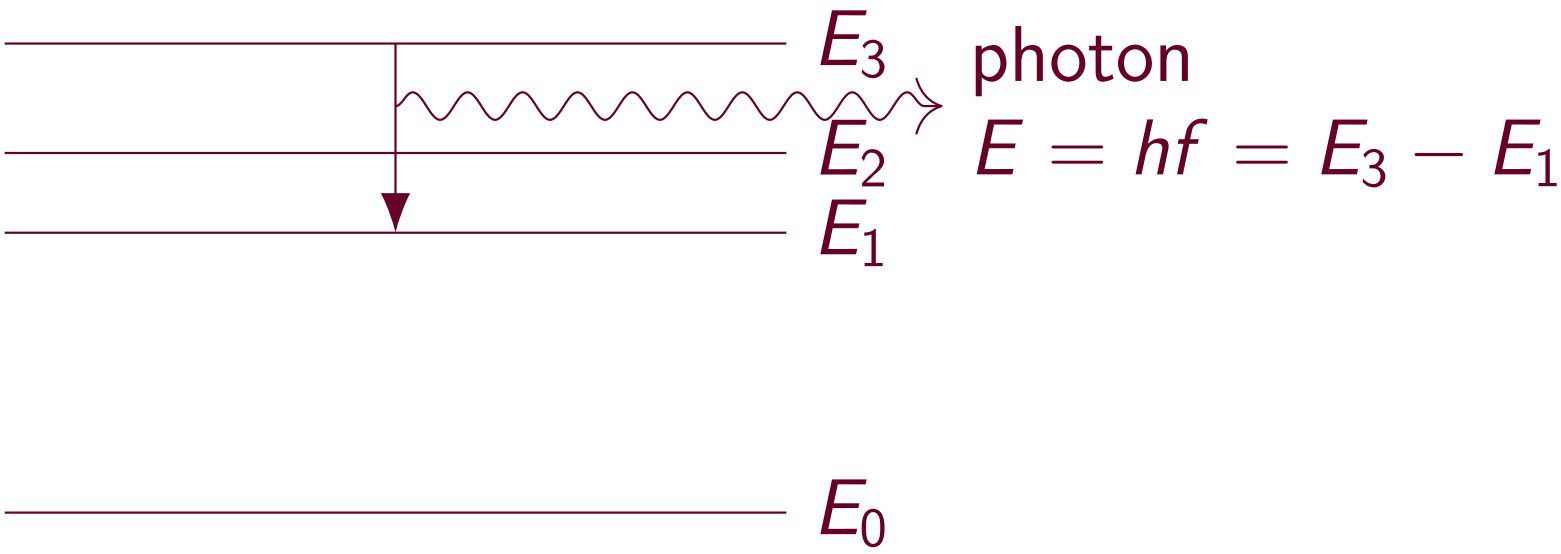
Excited states are usually (*not always!*) short-lived, 10 ns or so is typical

Spontaneous emission is when an atom emits its overload of energy as a photon



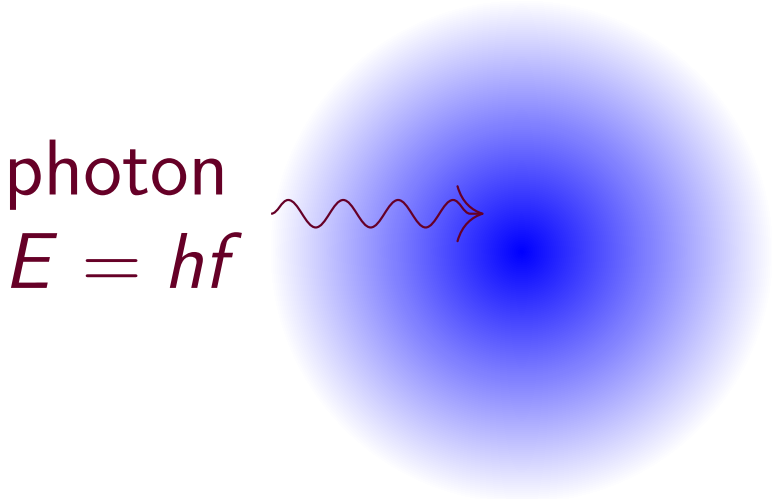
An atom might emit some or all of its extra energy at any time as a photon

Spontaneous emission is when an atom emits its overload of energy as a photon



In doing so an electron reverts ('falls') to a lower energy state

Stimulated emission: a photon causes an excited atom to dump energy



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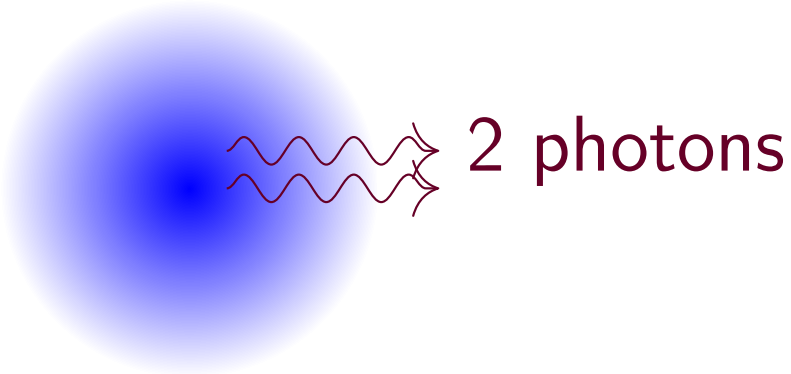
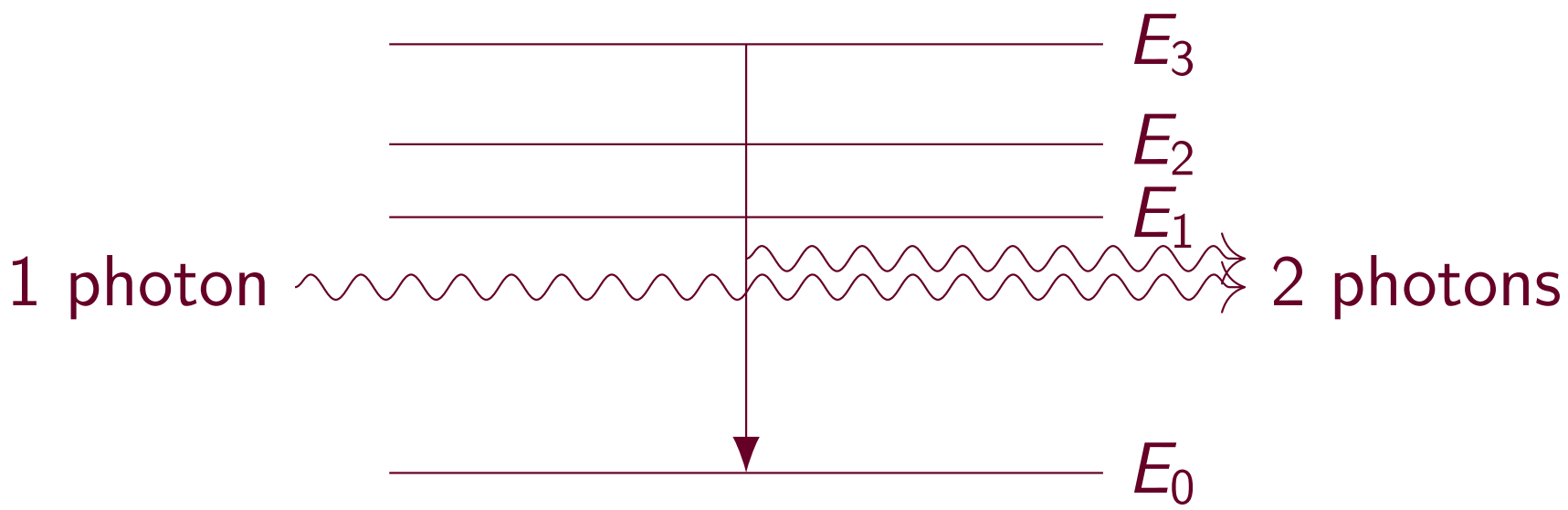


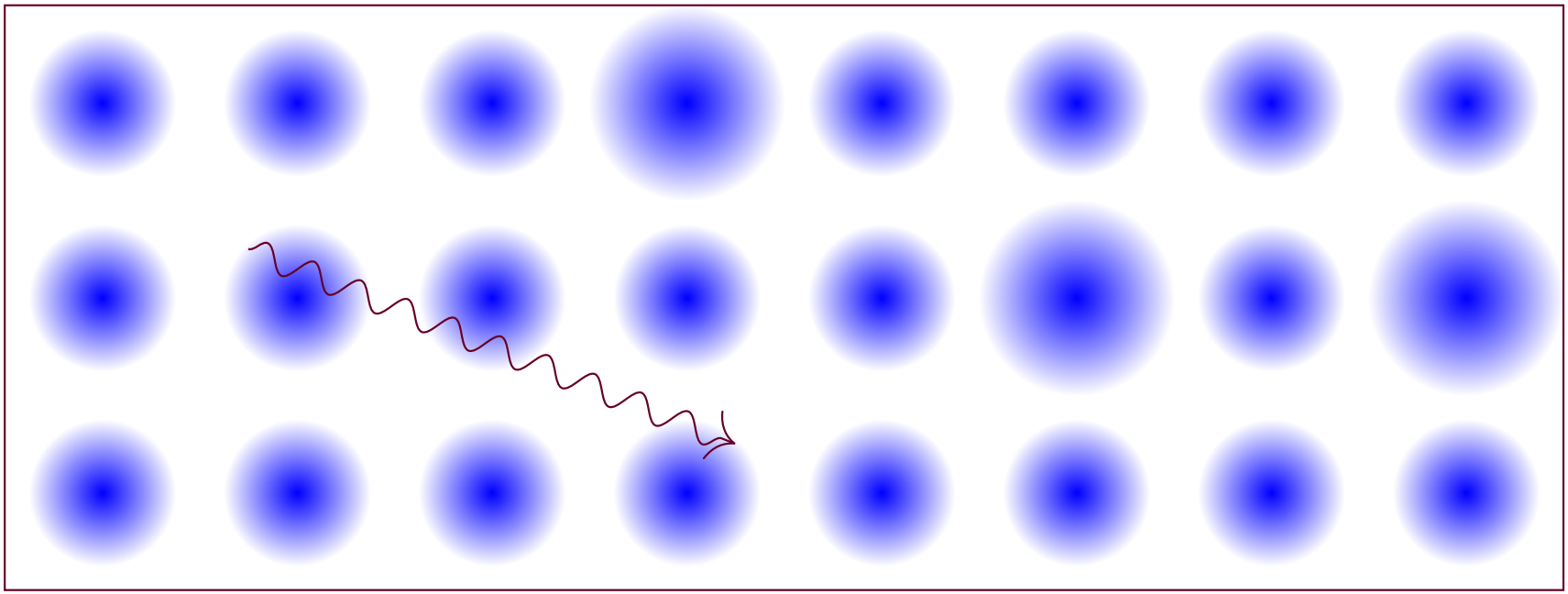
The atom loses energy by emitting another photon, in-step with the incoming photon.

Stimulated emission: a photon causes an excited atom to dump energy



- Predicted by Einstein in 1916
- Crucial to the operation of lasers (developed 1960)

What happens in a collection of atoms which are almost all excited?



In ordinary circumstances, not many atoms are excited: absorption is more likely than stimulated emission

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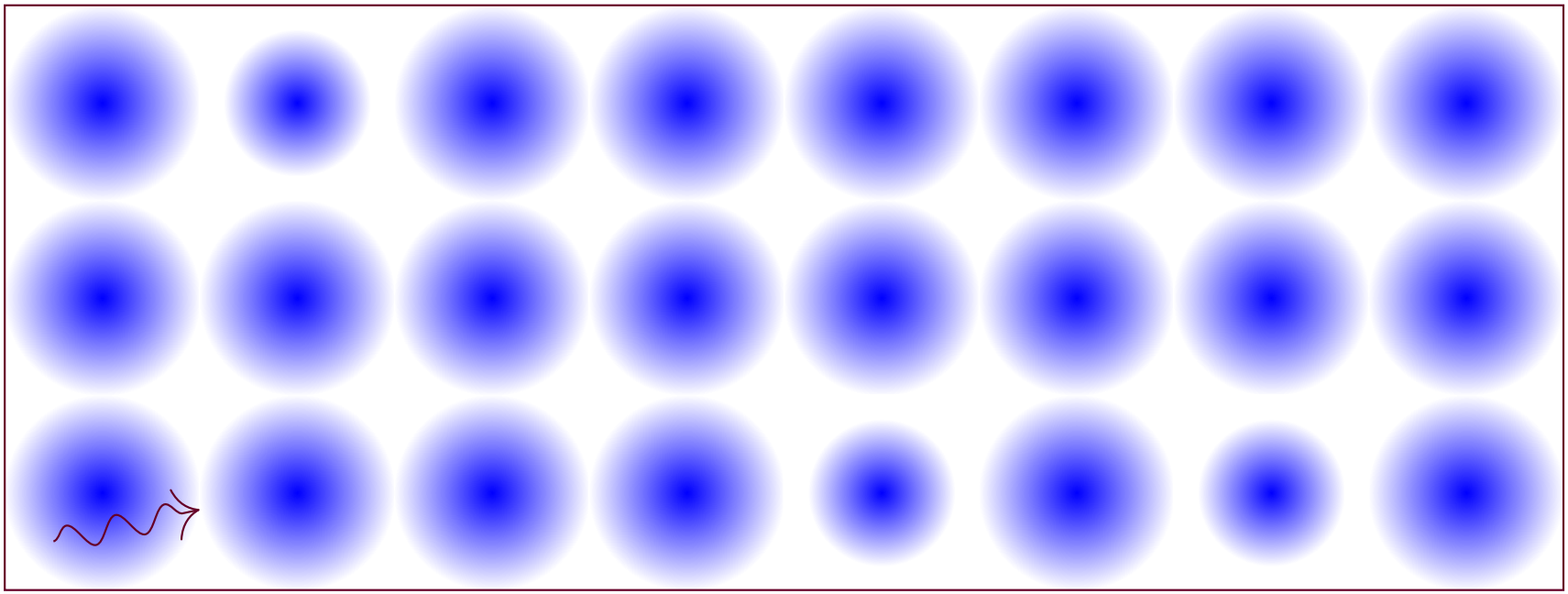

This is known as a *population inversion*. The lower state is all but empty.

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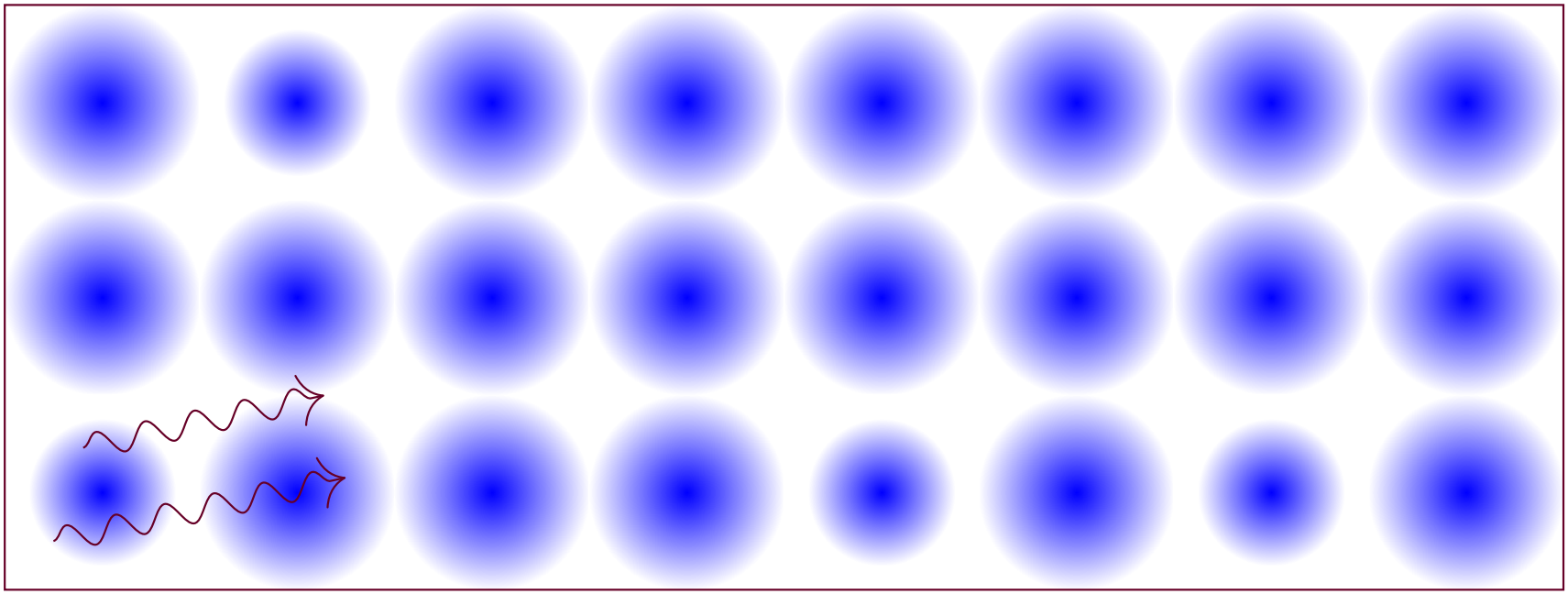

An incident photon of the proper frquency could then trigger an avalanche of photons by stimulated emission—*all in phase*

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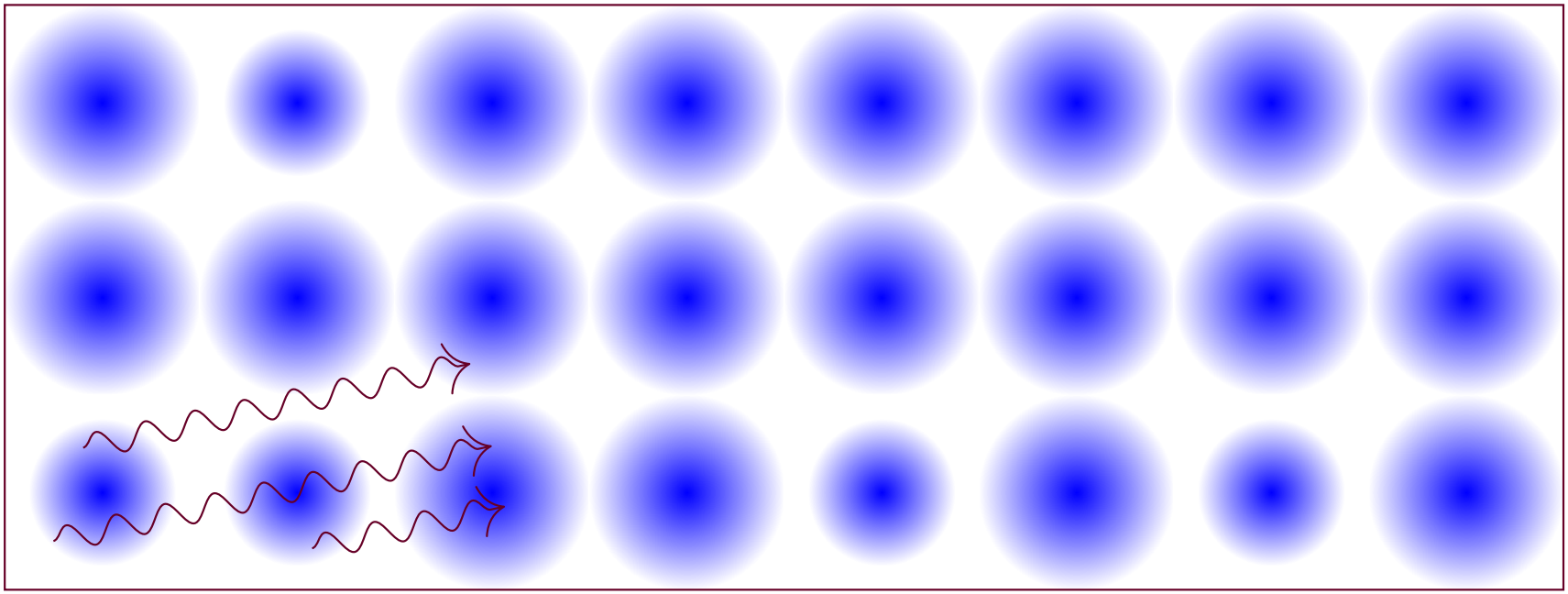

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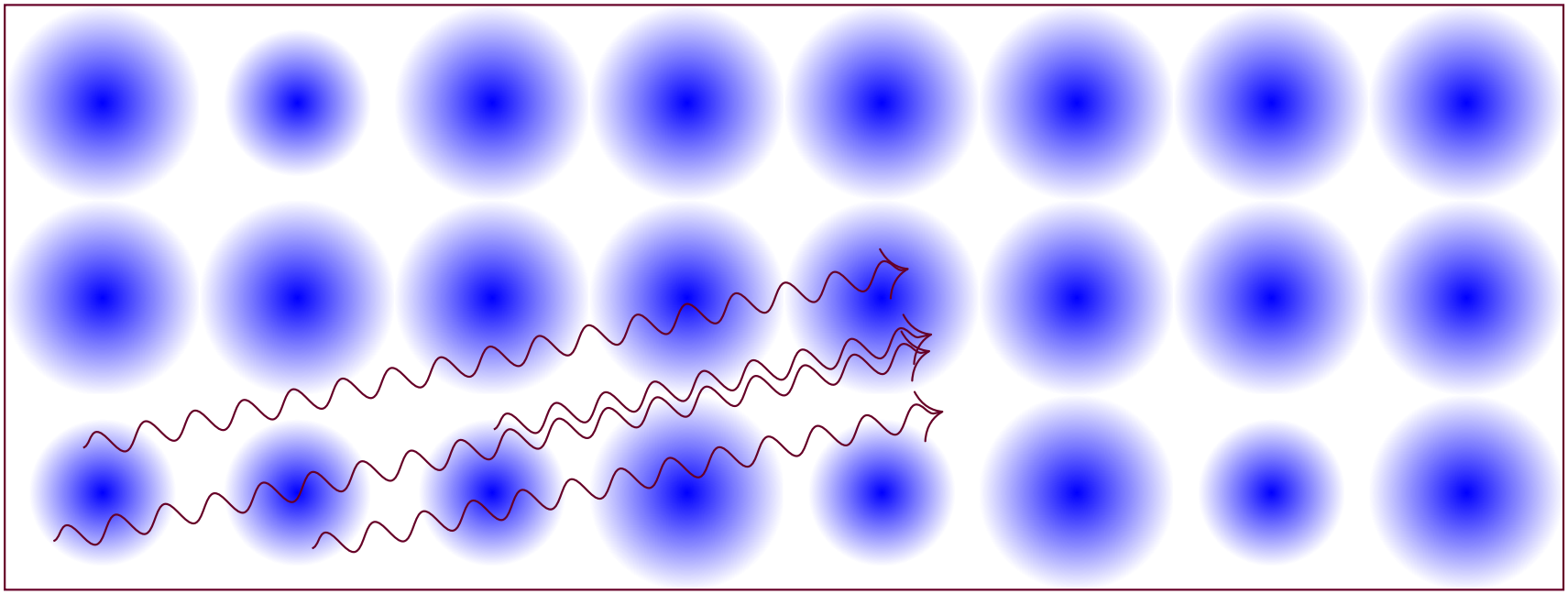

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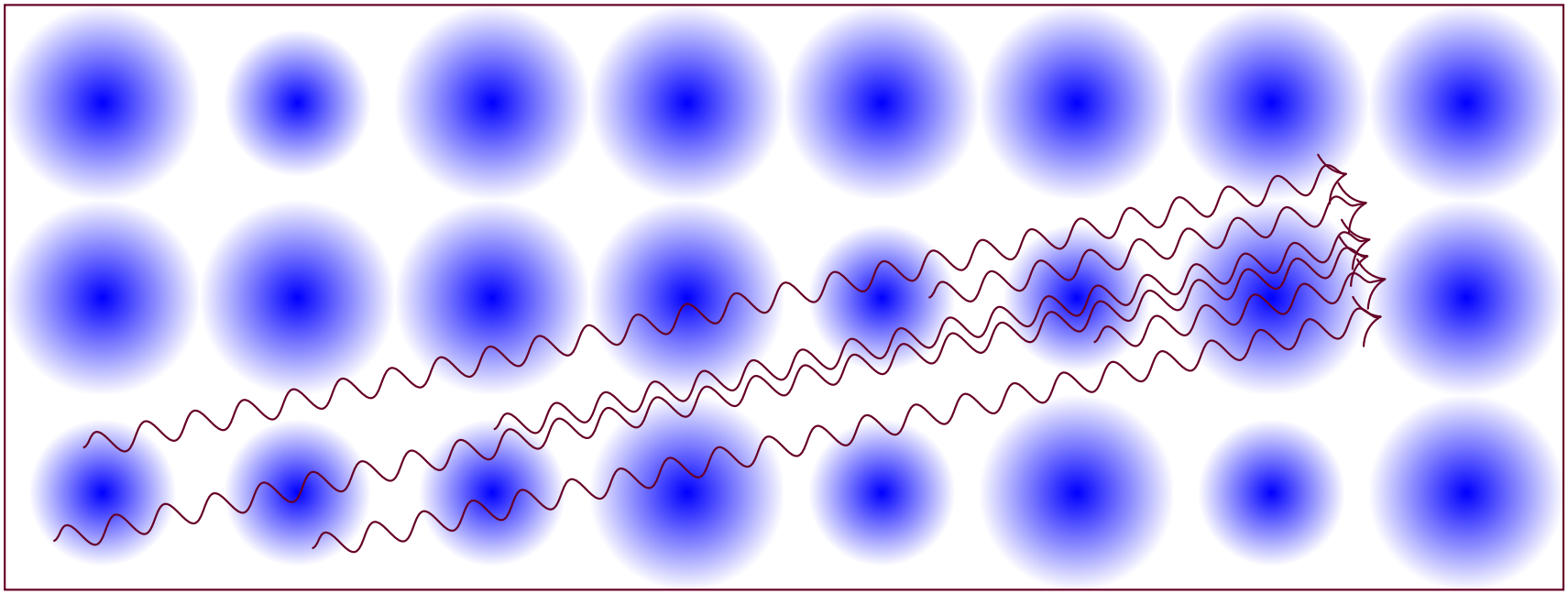

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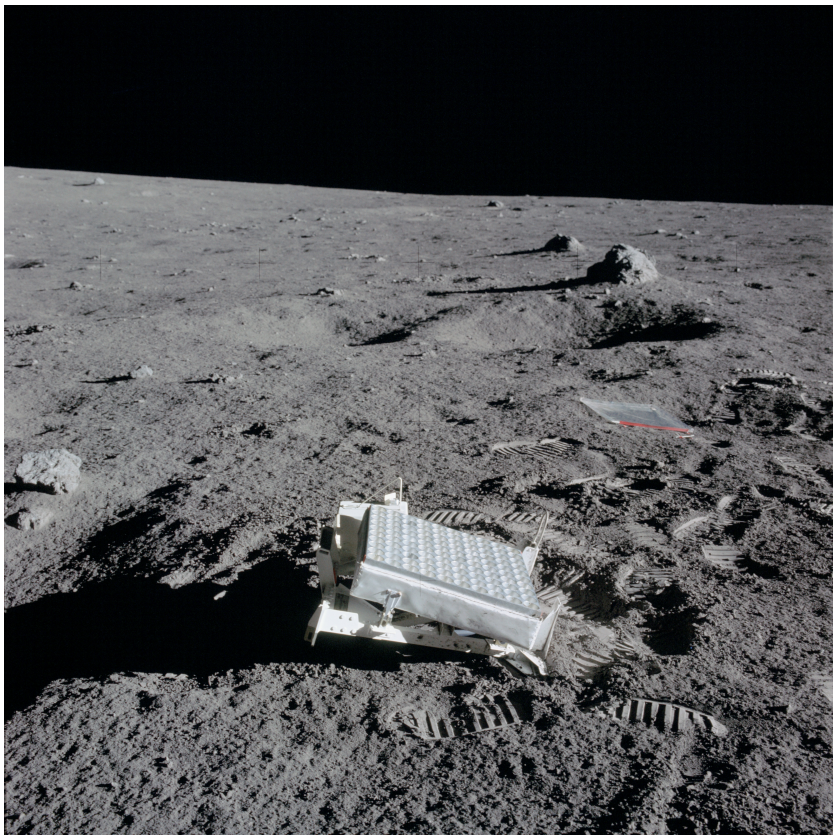
The laser: *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation

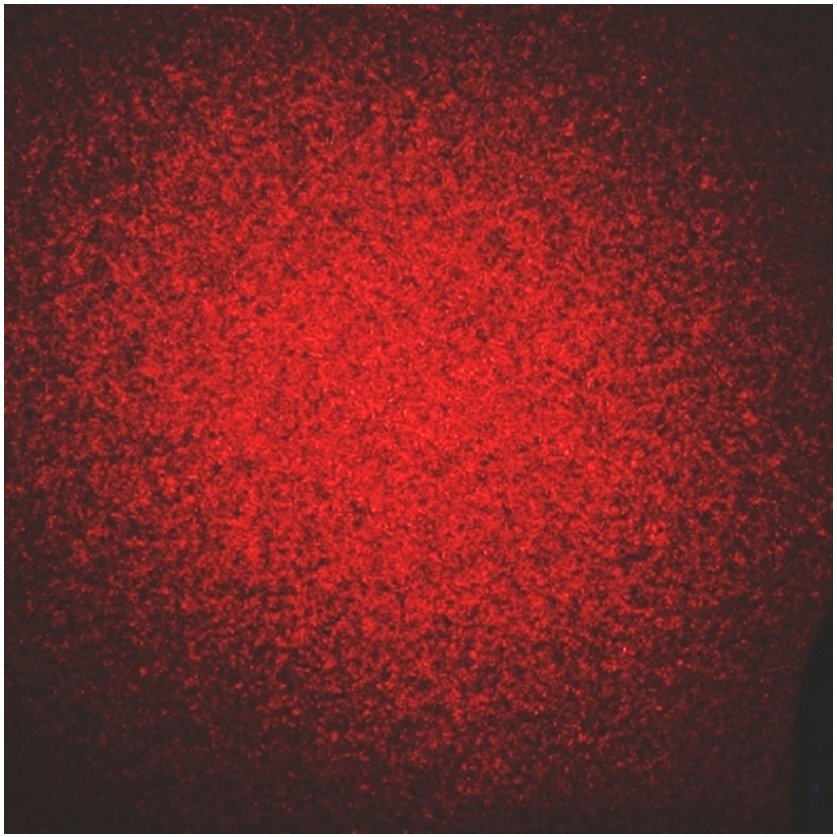
Lasers aimed at the moon allow ranging to a few cm in 4×10^5 km



[Image: Apollo XIV / NASA (public domain)]

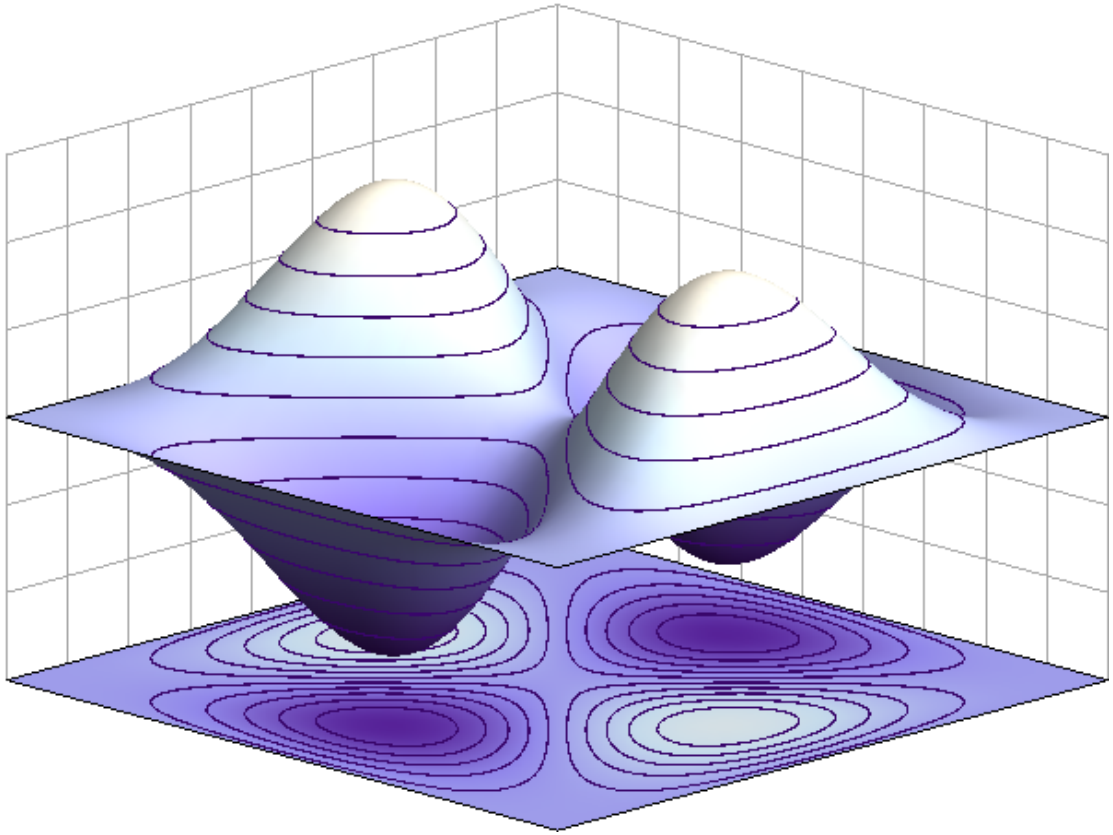
Lasers are coherent

Laser speckle



Lasers work since photons are bosons, and get into the same quantum state

Fermions



[Image: Wikimedia / Timothy Rias (CC-BY)]

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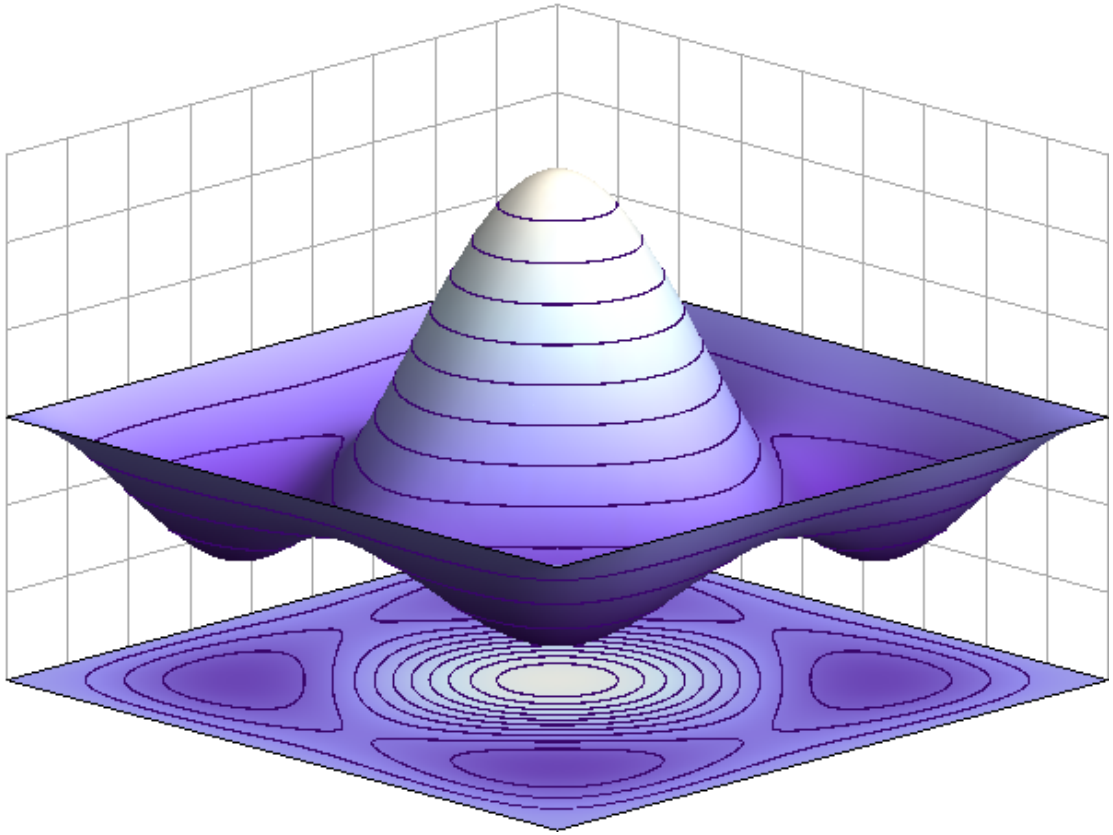
Bosons



[Image: Wikimedia / Timothy Rias (CC-BY)]

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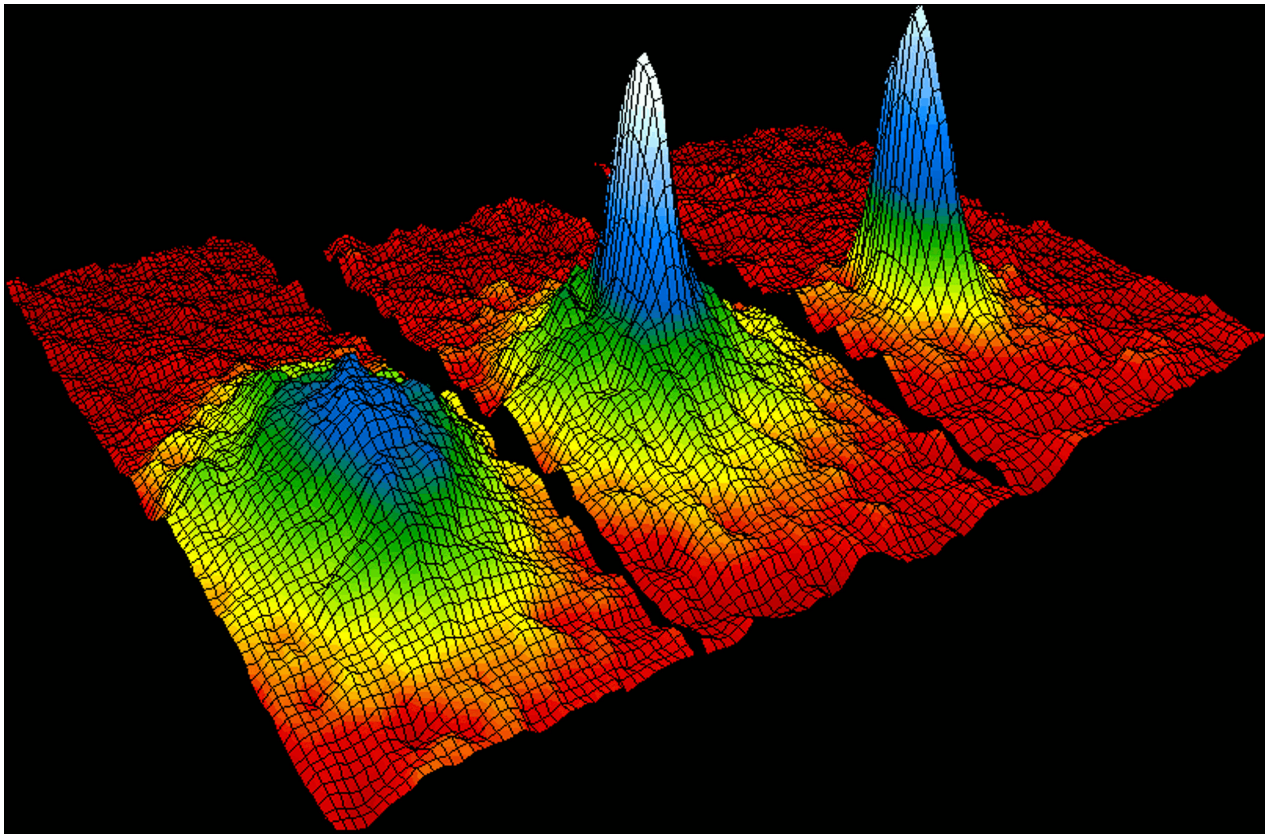
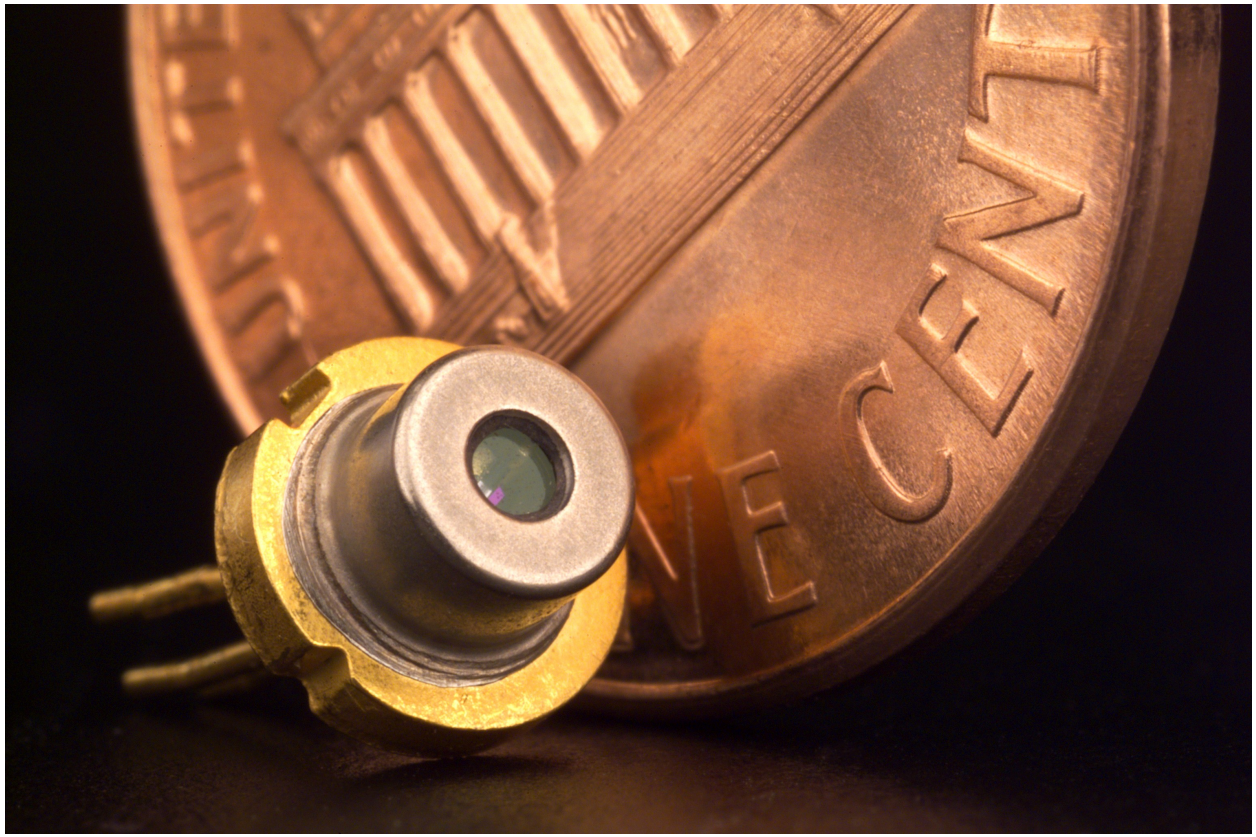


Semiconductor laser diodes are now the most common type of laser



Semiconductor laser diodes are now the most common type of laser

- small
- cheap
- far more efficient

Uses:

- fibre optics telecommunications
- barcode readers
- laser pointers
- CD/DVD/Blu-ray Disc reading / recording
- laser printing / scanning
- (increasingly) directional lighting sources

Problem: designing a laser

A material has six energy levels A–F above the ground state, G. The time constants in ns are shown on the diagram. Suggest possible optically pumped lasers working with this material, and give pumping and output λs.