Sound amplification by the stimulated emission of radiation (SASER)

PRESENTATION FOR PHYSICS 536 – WINTER 2023

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LASERS are cool!

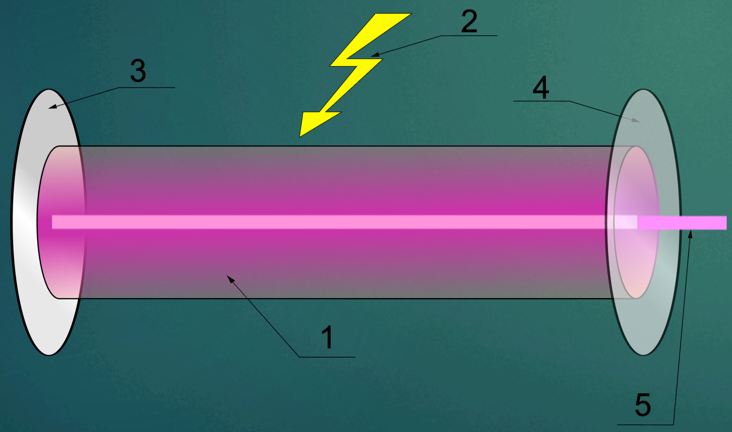
They provide a source of light waves that is

- High intensity
- Monochromatic
- Highly columnated
- Spatially Coherent

Can we do the same thing for sound waves?

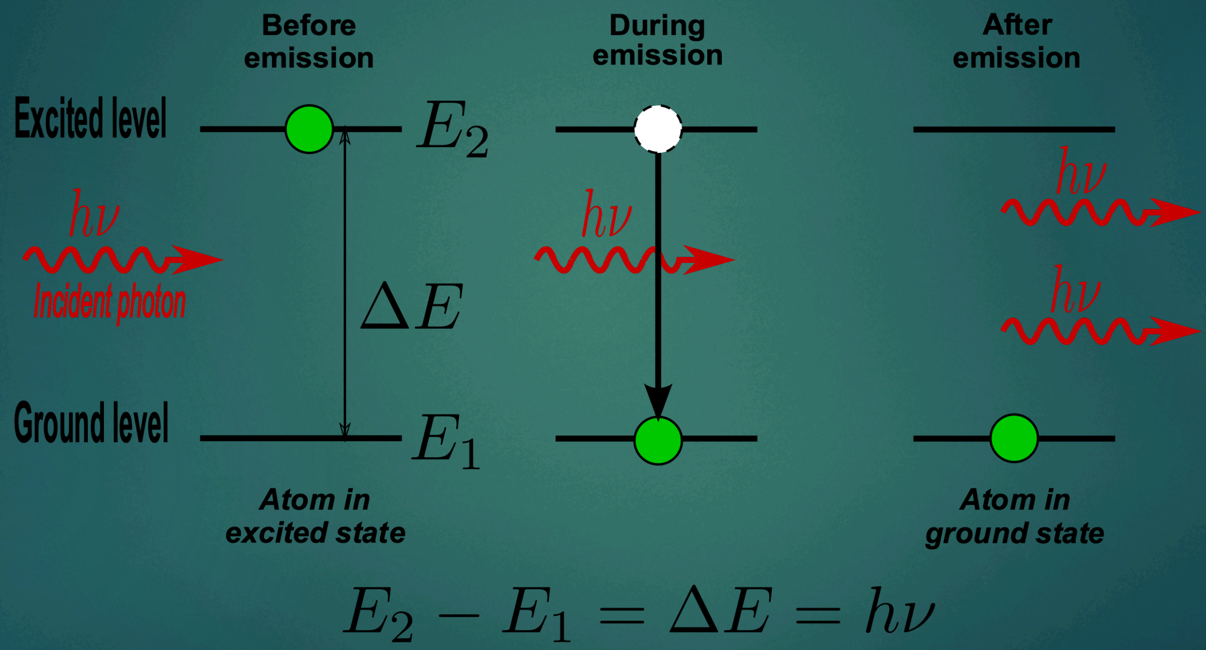
What makes a LASER a LASER?

- Stimulated emission
- Population Inversion



1.Gain medium
2.Laser pumping energy
3.High reflector
4.Output coupler
5.Laser beam

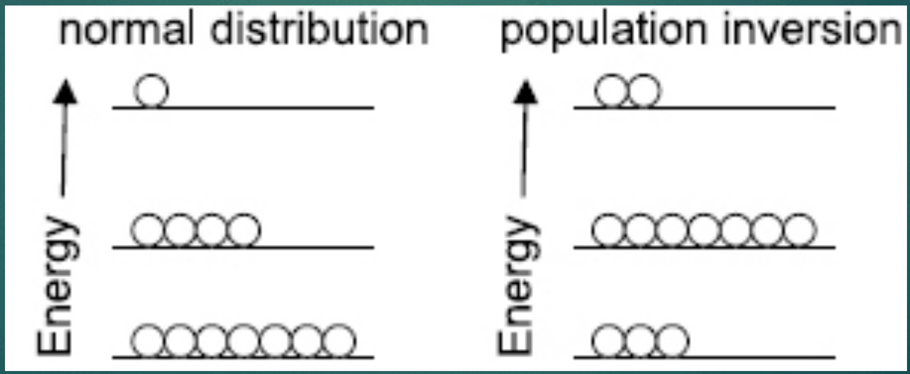
Stimulated emission



Population Inversion

Ratio of two populations of Boltzman distributions at thermodynamic equilibrium:

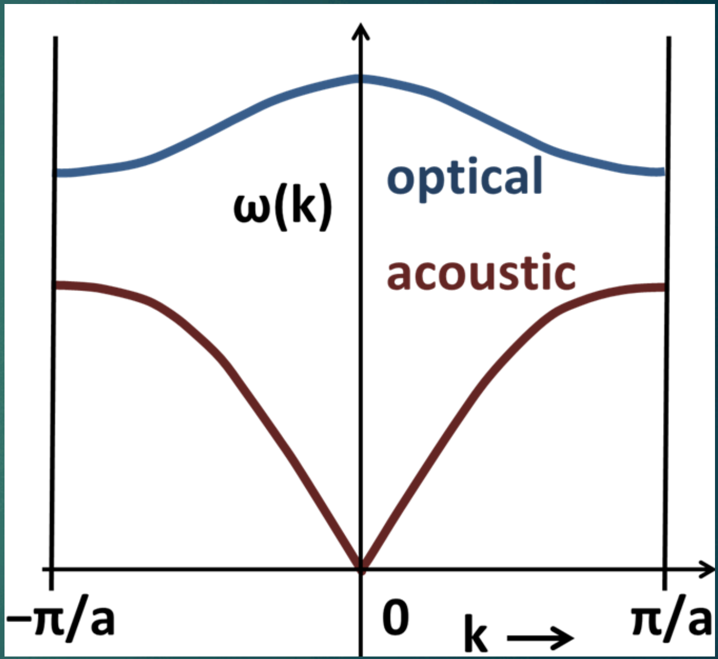
$$N_2/N_1 = \exp\left[-(E_2 - E_1)/kT\right]$$



D. W. Ball, *Field Guide to Spectroscopy* (SPIE Press, Bellingham WA, 2006).

Phonons

- Phonons are the quantized form of acoustic radiation, derived from the quantization of the vibrational modes of a crystal lattice.
- Like photons, phonons are bosons and obey $E=\hbar\omega$
- Because of the inhomogeneous nature of crystals the dispersion relations linking frequency and momentum are complex, typically with multiple branches.



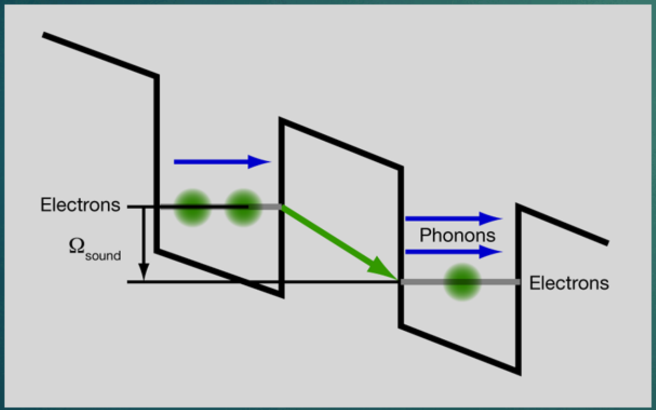
Maybe SASERS really aren't that cool?

"Saser beams that operate at much lower frequencies, in which the phonons oscillate a billion times per second (gigahertz) rather than a trillion times per second (terahertz), have been made before. However, they have had little impact because there are other methods of generating sound at such frequencies, says Kent"

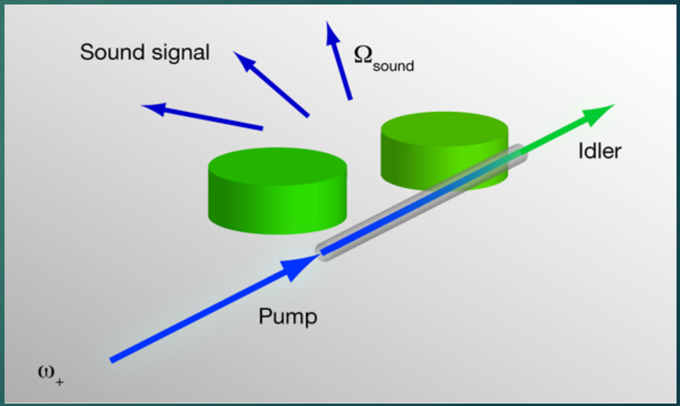
C. Baras, *Most Powerful "sound Laser" to Shake up Acoustics*, https://www.newscientist.com/article/dn17310-most-powerful-sound-laser-to-shake-up-acoustics/.

In 2010 two laboratories published implementations of SASERS using two very different systems and attracted a lot of press.

GaAs/AlAs superlattice (University of Nottingham)



Coupled microcavities (Californian Institute of Technology)



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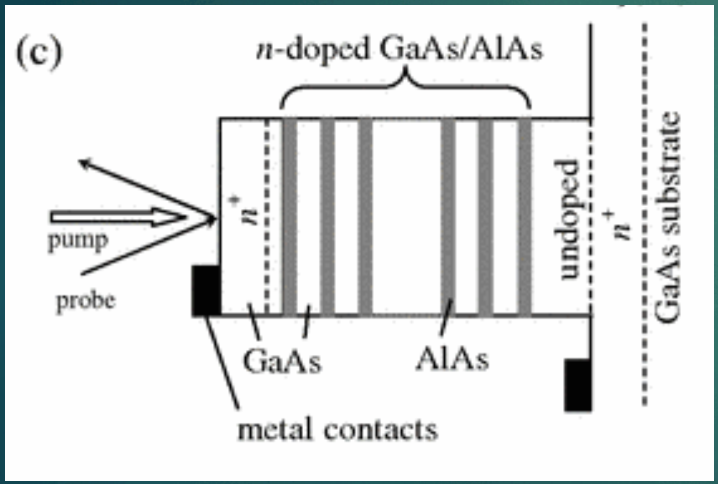

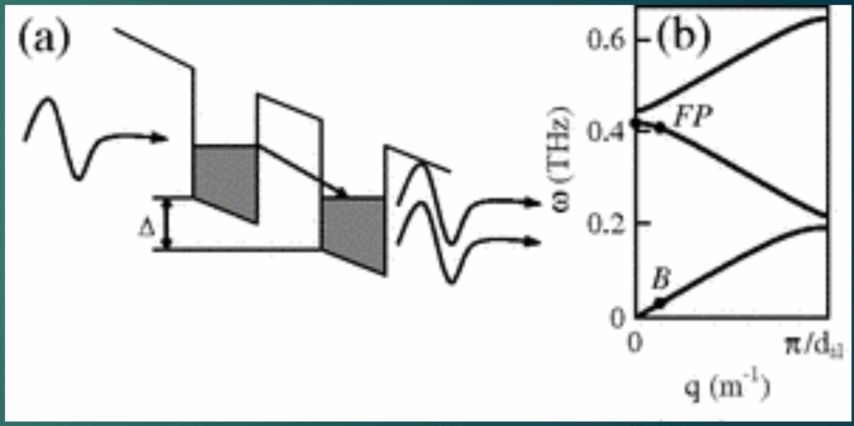

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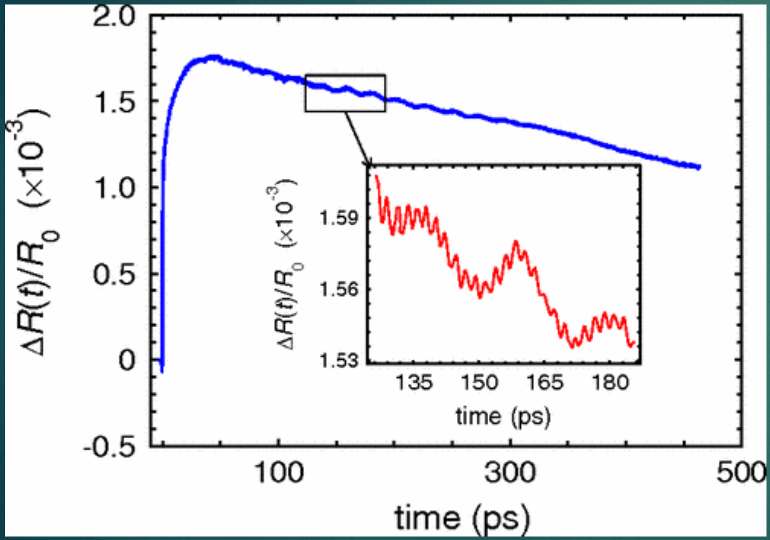

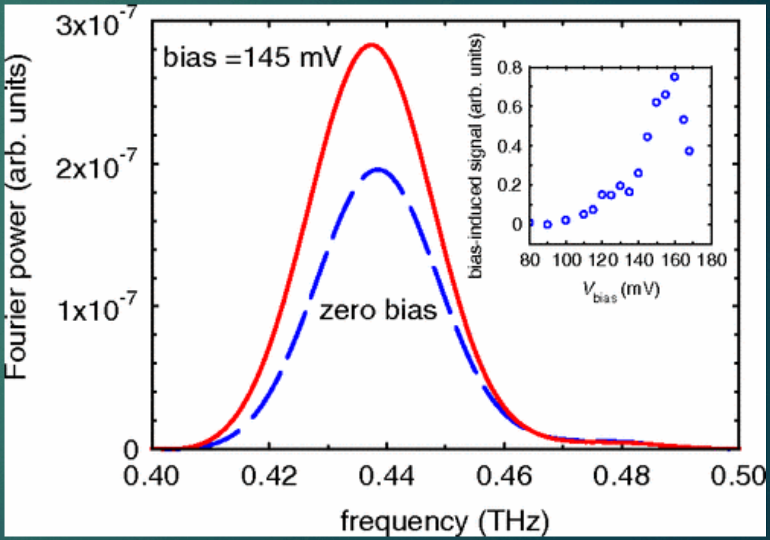

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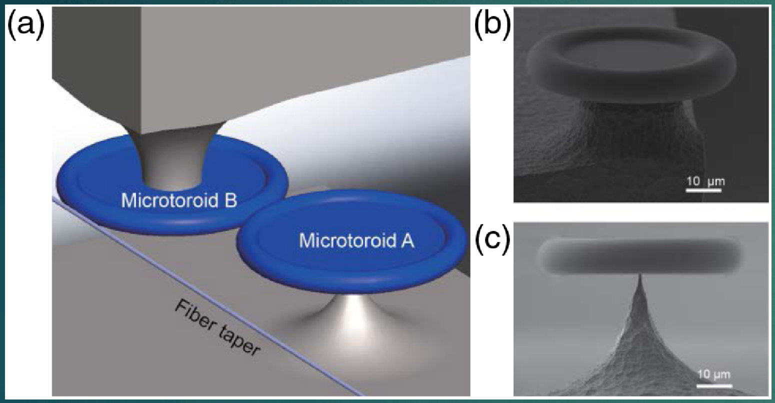

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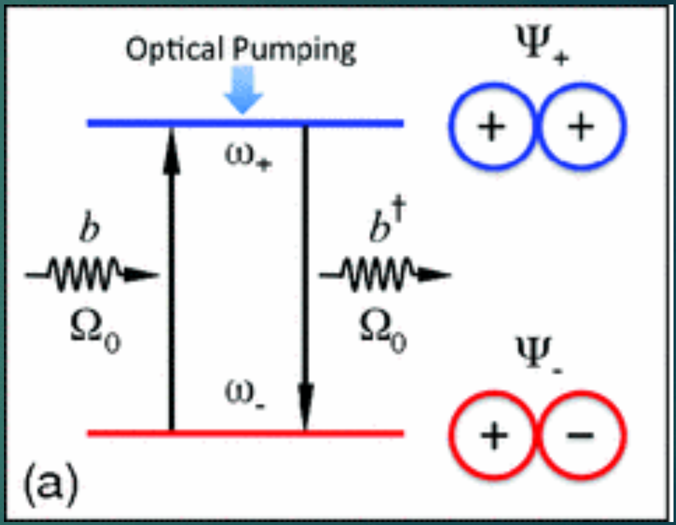

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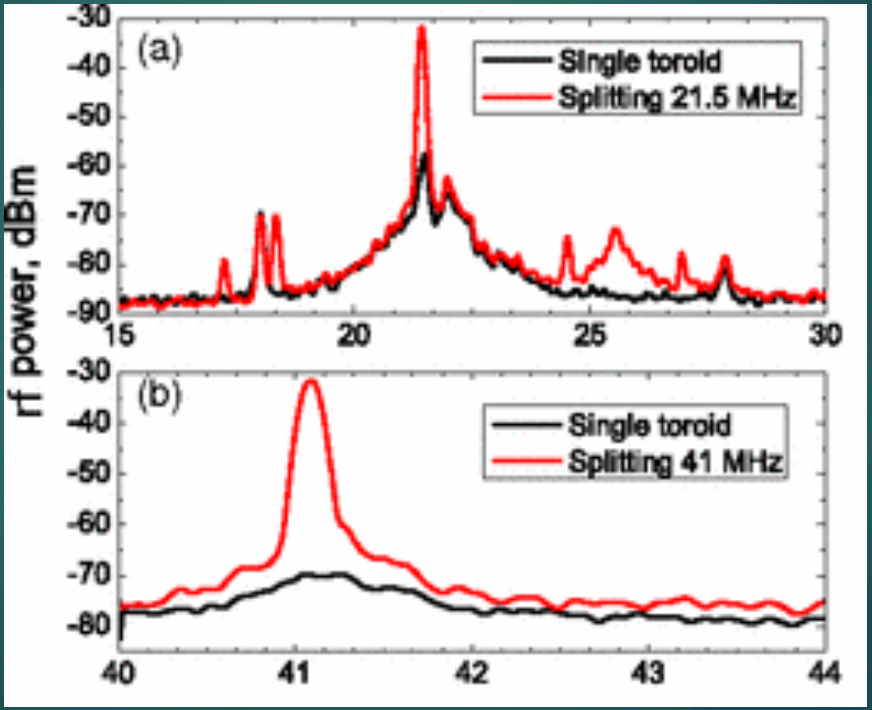

Pros and cons of the two systems

- The Nottingham group's superlattice device produced phonons that were near half a THz, which is where the interesting applications seem to be.
- Coherence was only demonstrated for a few hundred picoseconds, responding to femtosecond LASER pulses.
- It's easer to envision the superlattice being integrated into larger semi-conductor components.
- The CalTech group's microresonator device could be operated continuously, but only produced 41 MHz phonons, far below the frequencies of interest.
- It's not clear how to get phonons out of the microresonator and into a larger experimental system.

The Outlook for SASERS

“Ultimately, it's still rather unclear what sasers will be useful for. "They will find applications, but honestly I don't know where or for what,"

Jérôme Faist, a researcher at the Swiss Federal Institute of Technology in Zurich

G. Brumfiel, *“Sasers” Set to Stun*, Nature (2010). https://www.nature.com/articles/news.2010.92

“It is a great work. A high-energy coherent phonon source like a saser is the best tool we can have to noninvasively probe the unknown nanoworld.”

Chi-Kuang Sun a laser specialist at the National Taiwan University in Taipei City

C. Baras, *Most Powerful “sound Laser” to Shake up Acoustics*, https://www.newscientist.com/article/dn17310-most-powerful-sound-laser-to-shake-up-acoustics/.

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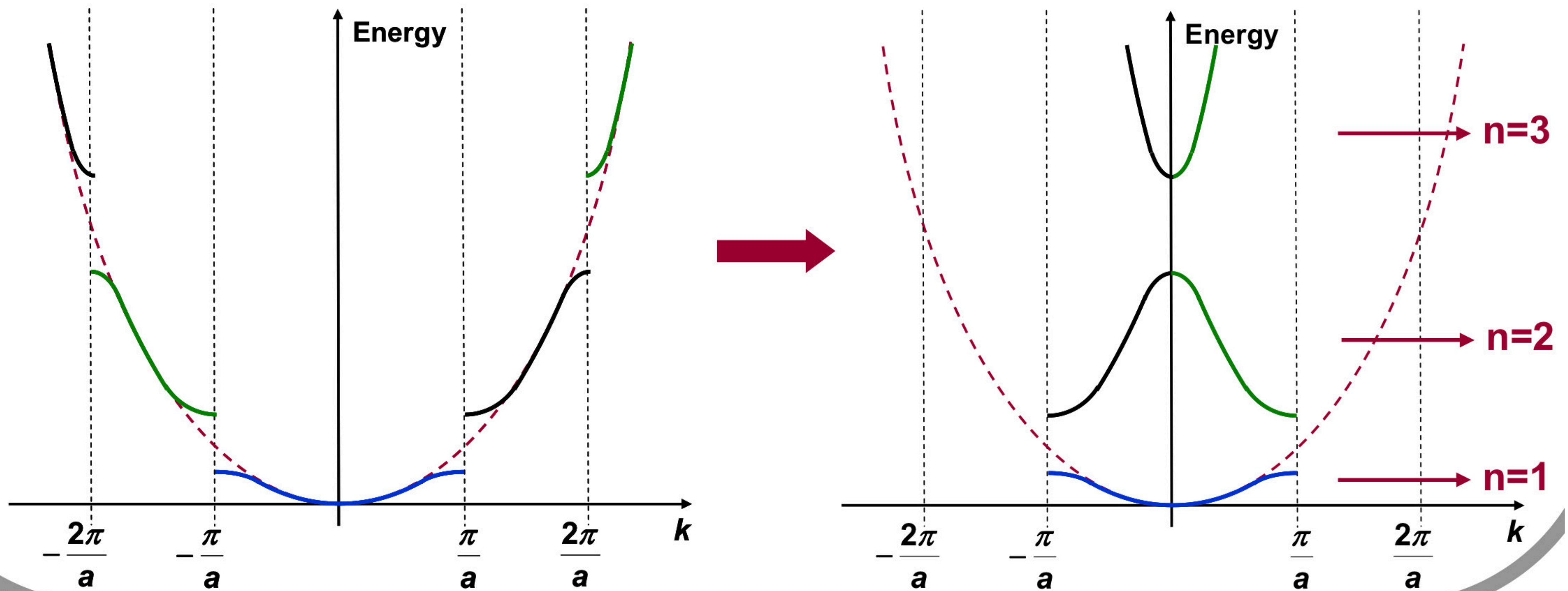
Wikipedia contributors, *"Stimulated Emission,"* https://en.wikipedia.org/w/index.php?title=Stimulated_emission&oldid=1112083365.



https://physics.stackexchange.com/questions/546435/loss-of-momentum-information-v