Hail the first sound 'lasers'

Feb 25, 2010 5 comments

Saser on a slant

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Two independent groups of physicists have unveiled the first phonon "lasers" – devices that emit coherent sound waves in much the same ways as lasers emit coherent light waves. Sometimes called "sasers", one of the devices emits sound at about 400 GHz while the other operates in the megahertz range.

Such very high frequency sound could be used to probe the interiors of tiny objects – and the ability to create laser-like beams of sound could lead to new imaging applications. Indeed, the differences between the two devices suggest that sasers could be made to operate over a wide range of frequencies.

At the heart of any optical laser is a medium with an electronic transition that involves the emission of a photon. The medium is "pumped" by an external energy source so that the majority of the electrons are in the higher energy state of the transition. When such a state decays, it emits a photon that can stimulate the emission of many more photons – which in turn stimulate further emission. Because they are all produced by the same quantum process, the photons emerge as a coherent beam of light.

Spontaneous emission problems

Just as light behaves as both particle and wave, so sound can be described in terms of particles called phonons – quanta of vibrational energy that behave in much the same way as photons. While there is no reason why stimulated emission shouldn't also work for phonons, physicists had struggled to find materials in which stimulated emission – rather than random spontaneous emission – is the dominant decay process.

Now, two independent groups have come up with two very different solutions to this problem.

At the University of Nottingham in the UK, Tony Kent and colleagues have made a saser that operates at about 440 GHz. Their device comprises alternating layers of the semiconductor gallium arsenide (GaAs) and the insulator aluminium arsenide (AlAs). The GaAs layers act as quantum wells, which can trap electrons. If an electrical bias is placed across the layers, the electrons are inclined to hop across an AlAs barrier into the next well – emitting a phonon in the process. Crucially, such a hop can be stimulated by a similar phonon. To ensure that the phonons bounce back and forth through the structure like photons in a laser cavity, the team set the distance between the repeating layers to resonate with the wavelength of the phonons.

The team tested the device by firing a femtosecond laser pulse at one end of the layered structure. This creates phonons that initiate the stimulated emission. A second laser pulse is then bounced off the device to measure the reflectance of the material over several hundred picoseconds. Kent and colleagues observed oscillations in the reflectance that are caused by coherent phonons.

As the team increased the bias voltage from 80–180 mV, it saw an increase in the amplitude of the coherent phonons that peaked at

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about 160 mV before falling at higher voltages. According to Kent, the peak occurs when the phonon wavelength resonates with the device.

Pair of resonators

Meanwhile at the California Institute of Technology (Caltech), Ivan Grudinin and colleagues use two microwave resonators – each about 6 µm in diameter and made of silica – to create the phonon-producing transition for their saser. The resonators are separated by a gap of about 1 µm, which is small enough for the devices to be coupled via light waves to form a two-state quantum system.

A laser is used to pump the system to the higher energy state. Phonons at megahertz frequencies are emitted, stimulating the further emission of phonons. The team confirmed that the system was indeed a phonon laser by turning up the pumping power and observing no sound emission until a threshold level – above which the power increased rapidly and sound was emitted in a very narrow frequency range.

Kent told *physicsworld.com* that the two approaches are complementary and it should be possible to use one device or the other to create coherent phonons at any frequency in the megahertz to terahertz range.

Probing nanotechnology

A terahertz saser would be particularly useful in nanotechnology because its phonons would have a wavelength of about one nanometre and could penetrate relatively deep into a solid structure – opening the door to 3D imaging of nanostructures. This is unlike current analysis techniques such as electron microscopy, which are limited to surface analysis.

Sasers could also be used to cause the periodic strain of a material – modulating its optical or electrical properties. This could be used to create very fast switches or to generate terahertz electromagnetic radiation – something that is currently difficult to do.

"The next step is to optimize the device to increase the coherent acoustic output and minimize the background from spontaneous emission," said Kent. "We are also working on devices that can be integrated with a saser to make a kind of acoustic lab on a chip to measure nanostructures."

The devices are described in *Phys. Rev. Lett.* **104** 083901 and *Phys. Rev. Lett.* **104** 085501.

About the author

Hamish Johnston is editor of *physicsworld.com*

5 comments

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1 **jimbo**
Feb 26, 2010 4:51 AM
eugene, United States

Who can resist the analogy, & perhaps it should NOT be resisted:
PASES (phonon amplification by stimulated emission of sound).
I forsee the finest stereo system ever created !

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2 **abdilridahasaani**
Feb 26, 2010 1:11 PM

In such achievement, we shall have uniquely characterized sound wave as we have had a light wave with laser and a microwave with maser. As light waves with lasers are highly ordered in both space and time these saser waves would coherently do the same. Optimistically, scientific and medical applications of these waves will be witnessed soon with their adequate power and frequency.
Dr A S Hasaani
Departmnt of Physics
College of Science
University of Baghdad

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3 **franklinhu**
Feb 26, 2010 5:02 PM
Seattle, United States

Sound and light really aren't that different

I think this experiment along with experiments which can polarize sound show that the phenomenon of light and sound could be identical. In the case of sound, we know that it is not both a wave and a particle.

The behavior can be entirely explained in terms of a wave in a medium. Perhaps in the future, light phenomenon can be explained in a similar manner of a wave in a medium and we can dispense with this contradictory wave/particle duality.

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4 **Ragtime**
Feb 27, 2010 10:07 AM
Prague, Czech Republic

Quote:

> *Originally posted by* ***franklinhu***
> in the future, light phenomenon can be explained in a similar manner of a wave in a medium

In dense aether theory the spreading of light through vacuum could be modeled by spreading of sound through condensing supercritical fluid at the moment, when energy propagates most slowly through it along surfaces of newly formed fluid surfaces, which are having character of fractal foam in this environment. Another quite viable model is the spreading of light through metamaterial foam on which formation of event horizon of black holes was modeled.

www.noosphereforum.o...blue-hole.jpg

Spreading of light through supercritical foam has an advantage, the particles are interacting with energy in similar way, like soap foam being shaken inside of evacuated vessel: it becomes more dense temporarily, thus mimicking the formation of photon particles during passing of light wave through quantum foam, forming vacuum.

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5 **GEORGEP**
Mar 12, 2010 2:38 PM

Wave-particle Duality

Quote:

> *Originally posted by* ***franklinhu***
> I think this experiment along with experiments which can polarize sound show that the phenomenon of light and sound could be identical. In the case of sound, we know that it is not both a wave and a particle. The behavior can be entirely explained in terms of a wave in a medium. Perhaps in the future, light phenomenon can be explained in a similar manner of a wave in a medium and we can dispense with this contradictory wave/particle duality.

A "wave" is a mathematical abstraction that describes the organized motion of the medium in which it travels (usually air for sound, water for water waves, the EM field itself for light--rough analogy). Water waves are clearly waves, right? Yet I recall some papers (AGU publication, sorry I can't give the exact references) in which treating them as particles described their behavior. It's fair to say that a "particle" is also a mathematical abstraction. How can an object of zero size have a finite mass? The wave-particle duality is an aspect of the math used to describe nature. For example, it is well known that there is an uncertainty relation that comes out of Fourier analysis.

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