INDUSTRY DEVELOPMENTS:

COOLING WITH LASERS

The concept of cooling anything with the use of a laser contradicts the way many engineers think about their typical applications. For example, lasers are used around the world for welding and cutting materials, including metals, with high levels of energy. But in certain situations, using lasers can provide a cooling condition.

Laser cooling occurs when the amount of energy emitted by a solid, when exposed to an energy source, is more than the energy it absorbs. In other words, a laser aimed at certain materials will excite the materials' atoms to a higher energy state. These excited atoms absorb a little extra energy from the heat of the surrounding material. When they produce photons, the photons are of a higher energy than the initial laser energy and this radiation of energy cools the material. [1]

COOLING WITH LASERS

While the electronics inside laser systems may require thermal management, lasers may one day have a major role in cooling electronic components. A research team at Singapore's Nanyang Technological University (NTU) successfully used a laser to cool down the semiconductor material cadmium sulfide, CdS. The results of their study could lead to the development of self-cooling computer chips and smaller, more energy efficient air conditioners and refrigerators that don't produce greenhouse gases [2].

Having a laser to annihilate something isn't usually associated with chilling anything down. But a new experiment reduced the temperature of a semiconductor by about 40°C using a laser. Cadmium sulfide is an inorganic compound commonly used as a thin-film layer in solar cells, sensors and electronics. The NTU researchers fabricated narrow strips of CdS, deposited on a substrate of silicon and silicon dioxide at room temperature. They used an optical-wavelength laser, tuned to the precise wavelength to interact with multiple modes of phonons in the semiconductor. When the laser photons interacted with this excitation, they canceled it out, damping the thermal fluctuations in the material. Because of this, the NTU research team successfully optically-refrigerated CdS from 20°C (68°F) down to -20°C (-4°F), a 40°C drop in temperature.

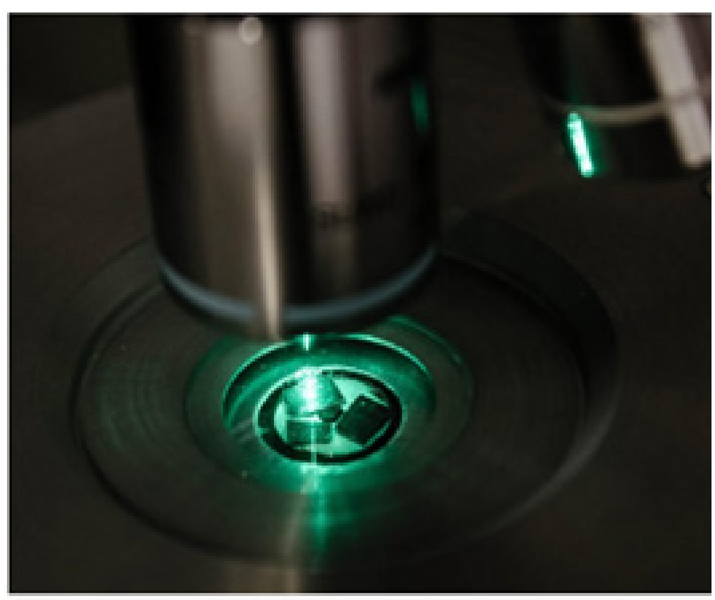

Figure 1. Researchers at Nanyong Technological University Used a Laser to Cool Cadmium Sulfide [2]

Advances in cooling by laser, also described as optical refrigeration technology, could lead to compact, cost effective, vibration-free and cryogen-less cooling systems in many different applications. CPUs could reduce their reliance on heavy cooling systems like fans and heat pipes, and incorporate built-in laser controlled systems within the package instead. Cooling by laser might also be used one day to minimize heat and extend battery life in tablets and smartphones, and bring a solid state cooling solution to instruments that require very low temperatures.

Professor Xiong Qihua of NTU said "If we are able to harness the power of laser cooling, it would mean that medical devices which require extreme cooling, such as MRI which uses liquid helium, could do away with bulky refrigerant systems with just an optical refrigeration device in its place." [2]

NEAR ABSOLUTE ZERO COOLING

Researchers at the Niels Bohr Institute, part of the University of Copenhagen, discovered a method for laser cooling of semiconductor membranes. In fact, using lasers, researchers there have cooled membrane to -269°C. [3]

The Institute's scientists developed the new laser cooling method which actually works by heating material. Their technique combines quantum mechanics with nano physics. Laser cooling of atoms has been practiced for several years in experiments in the quantum optical laboratories of the Quantop group at the Institute. Researchers have cooled gas clouds of cesium atoms down to near absolute zero, -273°C, using focused lasers at the atomic level.

While laser cooling of gases has been standard procedure for many years, solids are another issue. Success has only come with a few specially prepared materials. For solids, the thermal motion of the atoms takes the form of phonons: vibrations moving through the material. Being quantum excitations, phonons behave like particles: they can collide and scatter. One way to optically cool solids, therefore, would be to annihilate the phonons with laser light.

In their experiments, the Niels Bohr Institute scientists shone laser light onto semiconductor nanomembranes with a thickness of 160 nm and a surface area of 1 x 1 mm. This was done inside a vacuum chamber. They then allowed the membrane to interact with the laser light within the chamber in such a way that its mechanical movements affected the light that hit it. When the laser light hits the semiconductor membrane, some of the light is reflected and the light is reflected back again via a mirror so that the light travels back and forth in this space and forms an optical resonator. Some of the light is absorbed by the membrane and releases free electrons. The electrons decay and thereby heat the membrane and this gives a thermal expansion.

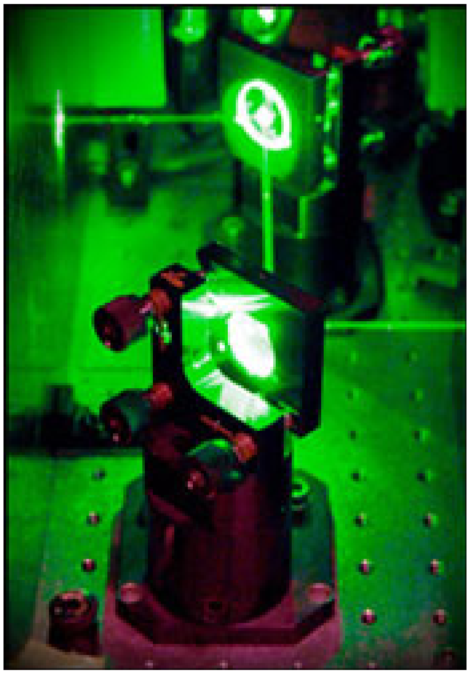

Figure 2. Laser Light Directed at Semiconductor Membranes is Controlled with Multiple Mirrors [3]

In this way, the distance between the membrane and the mirror is constantly changed in the form of a fluctuation. Due to the interplay between the movements of the membrane, the properties of the semiconductor, and the optical resonances, the membrane could be cooled to -269°C.

The potential of optomechanics – the interaction between light and mechanical motion – could pave the way for cooling components in quantum computers. Efficient cooling of mechanical fluctuations of semiconducting nanomembranes by means of light could also lead to the development of new sensors for electric current and mechanical forces.

LASER COOLING'S FUTURE

Lasers designed for cooling solids would be entirely solid-state devices. They would generate no vibrations and could survive unmaintained for years in the harsh environments of space. In the future, laser cooling devices may even find uses in personal computers where they could cool superconducting circuits, allowing the circuits to operate at speeds hundreds of times faster than today's conventional electronics without overheating.

Particularly worth noting is the possibility that laser cooling could lead to a new form of computer chip that could cool itself on its own. Having this sort of functionality would allow the technology to minimize the amount of heat it produces which, in turn, would help prolong the battery life of devices like smartphones and tablets. [1]

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