of the beam energy into gamma-rays; the highest beam density (6×10^{20} cm^{-3}) would bring an unprecedented conversion efficiency of ~60%.

An LWFA has been employed for generating gamma-rays in a gas jet[12], via the scattering of a counter-propagating laser pulse by the accelerated electron beam[13,14], or in a secondary solid target[15]. The predicted brilliance and efficiency of gamma-ray emission in the regime investigated by Benedetti et al. appear to be much higher than those in the above-mentioned experiments but it requires a beam density beyond that obtained by a currently available LWFA. In the future, such high beam densities exceeding 10^{20} cm^{-3} might be possible via direct interaction of an intense laser pulse with a solid target using next-generation laser facilities. Previous research presenting simulations of such interactions using a 10 PW laser pulse have shown a regime in which gamma-ray generation efficiency reaches 35%[16].

In summary, the simulations of Benedetti et al. suggest a novel scenario of a plasma instability where most of the driver energy is converted to gamma-rays. To design a suitable experiment to test their predictions, further numerical studies are needed to investigate the generation of the electron beam and its interaction with a background plasma. These studies may also clarify the nonlinear evolution of the instability in the presence of strong radiative losses, which could shed some light on the physics of relativistic many-body systems. ❐

Andrea Macchi[1,2]* and Francesco Pegoraro[1,2]*
[1]*CNR/INO (National Research Council, National Institute of Optics), Adriano Gozzini laboratory, Pisa, Italy.* [2]*Enrico Fermi Department of Physics, University of Pisa, Pisa, Italy.*

**e-mail: andrea.macchi@ino.cnr.it; francesco.pegoraro@unipi.it*

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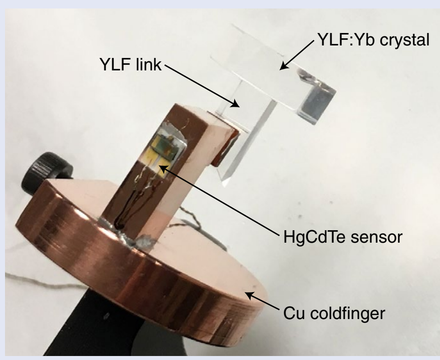
OPTICAL REFRIGERATION

Payload success

An all-optical refrigeration scheme has successfully cooled a photodetector to cryogenic temperatures for the first time. Mansoor Sheik-Bahae and co-workers from the University of New Mexico and Los Alamos National Laboratory in the US used anti-Stokes fluorescence from an optically pumped Yb^{3+}-doped $YLiF_4$ (YLF) crystal to cool a HgCdTe infrared sensor to 135 K (*Light. Sci. Appl.* https://doi.org/10.1038/s41377-018-0028-7; 2018). The sensor was part of a Fourier-transform infrared spectrometer and 47 W of 1,020 nm laser light was required for the cooling. Various demonstrations of all-optical refrigeration have been previously reported, indeed cooling temperatures to as low as 87 K have been achieved, but this is the first where an attached payload has successfully been cooled. Key to the success was the use of a specially designed transparent thermal link, made from a kinked undoped YLF waveguide, which connects the cooling crystal to the sensor (pictured). The cooling crystal was placed inside a Herriott cell (two mirror cavity) to allow for multiple passes of the pump laser light and the entire apparatus was placed within a vacuum chamber to minimize unwanted heat flow.

Optical refrigeration works by using a material that can emit light at a shorter wavelength than it absorbs, with the energy difference between the absorption and emission being provided by phonons (heat) from the material. A variety of materials, such as doped optical fibres and semiconductors, have been tested, with Yb^{3+}:YLF being the most effective to date.



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The team are now exploring the opportunities for cooling with other crystal materials and potential applications. “We are also getting close on achieving cryogenic cooling in Tm- and Ho-doped crystals (at 2 μm wavelength) that show twice the efficiency over Yb-doped materials that use pumps at 1 μm,” Sheik-Bahae told *Nature Photonics*. “We have already cooled these materials, but have not attempted ‘power cooling’ or to use them for cooling a device yet.”

As for applications, optical cryocoolers could prove useful wherever there is a need for minimal or negligible vibration that precludes the use of traditional mechanical means, such as a Stirling or Gifford-McMahon refrigerator that feature moving parts. Potential examples that may benefit include germanium gamma-ray detectors, cryogenic microscopy and space-based sensors.

“The most exciting application that we are currently working on is in collaboration with Jun Ye’s group at NIST,” explained Sheik-Bahae. “We hope to soon cool their single-crystal Si cavity to 124 K using our Yb:YLF cooler in a totally vibration-free environment. This will be a game-changer as it will allow these ultra-stable lasers to be portable and accessible for myriad of high-precision meteorology and clock applications.” ❐

Oliver Graydon

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