Thermal Link for Attaching Heat Loads in Optical Refrigeration

Los Alamos National Laboratory

Background
The Los Alamos Solid-State Optical Refrigerator (LASSOR) project has been working for a number of years on developing a practical system for laser cooling of solids, and has led the field since its first demonstration (Epstein et al., Nature, 377, 500, 1995). Optical refrigeration works by shining a high-power laser into a condensed phase material that absorbs the laser light. If the average fluorescence wavelength of the material is shorter (i.e., higher energy) than that of the laser, there can be a net flow of energy out of the system – the result of which is that the system cools. The current record, set by our group in 2005, is cooling down to 208 K from room temperature (around 295 K).

Optical refrigeration has a number of advantages over conventional methods, including being compact, all solid-state, scaleable to small dimensions, and vibration-free. Potential applications include demanding scientific problems such as gravitational wave detectors (which cannot tolerate any vibrations) and space-borne infrared sensors where the reliability and long life of a rugged solid-state cooler is important.

There are two major hurdles to making optical refrigeration practical: (1) achievement of lower temperatures, and (2) successful development of a thermal link by which the heat load (e.g., a sensor) is attached to the cooling element. The Los Alamos group is currently working on improved materials that will cool to the required temperatures of 150 K or below. However, a practical system for connecting the optical refrigerator to a load is an unsolved problem.

Problem Statement
The figure at right shows a conceptual design of an optical refrigerator. The thermal link (“cold finger”) is shown on top. The thermal link must provide good thermal contact between the cooling element and the load (not shown), but can’t let any light reach the load, nor can it absorb any light itself. Although there is a dielectric mirror between the cooling element and the thermal link, some of the fluorescence escapes, especially angles approaching grazing incidence. Because the heat taken away by an individual photon is a small fraction of the photon’s energy, absorption of any photons by any of the cold components will quickly overcome the cooling power and ruin the system’s performance.

Work Statement / Deliverables
The clinic team will need to come up with conceptual designs for various link ideas, model them using advanced optical design software (ZEMAX), and fabricate and test prototypes made from inexpensive surrogate materials, e.g., PMMA. Additionally, thermal modeling may be used to evaluate early-stage designs. A final, detailed design and model for the actual materials (perhaps sapphire) will be the primary deliverable of the clinic; if funding and time permit, an actual thermal link will be delivered. The LASSOR team will provide technical assistance where needed, and will share existing thermal link ideas. We anticipate that the clinic results will be published and/or patented.