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X-693-77-164

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AN ACTIVE THERMAL COMPENSATOR FOR CLOSED-CYCLE HELIUM REFRIGERATORS

(NASA-TM-X-71367) AN ACTIVE THERMAL COMPENSATOR FOR CLOSED-CYCLE HELIUM REFRIGERATORS (NASA) 8 p HC A02/MF A01 CSCL 20K
N77-30272
Unclas
G3/31 42958

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JULY 1977

GSFC — GODDARD SPACE FLIGHT CENTER
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AN ACTIVE THERMAL COMPENSATOR FOR CLOSED-CYCLE HELIUM REFRIGERATORS

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In spectroscopic applications of tunable semiconductor diode lasers, a closed-cycle helium refrigerator is frequently used to maintain the cryogenic temperatures necessary to achieve lasing. The advantages of a closed-cycle refrigerator as compared to a liquid helium dewar, besides being simpler to work with, are the indefinite refrigeration periods possible and the wide temperature range over which the laser can be operated (the lasing frequency is coarsely tuned by varying the diode temperature).

A difficulty encountered in using closed-cycle refrigerators with diode lasers results from the fact that the temperature at the cold-tip of the refrigerator oscillates slightly during the Solvay cycle at a frequency of a few Hertz. The amplitude of this oscillation, which is very close to sinusoidal, may approach 0.5K, and since the tuning rate of most diode lasers is on the order of 1 cm^{-1}/K the corresponding fluctuation in frequency is much larger than the intrinsic resolution of the laser (10^{-4} - 10^{-6} cm^{-1}). The oscillation tends to be more pronounced at lower operating temperatures, decreasing as the thermal load on the refrigerator is increased.

The common technique for reducing the amplitude of this temperature oscillation at the laser is the placement of some kind of passive thermal damper, typically consisting of a Pb-In alloy, or several alternating layers of indium and mylar, between the laser and the cold-tip. A damper can reduce the temperature amplitude by a factor of 100 or more, but it also introduces a thermal discontinuity between the laser mount and the cold-tip, resulting in a loss of tuning range and a reduction in refrigeration capacity at the laser.

We have developed an alternative technique for reducing the amplitude of the temperature oscillation. The device shown in Figure 1 uses a second semiconductor diode (a defunct laser diode) as a heating element to actively supply a small oscillating input of heat at a point between the laser and the cold-tip to cancel the heat oscillations due to the refrigerator. (In our case a Displex Model CSW-202 manufacture by Air Products and Chemicals, Inc.) The configuration is such that by holding the temperature constant at the heat sink of the heater diode the temperature at the laser mount will also be constant. The size of the heat sink of the heater diode has been kept as small as possible to minimize its thermal mass and the thermal time lag across its dimensions. It was found that the heater diode could drive the temperature of the heat sink more effectively, i.e., with lower current and therefore less heat, if the heat sink was insulated slightly from the rest of the mount. This was done on both sides of the heat sink, where contact was made with the mount, with a layer of mylar sandwiched between two layers of indium. This insulation confines the short-term heat fluctuations from the heater diode to the region of the heat sink, while maintaining the steady-state conduction of heat from the laser to the cold-tip. The temperature discontinuity caused by the insulation is small compared to that caused by a conventional damper.

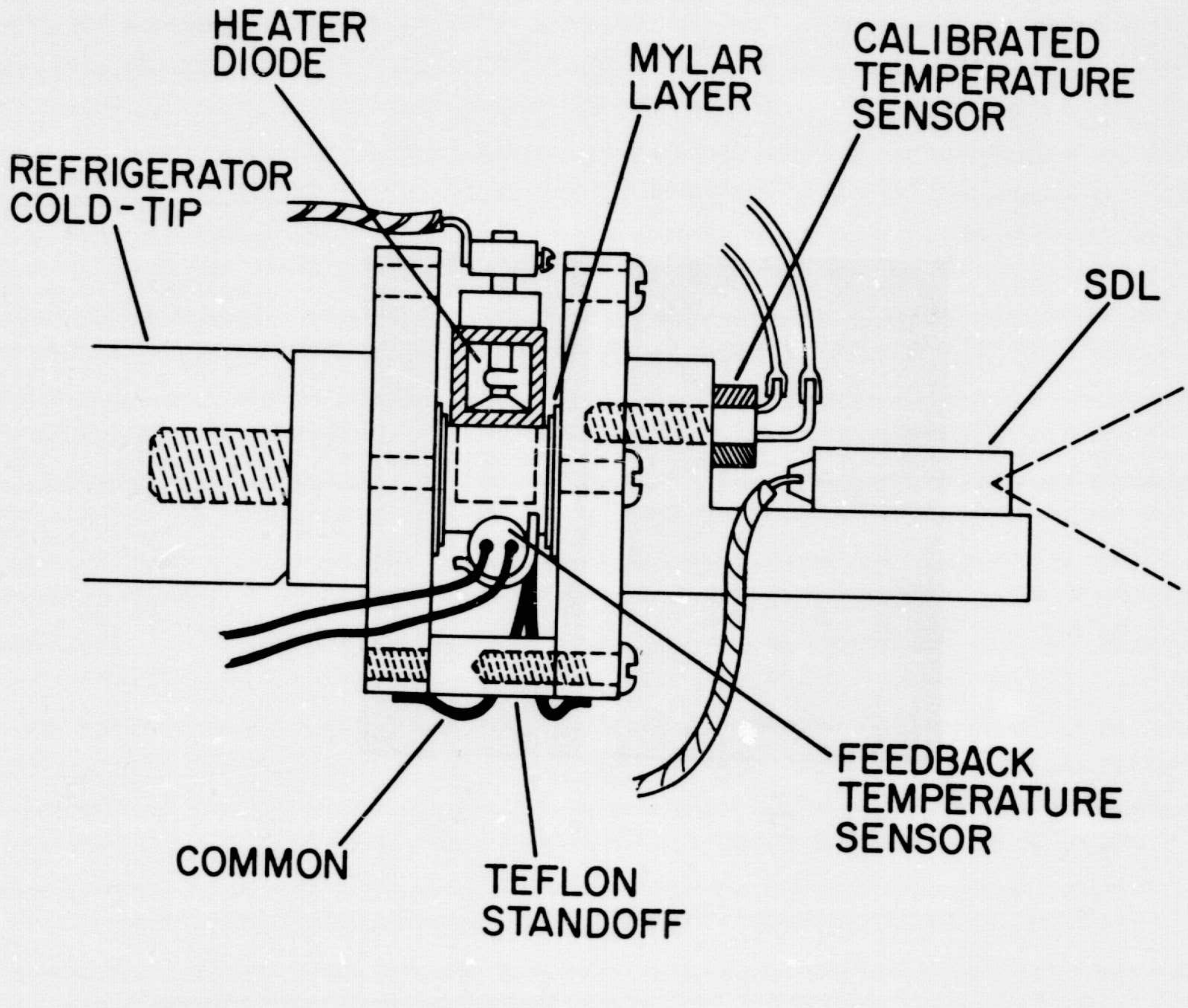
We have tried two techniques for driving the heater diode. In the first configuration a silicon diode temperature sensor, fastened directly to the heat sink of the heater diode (see Figure 1) provided a signal to a negative feedback circuit which in turn supplied an offset current to the heater diode. This resulted in a reduction of the temperature oscillation at the laser from 0.46K to about 0.01K peak-to-peak at an operating temperature of 9.5K. The residual fluctuations were not sinusoidal and were evidently due to a slight thermal lag between the heater diode and the feedback sensor.

In an effort to further reduce the residual fluctuations, the negative feedback technique was abandoned and, instead, a sine-wave generator was used to drive the programmable supply which provided the offset current to the heater diode. By matching the frequency and phase of the oscillator to that of the refrigerator cycle, and by adjusting the amplitude of the oscillator signal, the temperature fluctuations at the laser could be minimized (see Figure 2). Residual fluctuations were about 0.003K peak-to-peak, again at an operating temperature of 9.5K.

As expected, the active thermal compensator has been found to increase the refrigeration capacity at the diode laser over that obtainable with passive thermal dampers used in similar applications.

Figure 1. Thermal compensator. The heater diode drives the thermal link between the laser (SDL) and the cold-tip of the refrigerator. A calibrated sensor monitors the SDL temperature. Electrical continuity to the heater diode and SDL are provided by a common wire. Four teflon stand-offs (only one is shown) insulate the SDL mount from the cold-tip.

Figure 2. Temperature oscillations at laser with heater diode driven by sine-wave generator: a) generator slightly out of phase with refrigerator; b) in phase with refrigerator. In a) the sweep rate is 2 sec/div and the amplitude is 0.2K/div. In b) the sweep rate is 0.5 sec/div, and the amplitude is 0.03K/div. The 'white' noise in b) is due to the sensor circuit and is not reflected in the laser stability. Operating temperature in b) is 9.5K.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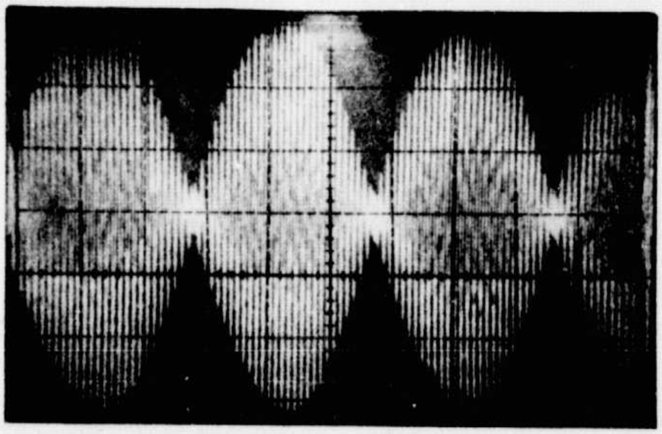

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