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Dither-Free Stabilization of CO_2 Lasers for Far Infrared Pumping: A Photoacoustic Approach

C. A. Bennett, Jr.

D. P. Hutchinson

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C. A. Bennett, Jr.,* and D. P. Hutchinson

*Department of Physics, University of North Carolina at Asheville, Asheville, NC 28814

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ABSTRACT

A method based on the photoacoustic technique is described for dither-free frequency stabilization of the optical pump in a CH_3OH laser operating at 119 μm. Heterodyne measurements on two independently locked FIR lasers indicate excellent long term frequency and power stability. This stabilization scheme should be applicable to all optically pumped FIR lasants.

INTRODUCTION

Although several methods exist for frequency stabilizing the optical pump of a far infrared (FIR) laser,[1-6] most employ an internal frequency dither of the pump which results in a frequency modulation of the FIR output. A stabilization scheme which avoids this effect was reported on recently by Lachambre et al.[6] in which the optical transmission through an absorbing cell provided an error signal necessary to stabilize the 214 μm line of CH_2F_2. When we attempted to apply this technique to the 119 μm line of CH_3OH, however, we found that at pressures high enough to produce appreciable attenuation, collisional broadening of nearby non-lasing absorption lines tended to eliminate the discriminator output. The use of a photoacoustic cell in place of the transmission cell allowed us to reduce this effect by utilizing lower pressures in the absorbing path. The resulting stabilization loop was effective at maintaining stable FIR power for long periods of time.

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*Department of Physics, University of North Carolina at Asheville, Asheville, NC 28814

The stabilization setup is shown in Fig. 1. Invar rods supported the 2 m long CO_2 laser cavity and the cavity length was controlled by a piezoelectric transducer (PZT) driven by a high voltage amplifier. The 9P(36) pump beam entered the 2.1 meter waveguide FIR cavity, also mounted on invar, through a 4 mm hole and the FIR output beam was coupled from the other end through a 13 mm hole. A fraction of the pump beam was split and amplitude modulated at 880 Hz prior to entering the photo-acoustic cell filled with CH_3OH. A pyroelectric detector was used to measure the intensity transmitted through the cell. Lock-in amplifiers, referenced by the chopper, analyzed the signals from the microphone and the pyroelectric detector. The outputs of the lock-in amplifiers were connected in opposite polarity to a variable gain operational amplifier which provided a difference signal used as the discriminator output. A potentiometer on the output of one of the lock-in amplifiers accurately determined the zero of the discriminator crossing and hence determined the lock point of the servo loop.

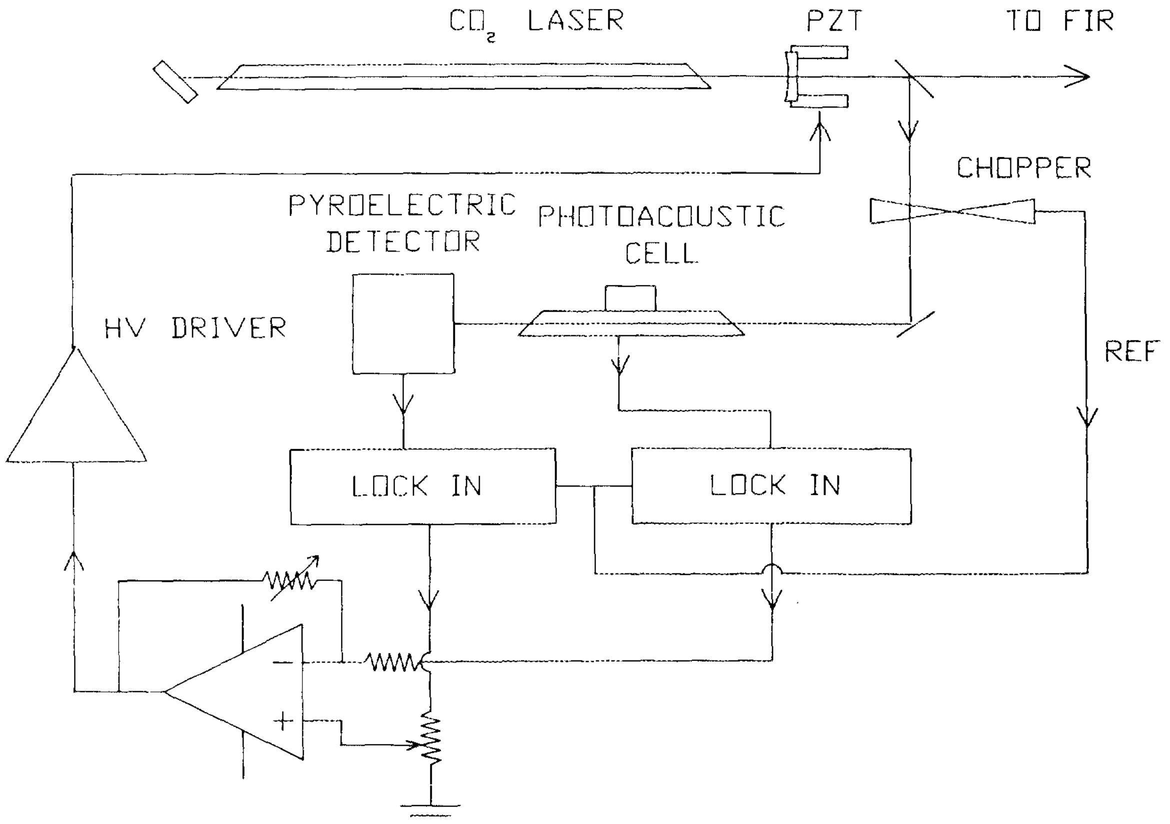

Fig. 1. CO_2 stabilization loop

Figure 2 shows some typical results. The lock point is determined by adjusting the FIR laser for maximum output at the desired operating frequency and then adjusting the potentiometer for a discriminator zero before closing the loop. A pressure of 600 millitorr in the photoacoustic cell was found to provide good stability along with good discriminator output. A change in the CO_2 laser cavity length produces a correction voltage which, for sufficient discriminator slope, leaves only a small residual frequency shift. Excessive discriminator gains amplified extraneous noise (primarily photoacoustic) resulting in an increase in the pump frequency jitter; however, the intrinsic stability of the CO_2 laser made the use of such high gains unnecessary. The FIR output was found to stay constant for many hours under locked operation when only moderate gains were used.

To determine the amounts of frequency jitter introduced in the submillimeter output by the stabilization loop, the outputs of two independently locked FIR lasers were mixed on a Schottky diode detector as shown in Fig. 3. By modulating beams from the two pump lasers at different chopping frequencies and appropriately referencing the lock-in amplifiers, two discriminators could be obtained from a single photoacoustic cell and pyroelectric detector. The two FIR lasers were locked to different frequencies and the beat note was recorded by a spectrum analyzer. After thermal stabilization of the FIR cavities, the frequency of this beat note (typically 1 MHz) was observed to stay constant for long periods of time while the short term (5 sec) jitter was not noticeably increased over unlocked operation (~200 kHz). Random fluctuations in the discriminator voltage, primarily from the photoacoustic signal, resulted in voltage fluctuations at the PZT on the order of 10 V corresponding to pump frequency excursions of about 1 MHz. The design of our photoacoustic cell was by no means optimized and much improvement in signal to noise is possible; however, FIR cavity pulling effects tend to diminish the effect of these fluctuations and the output beam remains stable in both frequency and power.

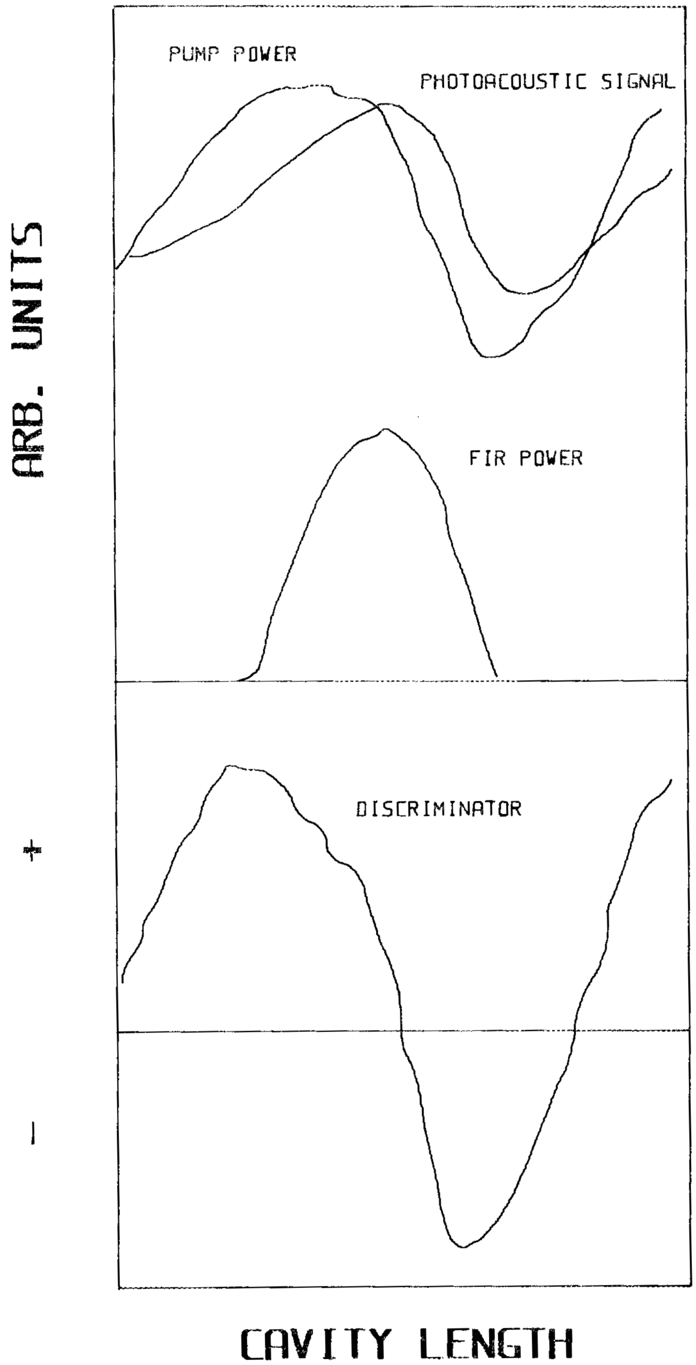

Fig. 2. CO_2 laser output, photoacoustic signal, FIR power and discriminator output as a function of CO_2 laser cavity length. The free spectral range of the CO_2 laser is about 75 MHz.

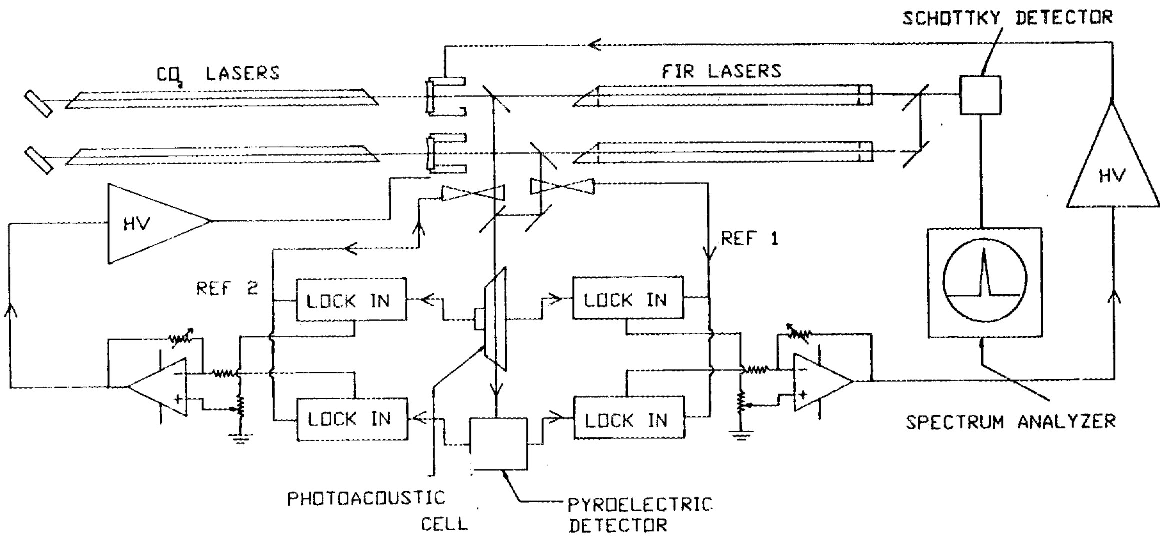

Fig. 3. Two laser stabilization loop

In conclusion, a dither-free stabilization scheme has been described which is effective at compensating for thermal drift of the pump cavity in an optically pumped FIR laser. The technique is applicable to all FIR lasants, particularly those for which the method of reference 6 is untennable due to lack of sufficient contrast in active absorption features over the free spectral range of the pump. Heterodyne measurements on two locked lasers indicate that this technique adds no significant levels of frequency jitter to the FIR output beam.

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