ABSOLUTE-FREQUENCY MEASUREMENTS OF THE 520 THz HYPERFINE COMPONENTS OF IODINE AND THE 260 THz EMISSION OF NEON

by

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The Consultative Committee for the Definition of the Meter (CCDM) has proposed that the meter be defined in terms of the second: "The meter is the distance travelled by light in a vacuum during the fraction of 1/299,792,458 of a second." With this definition, the meter would be realized from the wavelength of any laser which can be stabilized to a narrow atomic or molecular absorption line, and whose frequency has been measured. The wavelength would be simply c/ν where c is the fixed value of the speed of light, and ν is the measured frequency. To realize this definition, it will be necessary to measure the absolute frequency of these absorption lines in the visible and infrared spectral regions. In this paper we describe the synthesis and measurement of the frequencies of the 260 THz (λ = 1.15μm) lamb-dip stabilized laser line in ^{20}Ne, and the hyperfine components of the $^{127}I_2$ 17-1 P(62) transition at 520 THz (576 nm). The frequencies were measured by comparing them with the known frequency of the 11.515 μm $^{13}C^{16}O_2$ laser line by use of a 2.3μm color center laser and a 1.15μm He-Ne laser as frequency transfer oscillators as shown in the frequency synthesis chain in Fig. 1.

In this chain, approximately 5 harmonics of CO_2 laser radiation (26.0 THz) heterodyne with the 130 THz color center laser radiation. The color center laser radiation is subsequently doubled and heterodyned with the 260 THz He-Ne laser radiation which itself is either doubled and heterodyned with the visible (520 THz) radiation or directly heterodyned with 260 THz radiation from a pure neon laser.

The output of a 520 THz cw dye ring laser at the top of the chain was servo-locked to the individual hyperfine components of the $^{127}I_2$, 17-1 P(62) transition observed in saturated absorption. Each line had a full width at half maximum of 2 MHz or less for an iodine pressure of 4 Pa. The center of the transition could be determined to within 50 kHz. The He-Ne laser was frequency locked by heterodyning its second harmonic with the dye laser.

The He-Ne 260 THz laser consists of an 8M discharge tube and generates 100 mW of single mode output power. The He and Ne gas mixture was adjusted to optimize single mode output power. A resonant reflector with a thin lossy metallic film positioned 9 cm from the end mirror provided tuning and mode selection. Approximately 90 mW of the output power was focused into a temperature tuned lithium niobate frequency doubling crystal (T = 185°C) to generate ∿50μw of power at 520 THz. To measure the 520 THz frequencies, this radiation was collinearly mixed with a portion of the cw dye laser output on a Si photodiode to produce an rf beat frequency used to lock the two lasers together. Alternatively this laser was offset locked 60 MHz from signal from the radiation of a pure ^{20}Ne laser.

A cw color center ring laser operating at 2.3 μm was used as a frequency transfer oscillator for connecting the ^{20}Ne laser frequency to the accurately known CO_2 laser frequency. The color center laser used $(F_2+)_A$ centers in lithium-doped KCl, and provided broadly tunable laser output from 2 to 2.5 μm. When pumped with 5W from a cw 1.33 μm Nd:YAG laser, the color center laser produced over 100 mW of output power at 2.3 μm. The laser was operated in a ring configuration to insure efficient, simple, single mode operation, and was actively stabilized to an invar optical cavity, with a resulting linewidth of ∿20 kHz.

The 2.3 μm radiation was focused into a temperature phasematched lithium niobate frequency doubling crystal (T = 530°C) and generated approximately 10 μw of 1.15 μm radiation. The second harmonic was combined on a beamsplitter with 10 mW from the He-Ne laser, and both beams were focused onto a high speed Ge photodiode. The subsequent beat frequency was displayed on a rf spectrum analyzer and measured with an adjustable marker oscillator and counted.

The remainder of the non-doubled 2.3 μm radiation was focused onto a W-Ni point contact MIM diode. Coincident on the diode were the beams from two $^{13}C^{16}O_2$ lasers operating on the adjacent lines $P_I(50)$ and $P_I(52)$. The $P_I(50)$ laser was stabilized to the saturated fluorescence signal from an external 5.3 Pa $^{13}C^{16}O_2$ absorption cell. The $P_I(52)$ laser was phase locked to the $P_I(50)$ laser via a 61 GHz klystron.

The two CO_2 lines were selected such that twice the frequency of one CO_2 laser plus three times the frequency of the other CO_2 laser is nearly equal to the necessary color center laser frequency (130 THz). The free running CO_2 lasers each have approximately a 3 kHz linewidth; however, the relative frequency of the two lasers is held to within 1 Hz in a 1 second averaging period.

The absolute frequency of the γ-component of the $^{127}I_2$ 17-1 P(62) transition is 520 206 808.307 MHz ± .52 MHz and of the lamb-dip stabilized ^{20}Ne laser is 260 103 249.20 MHz ± .26 MHz. The reported standard deviation represents an accuracy of 1 part in 10^9, which is the present accuracy of the $P_I(50)$ $C^{13}O_2^{16}$ laser frequency (the $P_I(50)$ frequency was taken to be 26 035 339.973 MHz). Our measurements were able to determine the relative frequency of the I_2 transition with respect to the CO_2 laser to an accuracy of 4 parts in 10^{11}, and of the ^{20}Ne laser frequency with respect to the 520 THz I_2 frequency to 3 parts in 10^{10}. Future measurements of the CO_2 laser frequency relative to the Cs standard should improve the accuracy of the CO_2 laser frequency, and hence the absolute accuracy of the 520 THz I_2 frequency and 260 THz ^{20}Ne frequency.

Experimental details will be presented.

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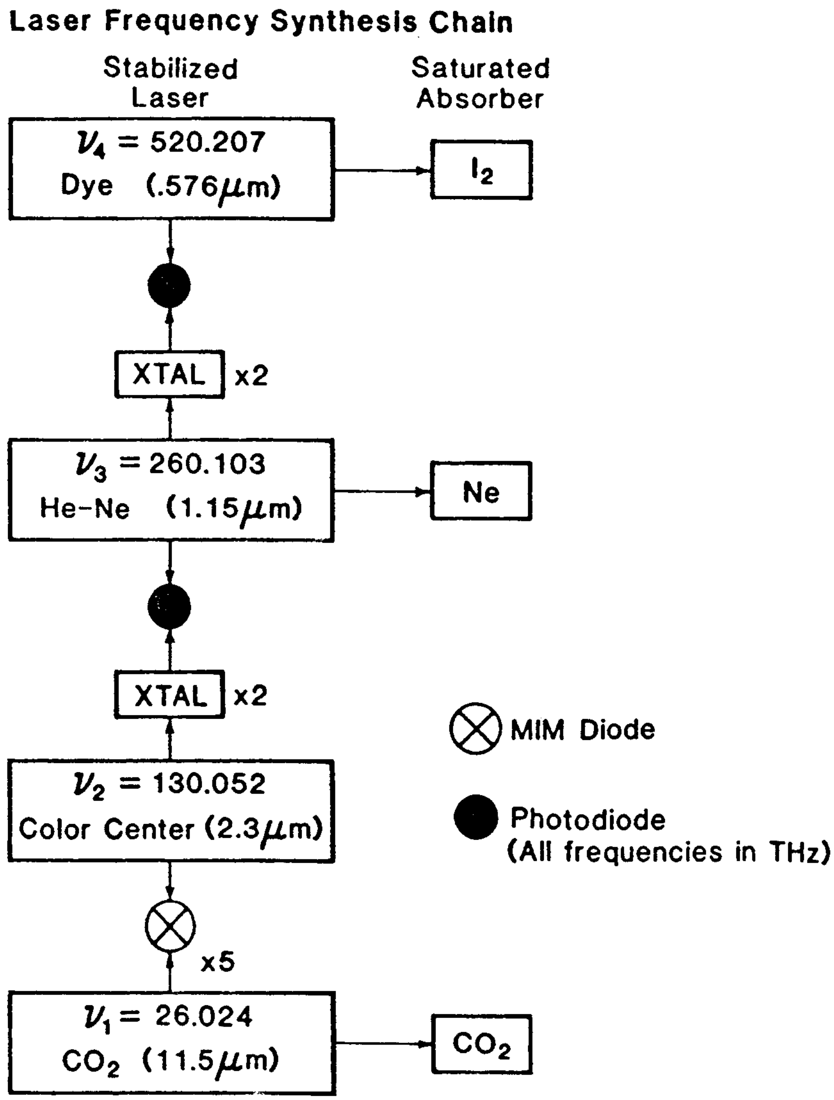
Laser Frequency Synthesis Chain
Stabilized Laser
Saturated Absorber
ν_4 = 520.207
Dye (.576μm)
I_2
XTAL x2
ν_3 = 260.103
He-Ne (1.15μm)
Ne
XTAL x2
MIM Diode
ν_2 = 130.052
Color Center (2.3μm)
Photodiode
(All frequencies in THz)
x5
ν_1 = 26.024
CO_2 (11.5μm)
CO_2

Figure 1.