TOWARDS THE ULTIMATE OPTICAL DETECTION SENSITIVITY: NEW SPECTROSCOPIC OPPORTUNITIES - AND A ZILLION NEW WAVELENGTH/FREQUENCY STANDARDS

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High sensitivity detection of quantum absorption is demonstrated at a sensitivity of 1 x 10^{11} integrated absorption, in 1 sec, using 10 mTorr total gas pressure. Achieving highly sensitive detection relies on simple, basic principles: 1) The molecule-generated electric field in the forward direction (the "darkness wave") is most precious, and contains the maximum available information. It is the physical manifestation of the -alpha*L term appearing when Beer's absorption law is expanded for low opacity. 2) After generating the molecular signal, the detected unabsorbed light sets the "shotnoise" measurement floor. We use an optical transmission cavity for the gas cell, since the high internal "build-up" field will elicit a strong molecular "darkness wave," for a given transmitted dc light on the detector. A more conventional explanation of Cavity Enhancement would be the extension of the effective cell length by the factor Finesse * $2/\pi$. 3) To avoid excess low-frequency noise, such small signals should be measured by ac methods, comparing on-resonant and off-resonant cases in quick succession. 4) By SIMULTANEOUSLY obtaining and subtracting these cases, one provides a signal channel with NO OUTPUT unless there is a resonance. This is conveniently accomplished by using the FM detection method with the optical heterodyne sidebands and carrier being transmitted through the cavity via adjacent axial orders. 5) A remarkable property of this configuration, when the modulation frequency = cavity mode spacing, is the suppression of ANY detection of laser frequency noise with the transmitted light. We can refer to this property as (laser FM-) Noise-Immune detection. This enables profitable use of cavity finesse in the range above 10,000, without a noise penalty. Altogether, we refer to this new spectroscopy as Noise-Immune, Cavity-Enhanced, Optical Heterodyne Molecular Spectroscopy, ie. "NICE OHMS". We have measured excellent saturated dispersion signals from HCCH in the band near 790 nm ($\nu_1 + 3\ \nu_3$), and recently, using a Nd:YAG source, from the HCCD P(5) line ($\nu_2 + 3\ \nu_3$) at 1064 nm. The saturation peaks broaden from the transit limit of 270 kHz near zero pressure at the rate 34.7 kHz/mTorr. We observe interesting narrow linewidths 8-fold below the transit limit, basically using optical selection of slow molecules by low power and pressure (2 mW and 2 mTorr). The absolute frequency is measured to be 281,635,363.960 MHz $\pm$ 45 kHz.