INTRACAVITY DYE-LASER ABSORPTION SPECTROSCOPY (IDLAS) FOR APPLICATION TO PLANETARY MOLECULES

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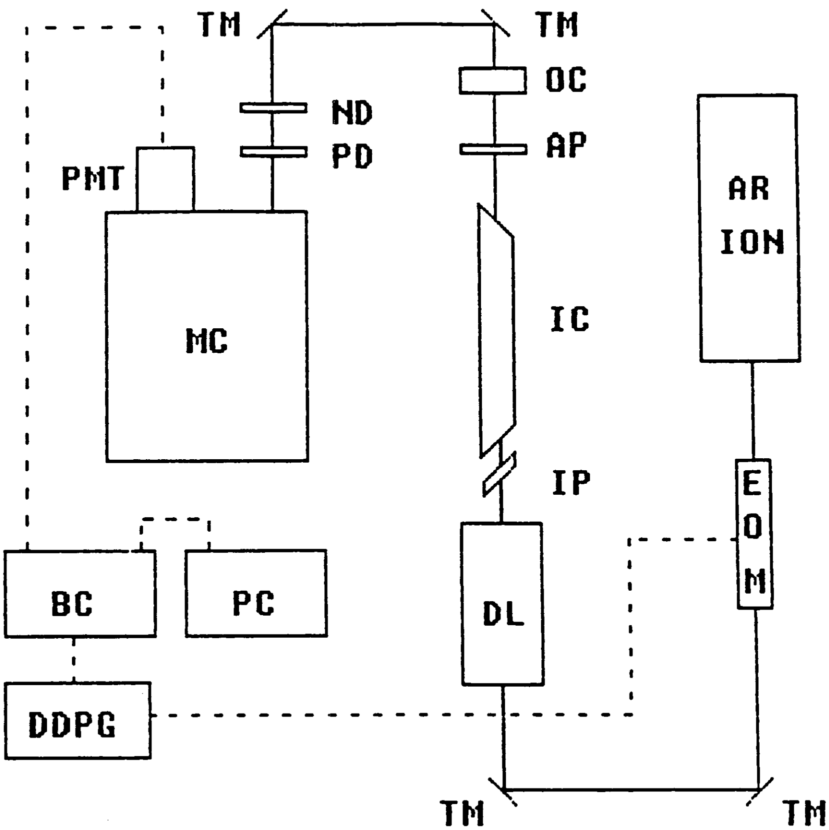
ABSTRACT

Time-resolved, quasi-cw, intracavity dye-laser absorption spectroscopy is applied to the investigation of absolute absorption coefficients for vibrational-rotational overtone bands of water at visible wavelengths. Emphasis is placed on critical factors affecting detection sensitivity and data analysis. Typical generation-time dependent absorption spectra are given.

Experimental Apparatus

The basic experimental apparatus is shown in Figure 1. Quasi-cw pumping of a Rhodamine 6G dye-laser is achieved by passing a 514.5 nm beam from an argon ion laser through a 25 ns rise/fall time electro-optic modulator. An output coupler taken from a synchronously pumped dye-laser is used to extend the cavity to a length of 1.8 meters to accomodate an absorption cell and other intracavity elements. A 5 micron intracavity pellicle functions as a tuning element over the broadband Rhodamine 6G dye gain curve. The intracavity aperture provides significant loss to higher order spatial modes while allowing the TEM_{00} mode. Prior to analysis, the dye-laser output is fed through a neutral density filter to reduce the signal to a level compatible with the photomultiplier tube. The beam then passes through a pseudodepolarizer to eliminate any polarization-dependent grating response. The beam then enters a microprocessor controlled scanning monochromator with a

FIGURE 1



AR ION	Argon Ion Laser
EOM	Electro-optic Modulator
TM	Turning Mirror
DL	Dye Laser
IP	Intracavity Pellicle
IC	Intracavity Cell
AP	Aperture
OC	Output Coupler
ND	Neutral Density Filter
PD	Pseudo-depolarizer
MC	Monochromator
PMT	Photomultiplier Tube
BC	Boxcar Averager
PC	Microprocessor/Terminal
DDPG	Digital Delay Pulse Generator

Experimental Setup

resolution of 0.006 nm in first order at 579.1 nm. The dispersed energy is detected by a photomultiplier tube close coupled to the monochromator. The signal from the photomultiplier is sent to a boxcar averager which is connected to the laboratory data acquisition unit that controls the monochromator. A spectral profile of the dye-laser output intensity and the attendant absorption dips appears on the video display and can be manipulated and/or plotted on a digital plotter. The boxcar and the electro-optic modulator are both driven by the same digital delay generator which provides picosecond accuracy. The delay allows the time position of the boxcar gate to be adjusted prior to data acquisition. In this way, it is possible to study the spectral intensity distribution of the dye-laser as a function of the generation time.

Theory

Intracavity dye-laser absorption has been shown to follow a modified Beer-Lambert type relationship and has demonstrated enhancements as great as a factor of 100,000 over conventional (extra-cavity) techniques. This is due to three main effects: the multipass effect, mode competition, and the threshold effect. Since the output coupler is highly reflective, photons make many passes through the cavity before being transmitted; this increases the likelihood of absorption by an intracavity sample. Mode competition is fostered by the homogeneous broadening of the dye gain; an added frequency selective loss due to an absorber allows all of the unaffected modes to steal energy away from the affected modes. And finally, when the dye-laser is operated near threshold, any slight increase in loss can destroy the lasing ability of the affected modes.

Results and Future Work

Typical absorption spectra of weak vibrational-rotational overtones of laboratory-air water vapor are shown in Figure 2. Quantitative determination of absolute absorption coefficients for specific lines will be determined in the near future.

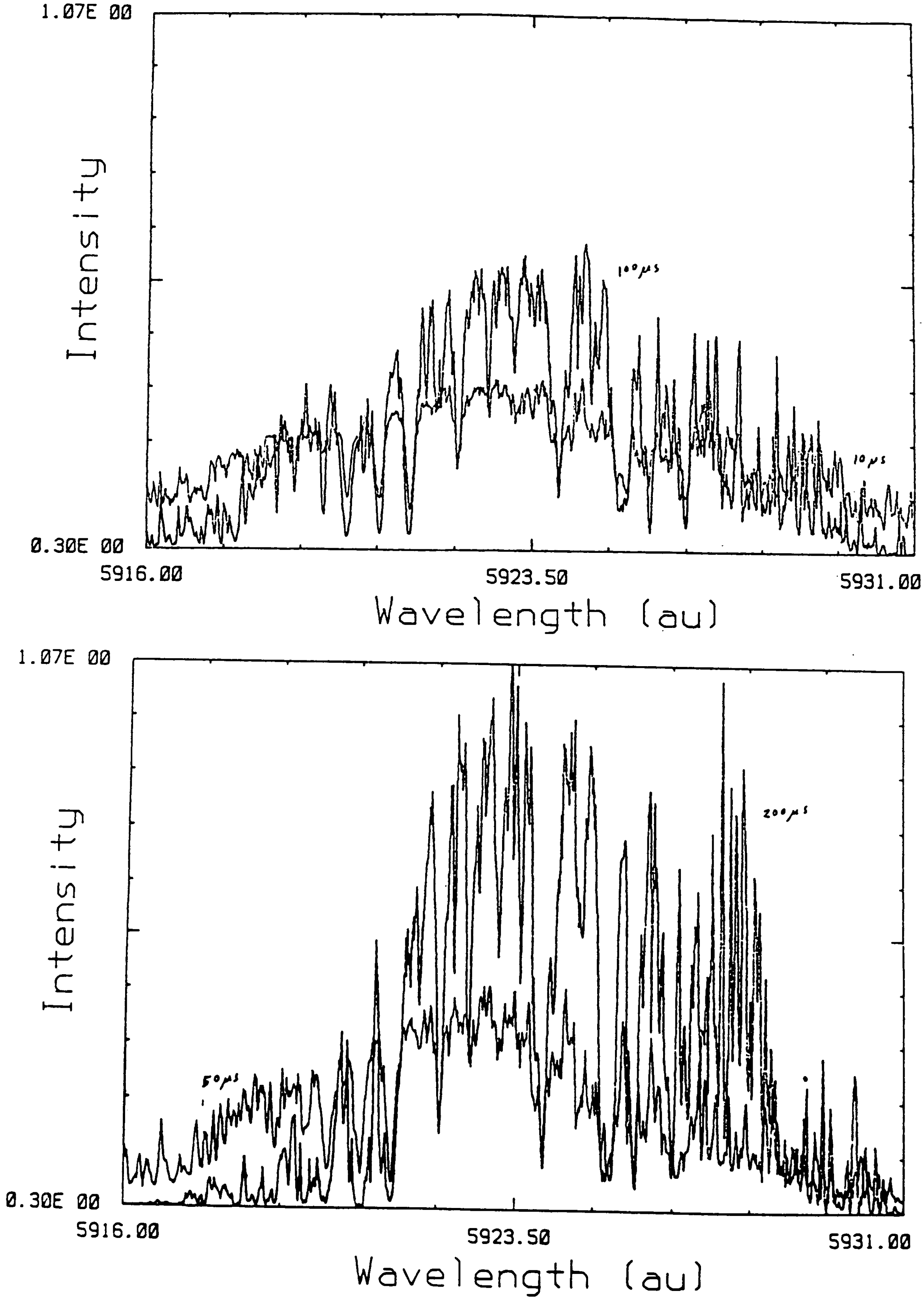


FIGURE 2 Typical Absorption Spectra

The design and construction of a low temperature intracavity cell is currently underway and will be used in the study of certain weak, visible rotational-vibrational transition coefficients of methane at temperatures simulating those of the outer planets. Specifically, the band at 619 nm will be studied. Laboratory measurements of this nature are of critical importance to those modelling planetary atmospheres.

Numerical simulations to determine critical factors affecting the sensitivity and data analysis of the technique of intracavity absorption spectroscopy are also underway.