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Helmholtz Resonance Cell for Gas Phase Photoacoustic Studies

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Abstract

The design and fabrication of a Helmholtz type gas phase photoacoustic cell are described. The cell which incorporates a miniature microphone (Knowles B.T.1759) along with a matching pre-amplifier is very sensitive and can detect very weak signals. The system can be effectively used for the study of overtone spectroscopy of molecules in gas phase and it is suitable for both intracavity and extracavity modes of operation. The working of the cell is illustrated by recording overtone photoacoustic spectrum of Toluene in the extracavity mode using a Ring dye Laser. Variation of the amplitude and phase of photoacoustic signal with modulating frequency are also studied along with the dependence of photoacoustic signal with laser power.

Key words: helmholtz resonance cell, intracavity mode, extracavity mode, photoacoustic spectroscopy.

Introduction

Generation of sound waves following absorption of light by a sample constitutes the photoacoustic effect. This has recently been established as an extremely sensitive technique to probe the thermal and optical properties of matter in all its phases.

In modern spectroscopy, photoacoustic technique is used to study very weak optical absorption. It has several advantages over other methods of spectroscopic measurements. For gas phase studies only very small amounts of sample are sufficient and the sample be successfully examined using a tunable dye laser as the light source thereby enhancing the sensitivity and resolution of the spectrum.

Considerable efforts have been made to enhance the signal to noise ratio of photoacoustic detectors. One of the methods is to use a Helmholtz resonator type photoacoustic cell consisting of two coupled cavity, one being the sample chamber and the other being the microphone chamber (Nordhaus & Pelzl 1981; Pelzl et al. 1982). In Helmholtz resonance type photoacoustic cell the volume is comparatively small with a low resonance frequency which enables the use of mechanical choppers for lock-in detection of the signal. The design of the cell described in this paper is also suited for both intracavity and extracavity studies. Intracavity method will enhance the sensitivity of the technique.

Cell Design

The present photoacoustic cell is fabricated in stainless steel. The details of the design are as shown in Fig.1. It consists of two identical chambers (length 4.5 *cm*, outer diameter 3.5 *cm* and inner diameter 4*mm*) which are connected by a narrow cylindrical tube (length 5*cm*, outer diameter 7*mm* and inner diameter 1.5*mm*). The interconnecting tube is coupled to the cavities of the cell using 'O' rings. By changing the dimensions of the interconnections the resonance frequency of the cell can be changed. The cavity V_1 is provided with suitable optical windows for admitting the laser beam.

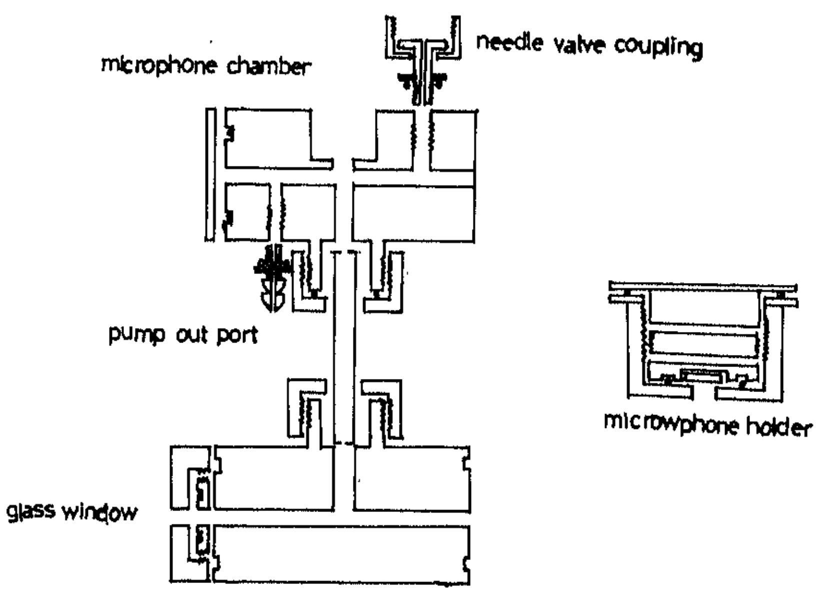

Figure 1. Details of the Helmholtz resonator type photoacoustic cell.

The pressure of gas inside the cell can be controlled using needle valve. Photoacoustic signal generated in the cavity V_1 is detected by the miniature microphone (Knowles B.T. 1759) placed in the chamber V_2. The cell parameters were determined by an extracavity experiments with Argon laser beam and with the tunable output from a Ring dye laser. The cell is properly mounted on a vibration isolated base plate. Chopped laser beam is passed through the cavity V_1 which is filled with Toluene gas kept at an optimum pressure. The photoacoustic signal from the microphone after preamplification was detected using a lock-in-amplifier. The amplitude and phase angle of the photoacoustic signal were recorded simultaneously as a function of the chopping frequency. The variation of amplitude with laser power is also studied.

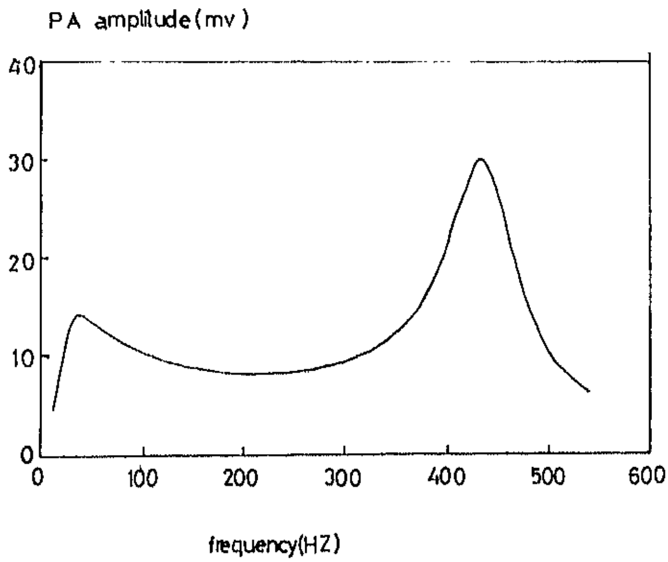

Figure 2. Variation of photoacoustic signal amplitude (mV) with chopping frequency (Hz).

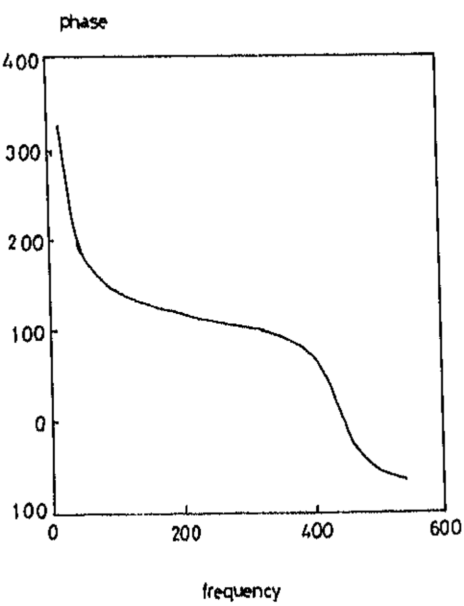

Figure 3. Modulation frequency (Hz) dependence of the photoacoustic cell.

Conclusion

The cell design is well suited for the study of weakly absorbing gases using a tunable laser. This is especially useful in the study of overtone absorption spectrum of many gas species in the Rh 6G dye laser tuning range (Yoh-Hau 1977). Because of its compactness and flexible mounting high sensitivity photoacoustic studies using intracavity techniques also becomes possible.

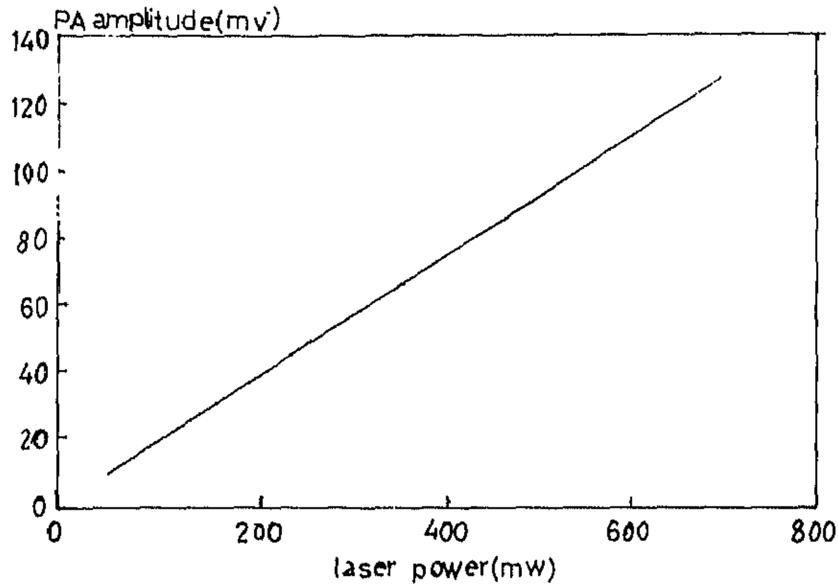

Figure 4. Photoacoustic signal dependence on laser power.

Fig.2 shows two resonances. The low frequency resonance corresponds to one of the transverse modes while the high frequency one corresponds to the axial mode. Observed frequencies are in agreement with theoretically calculated values using the cell dimension. Fig.3 shows variation of phase with chopping frequency, characterising changes in phase with frequency at resonances which are clearly seen in the graph. Fig.4 shows the variation of photoacoustic signal strength with laser power revealing a linear dependence of photoacoustic signal with laser power. However this curve need not be linear in the case of multiphoton absorption phenomena.

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