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Presented at the 4th International Meeting on Photoacoustic Spectroscopy, Ville d'Esterel, Quebec, Canada, August 5-8, 1985

PULSED PHOTOTHERMAL DEFLECTION SPECTROSCOPY IN FLOWING MEDIA

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June 1985

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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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PULSED PHOTOTHERMAL DEFLECTION SPECTROSCOPY IN FLOWING MEDIA*

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Abstract

Pulsed photothermal deflection was used to spatially map out flow velocity profile and to determine absolute flow velocities.

* Work supported by the Director, Office of Energy Research Physical and Technological Reference Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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Pulsed photothermal deflection detection provides a unique tool for the spatially-resolved, *in situ* characterization of flowing fluids. Basically, this approach is based on time-of-flight concept where a probe beam spatially scans the vicinity of an optically-heated region of the fluid. The temporal behavior of the deflection signal yields such information as the absolute flow velocity and its distribution profile.

In Figure 1 we show a schematic representation of the experimental arrangements. The optical heating was produced in the fluid (water) by the absorption of Nd:YAG, 10 nSec., 50 mJ laser pulses. The thermally-induced transient deflection of a cw HeNe laser probe beam was monitored with a position sensitive detector. Two detection schemes were employed:colinear and transverse.[1] The shape of the observed signal for the case of a cylindrical tube is also shown in Figure 1. The waveform of the deflection signal is determined by the gradient of the temperature distribution of the optically-heated volume along the direction of the flow. In Figure 2, we show the dependence of the signal amplitude and width on the distance between the pump and probe beams. It can be seen that the amplitude decreases and the width increases as the distance is increased. This is a direct consequence of thermal diffusion. We have found that thermal time response is inversely proportional to flow velocity (Figure 3). It should be noted that the sensitivity of this scheme enabled us to measure a deflection signal at distances up to 30 mm between the pump and probe beams at flow velocity 30 cm/sec. Preliminary results indicate that in case of spatial coincidence of pump and probe beams, the deflection signal amplitude is independent of flow velocities of the range of 0.01-30 cm/sec (for tube diameter of 3 mm). At higher velocities, the onset of turbulence introduces detectable noise. The determination of the absolute flow velocity was accomplished by measuring the time delay between the deflection signal from the

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two probe beams as shown in Figure 4. This value can also be readily obtained using only one probe beam with the pump beam laser pulse as a time reference point.

To determine the spatial profile of the flow velocity, we either scanned both the pump and probe beams; or more simply translated the fluid container in space. The results are shown in Figure 5-6. It can be clearly seen that the flow in this case is laminar as evident from the parabolic profile of the velocity distribution (Figure 5).

In conclusion, we have presented a noncontact in situ photothermal method for the characterization of fluid flow. An added attribute of this method is that it provides high spatial resolution (10^{-8} cm^3) and possibility of simultaneous determination of concentration, flow velocity and temperature by measuring amplitude, time delay and width of the deflection signal. The theory of photothermal deflection method in flowing media will also be presented and possible applications for the study of turbulence, flames and liquid chromatography will be discussed.

References

1. W.B. Jackson, N.M. Amer, A.C. Boccarra, and D. Fornier, Appl. Opt. *20*, 1333 (1981).

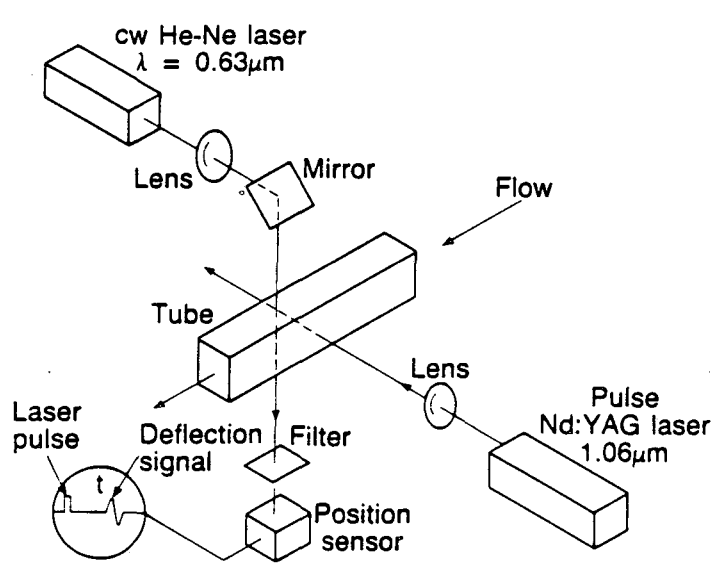

Figure 1 Schematics of the experimental arrangement for noncontact monitoring profile velocity of liquids with transverse geometry.

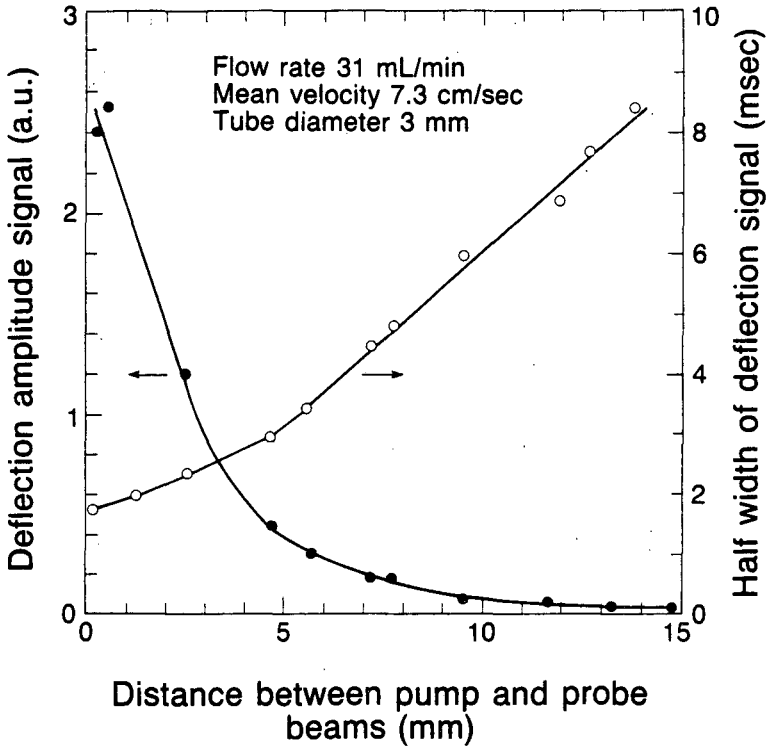

Figure 2 Dependence of deflection signal amplitude and width on distance between probe and pump beams.

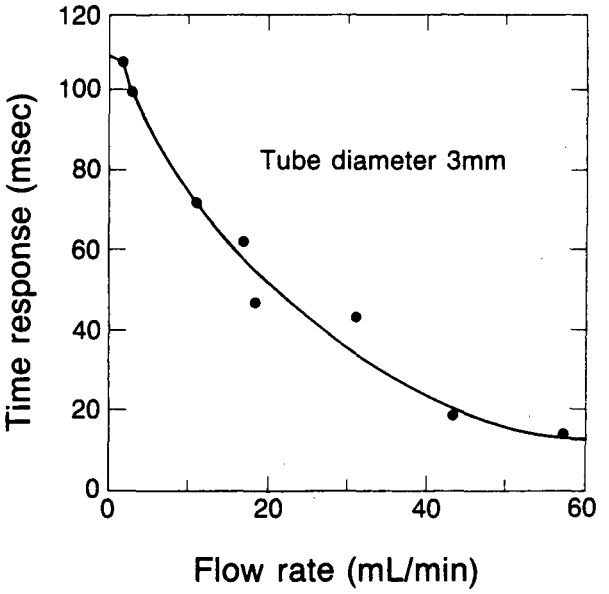

Figure 3 Time constant pulse photothermal deflection spectroscopy as a function of flow rate.

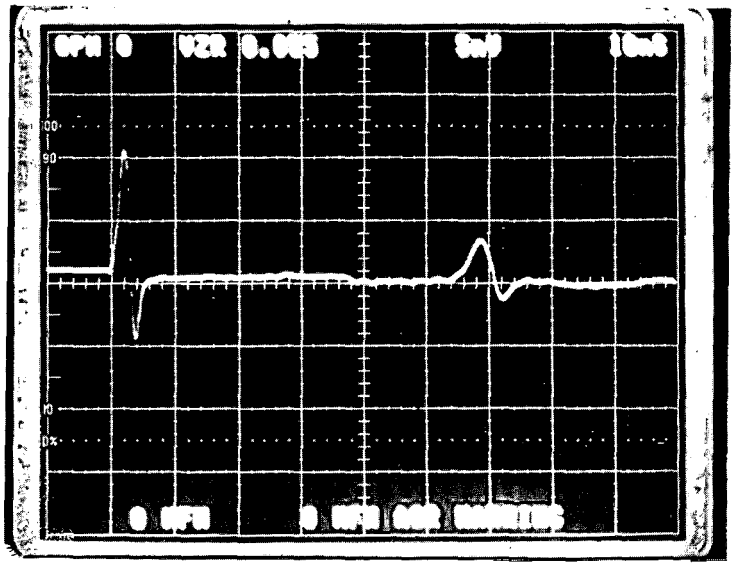

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Figure 4 The deflection signals of the two probe beams separated by a distance 6.5 mm in the tube with diameter 3 mm; The time scale is 10 ms/div; The flow rate of water is 25 mL/min

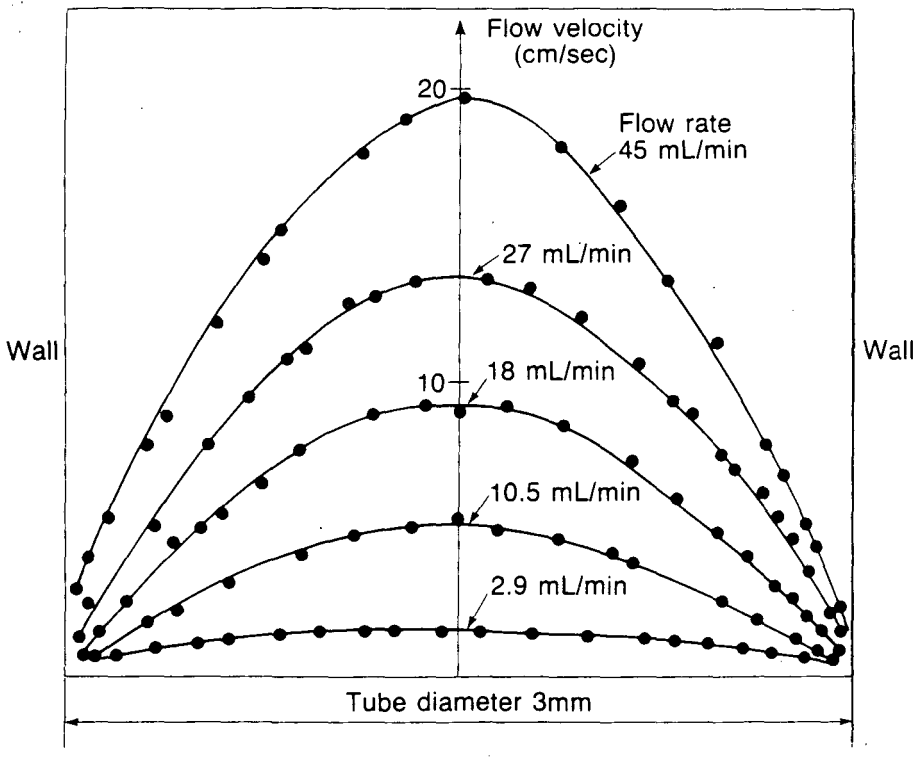

Figure 5 Profile of flow velocity as a function of the velocity of water for a cylindrical tube.

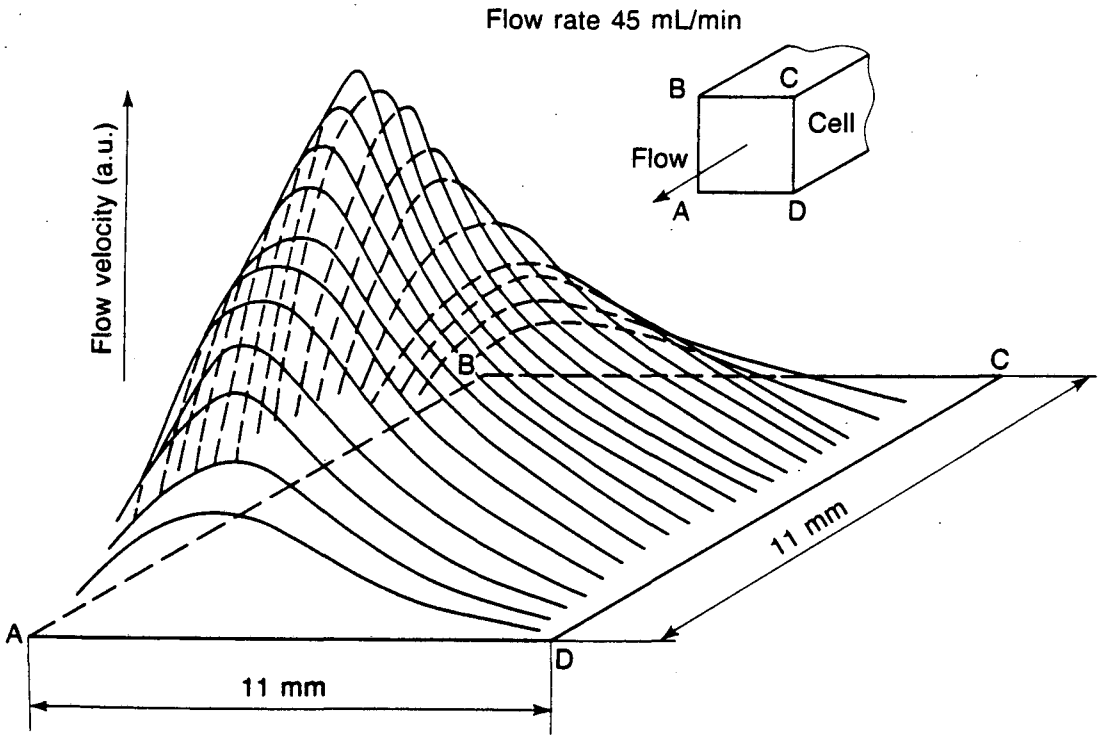

Figure 6 Complex profile of flow velocity in the liquid for a tube with a square cross-section.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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