# Measuring the speed of sound in dye solution using shock wave induced by laser pulse

**L. DeBoni, D. S. dos Santos Jr., F. J. Pavinatto, S. C. Zilio, C. R. Mendonça, L. Misoguti**

**Instituto de Física de São Carlos - USP - São Carlos, SP, Brazil**

**Abstract**

*A shock wave generated by a laser pulse in a weakly absorbing medium is used to determine the speed of sound in a solution. We presents experimental measurements of the speed of sound in six different solvents, namely methanol, acetone, ethylene glycol, chloroform, DMSO and ethanol. We have used the DO3 dye as absorbing material to convert the laser pulse energy in heat and than generating the acoustic shock wave that propagates in the solution. The traveling acoustic shock wave induces a strong local index of refraction modulation that can be probed by a cw laser. Measuring the time spent by the shock wave to propagate one given distance the speed of sound can be determined.*

## Experimental Setup

In our experiments we have used a 70 ps pulses at 532 nm from a doubled Q-switched Nd:YAG laser operating at 100 Hz repetition rate as excitation source to generate transient acoustic shock pulses. To probe radially the acoustic wave we also have used a cw He-Ne laser operating at 633 nm. The pulsed and cw laser beams are aligned parallel each other and then focused onto the sample with a f=12 cm focal length lens. The spot size in the focal point $w_0$ was about 25 μm.

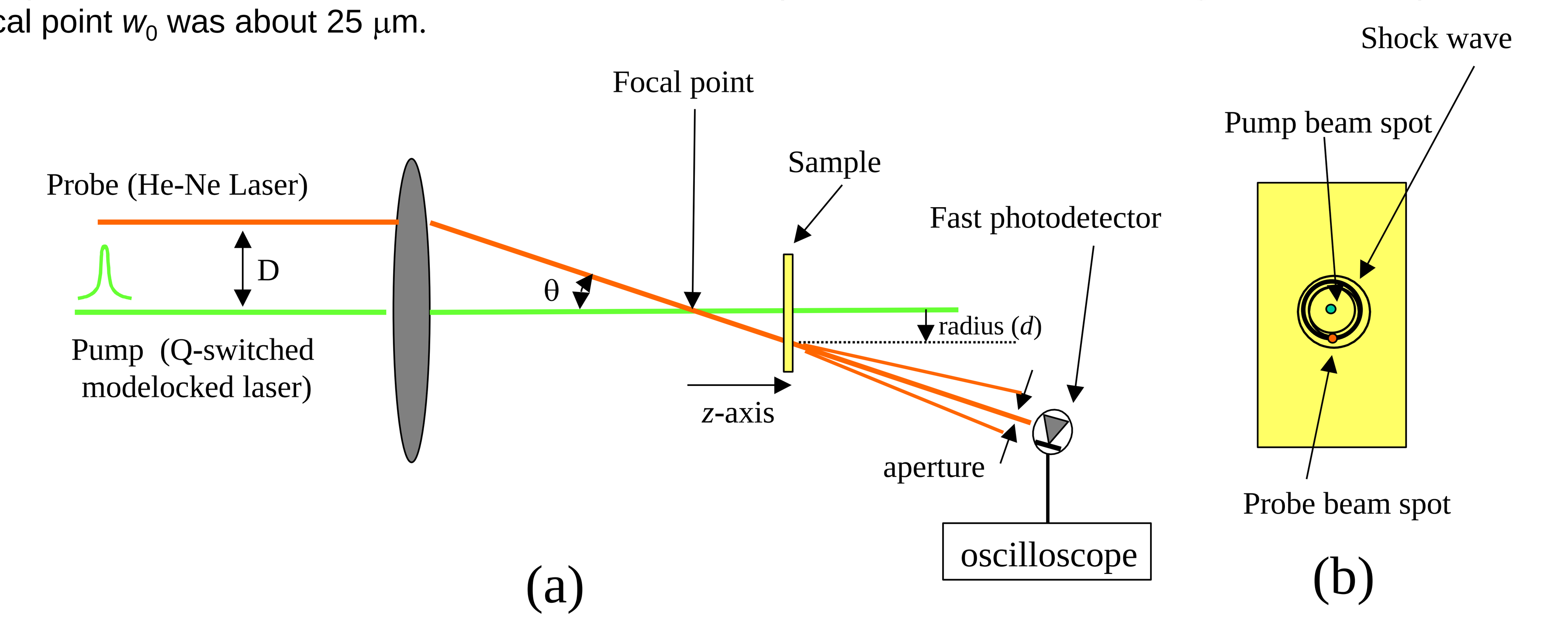


**Figure 1:** Experimental apparatus to measure the speed of sound in dye solutions. Side view of two beam pathway (a), and the front view of sample with the acoustic wave crossing the probe CW beam (b).

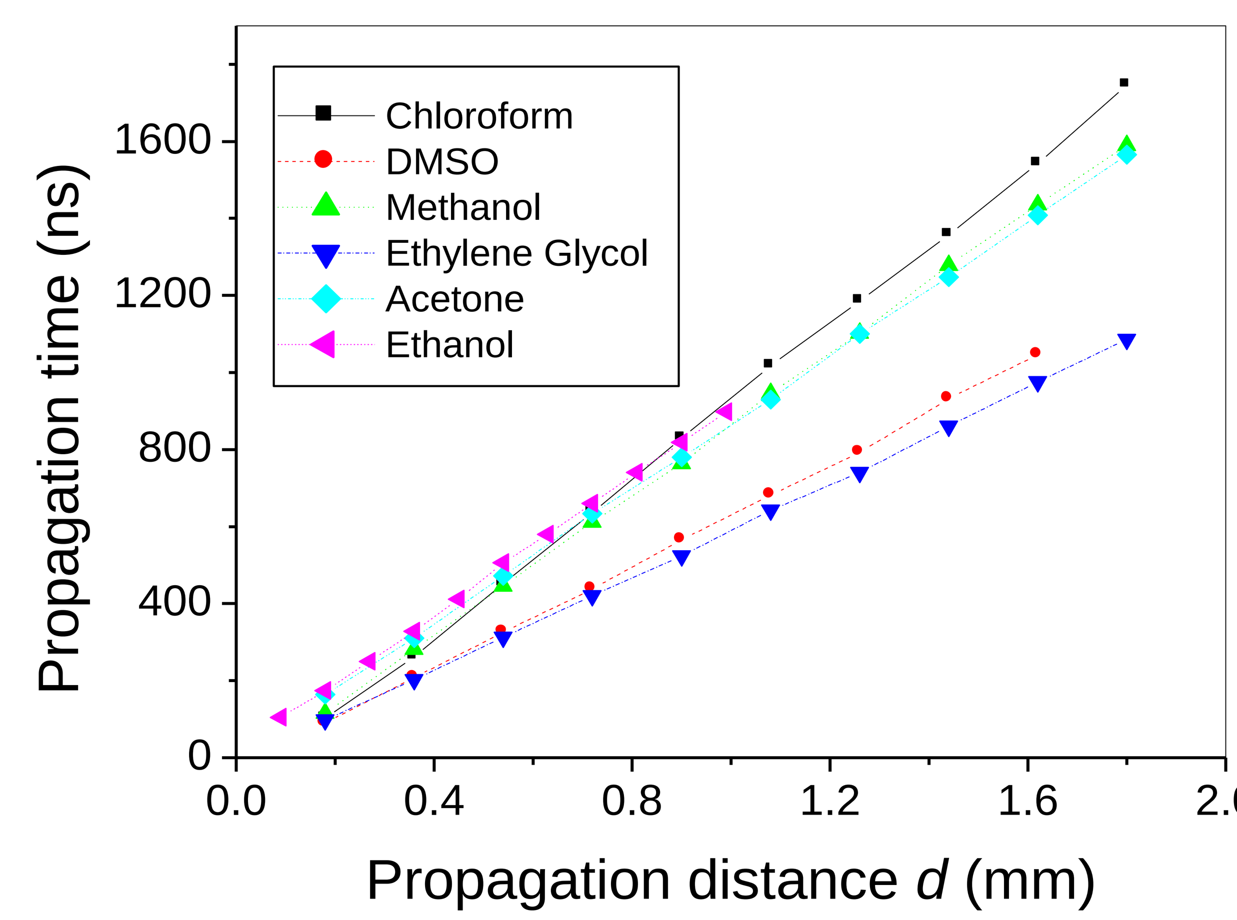


**Figure 3:** Measured propagation time at function of distance *d* of propagation for six solution of $DO_3$. The inverse of the slope of each curve is the speed of sound.

## Discussion

We have used a quartz cuvette with 2 mm pathway, filled with different dyes solutions as the sample to be studied. The DO3 was dissolved in six different solvents, keeping about the same concentration to have the same linear absorption. By the fast relaxation of dye in the solution, after absorbing the pulse radiation, a shock acoustic wave is generated. In Fig. 2 we can see three acoustic waves probed by the cw laser, captured at different distances from the source. Calculating geometrically the distance *d* from the point where the shock wave was created and the point where it was probed, and measuring the time *t* spent to the shock wave cover it, we can easily determine the speed of sound in the solution. For each dye solution we performed several measurements of *t* as a function of *d*. By the slope of the graph we determined precisely the speed of sound for the all six solvents.

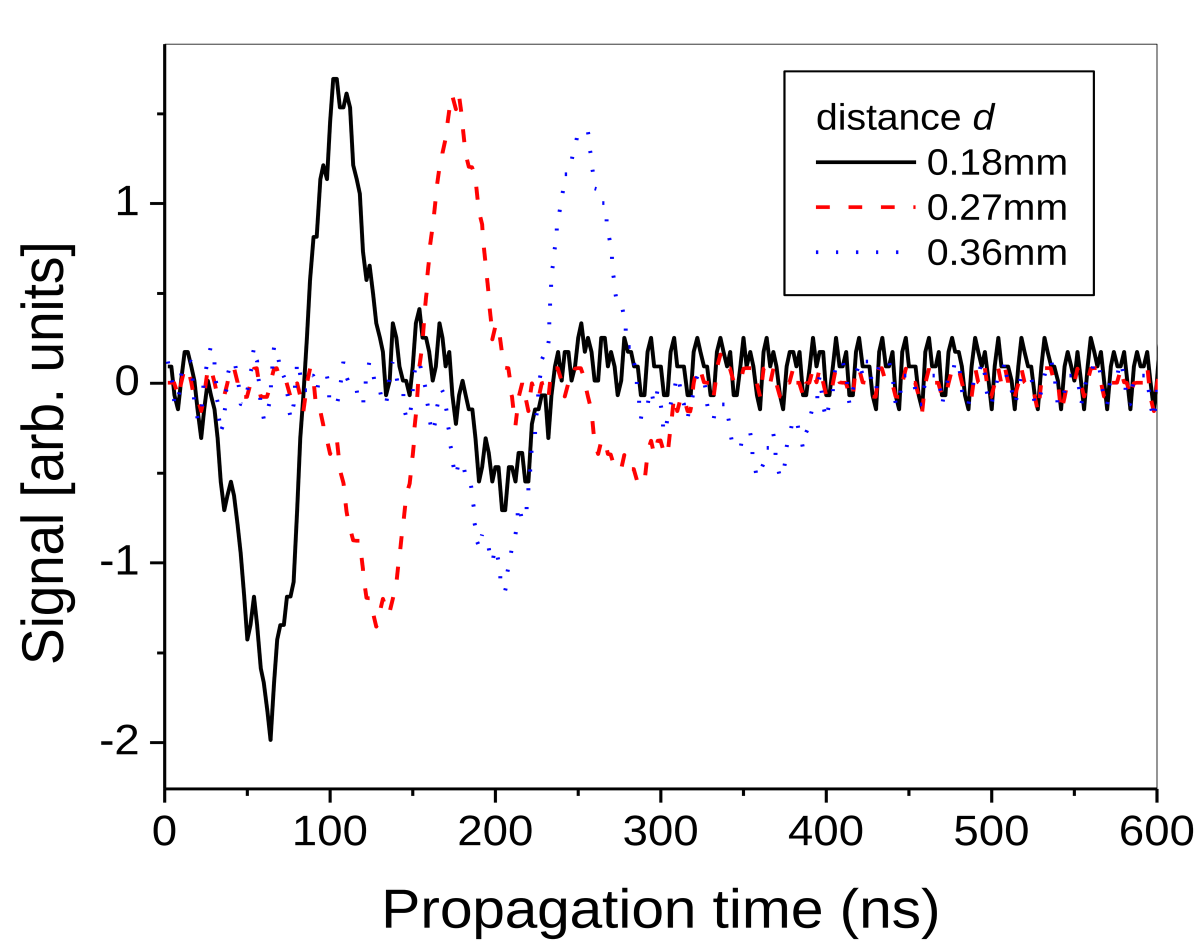


**Figure 2:** Propagation of the acoustic wave in a solution of DO3 in ethanol. Signal corresponds to the refraction of probe beam (He-Ne laser) measured in an aperture for three different distances *d*.

## Results

Through the curve slope for each solution in Fig. 3, we were able to determine respective speed of sound; chloroform: **986m/s, DMSO: 1506m/s, methanol: 1097m/s, ethylene glycol: 1646m/s, acetone: 1155m/s and ethanol: 1119m/s**. The precision in these measurements were about 10m/s.

## Conclusion

We have demonstrated the use of shock wave generated in a dye solution to measure the speed of sound in six different solvents. A picosecond laser pulse has been used to generate a shock wave and a cw laser to follows its propagation. We have shown experimentally that the speeds of sound obtained here are in agreement with those found in the literature. This method shows to be very simple and precise to determine the speed of sound in solutions and can be used for any absorbing sample.

.

## Acknowledgements

This work was supported by FAPESP (Fundação de Amaparo à Pesquisa do Estado de São Paulo), CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior).