MONITORING ACOUSTIC BUBBLE OSCILLATIONS WITH AN OPTOFLUIDIC INTERFEROMETER

Michael Ian Lapsley[1], Daniel Ahmed[1], Chandraprakash Chindam[1], Feng Guo[1], Mengqian Lu[1], Lin Wang[2], and Tony Jun Huang[1]

[1] Department of Engineering Science and Mechanics, The Pennsylvania State University, University Park, Pennsylvania 16802, USA, [2]Ascent Bio-Nano Technologies Inc., State College, PA 16801, USA

ABSTRACT

A system integrating a trapped bubble with an optofluidic interferometer is introduced. This system allows rapid analysis of the oscillatory characteristics of the bubble when it is excited by an acoustic wave. Such a system shows promise in studying the physics of these oscillations specifically the effects of surface tension and viscosity.

KEYWORDS

Interferometer, Bubble, Acoustic, High Speed Camera, Optofluidics

INTRODUCTION

Bubbles, usually unwanted in fluid systems, have recently become of interest for creating microreactors and manipulating particles in microfluidics via acoustic oscillation of the air-liquid interface. [1] The characterization of these oscillations typically requires an expensive high speed camera coupled with a powerful microscope. [2] In addition, data from a high speed camera requires substantial post processing to extract information about the system. We introduce a simple low-cost optofluidic system capable of measuring the acoustic oscillation of a microbubbles trapped in a microfluidic channel without the use of a fast camera or a microscope. With a powerful system to quickly analyze bubble oscillations, many tests can be performed. This could open new possibilities for using bubbles to analyze fluid samples and measure properties such as viscosity, and surface tension.

EXPERIMENT

Previously, we utilized an optofluidic Mach-Zehnder interferometer to measure the properties of fluids [3] which was inspired by previous interferometers. [4-5] Here we use a similar architecture with the addition of a trapped microbubble, as shown schematically in Fig. 1a. A polydimethylsiloxane (PDMS) microfluidic device was fabricated via rapid prototyping, treated with atmospheric plasma and bonded to a glass slide. In addition, a typical, inexpensive piezoelectric transducer was bonded to the glass slide with epoxy. When the piezoelectric transducer is activated, the bubble interface oscillates, and this oscillation caused a perturbation in the geometry of the interferometer which alters the output intensity. This output intensity was recorded using a PMT. We use a high speed camera to capture images of the bubble oscillation (Fig. 1b).

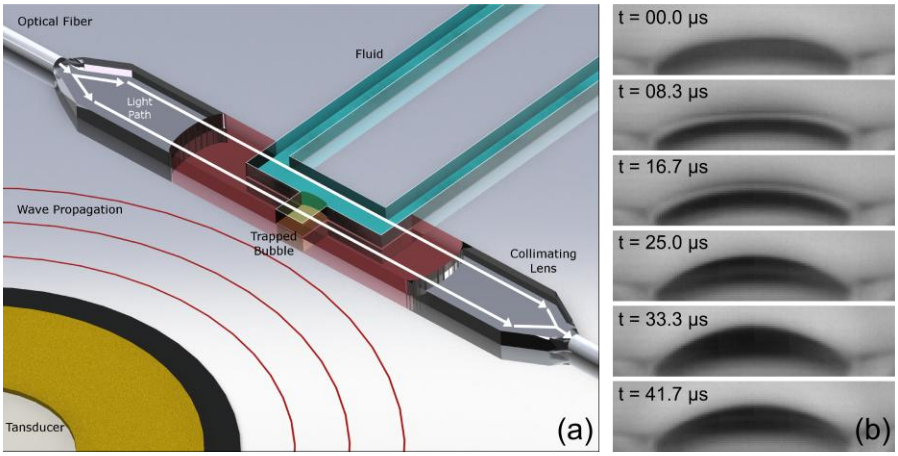

Figure 1: Schematic of the device (a). Frames of a video obtained using a fast camera, which recorded the oscillation of the bubble (b).

In Fig. 2, the results at 20 kHz from the interferometer and the high speed camera are compared. The raw data from the PMT is shown in gray and overlaid with a filtered signal in black. The interferometer data has some slight non-linearity at the high part of the signal. This was caused by the dependency of the interferometer ont eh shape of the bubble as well as the change in its position. A MATLAB program was written to analyze the high speed videos (Fig. 1b) and extract a plot of the interface passion over time. This analysis was repeated at several discrete frequencies, and the results are shown in Fig. 3. Based on our visual inspection, the data from the interferometer seems to match with that of the high speed camera. This indicates that the interferometer can provide information about the frequency response of the bubble which is comparable to that extracted from the fast camera videos. The step response on the system was analyzed by providing a puled electrical signal to the transducer, and the results are shown in Fig. 4. The transient response of the bubble oscillation is depicted here, as seen in the low amplitude at the beginning of the step and the exponential decay after the acoustic field is removed.

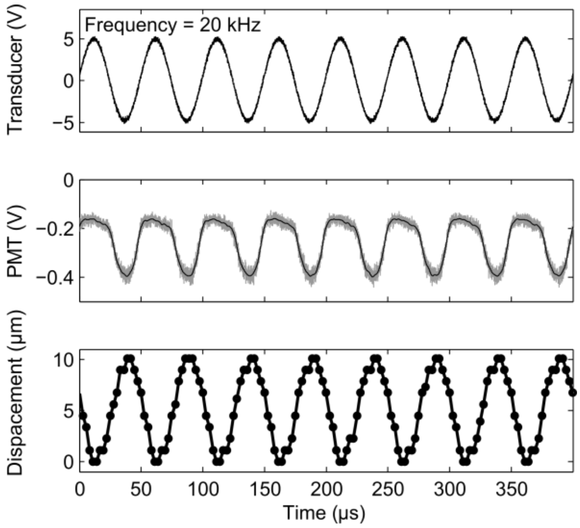

Figure 2: Input signal to the acoustic transducer (top). The output of the interferometer (middle). The analysis of the fast camera video (bottom).

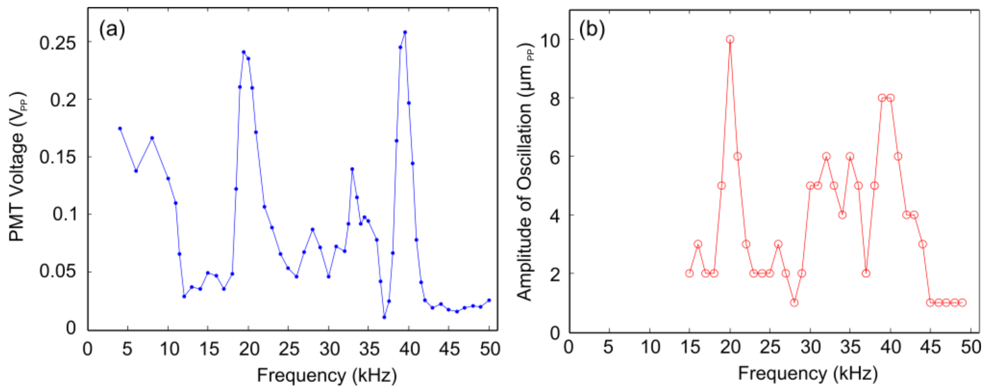

Figure 3: The frequency response of the bubble recorded using the interferometer (a) and the fast camera (b).

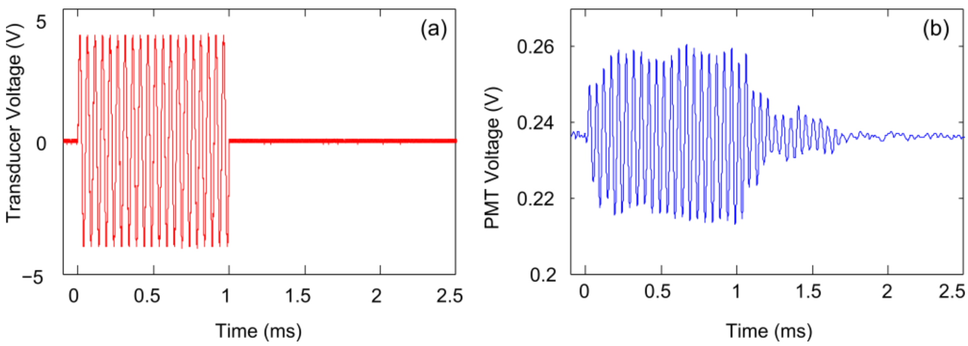

Figure 4: The step response of the bubble. The step input (a) produces an output (b) with an exponentially decaying oscillation.

One key advantage of this system is that the data files from the interferometer are relatively small in size and require little post processing when compared with videos from a fast camera. Thus, expensive high speed cameras, obnoxiously large video files and time consuming analysis and no longer necessary to characterize the oscillations of bubbles. This allows for rapid assessment of many experimental conditions. Such a system could be applied for a wide range of applications including fundamental studies on bubble oscillations, or applications in measuring viscosity or surface tension. In addition, if a phospholipid bylayer could be configured at the surface of the bubble, this system could be used to investigate properties of cell membranes under acoustic oscillation.

CONCLUSION

We have introduced a rapid method, using an optofludic interferometer, for extracting information about the oscillation of a bubble under exaction by acoustic waves. At this point, we are analyzing the physics of these results and developing the necessary optical and acoustomechanical theories necessary to understand these results. We suspect that the frequency response will be dependent on surface tension and the step response should depend on viscosity. This is a powerful platform capable of contributing to a number of important applications in the fluidic and biological field. Specifically, we hope to extend this work for measuring surface tension, viscosity, and studying acoustic oscillations of phospholipid bilayers.

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CONTACT

Dr. Tony Jun Huang 1-814-863-4209 or junhuang@psu.edu