P-9: Acoustic Detection of Foreign Bodies near a Single Bubble in a Levitation Cell

William Montes, Fabien Baillon, Olivier Louisnard*, Bruno Boyer, and Fabienne Espitalier

Centre RAPSODEE, UMR CNRS 5302, Université de Toulouse,
Ecole des Mines d'Albi, 81013 Albi Cedex 09, France
81013 Albi Cedex 09, France
olivier.louisnard@mines-albi.fr

Single bubble levitation cells have become popular over the last twenty years, in connection with single-bubble sonoluminescence (SBSL). They can also be used as an ideal experimental setup to study physical or chemical process linked to acoustic cavitation. Among the latter, mechanisms involving a foreign body, such as droplets or solid particles are of special interest. The presence or appearance of such an object near the levitating bubble may perturb the latter and alter the periodicity of its oscillation. This loss of periodicity can be detected by listening to the bubble with one or several piezo-ceramic pills glued on the side of the cell, by performing autocorrelation on the signal emitted by these sensors. This may allow for example the early detection of crystals nucleation, before optic detection.

1. Introduction

Single bubble levitation cells consist in cavities filled with fluid, driven at their first resonant mode by piezoelectric ceramics, so that a single pressure antinode appears near the center of the cell. Provided the liquid is degassed enough, a single bubble nucleated somewhere is attracted to this antinode where it can oscillate periodically for billions of acoustic cycles. Since the pioneering work of Gaitan et al (1992), such experimental setup has been used extensively by various research teams (among others Barber et al., (1997), Gompf et al. (1997), Matula (1999), Holzfuss et al. (2002); Flannigan & Suslick (2005)), and constitute the experimental ground of single-bubble sonoluminescence (SBSL) experiments. In their simplest form, levitation cells are reasonably easy to build, and have become a classical topic for personal work of pre-graduate students. Interestingly, levitation cells have also been used in other contexts than SBSL, for example sonochemistry (Lepoint & al., 1999; Troia et al., 2004), ice sonocrystallization (Chow, 2003), and, although no results were reported, it may also be used for solute sonocrystallization (Grossier et al., 2007) and cavitation erosion (Vargas and Louisnard, unpublished). In such applications, a solid body may appear and perturb the bubble oscillations, which are otherwise perfectly periodic. Detecting this perturbation can be interesting for example in order to evidence the birth of a crystal, or more generally the hydrodynamic interaction between the bubble and a solid particle or droplet.

2. Listening to the bubble

The oscillation regime of the bubbles may be assessed by various methods, but a cheap one consists in gluing a piezoceramic pill on the wall of the cell. The response of such a sensor exhibits a superposition of the driving frequency (typicaly 20 kHz) and a signal originating from the acoustic emission of the bubble. Filtering off the driving frequency, the resulting signal constitutes a clear acoustic signature of the bubble: the non-periodicity of such a signal allows to assess bubble shape instabilities and/or diffusive stability, and, if periodic, its shape even allows the experimented user to distinguish the luminescing and non-luminescing regimes (SBSL howto), without even looking at the bubble.

In spite of its intrisic usefulness, this method of characterization has been generally used with some empirism, and we propose to explore it further, by either measuring the autocorrelation of a single ceramic pill, or the cross-correlation between the signals issed from two pills. This can be done in various situations, for example by approaching a sharp object at a controlled distance of the bubble.

3. Experiment

We use a 7 cm cubic cell with 1 mm thin PPMA walls and opened at the top. A piezoelectric ring is glued at the bottom to drive the cell to its first resonance mode. The static capacity of this ring is compensed by a series variable inductance. A degassing system allows to control the air content of the liquid before it fills the cell up to a controlled level between 4 and 6 cm. The two piezoelectric pills are glued at 3 cm above the bottom of the cell Fig. 1 shows experimental set up. The signals issued from the pills are amplified, filtered and numerized with a fast acquisition card, and correlations are calculated with Labview.

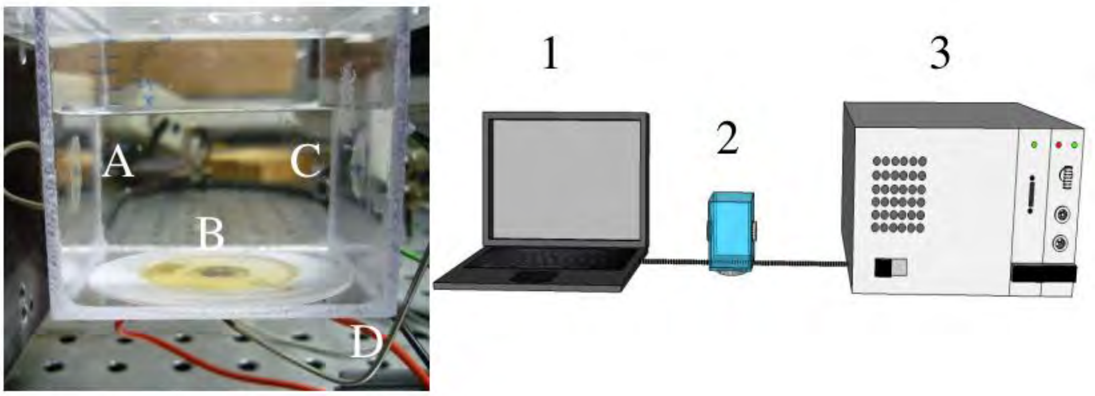

Figure 1: Left: Cavitation cell here: (A) left microphone piezoelectric pill (B) piezoelectric ring (C) right microphone piezoelectric pill, (D) filling/emptying pipe. Right: Schematics of the experimental set up here: (1) pc for processing signals from the piezoelectric, (2) cavitation cell, (3) fast acquisition card and function generation.

Acknowledgements:

The authors acknowledge the "Agence Nationale de la Recherche" for the financial support of ANR-09-BLAN-0040-02 project.

References

Barber, B. P., Hiller, R. A., Löfstedt, R., Putterman, S. J. and Weninger, K. R., 1997. Defining the unknowns of sonoluminescence. Phys. Rep., 281, 65–143.

Chow, R., Mettin, R., Lindinger, B., Kurz, T. and Lauterborn, W., 2003. The importance of acoustic cavitation in the sonocrystallisation of ice. In Proceedings of the IEEE International Ultrasonics Symposium, edited by D. E. Yuhas and S. C. Schneider, volume 2, 1447–1450. IEEE.

Flannigan, D. J. and Suslick, K. S., 2005. Plasma formation and temperature measurement during single-bubble cavitation. Nature, 434, 52–55.

Gaitan, D. F., Crum, L. A., Church, C. C. and Roy, R. A., 1992. Sonoluminescence and bubble dynamics for a single, stable, cavitation bubble. J. Acoust. Soc. Am., 91(6), 3166–3183.

Gompf, B., Gunther, R., Nick, G., Pecha, R. and Eisenmenger, W., 1997. Resolving sonoluminescence pulse width with time-correlated single photon counting. Phys. Rev. Lett., 79, 1405–1408.

Grossier, R., Louisnard, O. and Vargas, Y., 2007. Mixture segregation by an inertial cavitation bubble. Ultrasonics Sonochemistry, 14, 431–437.

Holzfuss, J., Ruggeberg, M. and Holt, R. G., 2002. Acoustical stability of a sonoluminescing bubble. Phys. Rev. E, 66(046630), 1–4.

Lepoint, T., Lepoint-Mullie, F. and Henglein, A., 1999. Single-bubble sonochemistry. In Sonochem- istry and Sonoluminescence, edited by L. A. Crum, T. J. Mason, J. L. Reisse and K. S. Suslick, 191–204. Kluwer Academic, Dordrecht. Proceedings of the NATO Advanced Study Institute on Sonoluminescence and Sonoluminescence, Leavenworth, Washington, USA, 18-29 August 1997.

Matula, T. J., 1999. Inertial cavitation and single-bubble sonoluminescence. Philos. Trans. R. Soc. London, Ser. A, 357, 225–249.

Troia, A., Madonna Ripa, D., Lago, S. and Spagnolo, R., 2004. Evidence for liquid phase reactions during single bubble acoustic cavitation. Ultrasonics Sonochemistry, 11, 317–321.