Comment on “Acoustical observation of bubble oscillations induced by bubble popping”

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We have reproduced the experiment of acoustic monitoring of spontaneous popping of single soap bubbles standing in air reported by Ding *et al.* [Phys. Rev. E **75**, 041601 (2007)]. By using a single microphone and two different signal acquisition systems recording in parallel the signal at the microphone output, among them the system used by Ding *et al.*, we have experimentally evidenced that the acoustic precursors of bubble popping events detected by Ding *et al.* actually result from an acausal artifact of the signal processing performed by their acquisition system which lies outside of its prescribed working frequency range. No acoustic precursor of popping could be evidenced with the microphone used in these experiments, whose sensitivity is 1 V Pa^{-1} and frequency range is 500 Hz–100 kHz.

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I. ARE THERE ACOUSTIC PRECURSORS TO BUBBLE POPPING?

Violent events, such as earthquakes or volcanic eruptions, are often preceded by the emission of acoustic precursor signals carrying useful information on the phenomena at play. For example, modeling the process of magma bubbles bursting atop lava lakes, Vidal *et al.* [1] have evidenced that precursor acoustic signals were linked in this context to bubble coalescence events under the surface, i.e., to hydrodynamic interactions between collection of bubbles. In 2007, Ding *et al.* [2] presented acoustic measurements of single bubbles bursting demonstrating the presence of acoustic precursors, even in the absence of any coalescence event. These results raised the exciting prospect of extracting informative data about the nucleation process from nonintrusive acoustic monitoring. Motivated by these observations, we have reproduced the soap bubble popping experiment performed in Ding *et al.* [2] with the aim of unraveling the physics underpinning this phenomenon. It was taking care of performing experiments in the same conditions as those reported in Ding *et al.* [2]. A 0.25% in weight aqueous solution of sodium dodecyl sulfate from Euromedex has been prepared, which is slightly above the critical micelle concentration of the surfactant [3]. We have formed isolated standing soap bubbles with typical diameters of 1 to 2 mm by injecting air through the outlet of a vertical top-oriented syringe previously wet with the soap solution. A Florida Research Instruments microphone having a 1 V Pa^{-1} sensitivity and a 500 Hz–100 kHz frequency range has been used to detect the acoustic emission associated with spontaneous bubble popping. The microphone was connected in parallel to two different signal acquisition systems, a Brüel & Kjær LAN-XI type 3050-B-040 acquisition system working with the Brüel & Kjær PULSE analyzer platform (called the B & K system hereafter) having a 131 kHz sampling frequency and a 24-bit dynamic range and a LeCroy 6050 oscilloscope (called oscilloscope hereafter) having a 500 MHz sampling frequency and an 8-bit dynamic range. Noticeably, a similar but earlier version of the Brüel & Kjær acquisition system having half its sampling frequency has been used in the experiments reported in Ding *et al.* [2]. Two signals resulting from the same bubble popping event, detected by the same microphone and acquired using both acquisition systems are shown in Fig. 1. Remarkably, immediately before the main pressure peak, which is assumed to correspond to the bubble popping event, the signal acquired using the B & K system, which encompasses the whole peak thanks to its large dynamic range, displays several oscillations with increasing amplitude and a frequency around 60 kHz, which are called precursor hereafter. On the contrary, the signal acquired using the oscilloscope displays no oscillations before the main pressure peak. Yet, its sensitivity is large enough to detect oscillations with such amplitude as shown by the resolved signal oscillations visible 0.5 ms after the main pressure peak. The differences between the two signals in the large energy part of the signal can be ascribed to the modest dynamic range of the oscilloscope, which results in the saturation of the signal recorded using the oscilloscope. These characteristic features are observed reproducibly in all the spontaneous bubble popping experiments we have performed.

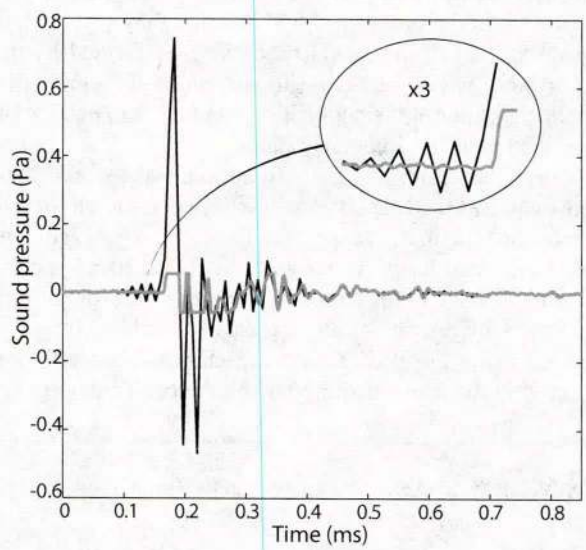

FIG. 1. Black curve: acoustic signal of a bubble popping event acquired using the B & K system. Gray curve: acoustic signal of the same bubble popping event acquired using the oscilloscope. Inset: $\times 3$ magnification of both signals at the beginning of the main pressure peak.

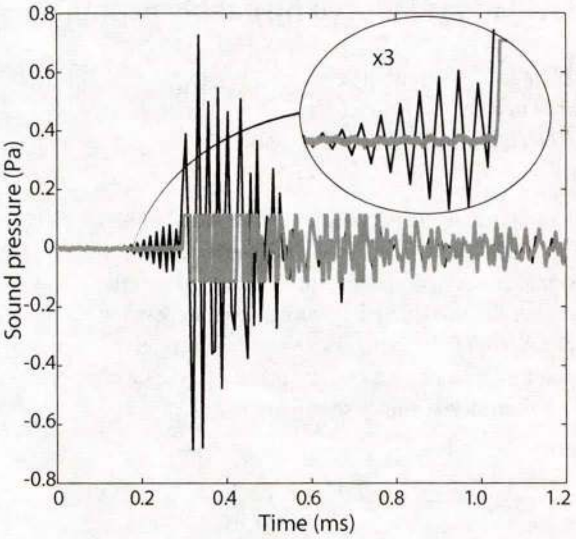

FIG. 2. Black curve: acoustic signal of an electric spark acquired using the B & K system. Gray curve: acoustic signal of the same electric spark acquired using the oscilloscope. Inset: $\times 3$ magnification of both signals at the beginning of the main pressure peak

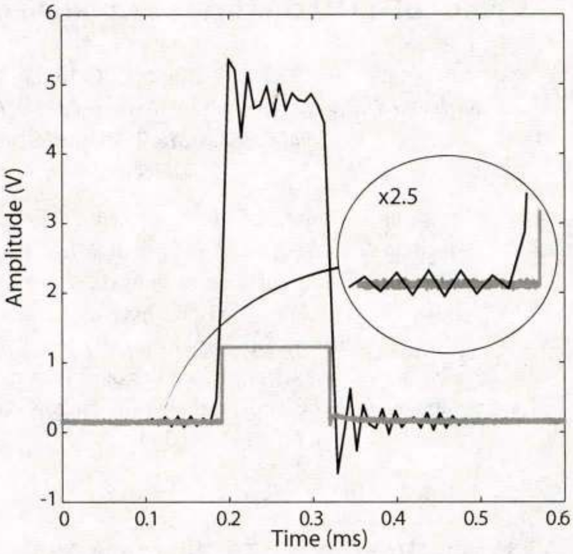

FIG. 3. Black curve: voltage signal of a pulse generator acquired using the B & K system. Gray curve: the same voltage signal acquired using the oscilloscope connected in parallel. Inset: $\times 2.5$ magnification of both signals at the beginning of the main square signal peak.

II. FURTHER EVIDENCE FOR SIGNAL PROCESSING ARTIFACTS

Noticing that: (i) In both the present experiment and the experiments reported in Ding *et al.* [2] the frequency of the observed precursor oscillations is exactly half the sampling frequency of the used B & K systems [4], (ii) it is prescribed by Brüel & Kjær to exploit the spectral content of the digitized signal below 25.6 kHz (51 kHz with the B & K system used in the present Comment, respectively) [5], i.e., below the precursor oscillation frequency reported in Ding *et al.* [2], and (iii) these precursor oscillations are absent when using the oscilloscope, we believe that these precursor oscillations are not present in the pressure signal and that they result from an acausal artifact of the signal processing performed by the B & K system which lies close to the cutoff frequency of the antialiasing filter of the acquisition channel, i.e., outside of its prescribed working frequency range.

In order to confirm this assumption, we recorded sharp acoustic pulses provided by an electric spark source for which no acoustic precursor is expected. The same signal acquisition lines have been used. The signals acquired using the same microphone and both acquisition systems are displayed in Fig. 2. Precursor oscillations are clearly visible in the signal acquired using the B & K system, whereas no oscillation is observed in the signal acquired using the oscilloscope.

Finally, in order to isolate electronic issues from acoustic issues, i.e., to test whether the precursor oscillations may result from an interaction between the microphone and the B & K system, we have acquired the square-shaped signal of a TTi TGP110 pulse generator using both the B & K system and the oscilloscope connected in parallel. The voltage signals acquired using both acquisition systems are displayed in Fig. 3. Here again, precursor oscillations are clearly visible in the signal acquired using the B & K system, whereas no oscillation is observed in the signal acquired using the oscilloscope.

III. CONCLUSION

From these three experiments, we conclude that the acoustic precursor signal preceding the spontaneous popping of single soap bubbles standing in air reported in Ding *et al.* [2] actually results from an acausal artifact of the signal processing performed by the Brüel & Kjær acquisition system which lies outside of its prescribed working frequency range. We note that no acoustic precursor of the soap bubble popping event could be detected using the highly sensitive broadband microphone used in the present experiments. If such precursors were to exist, then their characteristic frequency would be higher than 100 kHz, or their level would be undetectable with a standard acoustic instrumentation.

[1] V. Vidal, M. Ichihara, M. Ripepe, and K. Kurita, Phys. Rev. E **80**, 066314 (2009).

[2] J. Ding, F. W. Tsaur, A. Lips, and A. Akay, Phys. Rev. E **75**, 041601 (2007).

[3] P. Mukerjee and K. J. Mysels, in *Critical Micelle Concentrations of Aqueous Surfactant Systems*, NIST National Institute of Standards and Technology, Vol. NSRDS-NBS 36 (US Government Printing office, Washington DC, USA, 1971).

[4] The frequency of the precursor oscillations reported in Ding *et al.* [2] is claimed to be 30 kHz for a 65 kHz acquisition sampling frequency. In our experiments, the precursor signal frequency is exactly $F_s/2 = 65\,536$ Hz, where F_s is the sampling frequency.

[5] Technical documentation, pulse multianalyzer system, Brüel & Kjær.