Laser-induced shockwaves and cavitation bubbles in different water matrices

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Cavitation, nowadays a renowned topic among scientists, is a physical phenomenon accompanied by chemical processes that can occur in liquids. The phenomenon encompasses the growth and collapse of vaporous or gaseous cavities in a liquid, accompanied by shockwave emission. Even though cavitation has been in the centre of numerous investigations through the years there are many aspects of the phenomenon which still need to be elucidated. A big gap, for example, exists between observing and understanding the effects that addition of different compounds has on cavitation behaviour. Specifically, how it influences the governing mechanisms of cavitation, such as bubble growth and collapse, and how it influences the shockwave generation, propagation and pressure. To get a better understanding of this aspect, basic experiments should thus be conducted in a simple matrix – tap water (TW) and then compared to behaviour in more complex matrices.

Figure 1 shows the experimental setup.

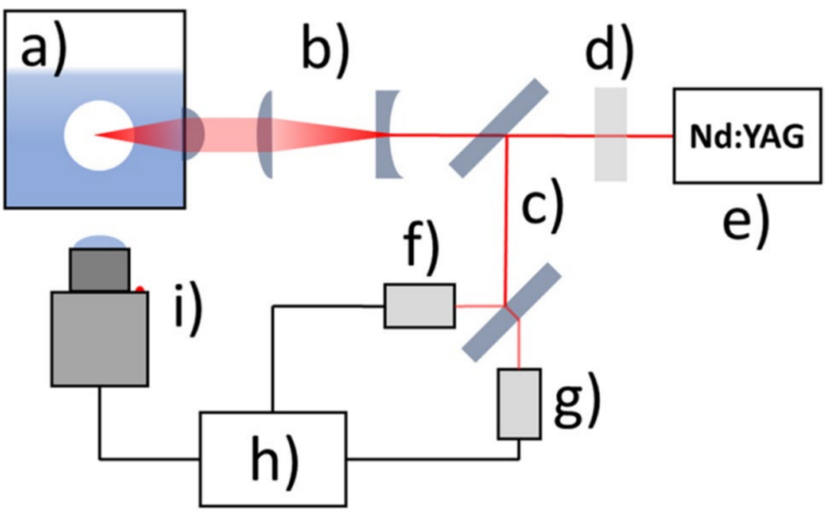

Fig. 1. Experimental setup

A similar setup was used as in [1] and was used to create a buble. A liquid container (a) with the wall integrated focusing lens (b) with the numerical aperture value of 0.23 was used, which helps minimize losses in the optical system. The beam expander (b), splitter (c) and attenuator condition the laser beam from the 1064 nm Q-switched Nd:YAG pulsed laser source (e), which has a pulse duration in ns range and up to 15 mJ with minimum attenuation. Laser pulses energy is measured at (f), assuring the variance is kept below 1.5%. A trigger photodiode (g) is used to synchronize the laser pulse and the high-speed camera (i).

The evolution of the cavitation bubble was recorded by a high-speed camera Photron Fastcam SA-Z with a frame rate of 210,000 fps (Fig. 2). The whole region of interest was 10×4 mm big and resolved by 384×160 pixels, leading to the pixel size of approximately 25 µm. LED light source Ryobi One+(50,000 lm) served as a backlight illumination source.

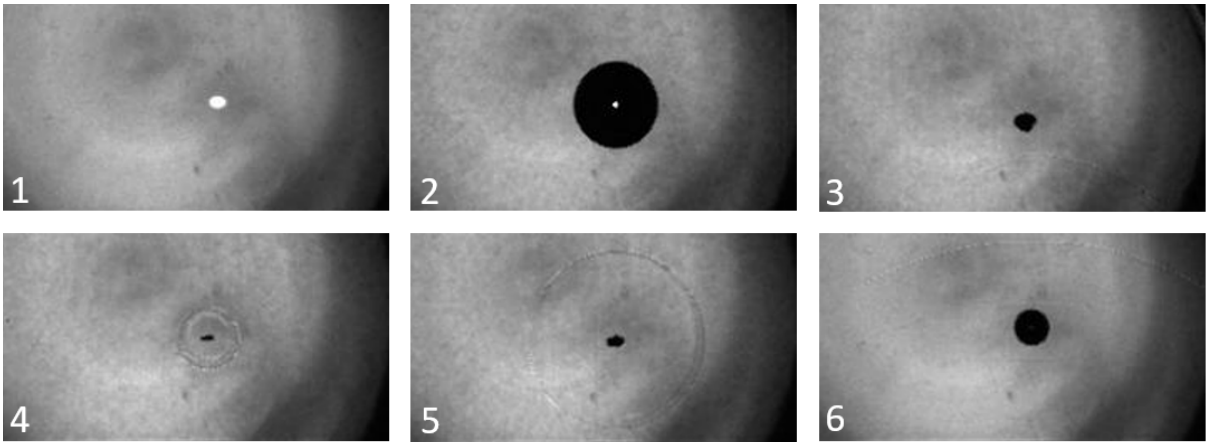

Fig. 2. Typical evolution of the bubble. Plasma initialization (1), max size (2), collapse (3) and the shock wave emission (4,5, and 6). The sequence is 230 µs long

Bubble was initiated in different water solutions containing different quantities of salt, ethanol, furfuryl alcohol, salicylic acid, histidine, methanol and hydrogen peroxide. All the solutions are commonly used in investigations of chemical effects of cavitation, hence it is essential to know their influence on the bubble dynamics and the characteristics of the emitted shock wave.

We show that even extremely low concentrations of additives significantly affect the extent and dynamics of cavitation and shock wave characteristics. This is mainly due to minute changes in surface tension which influences the last stages of bubble collapse.

Understanding the effects of water matrix on bubble dynamics and shock wave characteristics will enable the estimation of the usefulness of each additive in the process of wastewater treatment by cavitation and help to select the optimal concentration of the additive for the analysis of the chemical effects of cavitation. Further research, using higher optical magnification imaging combined with single-nanosecond illumination pulses, will be used for further investigation of detailed shockwave properties as possibly influenced by the different water matrices.

References

[1] D. Horvat, U. Orthaber, J. Schille et al,. Laser-induced bubble dynamics inside and near a gap between a rigid boundary and an elastic membrane, International Journal of Multiphase Flow, 100 (2018) 119–126. https://doi.org/10.1016/j.ijmultiphasefow.2017.12.010.