Abstract: The width and shape of the short light pulses emitted from a single air bubble trapped in a resonant sound field in degassed water has been measured with two independent methods: with time correlated single photon counting and with a streak camera. Both methods lead to the same results. The pulse width strongly depends on the parameters driving pressure and gas concentration and varies between 60 ps and more than 300 ps. The streak camera results additionally show that at low driving pressures the pulse shape is nearly Gaussian with a slightly slower decay. With increasing driving pressure the falltime and thereby the width of the pulses increases, while the risetime nearly remains constant.

Introduction

Single bubble sonoluminescence (SBSL), the emission of ultrashort light pulses by an oscillating cavity trapped in the pressure maximum of a resonant sound field in water, was first observed by Gaitan [1] in 1990. To test the different theoretical models describing the light emitting process in SBSL measurements of the width and shape of the emitted light pulses are essential. With a photon correlation technique Gompf et al. [2] were able to measure the real width of the SL pulses. They found that the SL pulse width at room temperature increases from about 60 ps at low gas concentrations and low driving pressures to more than 250 ps at high gas concentrations and driving pressures at the upper SL threshold. The advantage of this method is the low intensity one needs for detection, the disadvantage that it is a sampling technique, where one measures the autocorrelation of the SL pulse shape. The real pulse shape can be reconstructed afterwards by deconvolution but without information on the direction of asymmetry. Here we demonstrate that at low temperatures, where the SL intensity is higher the SL pulse shape can also be measured directly with a streak camera.

Experimental setup

Figure 1 shows the experimental setup. The SL-bubble was trapped in a water filled 250 ml spherical quartz glass flask which was driven with two piezo disks at its first radial oscillation mode at about 20 kHz. The resonator had two flat quartz windows of high optical quality on opposite sides to enable an undisturbed observation of the bubble. For the experiments we used filtered, demineralized and degassed water. The gas concentration was controlled with an oximeter, the amplitude of the driving pressure was determined with a calibrated PVDF needle hydrophone. As streak camera we use a Hamamatsu C5680 with fast speed single sweep unit M5676. Taking into account the aperture, the transmittance, the aberration of the optical system and the quantum efficiency of the photocathode of the camera tube it can be estimated, that about 0.01 % of the emitted SBSL-photons were detected by the streak camera. Assuming a SBSL intensity of $10^5-10^6$ photons/pulse [3] this leads to a number of 10 - 100 photoelectrons in every streak image of a single flash. The streak camera was triggered by a preceding SL-pulse using a photomultiplier and a time delay of one period. This is possible due to the high synchronicity of the SL pulses [4], which is much better than the time window of 2ns used for the measurements.

Results

Figure 2a) shows the profile of a streak image of a single SBSL-pulse at a water temperature of 8° C, an O₂ concentration of 2.1 mg/l and an amplitude of the driving pressure of 1.3 bar. 75 photeelectrones have been detected by the camera. With a quantum efficiency of 15% that corresponds to about 500 photons. Due to the low number of photons in this single shot streak image the pulse shape cannot be determined very accurately, but even with this bad statistics it can be seen, that the pulse is much larger than hundred picoseconds and that it seems to be slightly asymmetric. Figure 2b) shows now the result of 762 single SBSL pulse images averaged by overlaying their centres
of gravity. After deconvoluting this profile with the time resolution of the camera the FWHM can be determined to 208 ps (± 21 ps). This is in good agreement with time-correlated single photon counting (TC-SPC) measurements at low temperatures (Fig. 3). Fig. 3 also shows that at the same driving pressure and the same gas concentration the pulse width is independent from temperature. With a streak camera additionally to the pulse width the pulse shape can be determined. From Fig. 2b one gets as a scale for the asymmetry a risetime (10% - 90%) of 116 ps (± 12 ps) and a falltime (90% - 10%) of 188 ps (± 19 ps). Fig. 4 shows now this asymmetry in dependence of the driving pressure. The FWHM of the SBSL-pulses increases with the amplitude of the driving pressure, which is in good agreement with earlier TC-SPC results. Interesting is the different evolution of the risetime and falltime of the pulses. While the falltime increases with driving pressure nearly the same way like the FWHM, the risetime doesn't change very much.

Figure 2. a) Profile of a streak image of a single SBSL-pulse (water temperature: 8°C, O₂ concentration: 2.1 mg/l, amplitude of the driving pressure: 1.3 bar). b) Profile of 762 averaged single SBSL-pulses by overlaying their centers of gravity.

Figure 3. FWHM of the SBSL-pulses as a function of the driving pressure

Figure 4. Asymmetry of the SBSL-pulses as a function of the driving pressure

References