Event detection with acoustic and pressure sensors in Superheated Droplet Detector

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Introduction

Superheated droplet detector (SDD) consists of a large number of micron-sized droplets of superheated liquid dispersed homogeneously in a viscoelastic ultrasound gel medium [1]. Each droplet can be considered as a micron-sized bubble chamber, where a drop vaporizes (that is, phase transition or nucleation occurs) when sufficient energy is deposited by some incident energetic radiation e.g. neutrons, gamma rays and charged particles under certain operating conditions. The main advantage of this type of detector is that it can be made sensitive to neutrons while making insensitive to gamma rays and other lower ionizing radiations. This type of detector is demanding to be used as neutron monitor in the gamma ray background [2], specially in accelerator sites, medical physics applications etc. Superheated liquid detector is being widely used in search for dark matter by different world leading experiments. The change from metastable superheated state to stable vapour state starts with the formation of a critical-sized vapour embryo. This is described by Seitzs thermal spike model according to which, as the radiation deposits energy along its path inside the superheated liquid, embryonic vapour bubbles are formed. If radius of such a bubble is greater than the critical radius, then it expands very fast until the liquid droplet vaporizes. The vaporization of a superheated droplet to bubble (event) is associated with a change in pressure and the emission of an acoustic pulse. In the present work, the event detection has been done both by measuring the acoustic and pressure pulses by varying the droplet sizes. The frequencies of these bubble nucleation events due to background and the dead time for pressure recovery of the detector with varying sizes has been investigated.

Present work

The SDD was prepared by suspending superheated liquid of R12 (CCl2F2, boiling point: -29.8 ^{o}C) droplets in the gel matrix. Droplets of three different sizes were fabricated by varying the stirrer rotation speeds as 1400 rpm, 700 rpm and 300 rpm. Droplets from 5 micron to about 1mm diameters were created by this process. The experimental set up is shown in FIG.1. The acoustic sensor is a wideband AE amplifier sensor (WSa, Physical Acoustics Corporation), and the pressure sensor is a pressure transmitter (WIKA R1, Wika Instruments Ltd). The acoustic sensor was placed below the detector container, in contact with its bottom surface, coupled with gel and the pulses from the presure sensor are amplified using an IC circuit. Background events were detected by both the sensors and observed in 350 MHz, 2 GSa/s (Agilent Technologies) Cathod Ray Oscilloscope (CRO). These data were then saved and plotted in Origin software with Time (in seconds) along x-axis and amplitude of the pulse (in volt) along y-axis. The Fast Fourier Transform (FFT) of the acoustic signals was performed which provides the frequencies associated with the sound emmited during the bubble nucleation process. The presure pulses were fitted with the exponential decay function to extract the time of recovery of each nucleation event, which is the dead time of the device.

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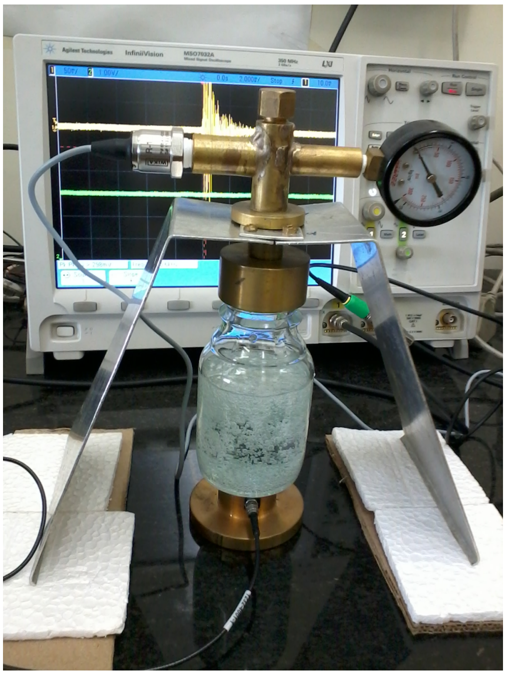

FIG. 1: The experimental set up.

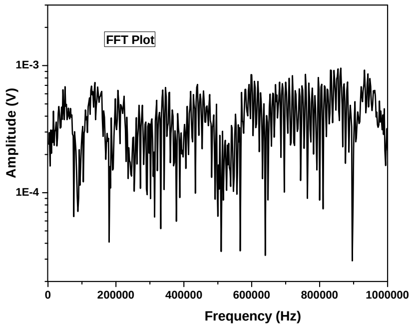

FIG. 2: Typical FFT plot of the acoustic pulse data.

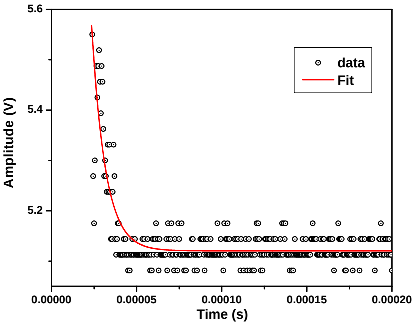

FIG. 3: Exponential fitting to the pressure pulse data.

Results and Discussion

The measurement shows that the probability of detection of events by the sensors increases as the droplet size increases. Typical FFT plot of one of such acoustic pulses for an event is shown in FIG.2. FFT of the acoustic pulses show that the range of frequency is in few KHz to about 2MHz range with several harmonics. The decay part of one of the pressure pulses as recorded by the pressure sensor is shown in FIG.3. The decay time contant of the pressure pulse varies from about 2 microsec to about 8 microsec for the different droplet sizes. Therefore the pressure recovery takes place in few microsec after each nucleation event, which is the dead time for pressure recovery of such a detector system. The decay time is not observed to be dependent on droplet diameter in the present range of investigation but the pressure pulses become more detectable with increase of droplet size.

Conclusion

The present work demonstrates the detection of bubble nucleation events in superheated droplet detector both by using the acoustic and pressure sensors with varying droplet sizes. Greater number of events has been detected for larger size of the superheated droplets and lesser volume of air in contact with the gel matrix in which the droplets are suspended. Best results have been obtained with the gel matrix filling the entire volume of the detector container.The Fourier transform of acoustic signals shows the wide band frequencies released during the bubble formation process and the exponential decay fitting to the pressure signals shows the dead time for pressure recovery of such detector as few microsec.

References

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