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SINGLE BURST ACOUSTIC STREAMING

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On a previous occasion[1] we reported observations of a new type of acoustic streaming which only occurred around a needle hydrophone positioned near the focus of a focusing ultrasound transducer. The streaming was observed even at burst repetition frequencies as low as 1 Hz. In an attempt to find the origin of this streaming attention was focused on possible excitation of evanescent waves on the probe surface. Presently we report results from a new experiment on this subject. Streaming was observed and measured using tiny tracer particles of polyamid which were recorded with a CCD-video camera and a frame grabber in a PC. The frames were analysed with a Matlab-program for obtaining stream lines and velocity measurements in a vertical plane through the sound axis. The results show that we also observe streaming in free field when using burst repetition frequencies lower than 1 Hz, and even when using single bursts.

1. EXPERIMENTAL SETUP

There are several possible ways to measure acoustic streaming, or more generally motion in fluids. In our experiments we chose Particle Image Velocimetry (PIV) for several reasons. PIV experimental setups can be made simple and inexpensive (many of the needed components are already available at our laboratory). The experimental setup is shown in Figure 1. The tank has dimensions 0.3 x 0.3 x 0.5 m, and is filled with tap water which holds a temperature of 20° C. The focusing transducer is a single element of PZT-4D, which has a nominal resonance frequency of 1MHz, a diameter of 36 mm and a nominal focal range of 100 mm. The transducer is mounted air backed in a brass housing, and it is powered by a HP8116A burst/function generator amplified with a ENI240 power amplifier. In addition a HP3312A function generator was used to get a lower burst repetition frequency than 1 Hz (which is the maximum burst repetition frequency possible from the HP8116A). A Saven CI-220 laser together with an external lens was used to produce a laser "sheet" to illuminate a thin slice of the water. The tracer particles used are "polyamid seeding particles", PSP-50, provided by Dantec Measurement Technology. The density of the particles is 1.09 g/cm^3, and the mean diameter is 50?. Unfortunately no data on sound velocity in these particles, or the material, are available from the producers. If the sound velocity differs a great deal from that of water, it is possible that we are studying the direct effect of the radiation pressure, and not the acoustic streaming. However, by using colour dye in the water one can make rough estimates of the acoustic streaming, and compare this with the quantitative measurements

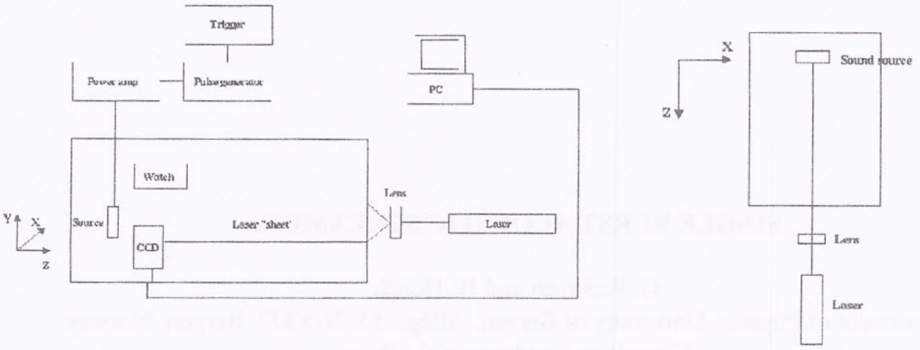

Figure 1. Experimental setup.

when using the tracer particles. Approximately the same velocities are obtained, indicating that we are indeed studying acoustic streaming. To capture the streaming a miniature black and white CCD-camera was used, model MTV-261CM, produced by Elfa. The camera sends signals to a frame-grabber (ATI All-In-Wonder 128) mounted in a Compaq Deskpro 2000 PC, where the pictures are stored for later processing. A clock was used to synchronize the pulse/function generator and the frame-grabber. As a basis for calculating streaming velocities MatPIV version 1.4 was used[2]. MatPIV contains a series of Matlab files written by Johan Kristian Sveen to analyse PIV data. Cross-correlation is used to determine the displacement in two captured pictures, two-dimensional FFT is used to calculate the correlation.

2. RESULTS

Acoustic streaming was studied under several different conditions. The following results show acoustic streaming along the sound-axis of the transducer. The primary parameters that were varied in this study are burst repetition frequency, burst length and burst amplitude. In the results shown in this paper burst amplitude provided to the power amplifier was held constant at a maximum of 1V. In Figure 2 burst length was varied from 100 Üs to 400 ?s in steps of 100 ?s, while burst repetition frequency was held constant at 10 Hz. Figure 2a shows streaming along the sound axis, while Figure 2b shows the transversal profile of the streaming at 110 mm from the sound source. The streaming was measured after it had reached its maximum value.

Limitations in the experimental setup reduces the maximum streaming velocity which can be measured. The main problem was lack of computer power, which limited the picture quality and the ability to obtain more than 10 frames per second. It is seen in Figure 2 that when the streaming velocity reached 10 mm/s the uncertainty in the measurements increased a great deal. By reducing the burst repetition frequency to 1 Hz, and again varying the burst length one obtained the results shown in Figure 3. The streaming decreased with a factor 5 when the burst repetition frequency was reduced from 10 Hz to 1 Hz. When we used a single acoustic burst, and the length of the burst was varied like in the previous cases, one could still observe acoustic streaming. The velocities are shown in Figure 4. The streaming decreased with a factor 3-4 from the case with burst repetition frequency 1 Hz. But the streaming was still observable. In this velocity range the uncertainty is large, but the results give an indication of the shape and velocity of the single burst streaming.

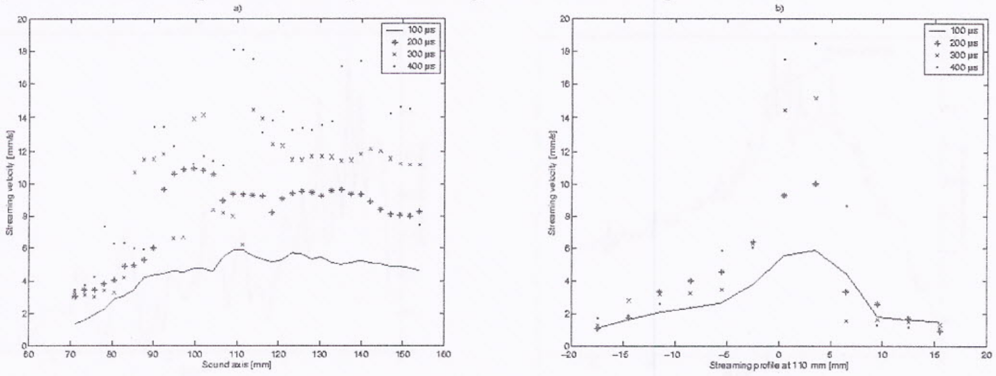

Figure 2 Acoustic streaming, burst repetition frequency 10 Hz.
a) along the sound axis, b) transverse to the sound axis.

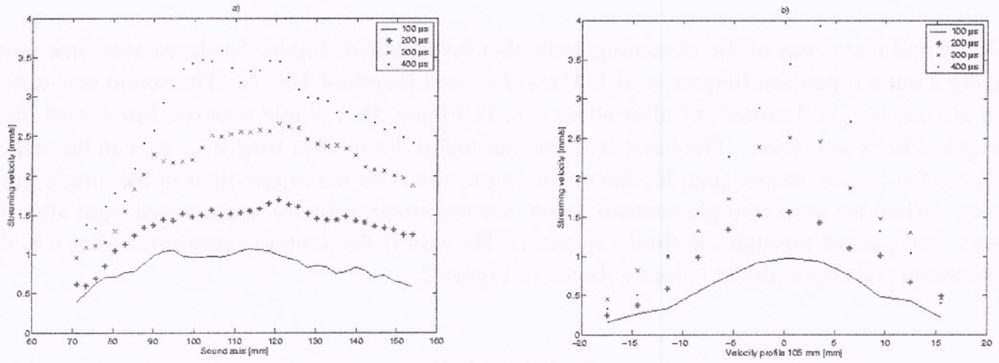

Figure 3. Acoustic streaming, burst repetition frequency 1 Hz.
a) along the sound axis, b) transverse to the sound axis.

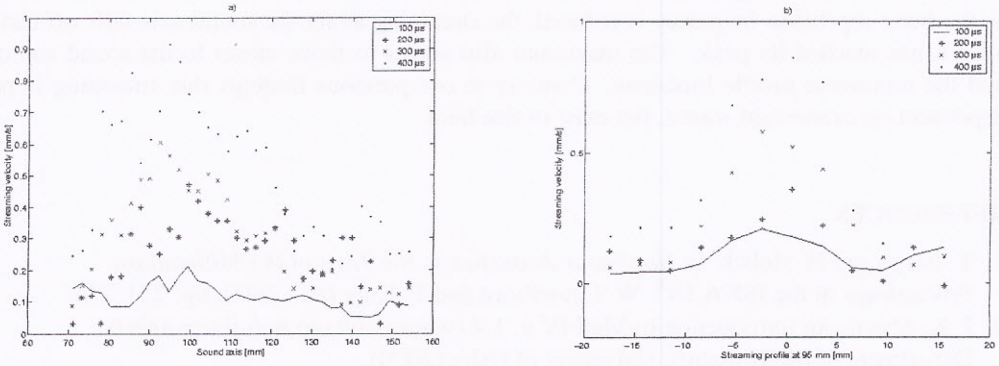

Figure 4. Acoustic streaming, single burst.
a) along the sound axis, b) transverse to the sound axis.

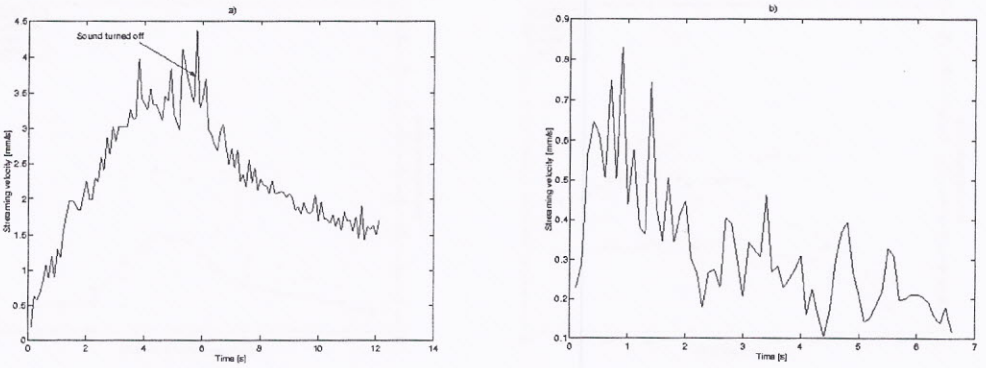

Figure 5. Acoustic streaming, decay and rise time.
a) 10 Hz burst repetition frequency, b) single burst.

Decay and rise times of the streaming were also investigated. Figure 5a shows rise time when using a burst repetition frequency of 10Hz and a burst length of 100 ?s. The sound was turned on at time 0 s, and turned off after about 6 s. In Figure 5b a single acoustic burst with burst length 400 ?s was used. The burst was transmitted to the fluid at time 0 s. As can be seen in Figure 5a, it took longer time for the streaming to reach its maximum than in the single burst case. When we used a single acoustic burst the maximum velocity was reached right after the burst had passed through the fluid. In the 10 Hz case if the sound is continued after 6 s, the streaming ends up with the velocity shown in Figure 2.

3. CONCLUSION

In this study we have investigated acoustic streaming. It has been shown that even a single burst can produce observable acoustic streaming. The streaming reaches its maximum value faster in time with a single burst than when using more than one burst. It is also observed that as the burst repetition frequency is reduced, the streaming along the sound axis falls off faster after it has reached its peak. The maximum also seems to move closer to the sound source, and the transverse profile broadens. Contrary to our previous findings this streaming is not dependent on evanescent waves, but exist in free field.

REFERENCES

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2. J. K. Sveen: An introduction to MatPIV v. 1.4 (www.math.uio.no/~jks/matpiv/). Department of Mathematics, University of Oslo. (2000).