How to drive a square flow in a liquid: acoustic stirring.

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"Not only a jet can generate sound but also sound can generate a jet!" [1]. This sentence by Sir J. Lighthill explains in a few words what acoustic streaming is: the possibility of driving steady and quasi-steady flows using acoustic waves. Such flows could exist in applications such as echography or sonotherapy and sono-chemistry. Acoustic waves can also be used to control hydrodynamic instabilities and thus control heat and mass transfer in engineering applications.

For a few years, our work has been focusing on flows driven by ultrasounds in liquids [2]. We will present our approach combining experimental measurements in water and numerical simulations using a commercial Navier-Stokes solver, STARCCM+™. The aim is to establish scaling laws relating the measured velocities to the used acoustic power, in simple configurations. The flow is investigated experimentally in a large container filled with water, where a plane ultrasound source is immersed far from the boundaries. This source is a 30 mm diameter piezoelectric transducer, which is operated in the MHz range. Particular attention is paid to account for the near-field/far-field structure of the acoustic field in order to be able to correlate the flow structure to the acoustic field structure. The acoustic pressure field is measured using a hydrophone. The velocity field is measured by Particle Image Velocimetry (PIV).

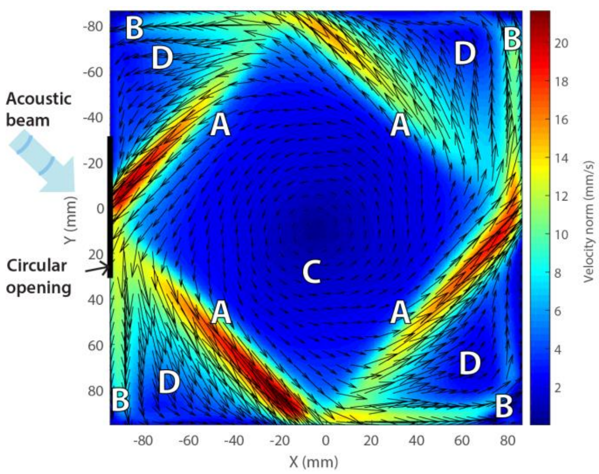

Figure: Typical flow pattern experimentally observed in the case of a flow driven by an ultrasonic beam reflecting three times on the side walls of a cubic water tank; view from above.

The developed numerical model is based on the incompressible Navier-Stokes equations, featuring an acoustic streaming force term computed with Matlab™ from linear acoustics. Possible acoustic beam reflections on flat walls are accounted for using a virtual sources approach. A good agreement is obtained between the numerical data and experimental measurements. Scaling laws are proposed and compared to formerly published results by other teams. We have already shown that, in the configuration where the acoustic beam undergoes a single reflection on one wall of the tank, an original *y*-shaped flow is observed [3]. We will present here another striking pattern obtained using three successive reflections on lateral walls: a square flow in a cubic cavity, which could be an interesting flow pattern for efficient stirring.

REFERENCES

[1] S. J., Lighthill, "Acoustic streaming", *J. Sound Vibr.* **61**, pp. 391–418 (1978).

[2] B. Moudjed, V. Botton, D. Henry, H. Ben Hadid, J.P. Garandet, "Scaling and dimensional analysis of acoustic streaming jets", *Phys. Fluids* **26**, 093602 (2014). http://dx.doi.org/10.1063/1.4895518

[3] B. Moudjed, V. Botton, D. Henry, S. Millet, H. Ben Hadid, "Y-shaped jets driven by an ultrasonic beam reflecting on a wall", *Ultrasonics* **68**, pp. 33–42 (2016). http://dx.doi.org/10.1016/j.ultras.2016.02.003.