Quasi-omnidirectional shear wave generation using acoustic vortices for elastography

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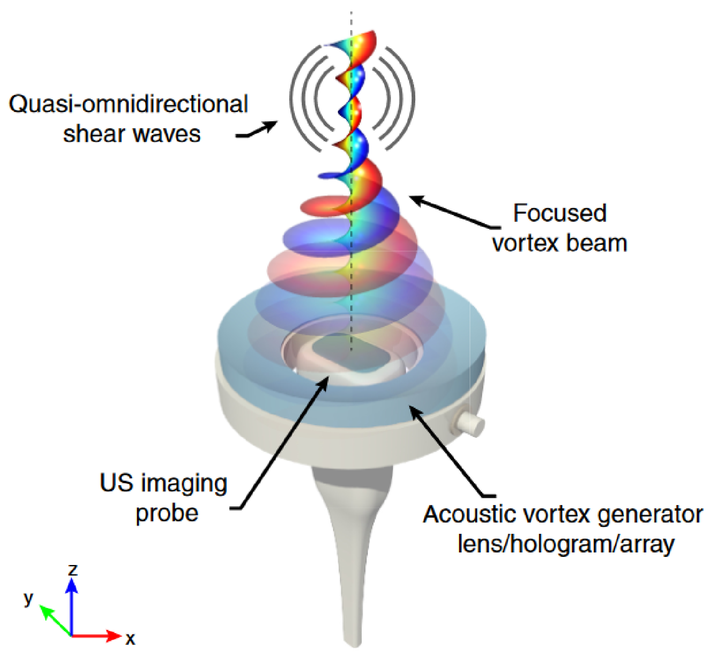
INTRODUCTION

Background

Ultrasound elastography is a reliable tool for medical diagnosis with the aim of finding pathologies that cause tissue stiffness irregularities. Currently, the most used techniques based on acoustic radiation force deform the tissue with a pulse in the direction of beam propagation resulting in **linear momentum** transfer, producing shear waves in the transverse direction of the beam.

Vortex Beam

Angular momentum



Our proposal

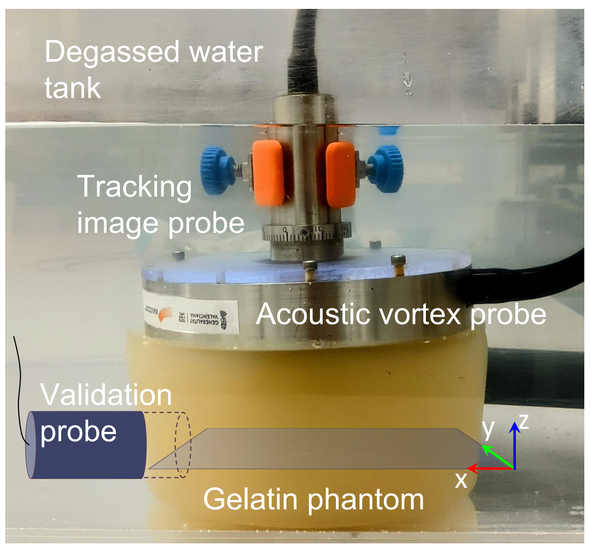
The goal of this work is to show the first experimental evidence of **angular momentum** transfer from a vortex to a soft elastic material and use this mechanism to improve tissue **elastography**.

METHODS

The magnitude and phase of the pressure fields are calculated to confirm vortex generation. Once confirmed, the elastography system is then implemented with the following

1 Acoustic twist beam

Custom 16-element sectorial focused transducer (125-mm OD, 50-mm ID, 125-mm ROC) was used to **twist [$L > 0$] (or push [$L = 0$])** the tissue by focusing a of 700-µs duration and 1.1-MHz pulse-burst at 105.79 mm depth.



2 Tracking beam

The tracking pulses were transmitted using a 5.2-MHz, 64-elements imaging probe, and a pulse repetition frequency of 4 kHz in z-x plane. In addition, a validation experiment was performed to test the twisting in the phantom in the x-y plane.

3 Shear-wave displacements

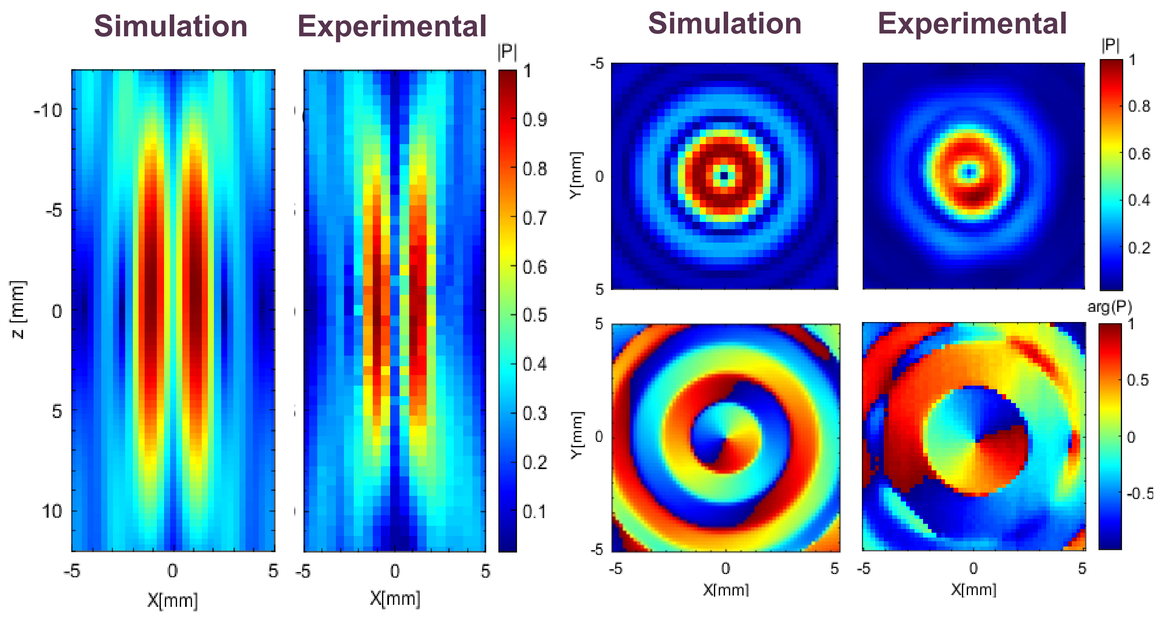
Shear-wave axial displacements were calculated by correlating different frames by Loupass[1] estimator.

4 Shear-wave velocity (elasticity)

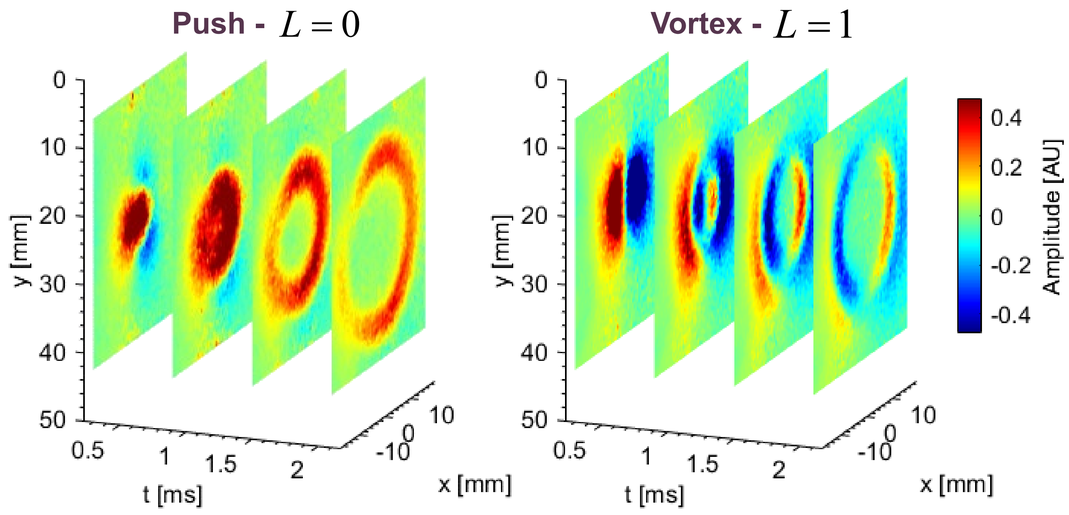
Calculated by time-domain tracking and spatio-temporal spectral analysis

RESULTS

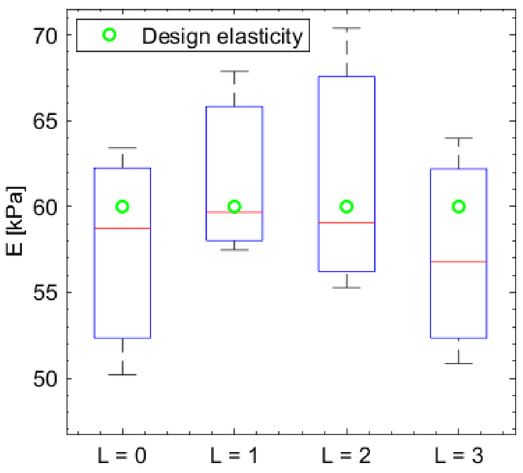
Acoustic fields obtained by simulation[2] and experimentally were in good agreement. The field of the vortex beam generated by the custom sectorial focused transducer shows a phase dislocation on the axis for a topological charge $L = 1$.



Shear-wave axial displacements in x-y plane for focused ($L = 0$) and vortex ($L = 1$) beam are compared. In the vortex case, transferring angular momentum into the medium results in a **source of torsional shear-waves** propagating quasi-omnidirectionally from the focus.



The elasticity of a gelatin phantom has been analyzed and values obtained without topological charge and with different topological charges agree with the design elasticity (60 kPa) with relative errors between 3% and 5%,



CONCLUSIONS

By using focused torques, shear waves are generated with a **quasi-omnidirectional radiation pattern**, extending both, the field of view, and the angular spectrum of the displacement field in a controlled manner. These finding pave the way to improve two-dimensional elasticity mapping techniques.

REFERENCES

[1] T. Loupas, et al. *IEEE UFFC*, 42(4), pp. 672-688, (1995)
[2] N. Jiménez, et al. *2020 IEEE IUS*, pp. 1-4, (2020)

Acoustic Vortex | Acoustic Radiation Torque | Tissue twisting | Elastography

2022 IEEE IUS International Ultrasonics Symposium Venice, Italy || October 10-13, 2022