# Transcranial multifocal acoustic holograms

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# Introduction

## Motivation

- Ultrasound-based transcranial therapy techniques are being developed.
- “Gold-standard”: MR-guided phased-array systems: complex and **expensive**.

## Goal

- The objective of this work is to design and validate **acoustic holograms for bilateral targeting**.

- An experimental prototype will be designed.
- Measurements will be made with an ex-vivo skull.
- The results will be validated with numerical simulations.

# Materials and methods

## Numerical simulation

- The resolution of the coupled first-order partial diferential equations will be carried out with a pseudospectral numerical method in k space, using the k-wave software.



**k-Wave**

A MATLAB toolbox for the time-domain simulation of acoustic wave fields

| | |
|---|---|
| $\frac{\partial \rho}{\partial t} = -\rho_0 \nabla \cdot \vec{v} - \vec{v} \cdot \nabla \rho_0$ | Mass conservation equation |
| $\frac{\partial \vec{v}}{\partial t} = -\frac{1}{\rho_0} \nabla p$ | Momentum conservation equation |
| $p = c^2 \left(\rho + \vec{d} \cdot \nabla \rho_0 - \mathbf{L}\rho\right)$ | Pressure-density relation |

$\alpha = \alpha_0 \cdot \omega^y$ [dB/(cm·MHz$^y$)] Absortion law

# Materials and methods

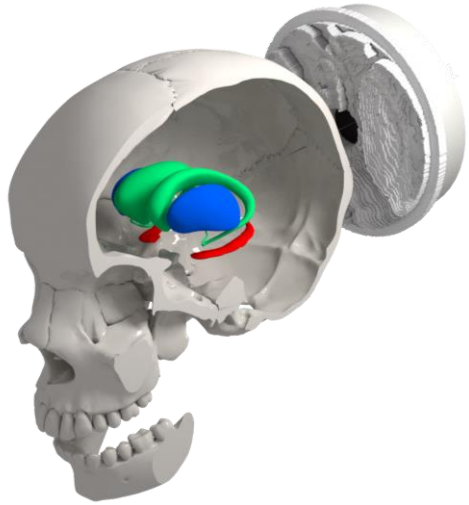
## Time reversal / phase conjugation method

**a)** CT images




- Ex-vivo skull
- HU to acoustic impedance and sound speed conversion

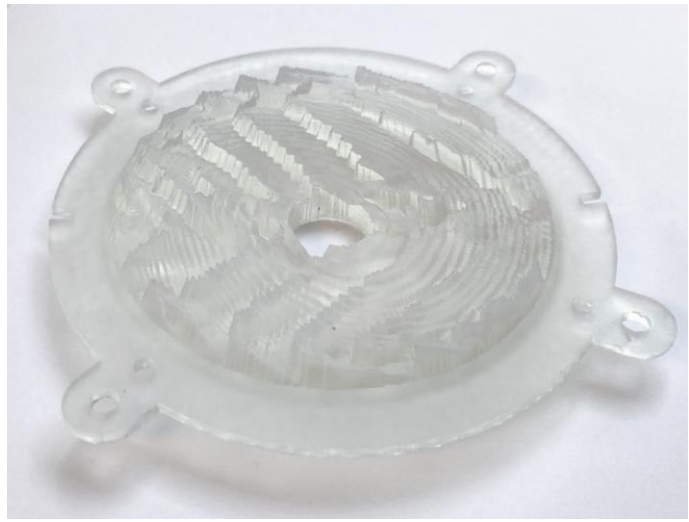
**b)** MRI data + virtual sources



- Hippocampus (Alzheimer)
- Striatum (Parkinson)

- Data from the open atlas from the Laboratory of Neuro Imaging

**c)** Lens design

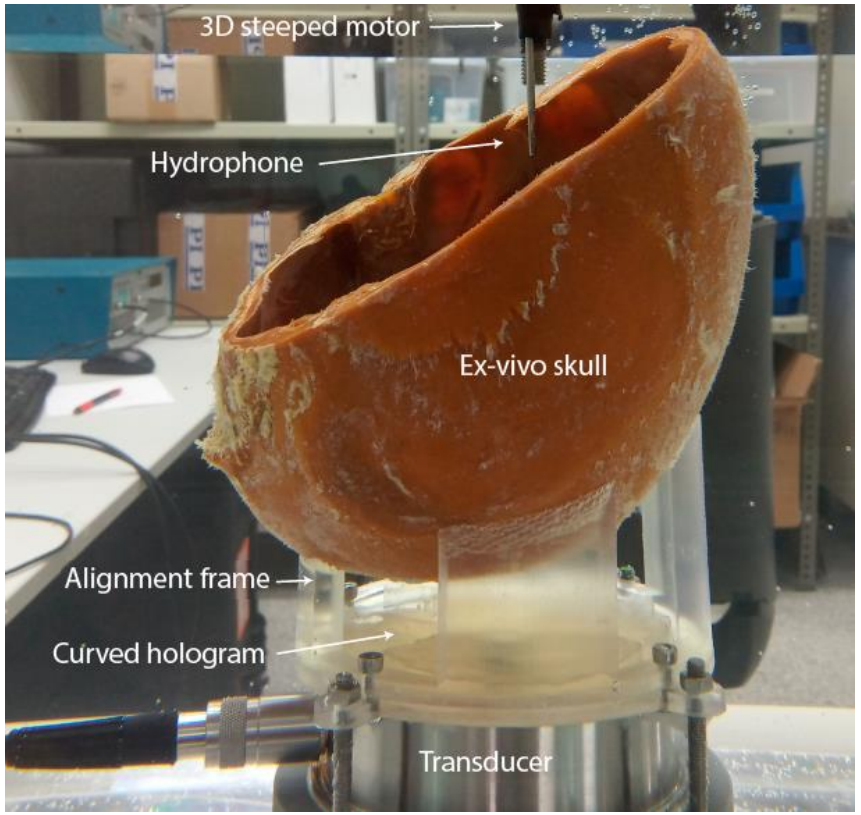


- Fabry-Perot longitudinal resonator

# Experimental setup

**Measurements in a water tank with an ex-vivo skull**

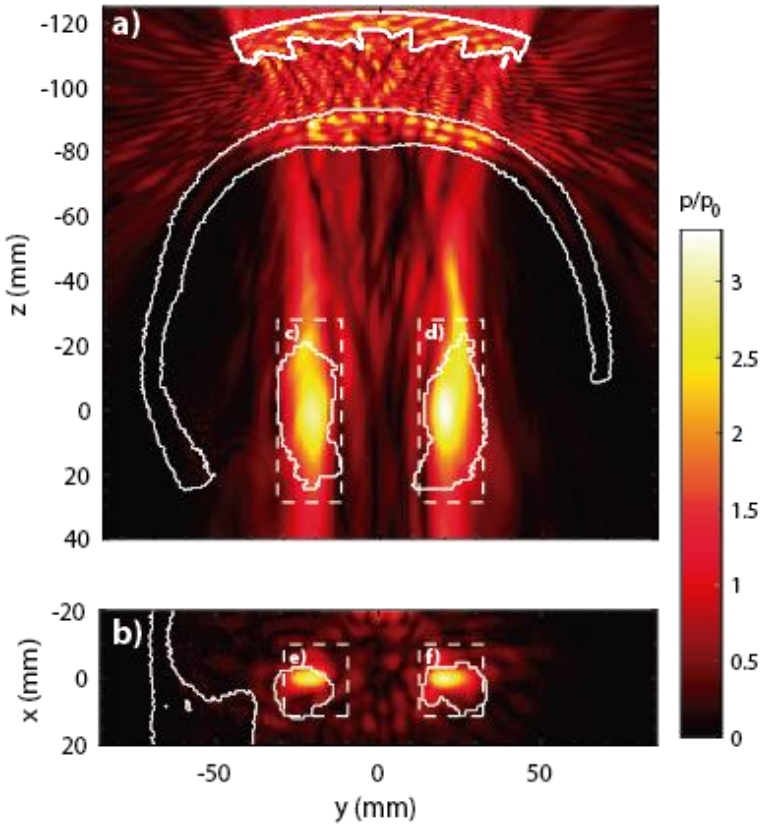
- A curved transducer of aperture 2a = 100 mm and focal F = 140 mm is used.
- We work with 20 cycles tone bursts at 500 kHz.



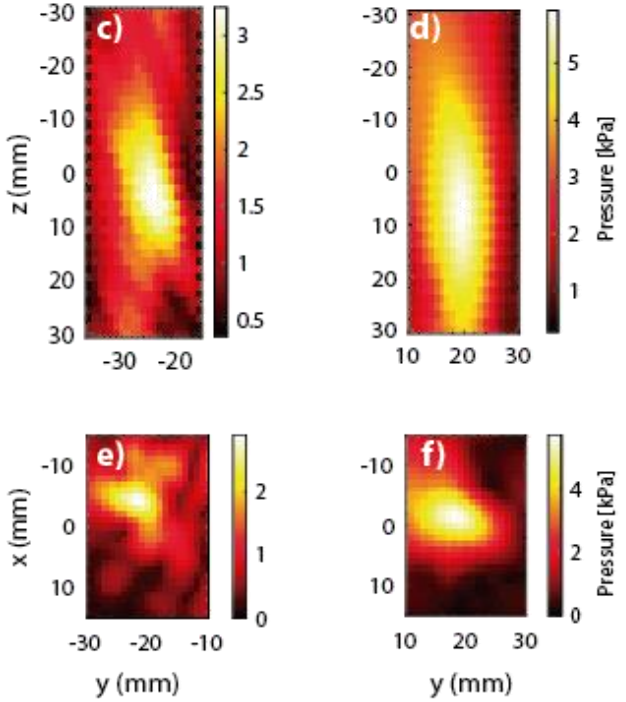


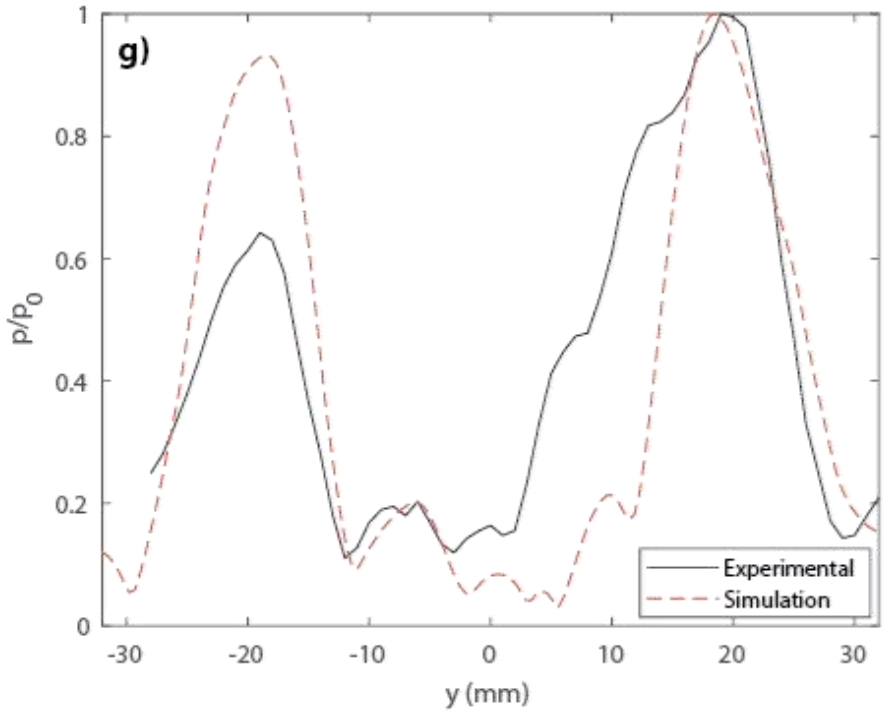

# Results

Simulation




Experiments




- Simulations:
  - Mean volume sonicated: 24% of the total volume
  - Mean gain: 3.5 p/p0
- Experimental measurements:
  - Good agreement with numerical simulations
  - Steering and bifocal focusing

# Conclusions

## Holographic lenses

- Allow bilateral focusing on specific targets in deep-brain nuclei.
- Skull aberrations are compensated.
- Number of sonications is reduced.

## Future works

- Apply these techniques to blood-brain barrier opening and/or neuromodulation.

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