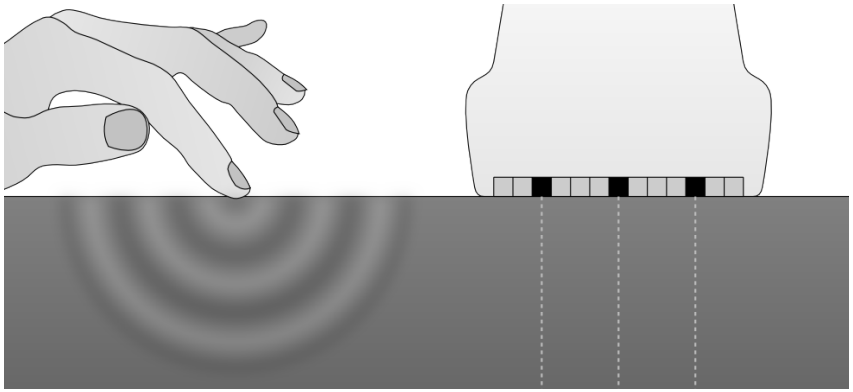


Measuring tissue stiffness using ultrasound

Final Project Presentation

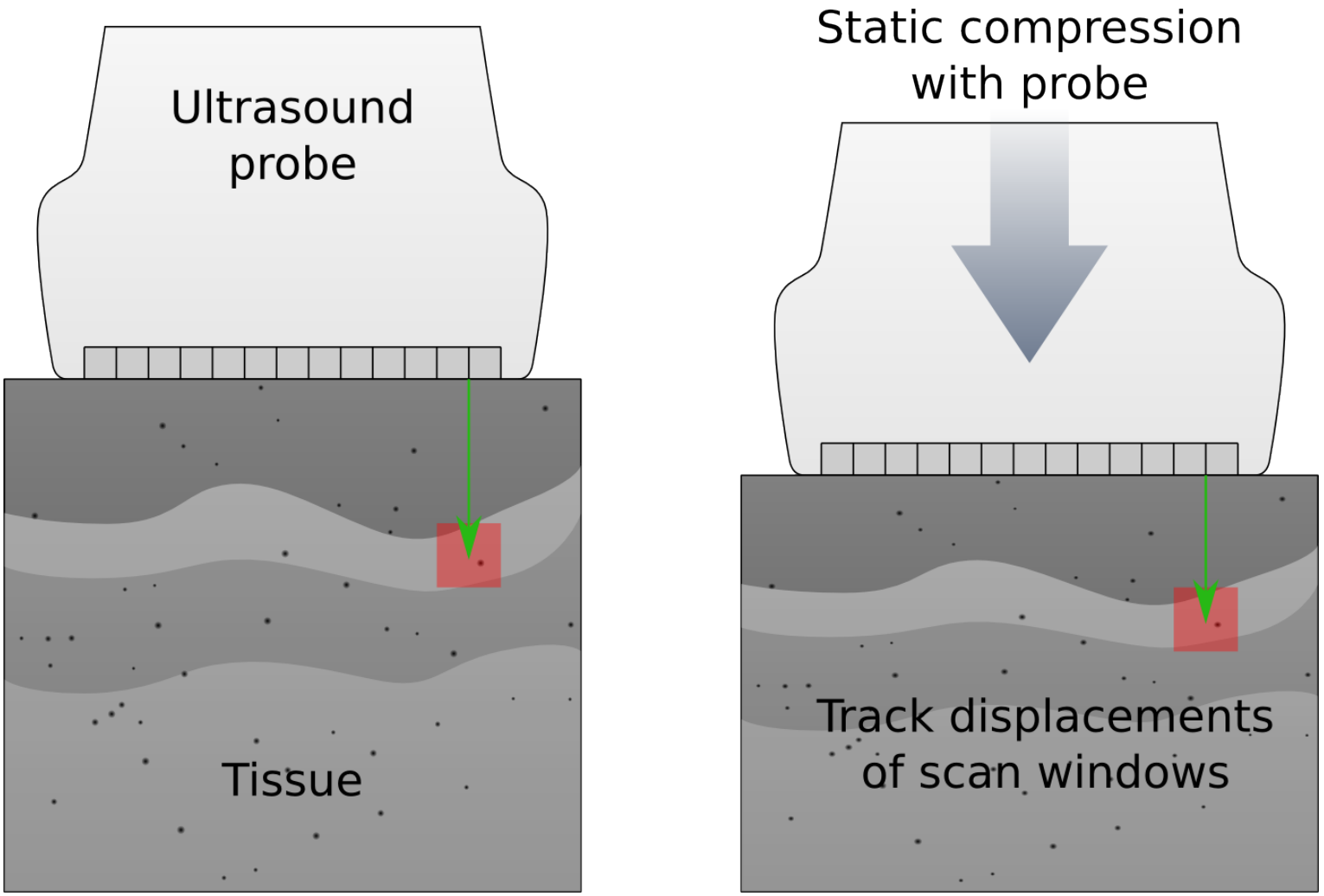
Matthew Graham (mmg32@cam.ac.uk)

Supervisor: Graham Treece

Motivation

- Elastic properties of tissue characteristic of some structures and pathologies
- Manual palpation - effective, but only for large near-surface structures
- Ultrasound elastography - images of tissue stiffness

Quasi-static ultrasound elastography



Quasi-static ultrasound elastography

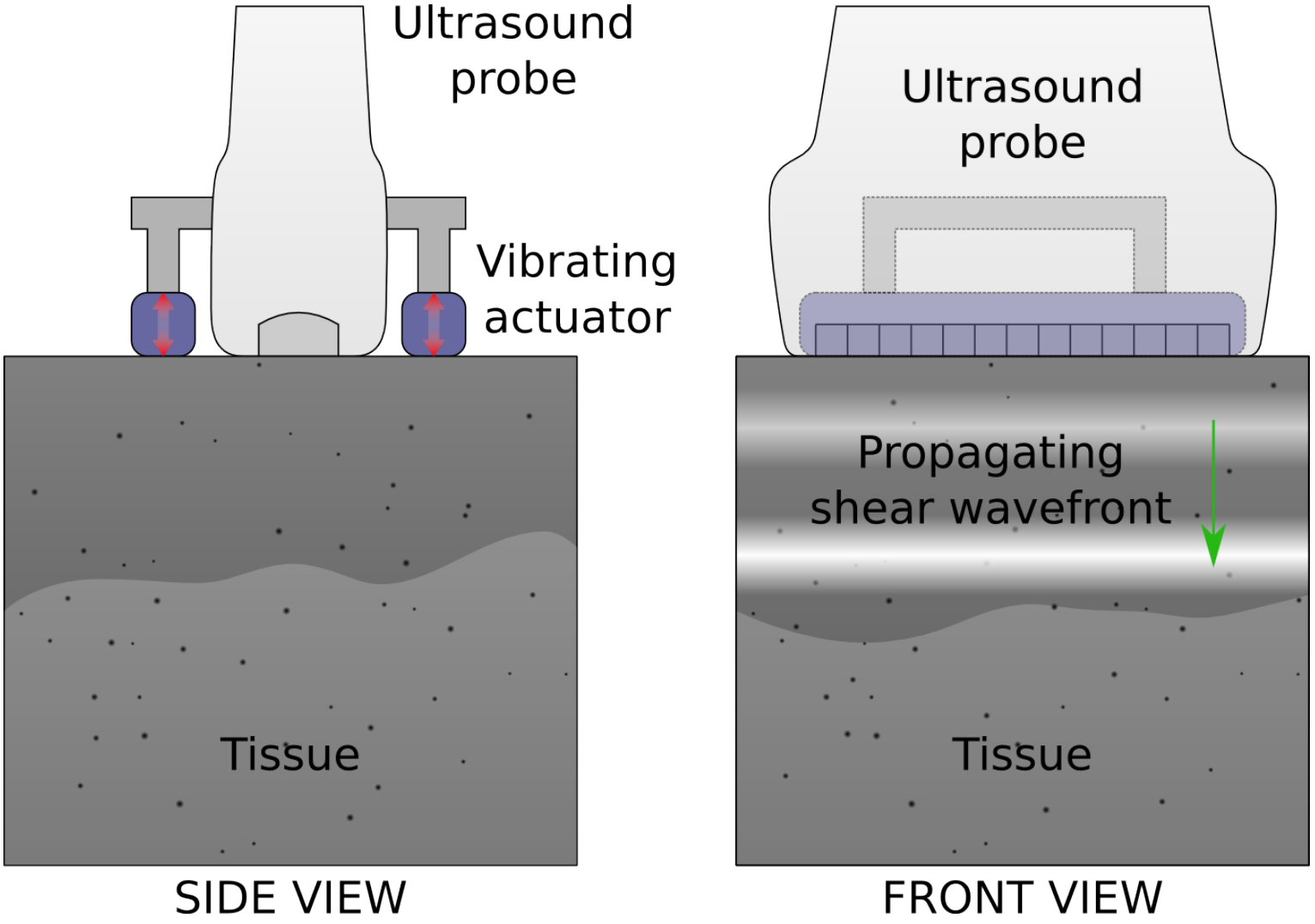
Advantage

- Requires only standard ultrasound hardware (software-based)

Disadvantage

- Gives only relative stiffness values - qualitative assessment only

Dynamic ultrasound elastography



Dynamic ultrasound elastography

Advantage

- Absolute stiffness values - quantitative assessment possible

Disadvantage

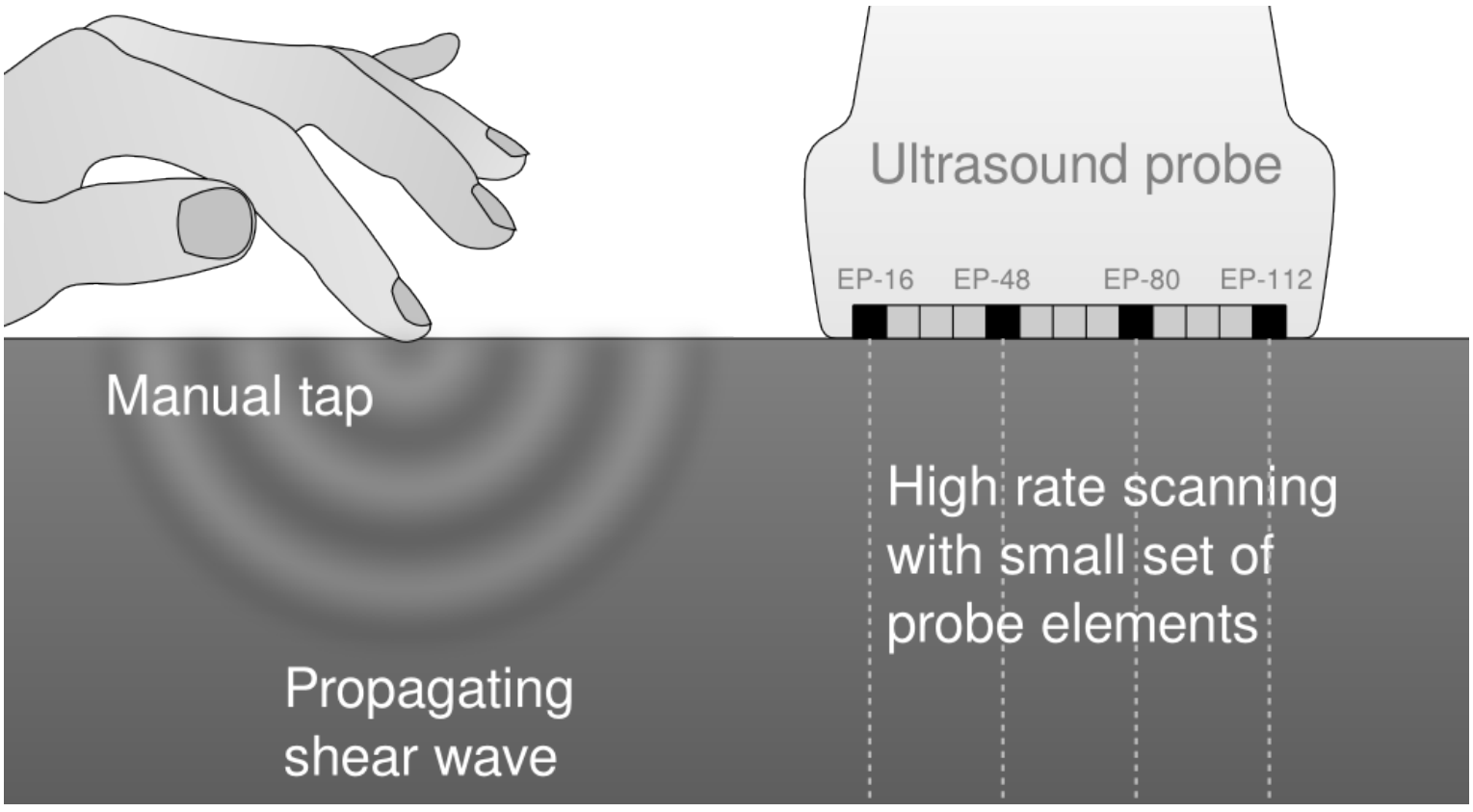
- Requires specialist hardware

Project aim

To develop an ultrasound elastography method which:

gives **absolute estimates of tissue stiffness** using only **standard ultrasound hardware**

Proposed method



Estimating stiffness: arrival time method

Shear wave speed

$$c_s = \sqrt{\frac{E}{3\rho}}$$

(c_s - shear wave speed, ρ - density, E - elastic modulus)

Cross-correlation based tracking of wave fronts $\Rightarrow$
Differences in arrival time of wave at different scan points $\Rightarrow$
Wave velocities from known separations of scan elements $\Rightarrow$
Elastic moduli ($\sim$ stiffness)

Estimating stiffness: inversion method

Governing equation of motion

$$\rho \frac{\partial^2 u}{\partial t^2} = \frac{E}{3} \nabla^2 u$$

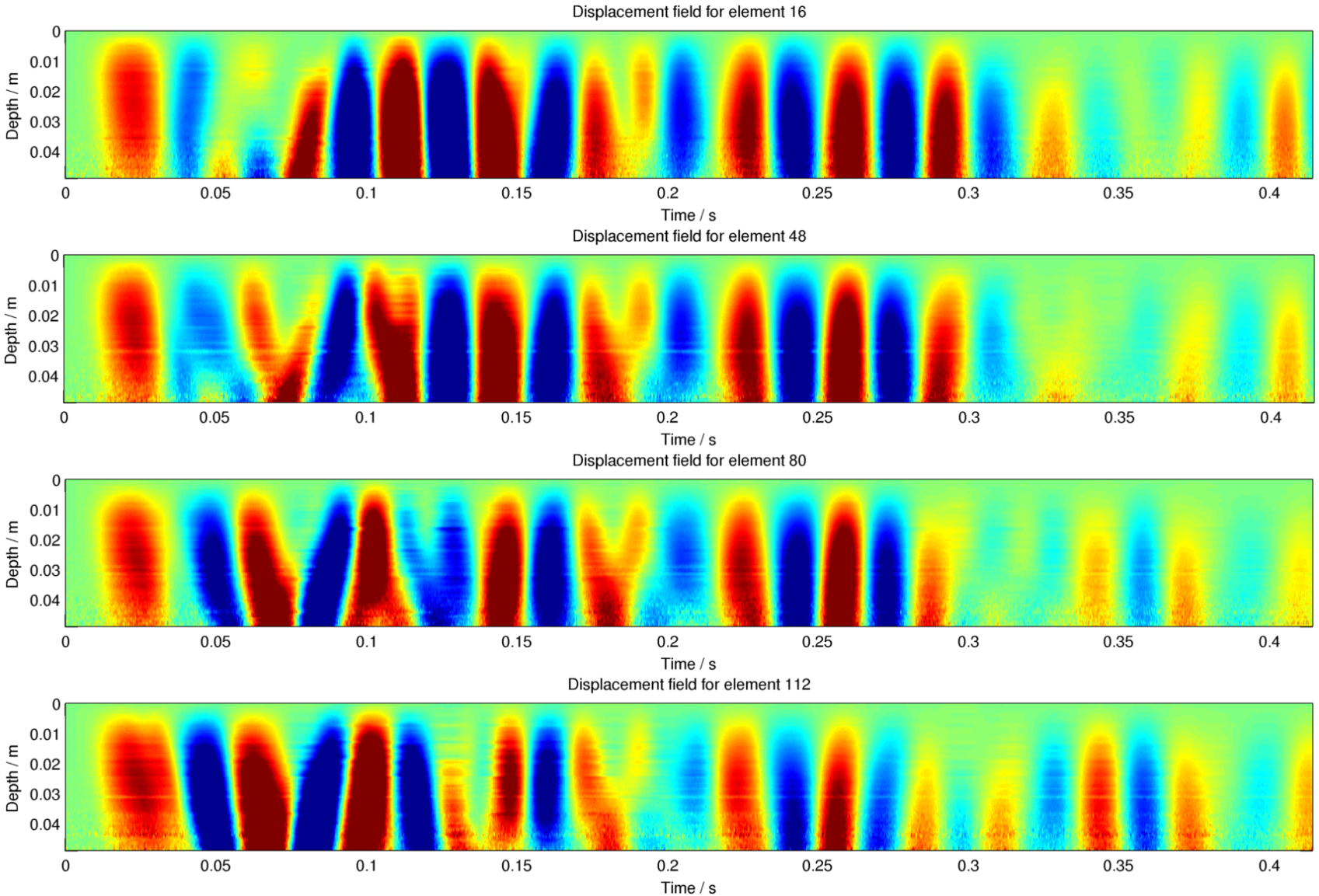
(u - displacements, t - time, ρ - density, E - elastic modulus)

Algebraic inversion under model assumptions

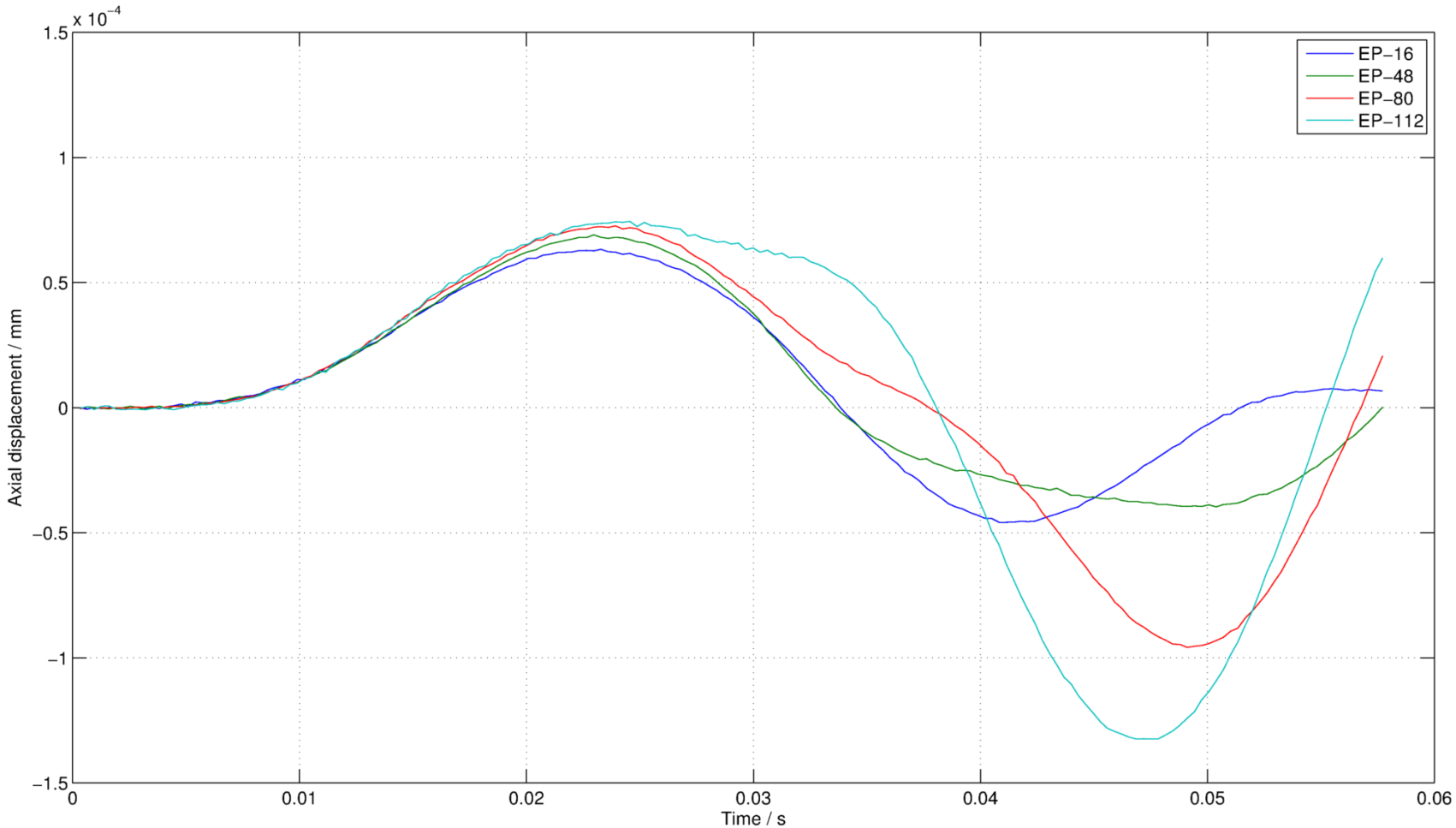
$$E \approx \frac{3}{n} \sum_{i=0}^{n} \rho \frac{\frac{\partial^2 u_i}{dt^2}}{\frac{\partial^2 u_i}{\partial x^2} + \frac{\partial^2 u_i}{\partial z^2}}$$

Tests with tissue mimicking phantom

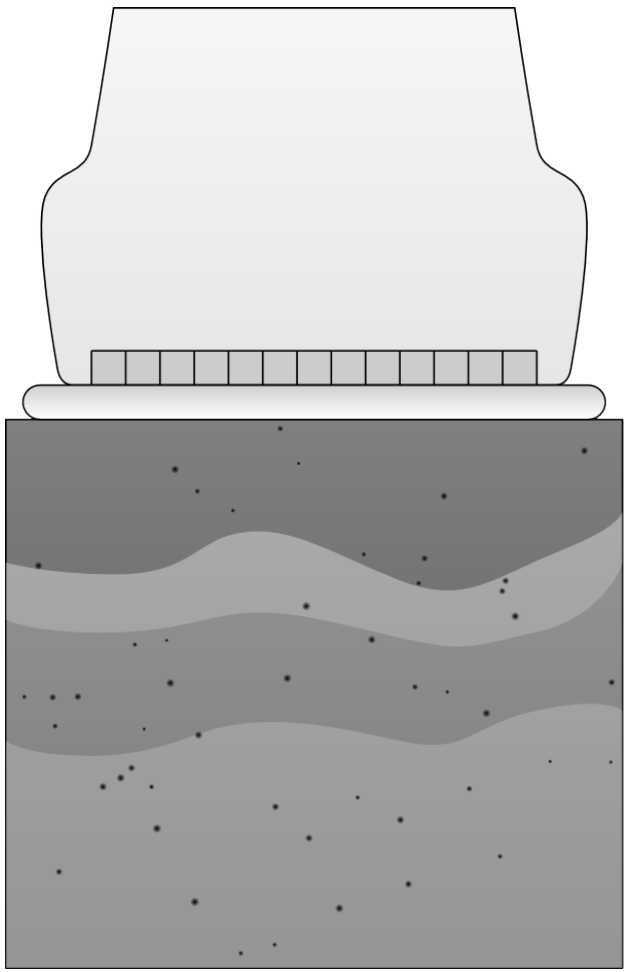
Tests with tissue mimicking phantom



Tests with tissue mimicking phantom



Probe motion



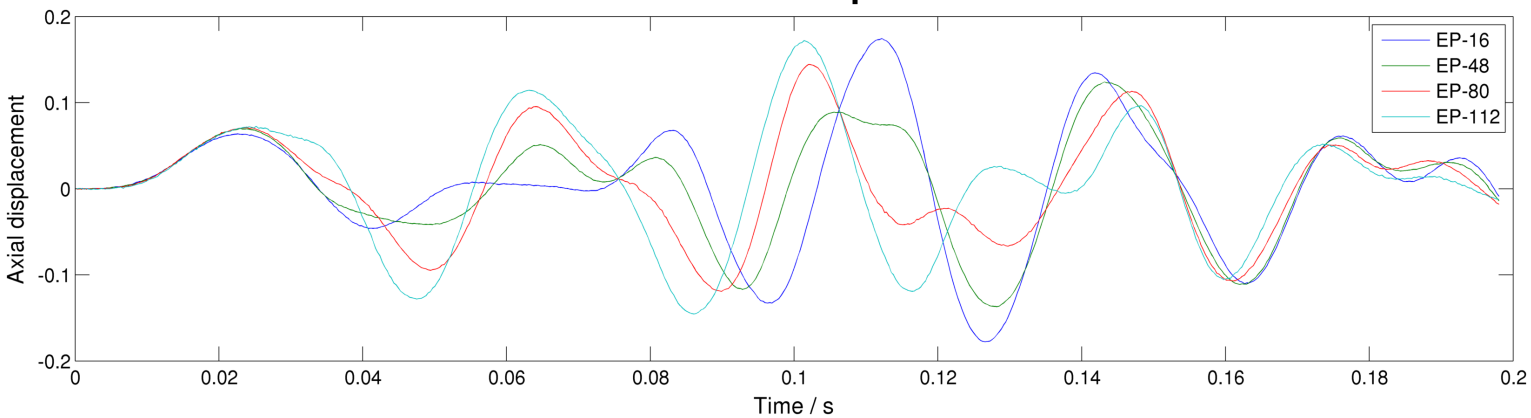
Probe

Acoustic gel layer

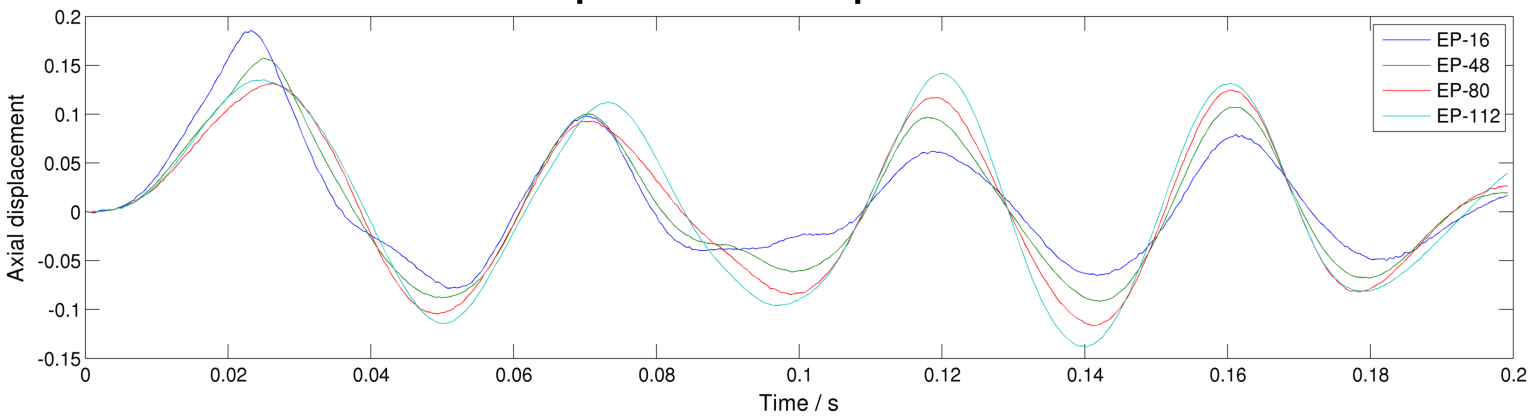
Tissue / phantom

Probe motion

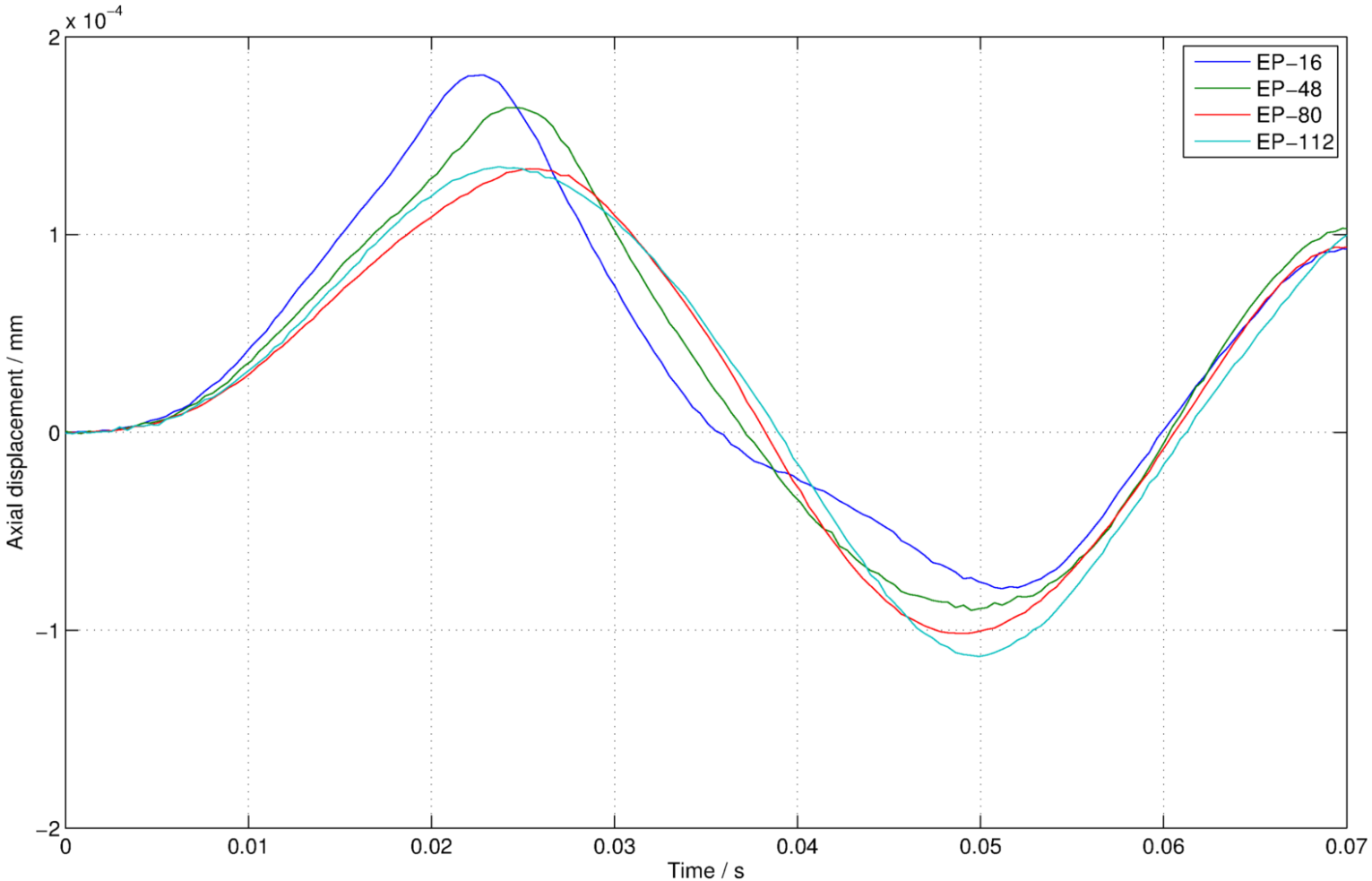
Probe in contact with phantom surface



Probe decoupled from phantom surface



Probe motion



Displacement responses with probe decoupled from phantom surface

Wave propagation theory

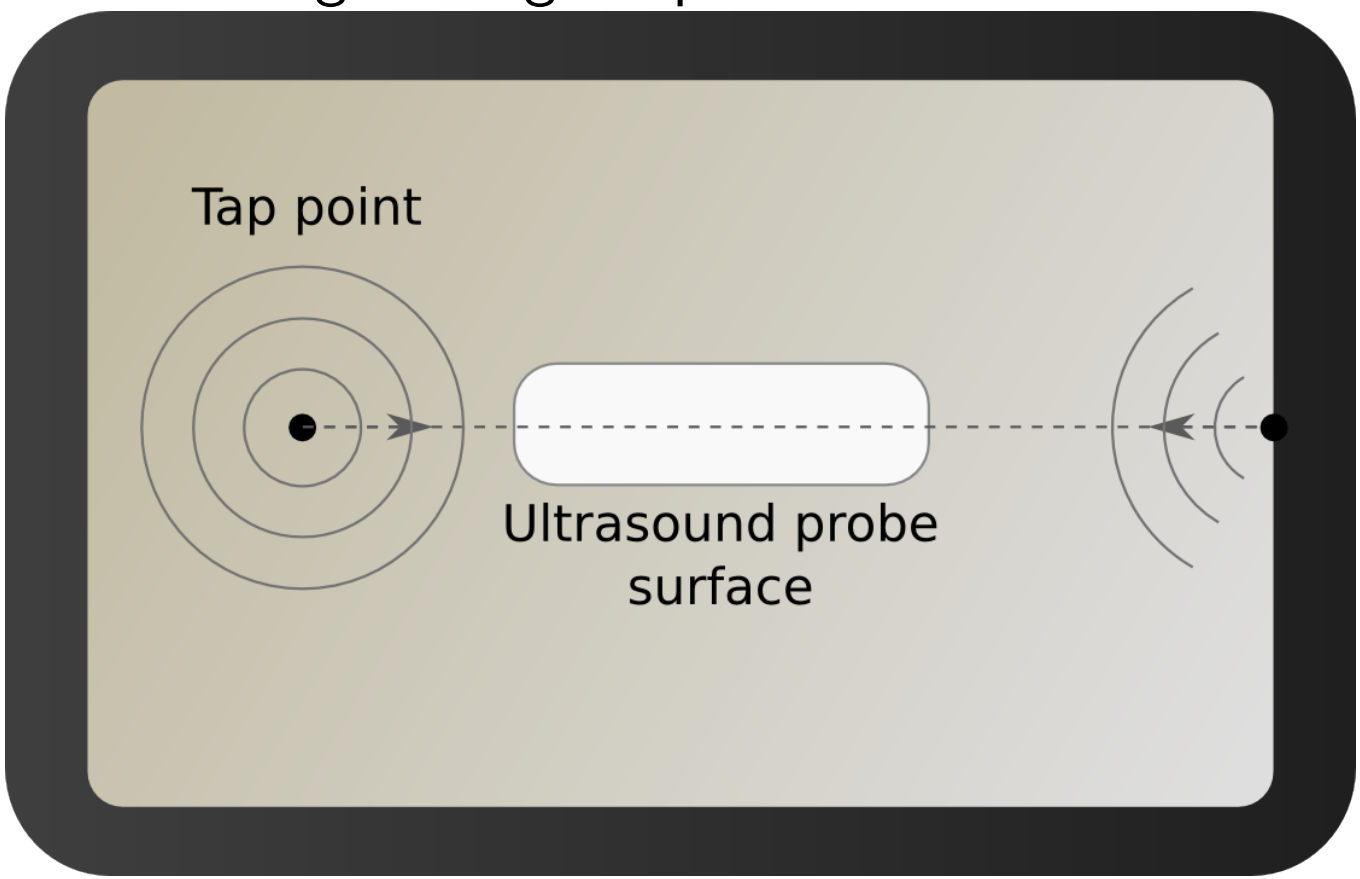
- Vector displacement field $\mathbf{u}$ combination of irrotational component $\nabla\phi$ and equivoluminal component $\nabla \times \mathbf{p}$

$$\mathbf{u} = \nabla\phi + \nabla \times \mathbf{p}$$

- Typical distinction between shear and compressional waves misleading
- Wave velocity dependent on wavefront and medium geometry, $\sqrt{\frac{E}{3\rho}}$ only a lower bound
- Minimising reflections and resulting interference reduces discrepancy

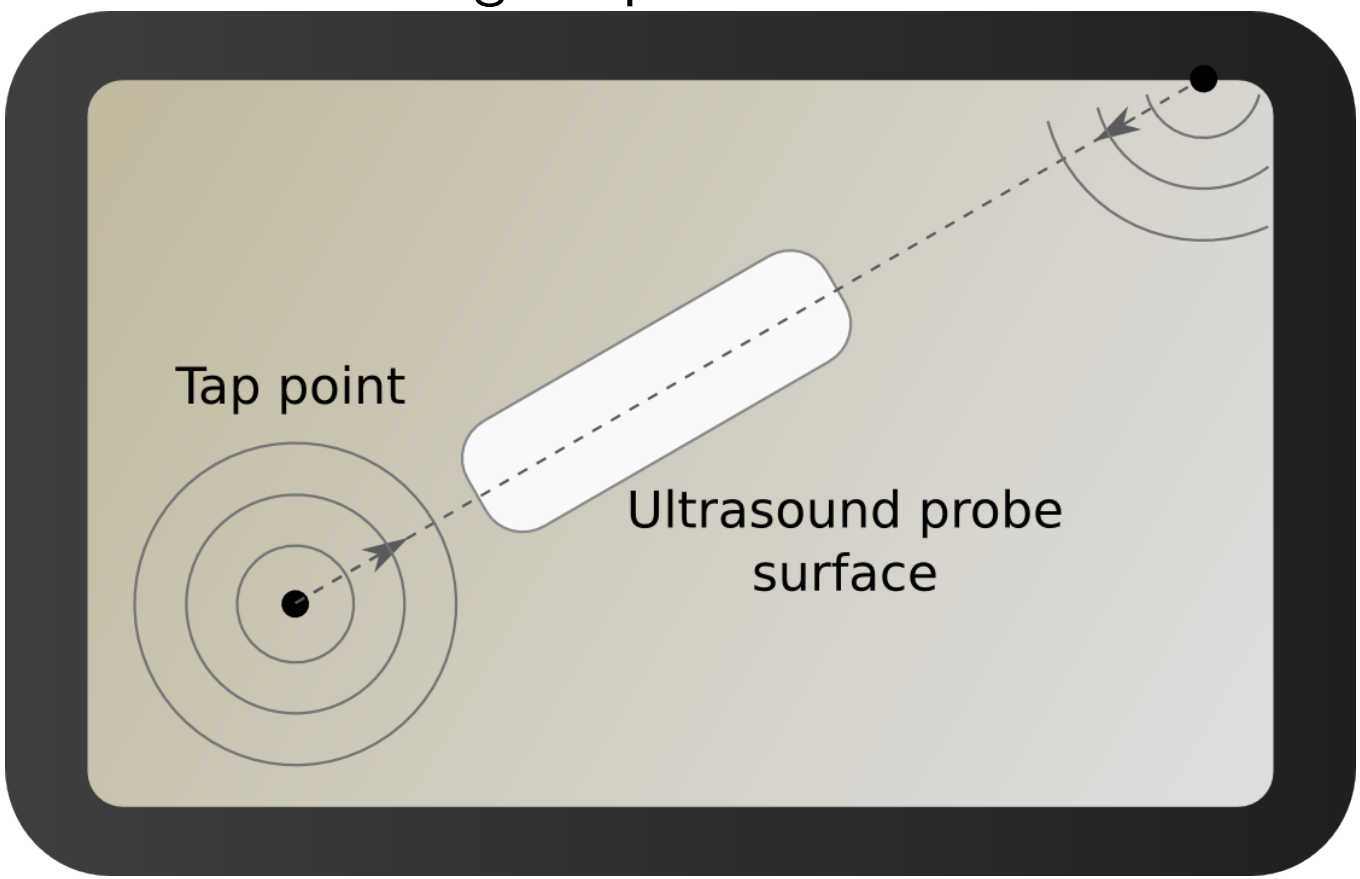
Wave reflections

Original aligned probe orientation

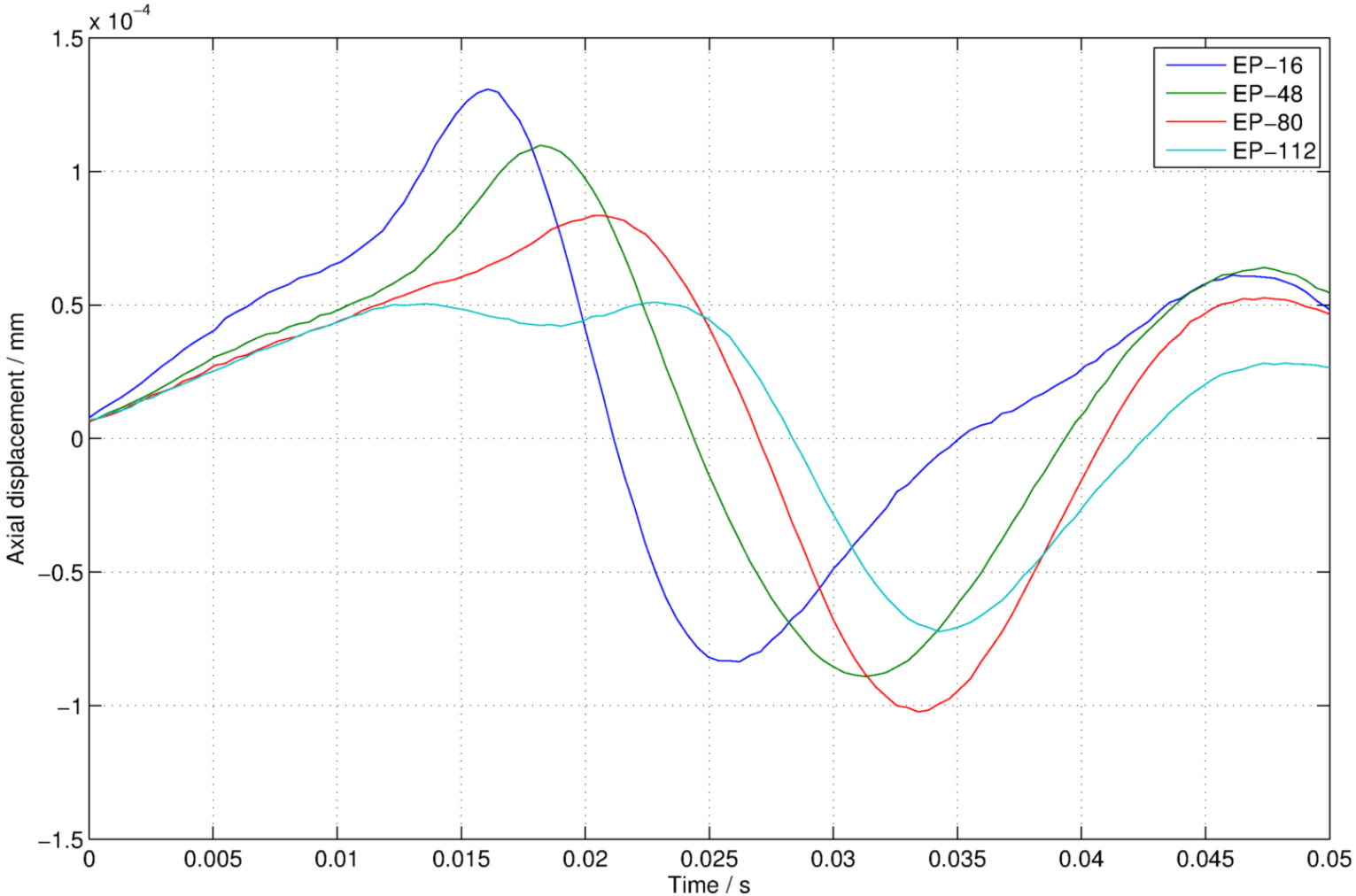


Wave reflections

Non-aligned probe orientation



Wave reflections



Displacement responses with probe angled to phantom walls

Results and conclusions

	Phantom		**Calf muscle**	
	c_s / ms^{-1}	E / kPa	c_s / ms^{-1}	E / kPa
Actual	2.9	25	2.3*	15*
Estimated	3.9	45	3.6	38

(* *typical figure*)

- Plausible shear modulus values measured in phantom and in-vivo
- Attempts at localisation not successful
- Unclear whether direct inversion viable

Thank-you

Any questions?