Élastographie et retournement temporel : une tomographie acoustique passive d'ondes de cisaillement dans le corps humain

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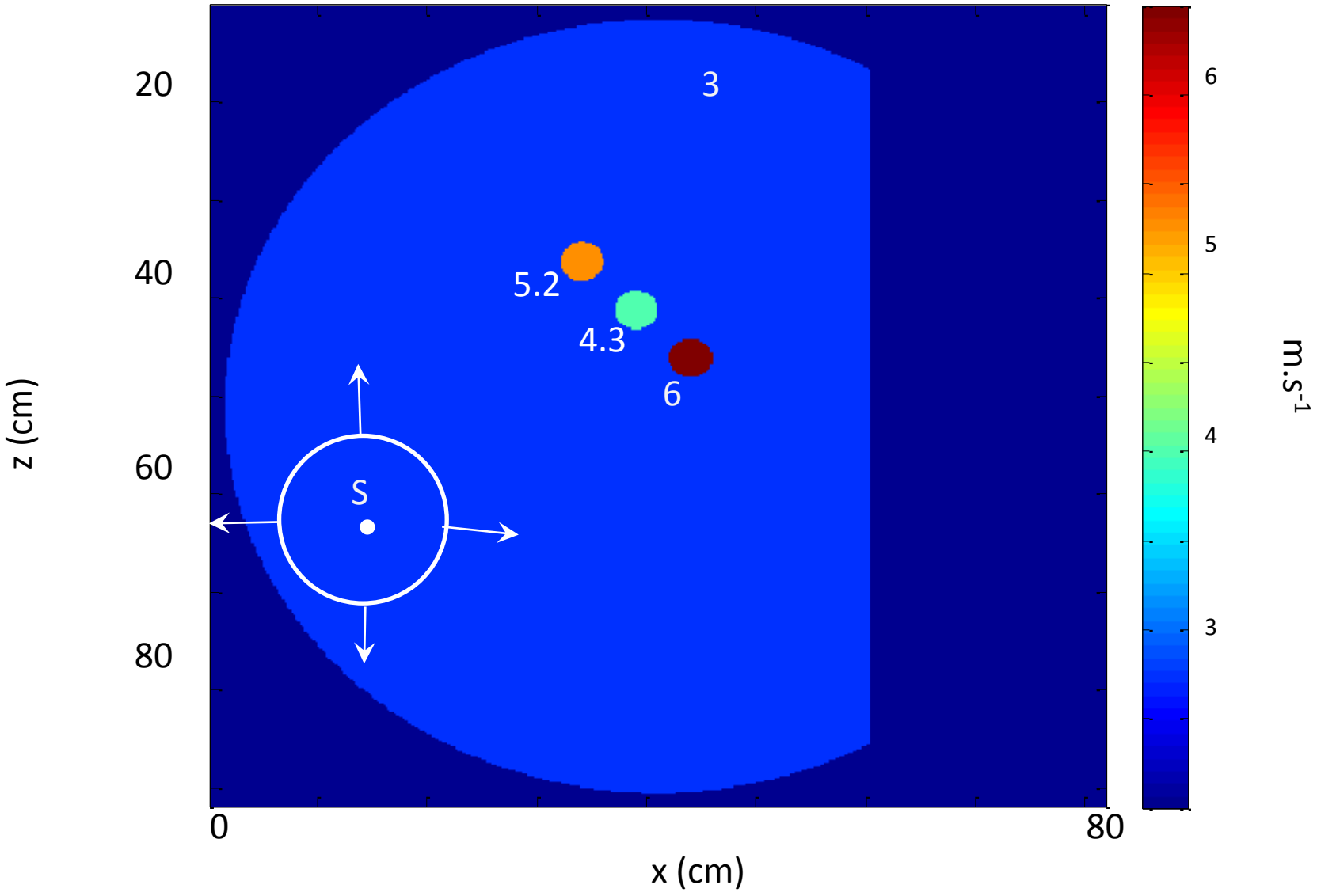
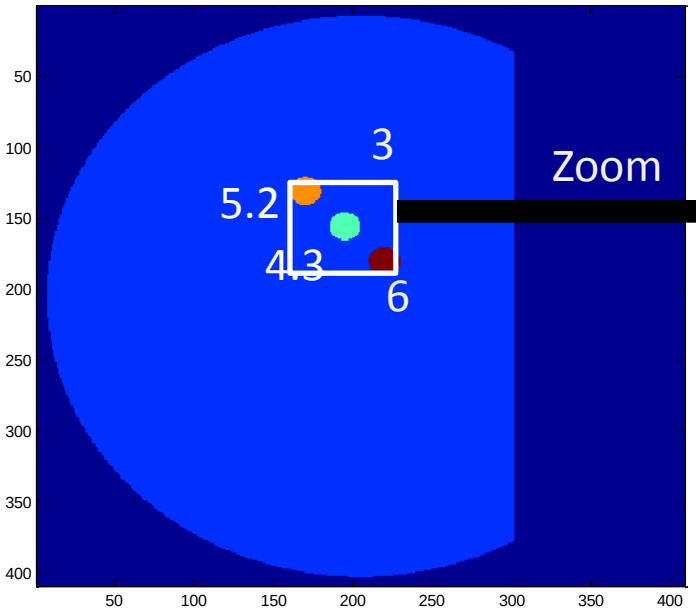
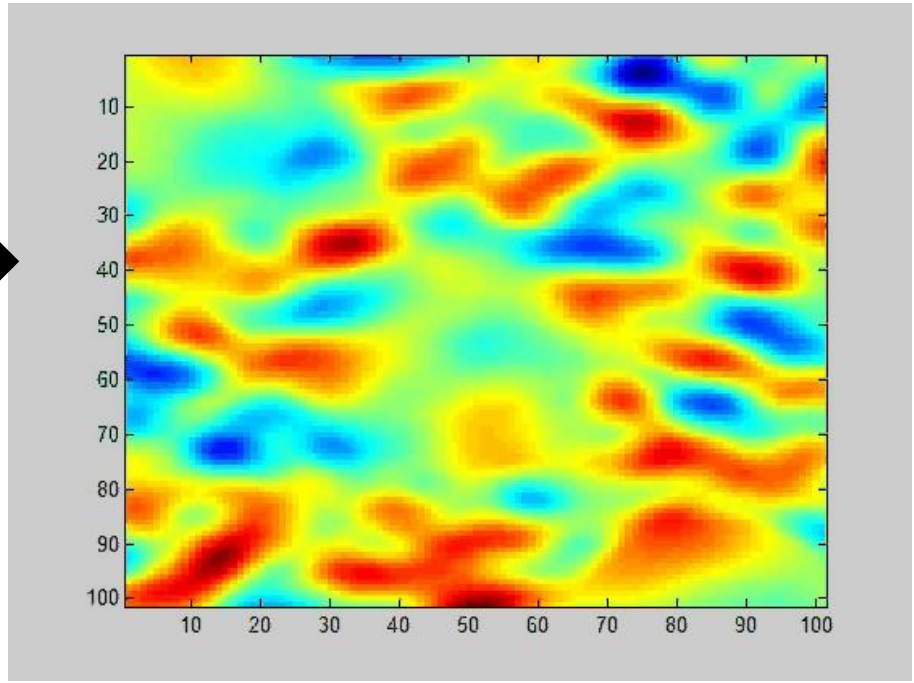
The diffuse field approach: finite difference simulation



The diffuse field approach





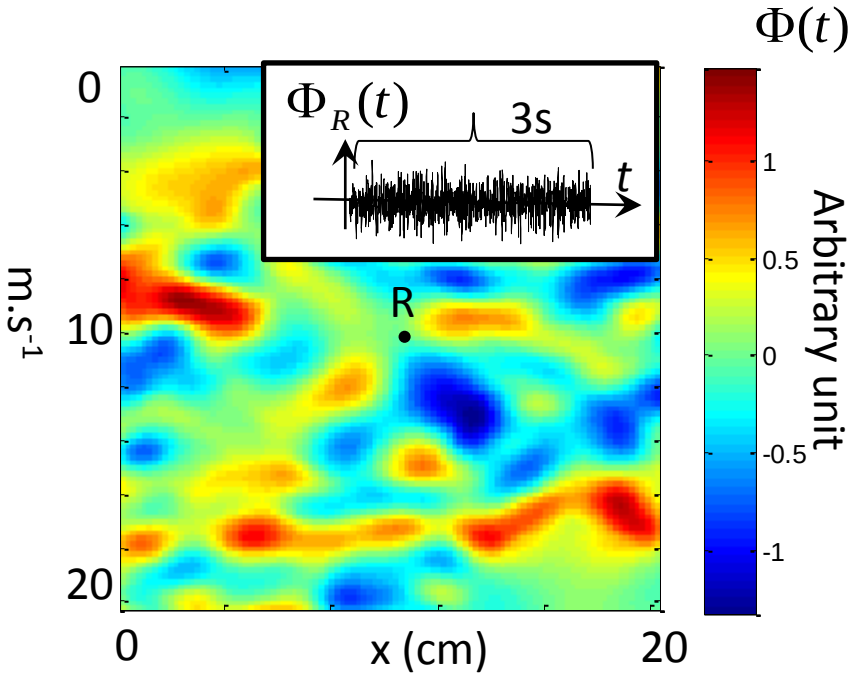
Time reversal

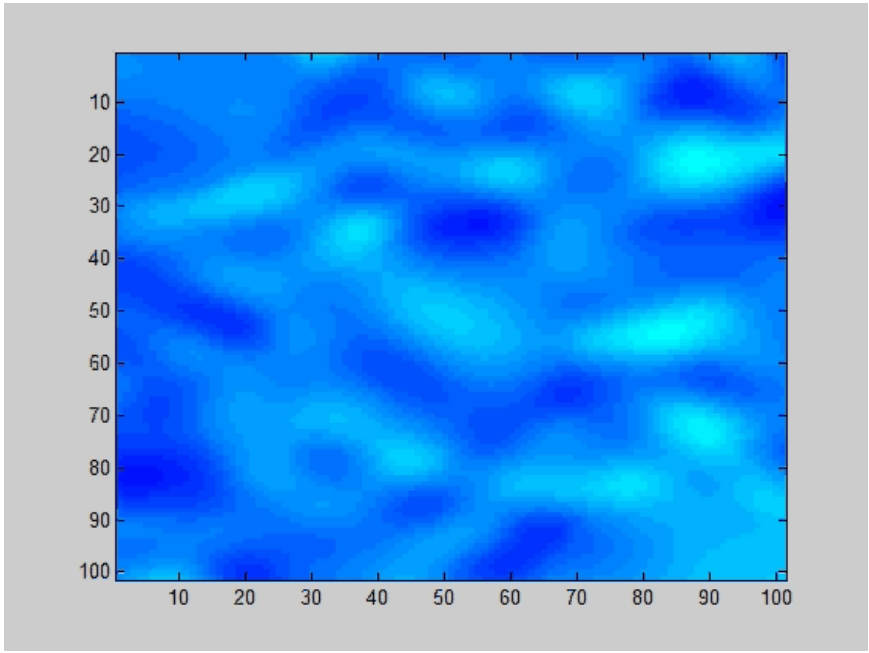
Key for speed extraction=TR

TR=spatio-temporal correlation

$$\Delta\Phi - \frac{1}{c^2}\frac{\partial^2\Phi}{\partial t^2} = 0$$

$$\rightarrow \quad \psi^{RT} = \Phi(\vec{r},t) \otimes \Phi(\vec{r}_0 - t) = \Phi\,\Phi^*$$





S.Catheline, N. Benech, X. Brum, and C. Negreira, *Phys.Rev.Letter.* **100**, 064301 (2008).

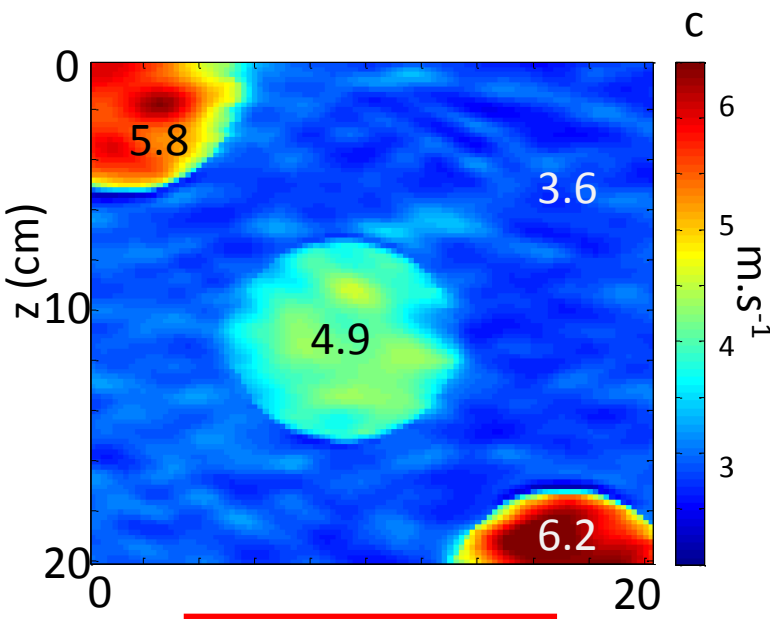
T.Gallot, S. Catheline, P. Roux, J. Brum, N. Benech, C. Negreira, *IEEE UFFC*, vol.58,6,p.1122 (2011)

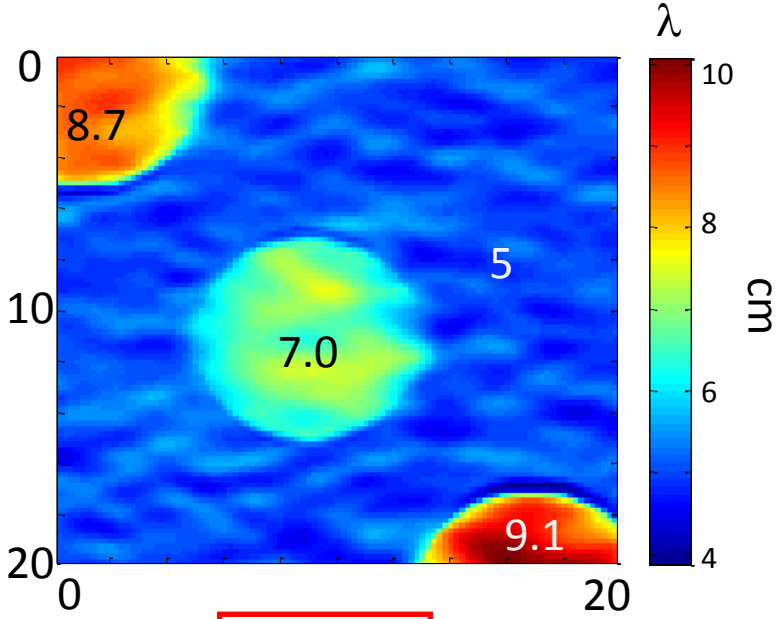
Generalised time reversal fields

$$\Delta\Phi - \frac{1}{c^2}\frac{\partial^2\Phi}{\partial t^2} = 0 \rightarrow \psi^{RT} = \Phi(\vec{r},t) \otimes \Phi(\vec{r}_0 - t) = \Phi\,\Phi^*$$

$$\varepsilon_z = \frac{\partial\Phi}{\partial z} \rightarrow \Delta\varepsilon_z - \frac{1}{c^2}\frac{\partial^2\varepsilon_z}{\partial t^2} = 0 \rightarrow \xi^{RT} = \varepsilon_z\varepsilon_z^* \quad \text{Plane wave} \rightarrow \xi^{RT} \approx -k^2\psi^{RT}$$

$$v = \frac{\partial\Phi}{\partial t} \rightarrow \Delta v - \frac{1}{c^2}\frac{\partial^2 v}{\partial t^2} = 0 \rightarrow V^{RT} = vv^* \rightarrow V^{RT} \approx -\omega^2\psi^{RT}$$

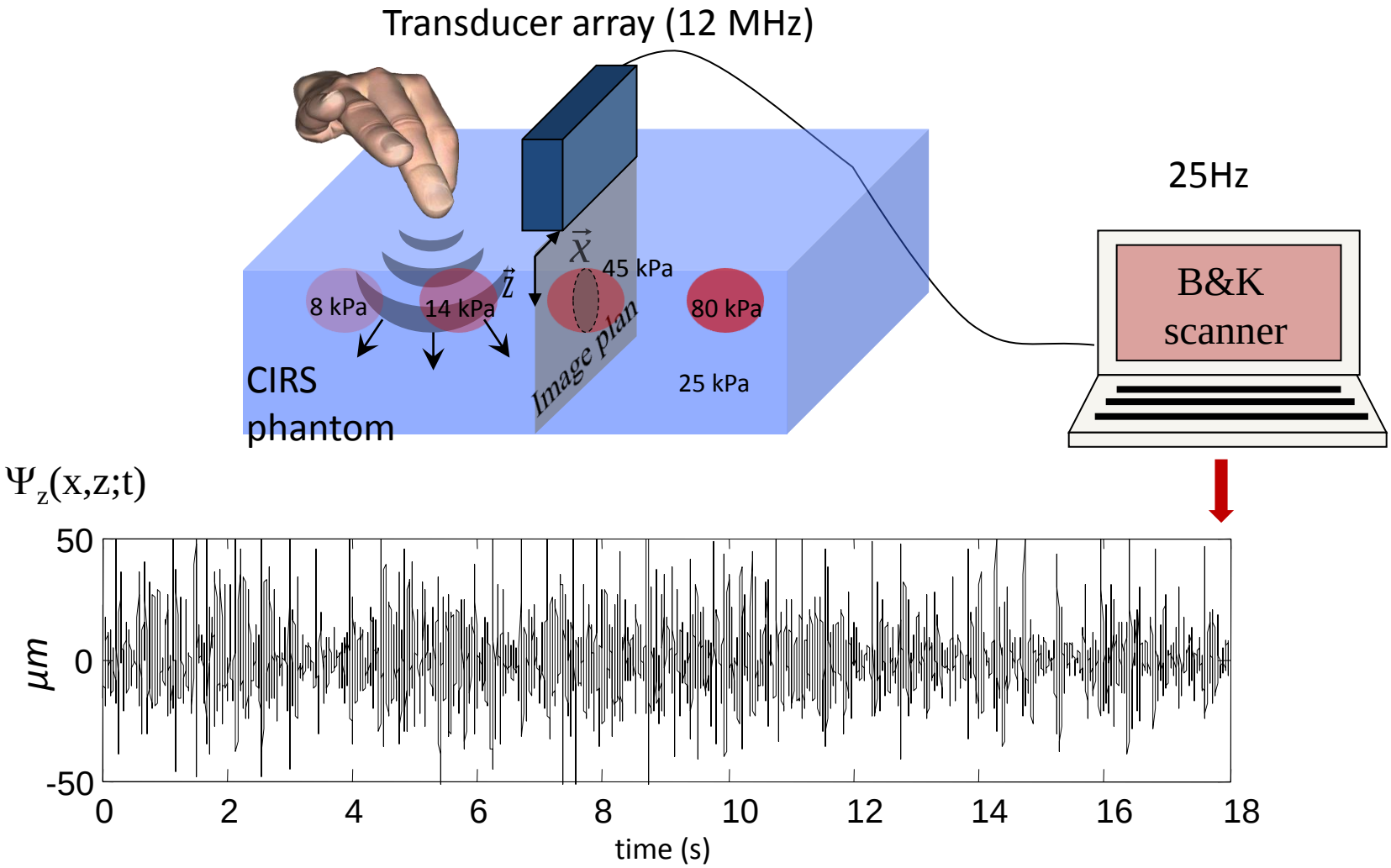




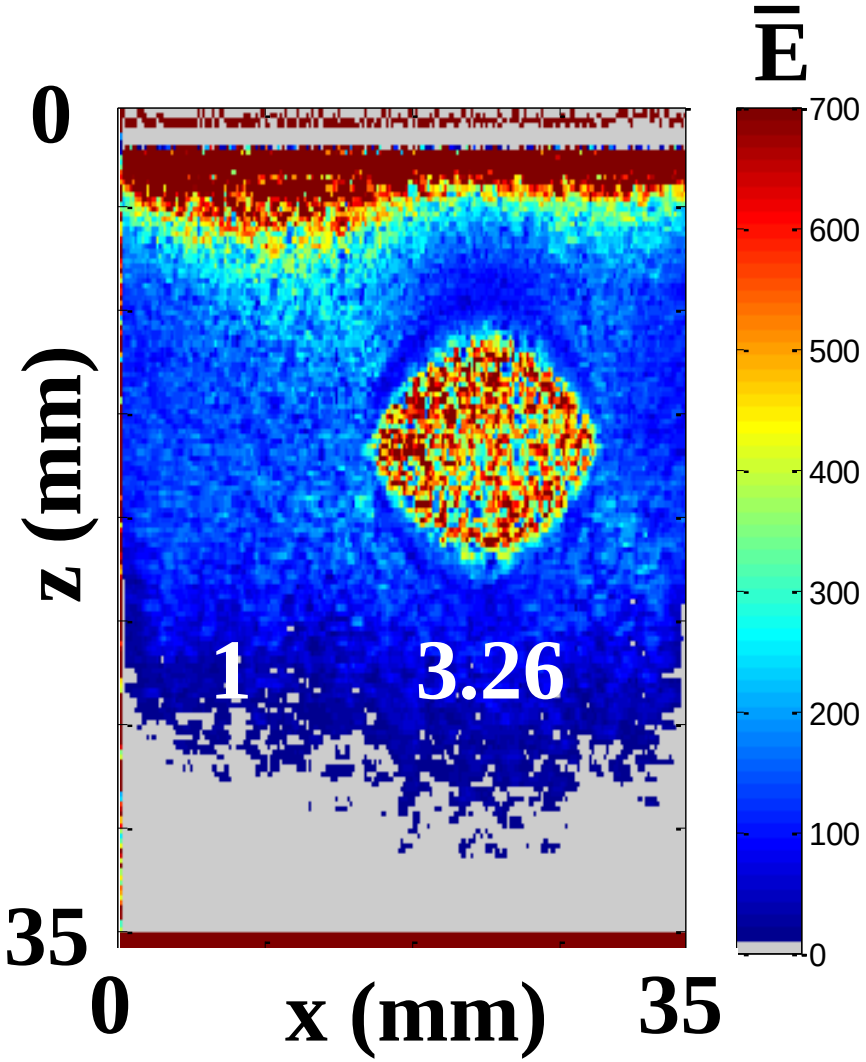
$$c = \frac{\omega}{\mathrm{Re}(k)} = \sqrt{\frac{V^{RT}}{\xi^{RT}}}$$

$$k = \sqrt{\frac{\xi^{RT}}{\psi^{RT}}}$$

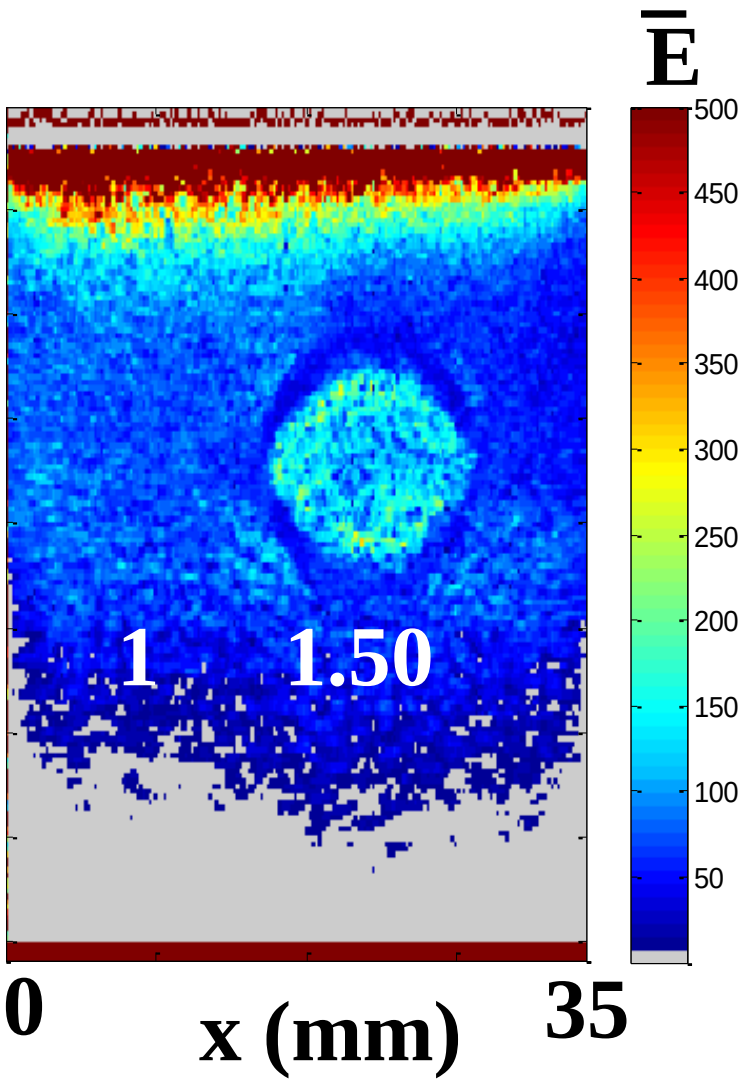
Phantom experiment



Phantom experiment

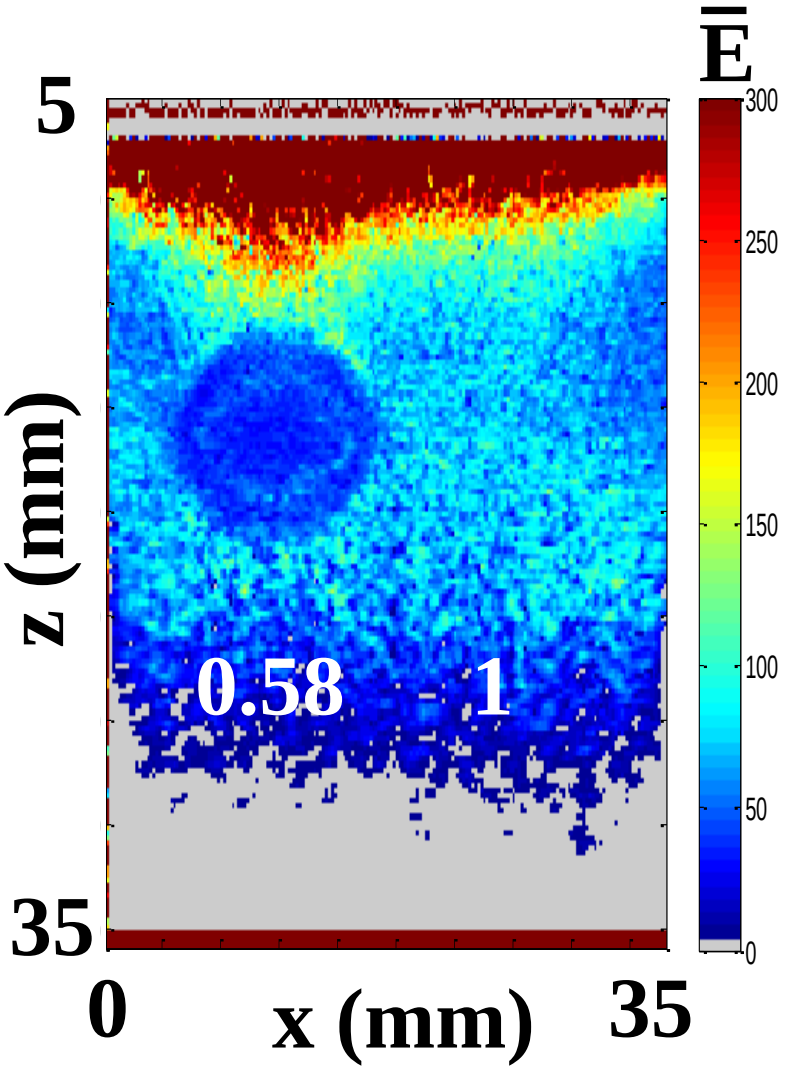


$$\frac{80kPa}{25kPa} = 3.20$$

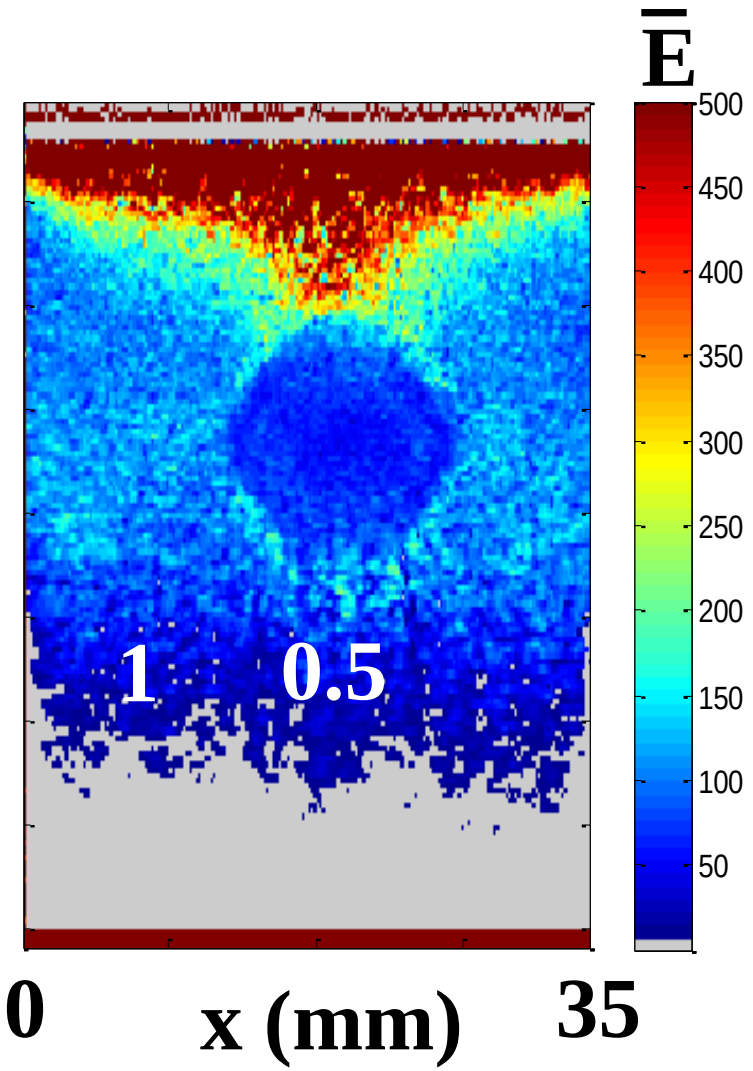


$$\frac{45kPa}{25kPa} = 1.80$$

Phantom experiment



$$\frac{14kPa}{25kPa} = 0.56$$



$$\frac{8kPa}{25kPa} = 0.32$$

Preliminary *in-vivo* experiment

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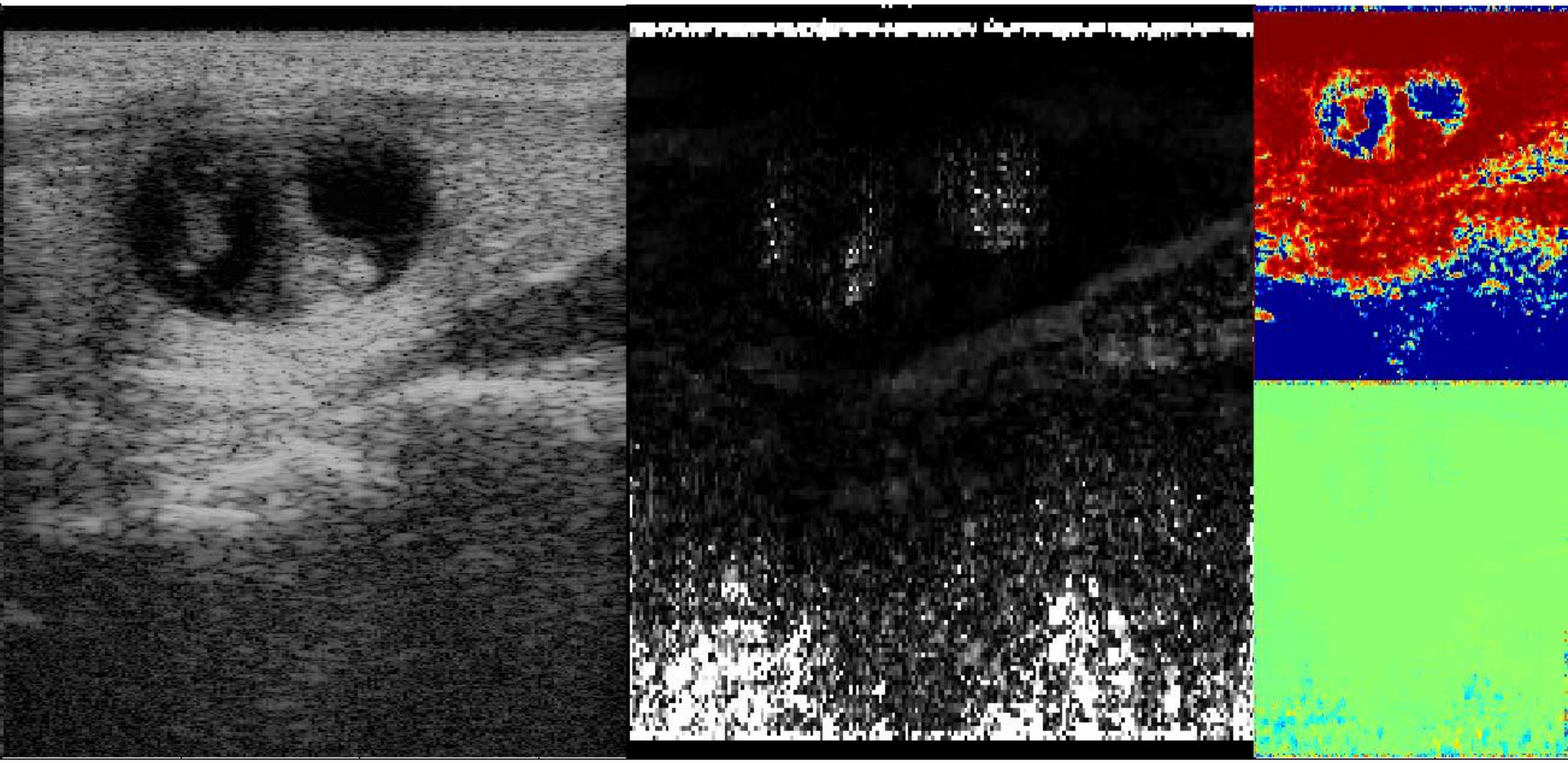
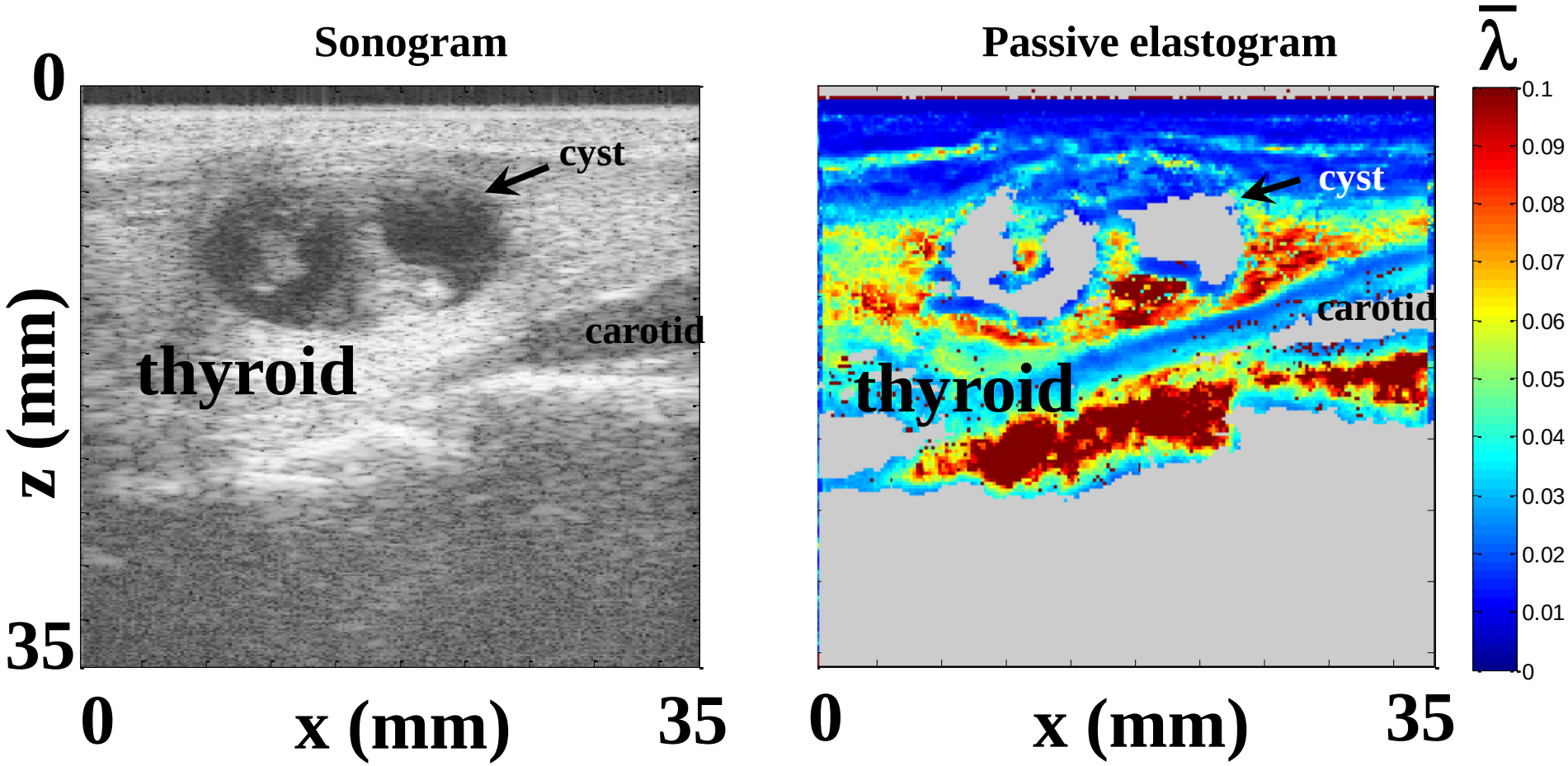
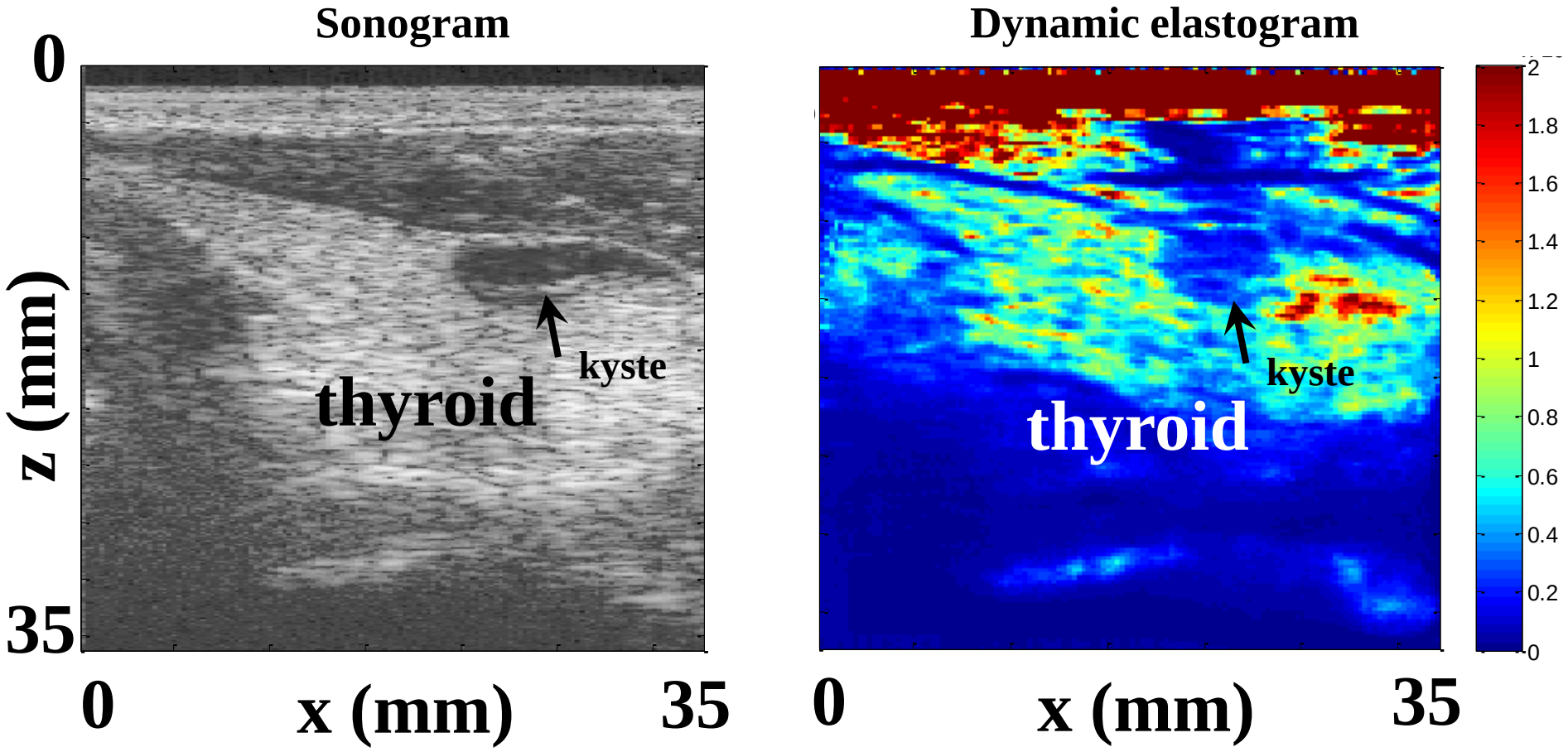


800 images @ 25Hz



$$k = \sqrt{\frac{\xi^{RT}}{\psi^{RT}}}$$

In vivo experiment

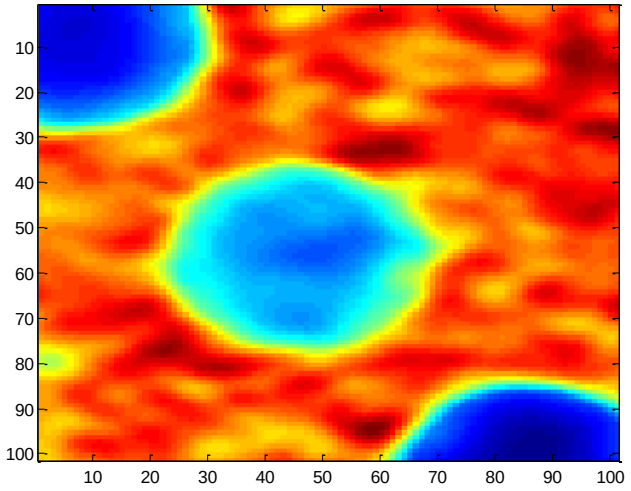


Equipartition-Green's function

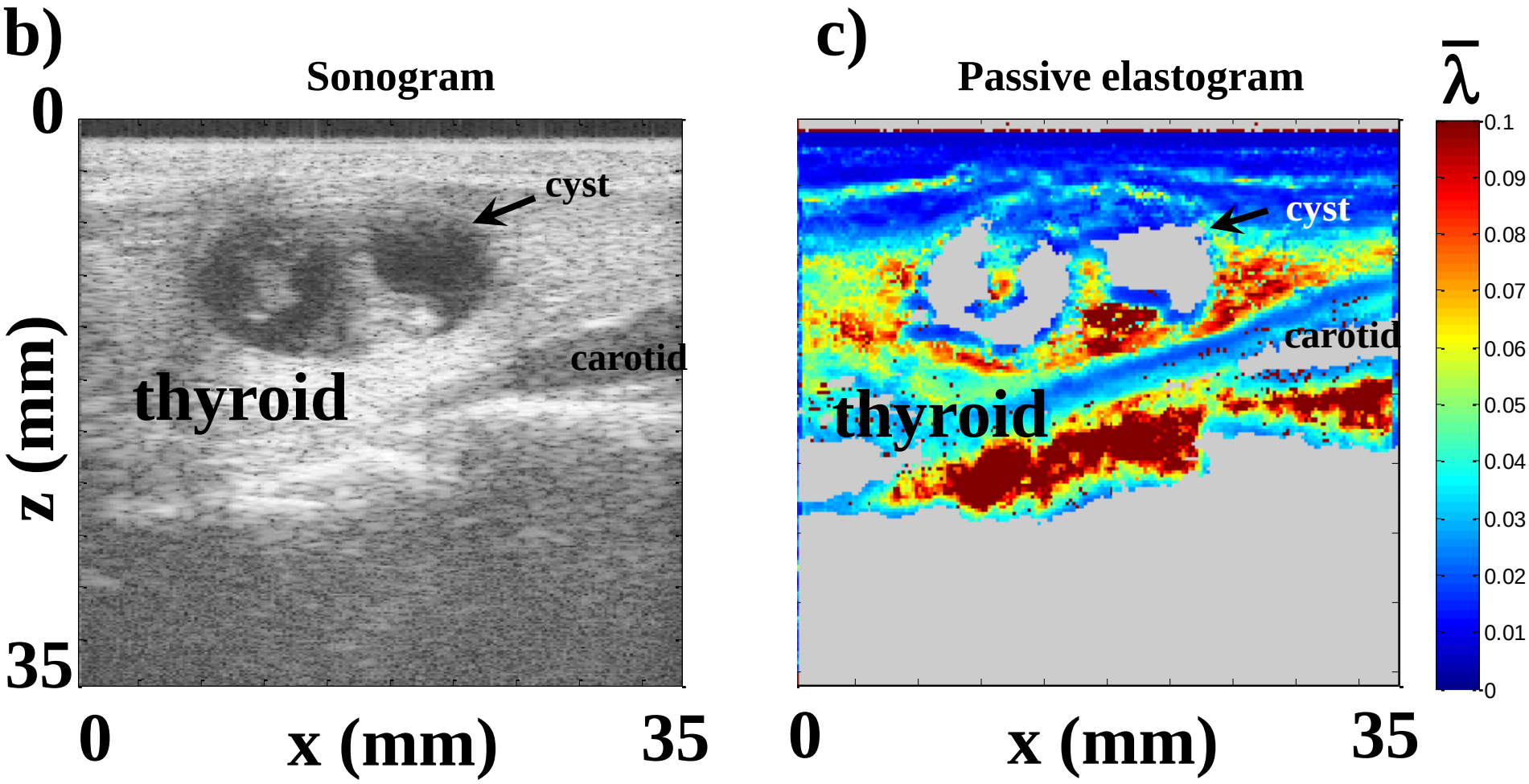
Equipartition of diffuse field: $\psi^{RT} \propto \frac{V}{\lambda^3}$

Green's function $\psi^{RT} = G^- - G^+$

with $G^- = \frac{1}{c^3}\frac{e^{-ikx}}{x}$



a)


b)
Sonogram
0
cyst
carotid
thyroid
z (mm)
35
0
x (mm)
35
c)
Passive elastogram
$\bar{\lambda}$
cyst
carotid
thyroid
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
x (mm)
35