Direct mapping of cardiac electrical activation in the isolated live rat heart using **Ultrafast Acoustoelectric Imaging**

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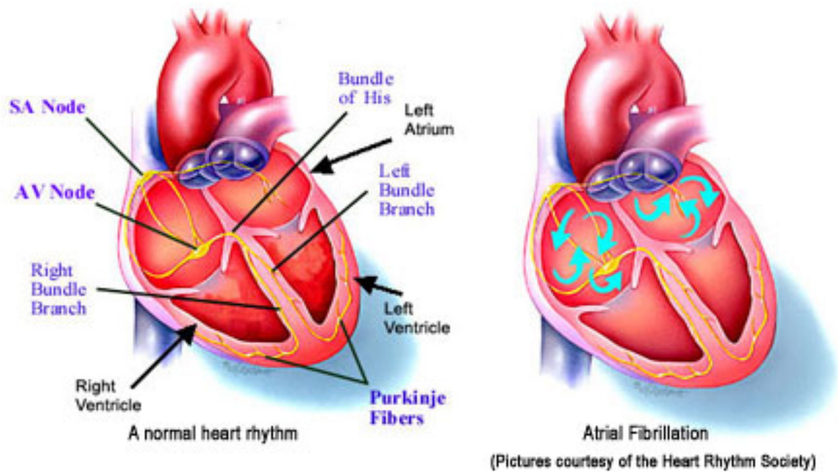
Non-invasive direct real-time imaging of the electrical activity in biological tissues is needed

For understanding and diagnosing cardiac arrythmias, and other electrical activation related diseases

Currently used techniques:

- ❖ Rely on physiological correlates[1-4] of the electrical activity
- ❖ Rely on complex modelling
- ❖ Require prior knowledge[5-6]

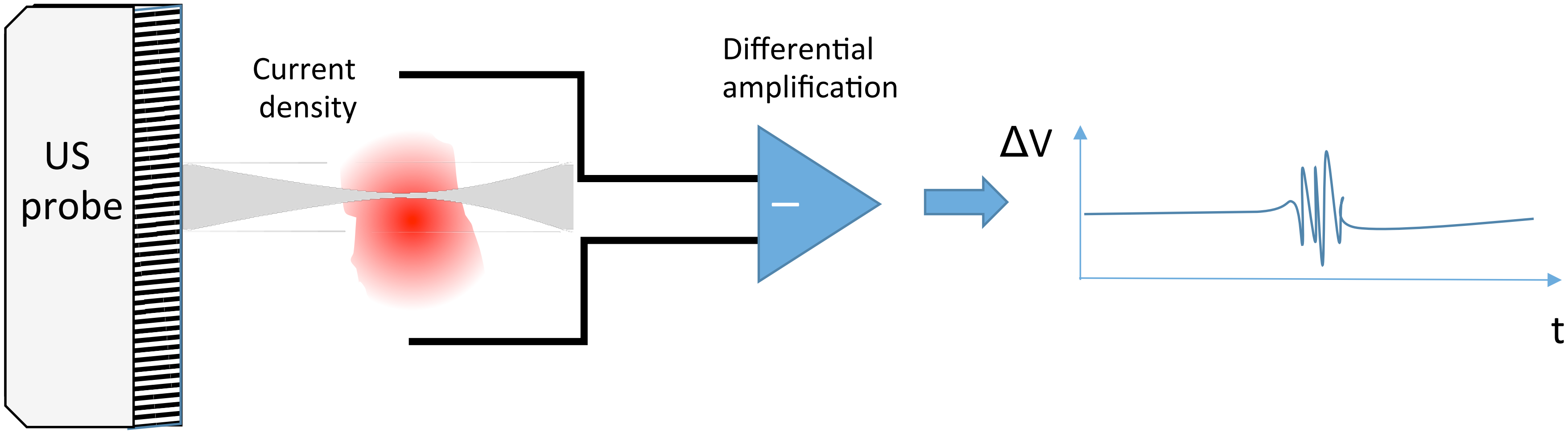


Acoustoelectric imaging allows for **direct** imaging of the electrical activation[7-9]

1. Kwong et al., PNAS, 1992
2. Mace et al., Nat. Meth., 2011
3. Villringer et al., Neuroscience Letters, 1993
4. Provost et al., PNAS, 2011
5. Ramanathan et al., Nat. Med., 2004
6. Zhang et al., Am. J. Physiol.-Heart C., 2005
7. Olafsson R et al., 2008 *IEEE Trans. Biomed. Eng.*
8. Olafsson R et al., 2007 *Ultrason. Symp. 2007. IEEE*
9. Witte R, et al., 2007 *Appl. Phys. Lett.*

The Acoustoelectric effect

Modulation of the medium's impedance caused by the US wave propagation[8-10]

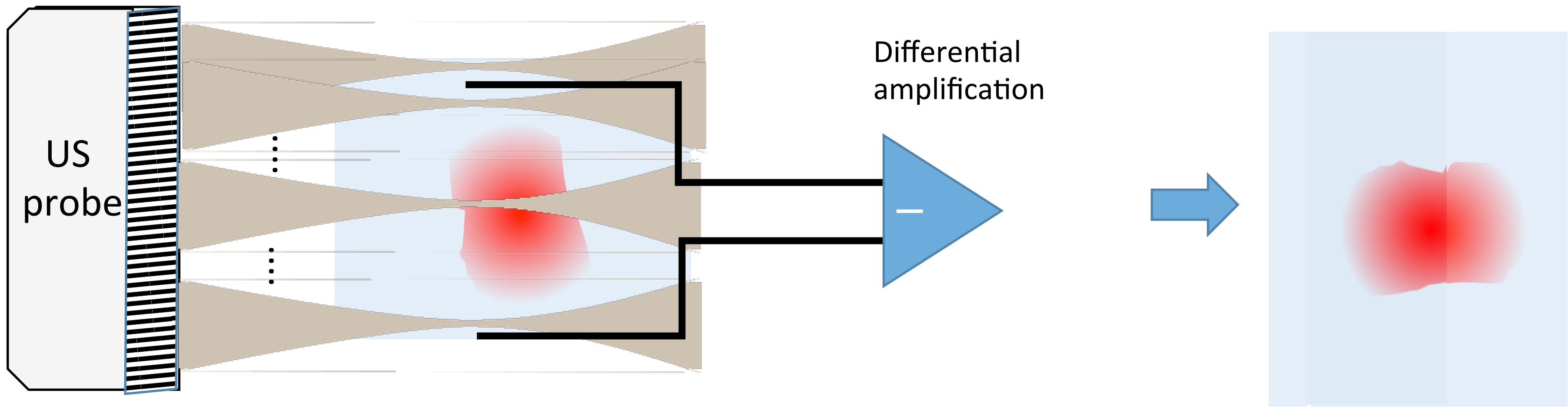


Proportional to current & pressure

$$\Delta V = \underbrace{\iiint \left(J_{E}^{l} \cdot J_{cur}\right) \rho_0 \, dxdydz}_{\text{Low frequency}} + \underbrace{\iiint -\left(J_{E}^{l} \cdot J_{cur}\right) K \rho_0 \, \Delta P \, dxdydz}_{\text{High frequency}}$$

8. Fox et al. 1946, Phys Rev
9. Jossinet J et al. 1999 Ann. N. Y. Acad. Sci.
10. Lavandier B et al., 2000 Ultrasonics

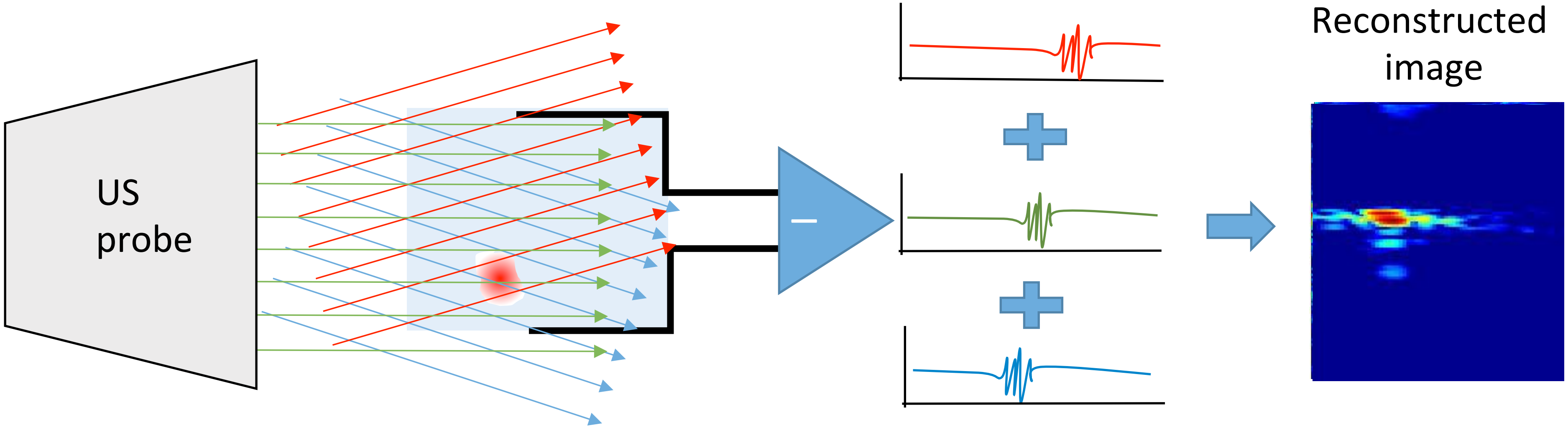
Focused Acoustoelectric Imaging



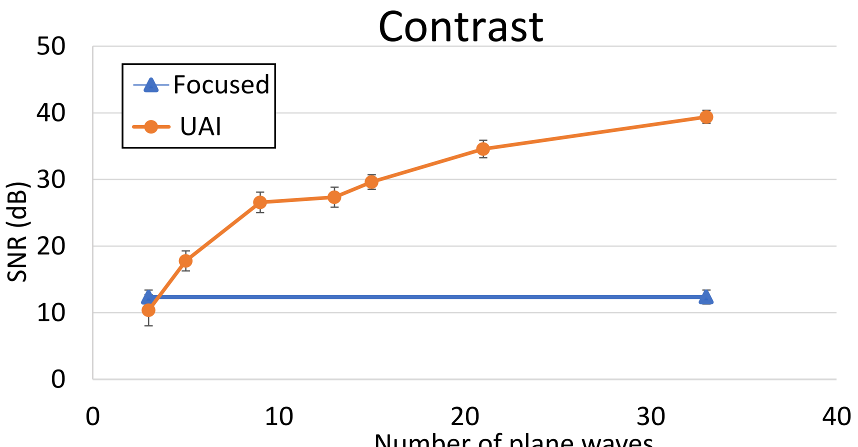
Focused Acoustoelectric Imaging has been applied ex-vivo to imaging of the live heart[11] and nerve[12] in animals

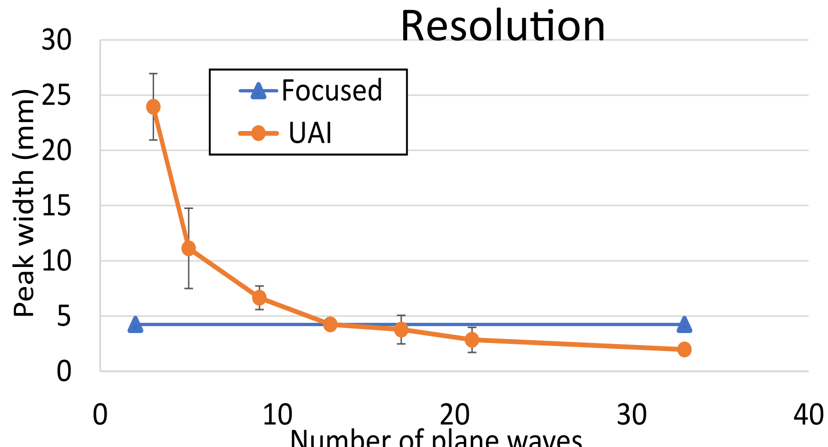
11. Olafsson R et al., 2007 *Ultrason. Symp. 2007. IEEE*
12. Witte R, et al., 2007 *Appl. Phys. Lett.*

Ultrafast Acoustoelectric Imaging (UAI)



UAI can yield higher image quality than focused acoustoelectric imaging[13]

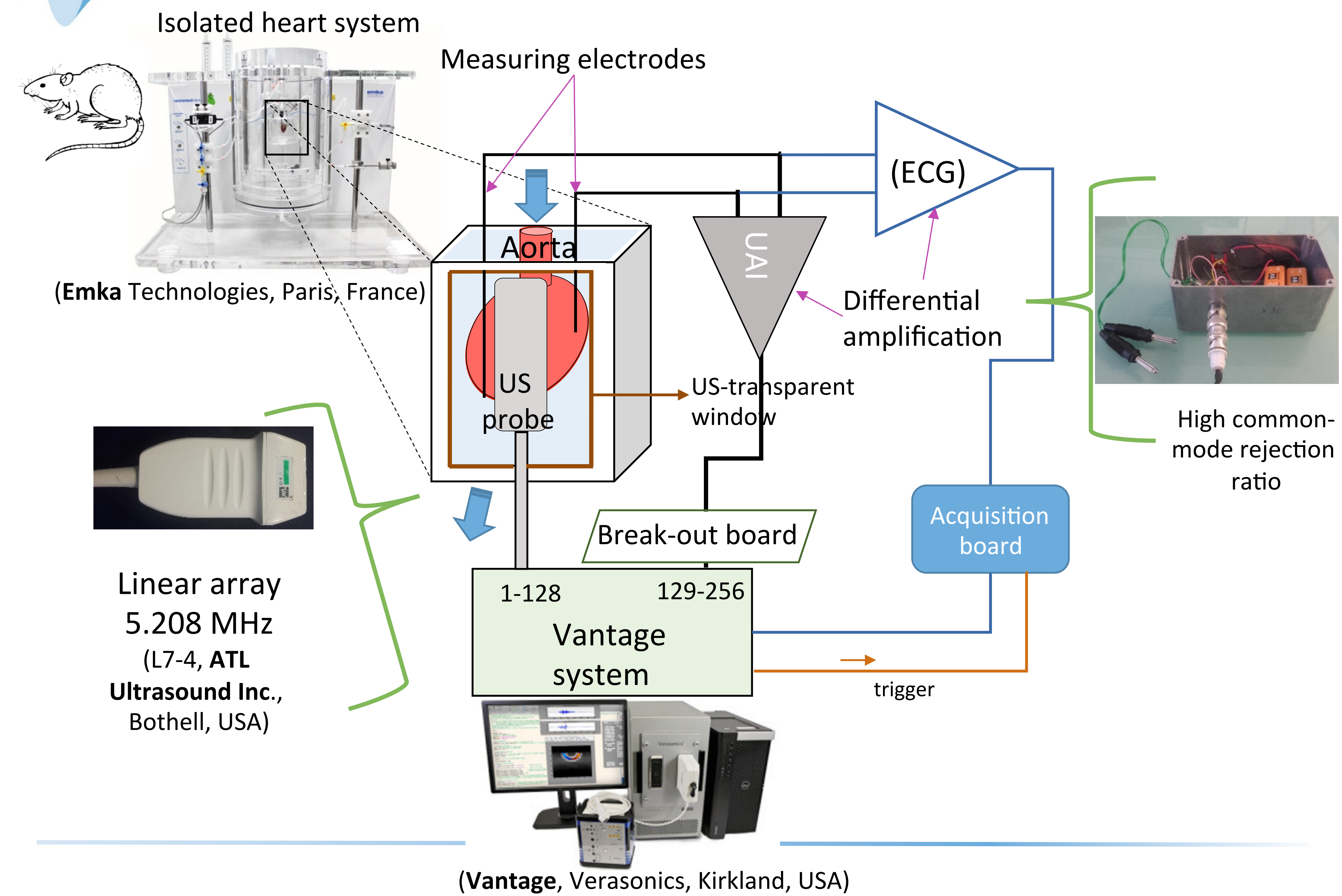




13. Ber

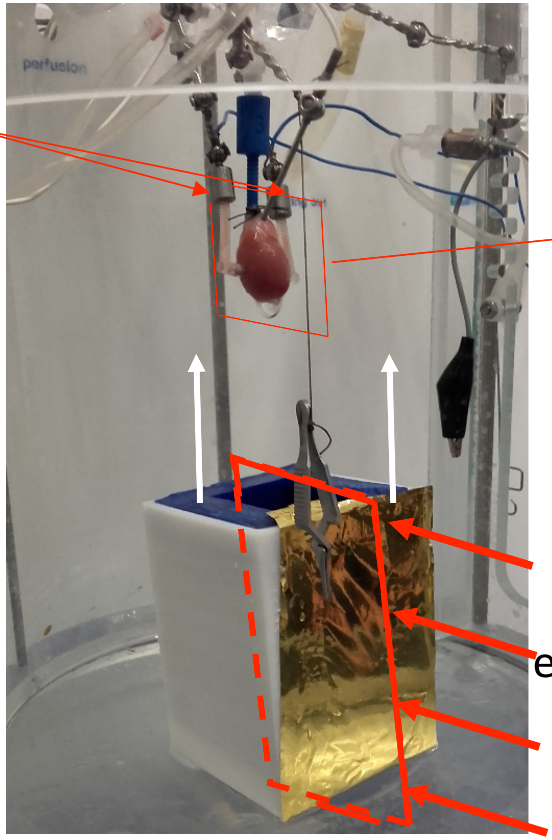
Can UAI also provide images of biological currents?

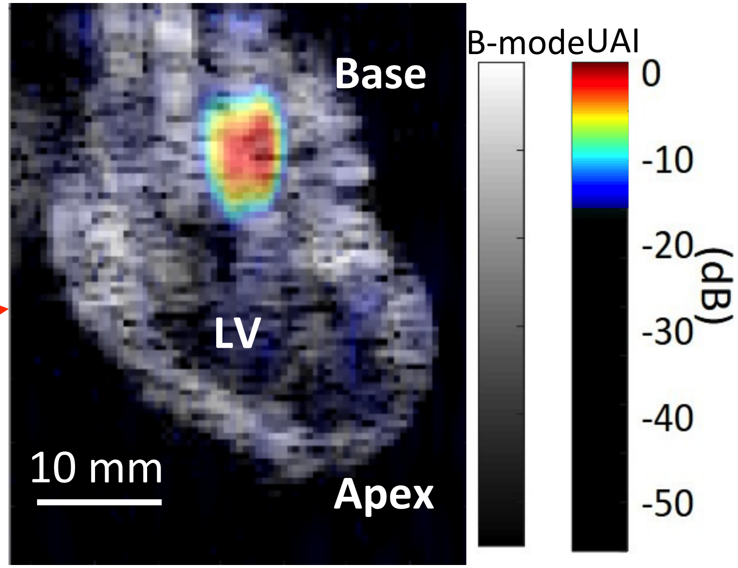
Experimental setup – *Ex vivo*



EX-vivo imaging with UAI

300-450g male rat hearts





3.5 MPa, 9 plane waves
(averaged)
MI = 1.5

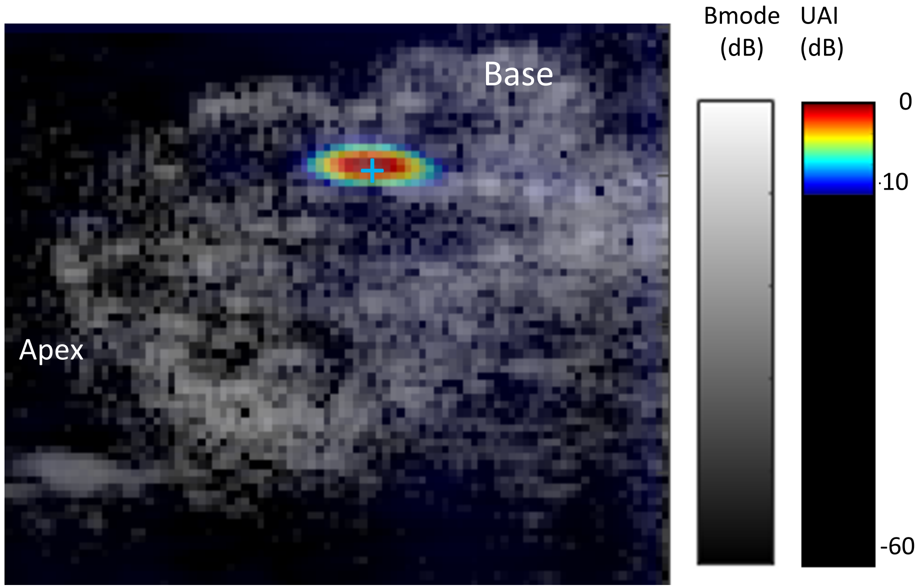
N=6
MI = 1.5
5-33 plane waves
60-1500 Hz

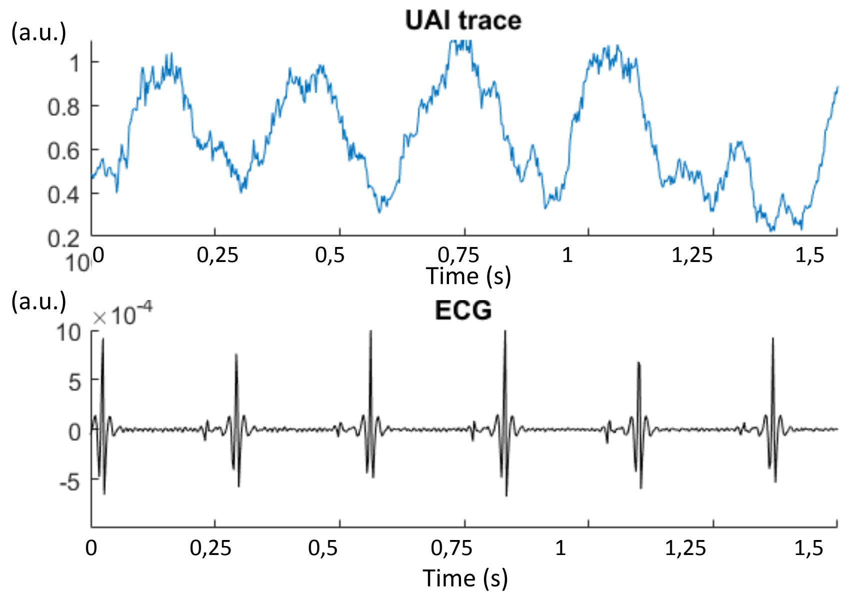
CNR 12.4 ± 1.9

UAI can detect and image electric currents in the isolated rat heart at biologically safe MI values

Measurement of cardiac frequency

With electro-mechanical decoupling (2,3-butane-dione monoxyme)

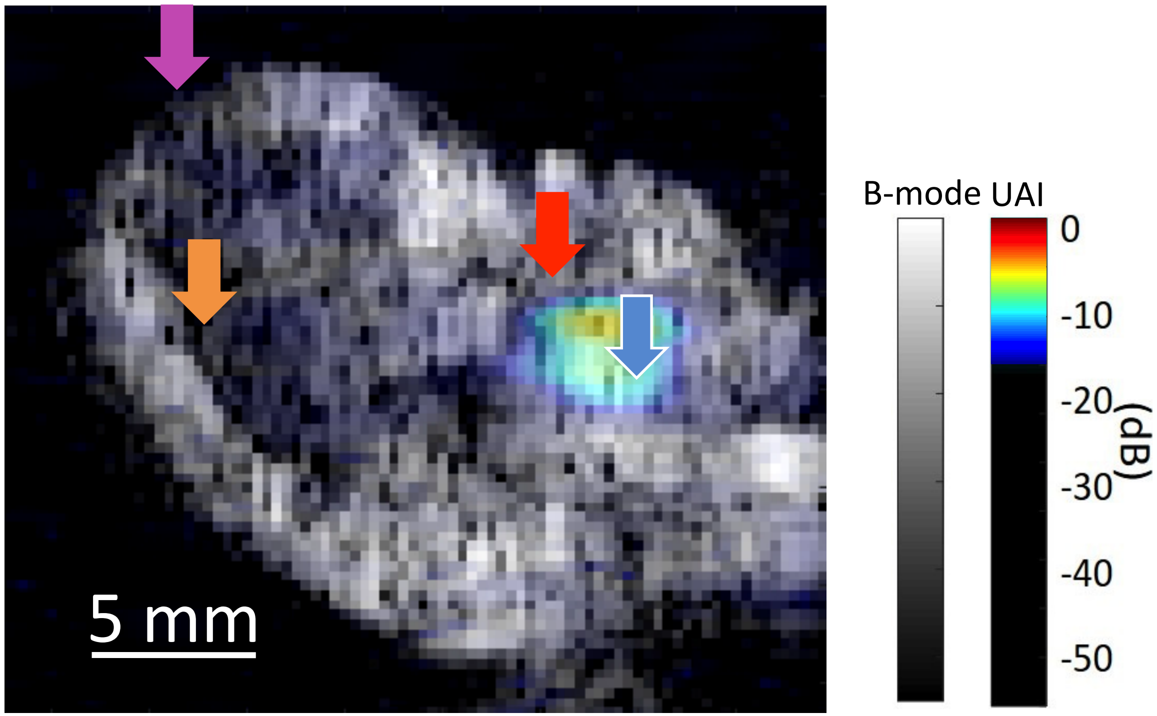




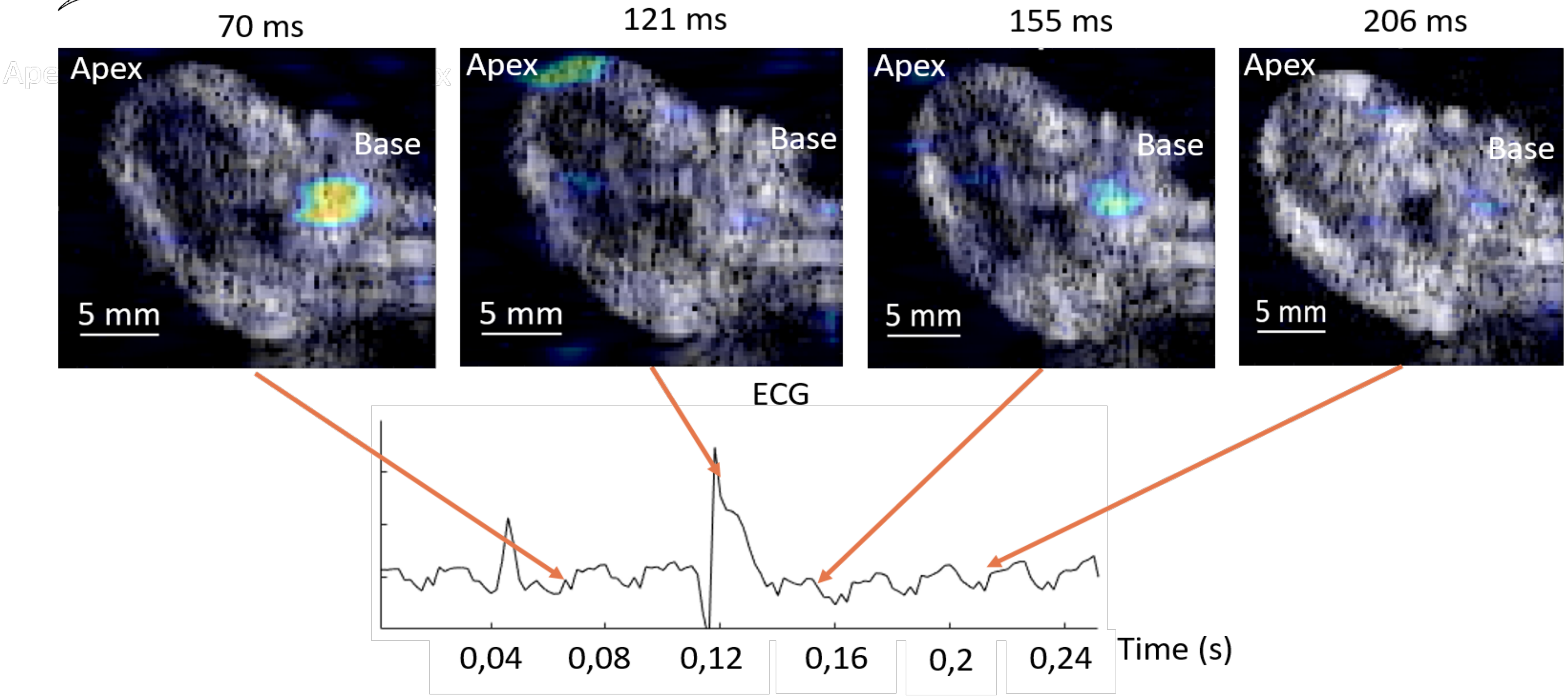
3,84 Hz

UAI provides a periodic signal which allows
accurate measurement of the cardiac electrical activation frequency

Electrical current propagation

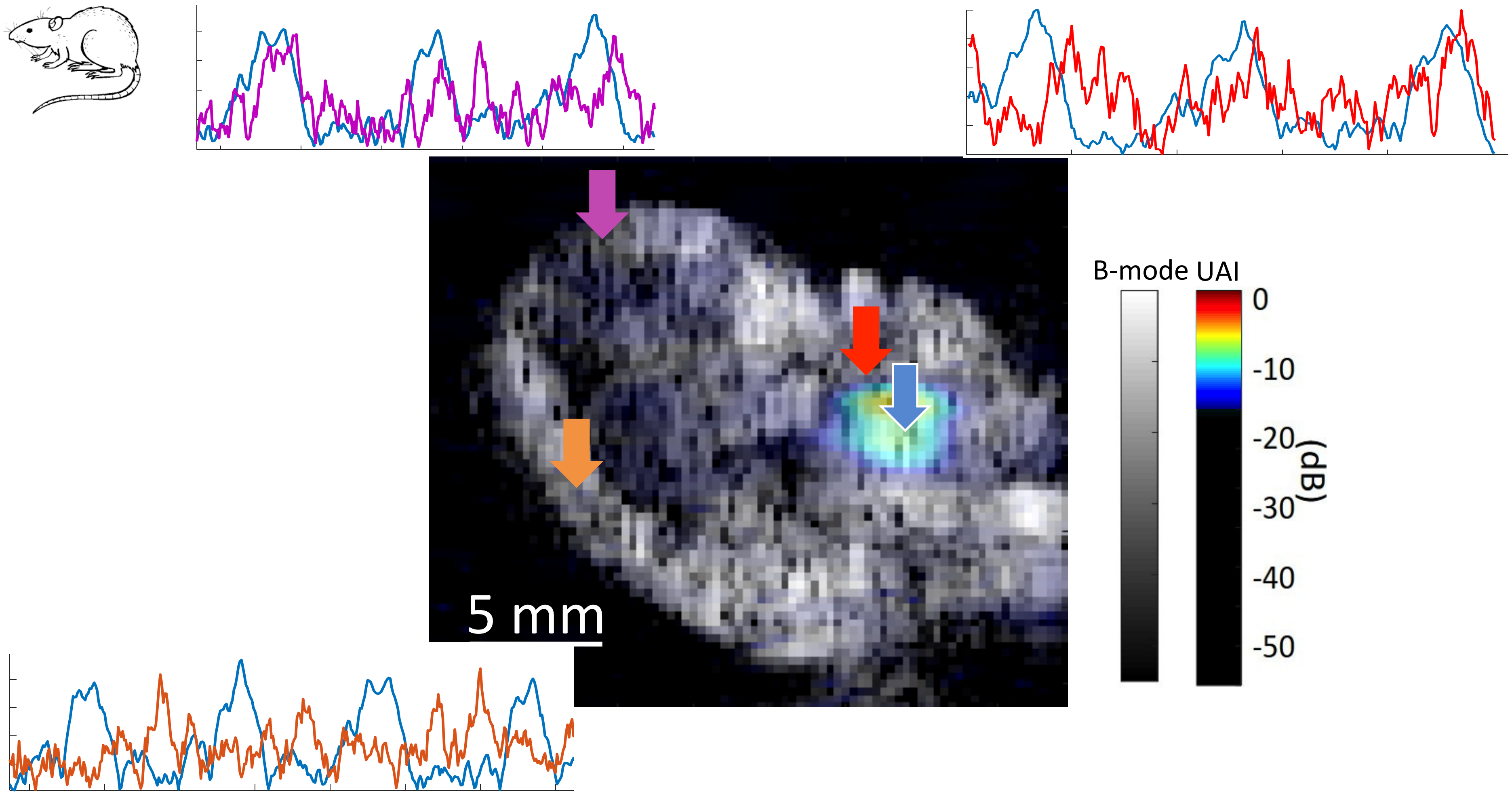


Electrical current propagation



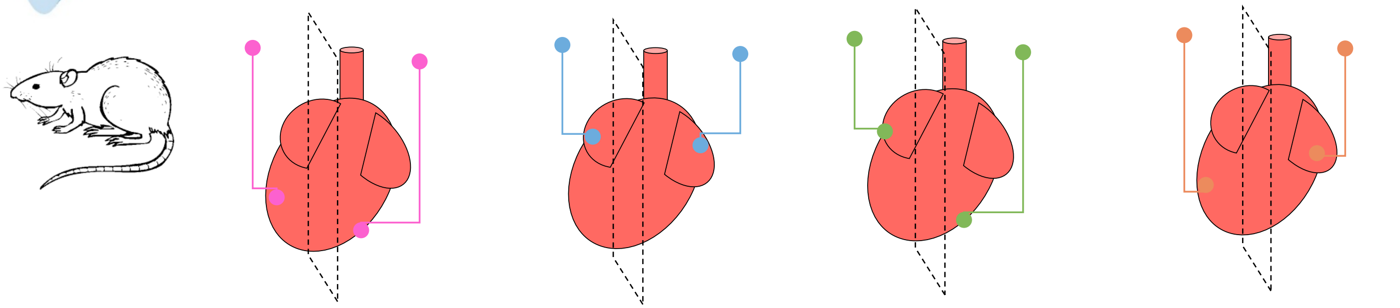
UAI signal is measured in different regions of the myocardium
at different time points of the cardiac cycle

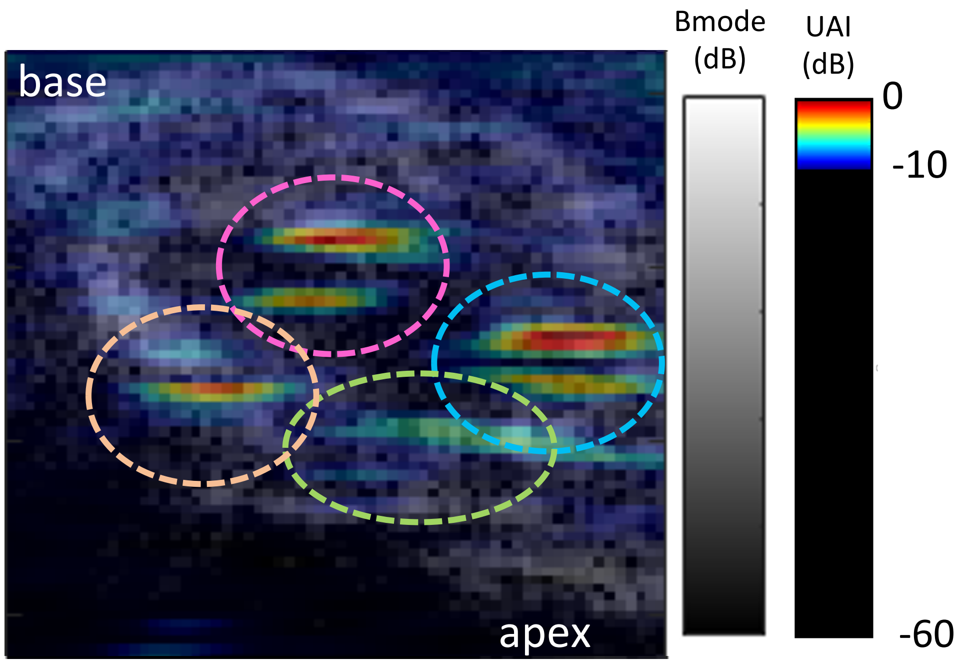
Electrical current propagation



The propagation of the signal between the different regions is visible.

Multiple electrode measurement

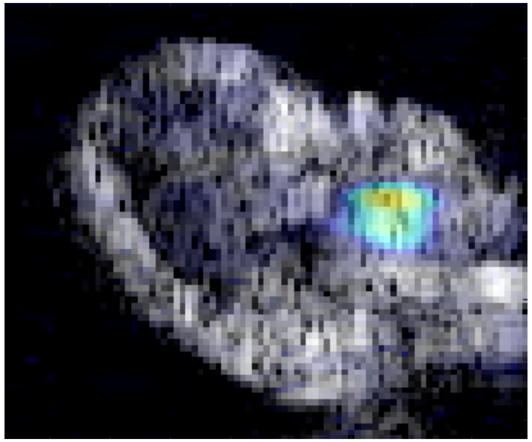


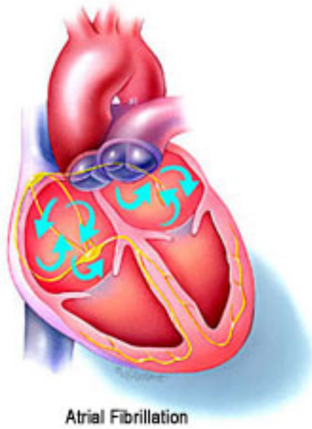


UAI can provide direct mapping of the electrical activation in the whole heart

Conclusion

We have designed a compact and fully integrated UAI system and performed ex-vivo UAI imaging for the first time





- High sensitivity
- High frame rate and image quality (frequency, propagation, etc.)

Future work

- ➢ Increased sensitivity
- ➢ More in-vivo imaging (heart, brain, etc.)
- ➢ Multi-electrodes system => 3D UAI

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