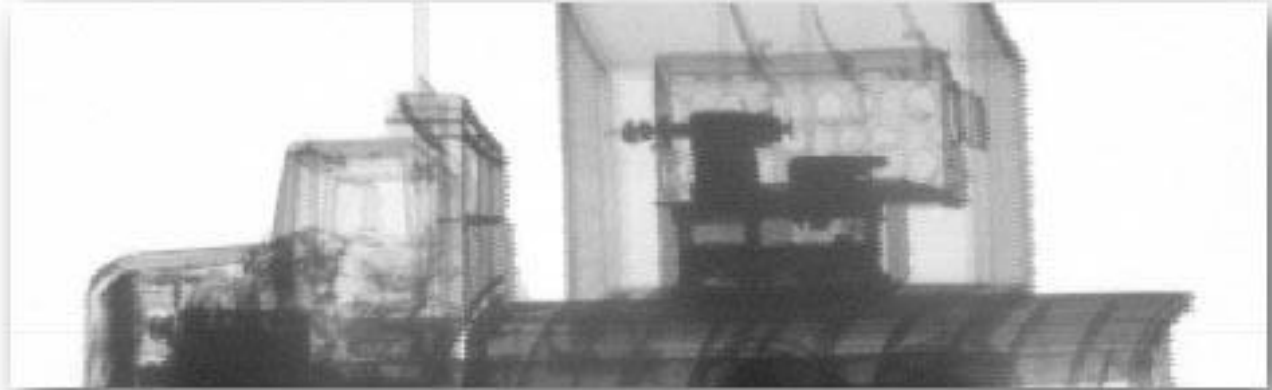


Magnetic Induction Tomography with Atomic Magnetometers

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Department of Physics & Astronomy
University College London



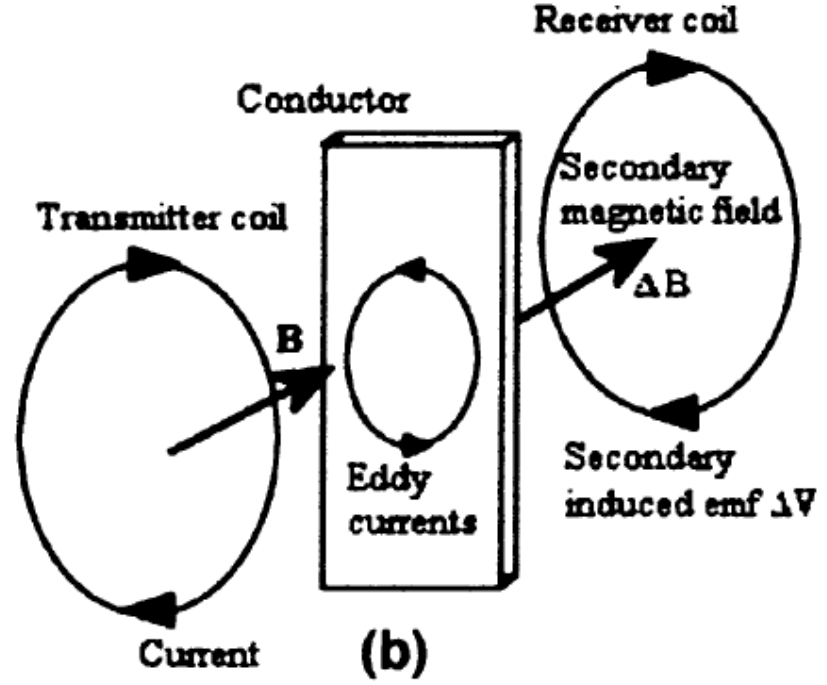
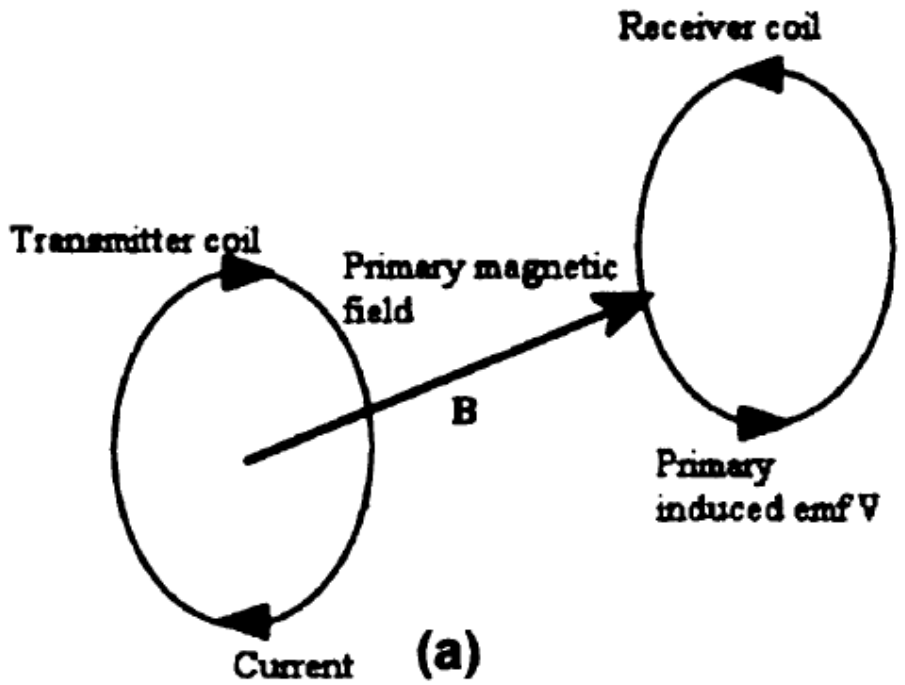
Widely used in medicine and in security applications (cargo scanning etc)



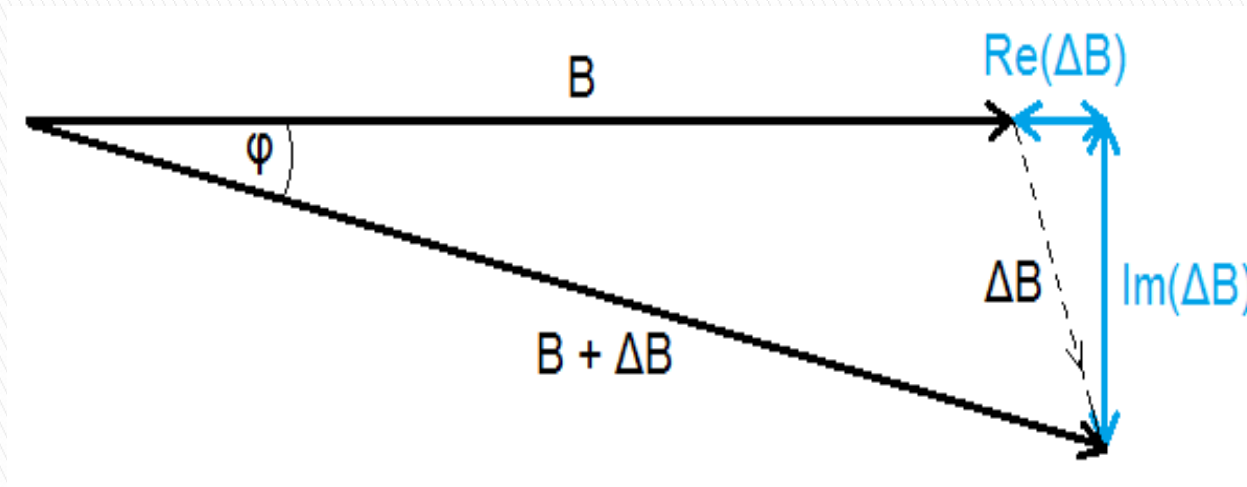
No imaging system is universal – limitations in performances or in use

Xray: **unsafe** (foetus)
illegal (cargo scanning in France)

Sometime the “right” imaging systems does not exist (e.g. how to image **current loops** in the **heart**)?

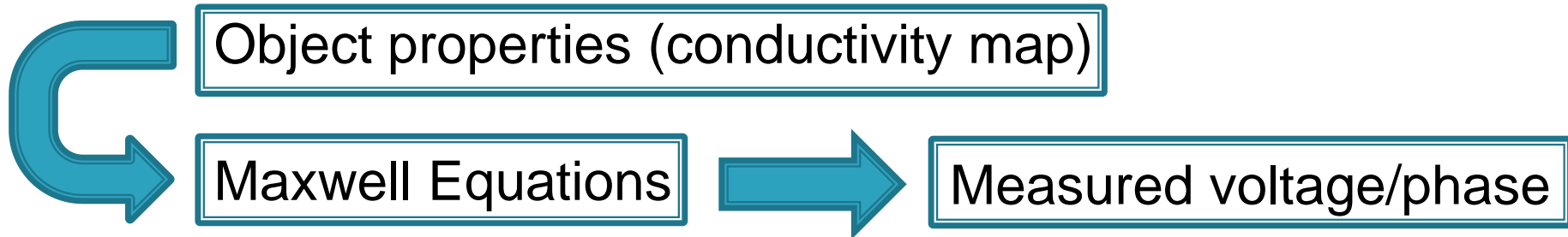


The secondary field has the same frequency of the driver, but **different phase**. From the phase lag and amplitude, one can reconstruct σ , μ_r , ϵ_r



$$\Delta B/B \approx Q\omega\mu_0[\omega\epsilon_0(\epsilon_r - 1) - i\sigma] + R(\mu_r - 1)$$

Forward problem (easy)

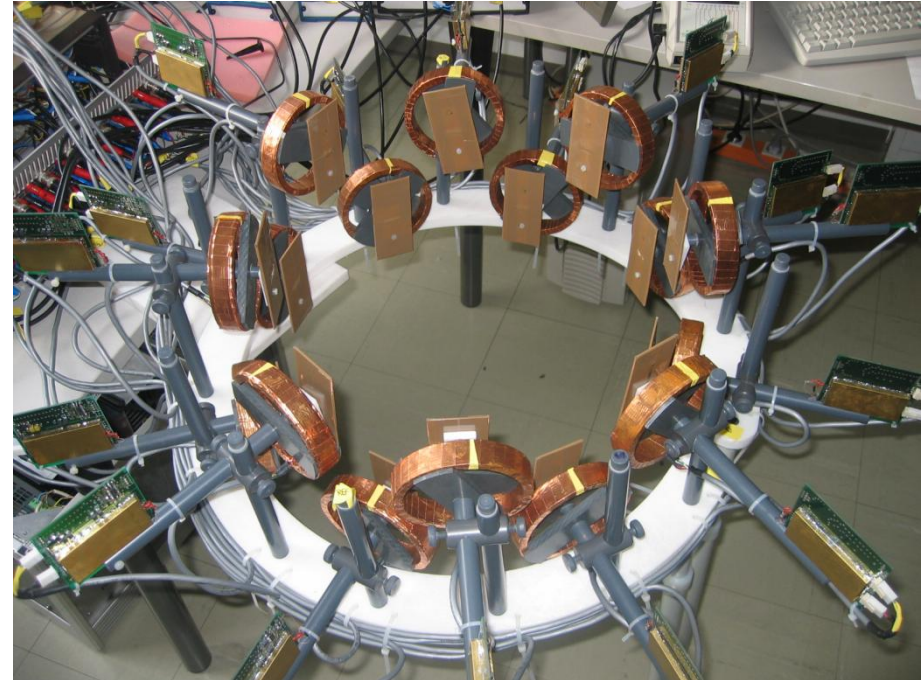
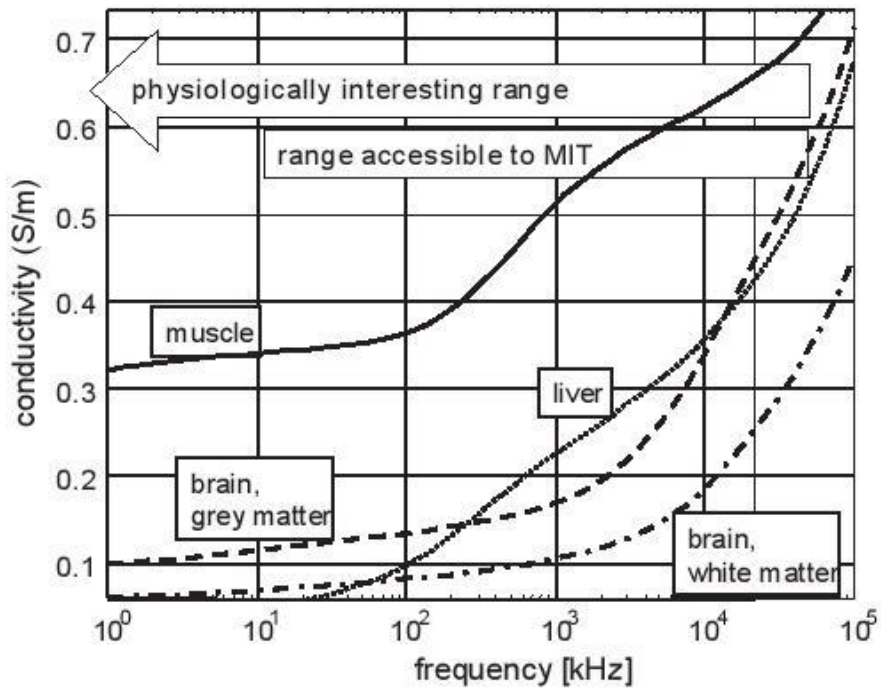


Inverse problem (hard...)

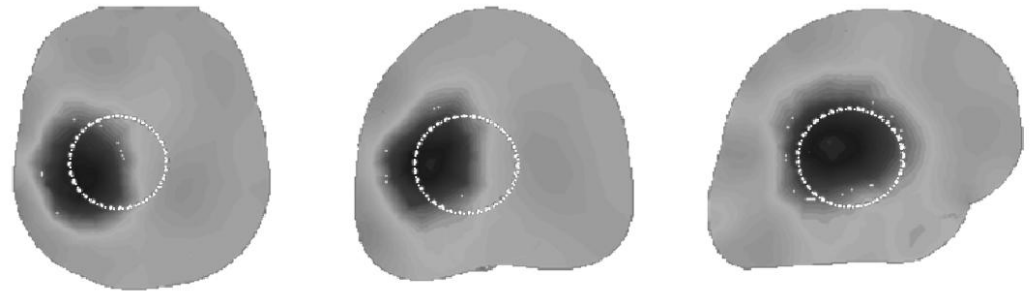
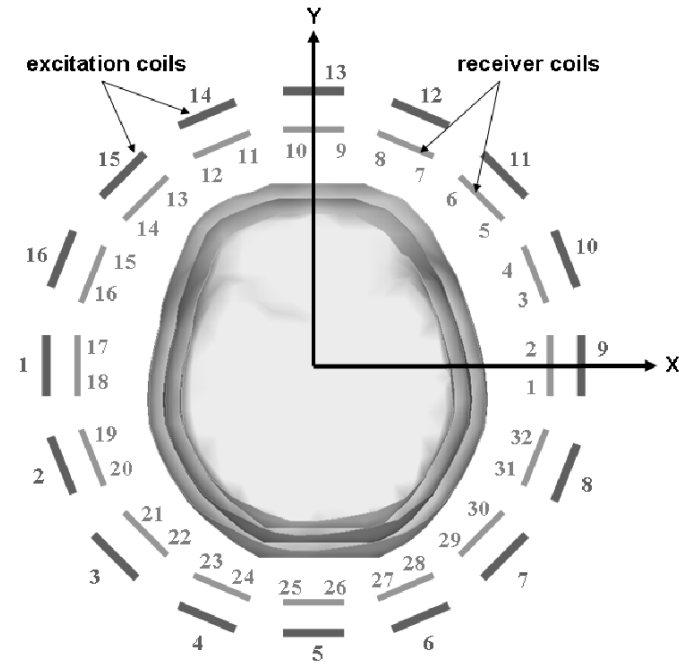
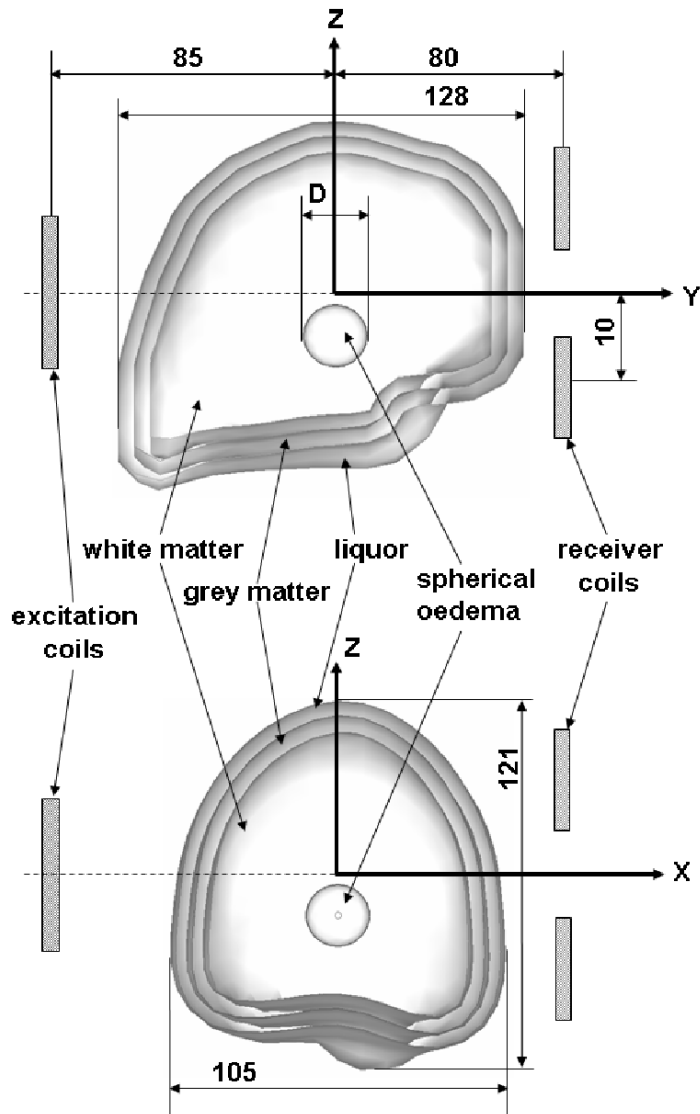
- Provides a 3D image (map of σ) given the measurements
- In general undetermined

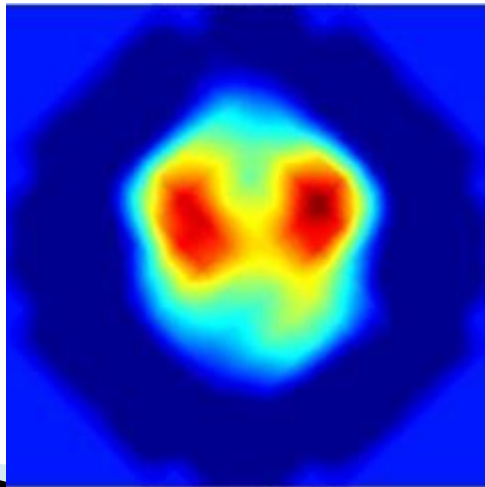
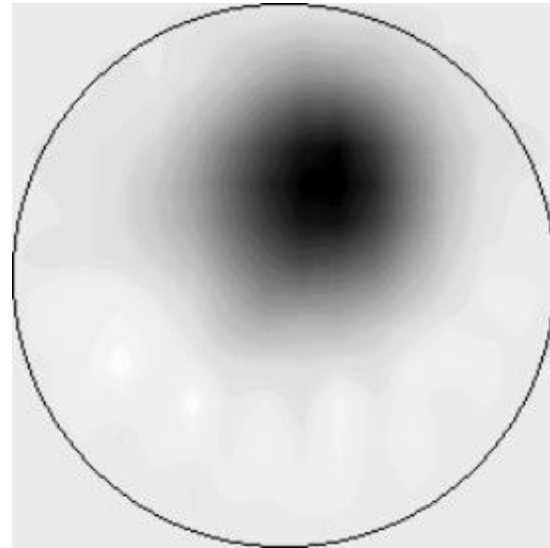
ad hoc solutions

Planar geometry
Back projection

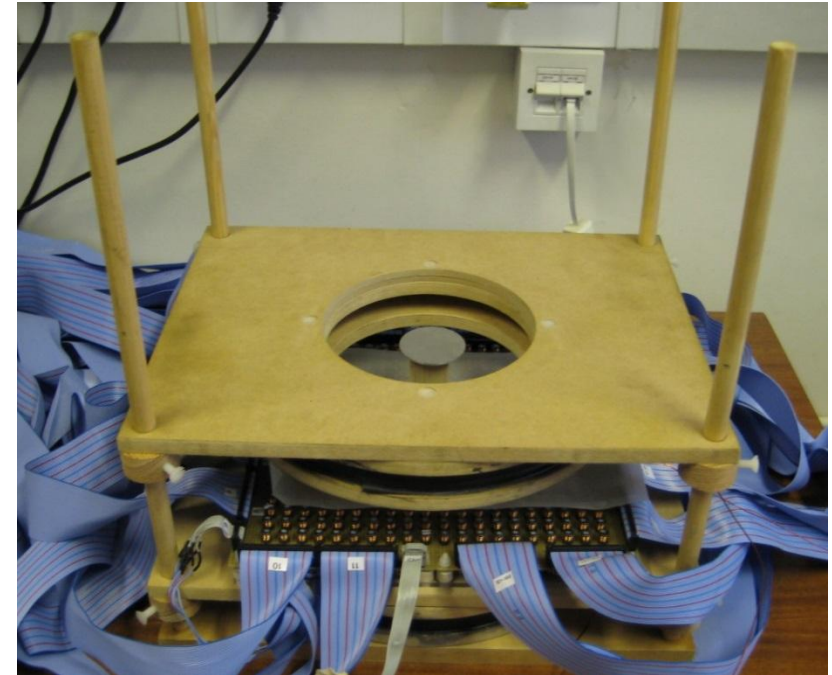
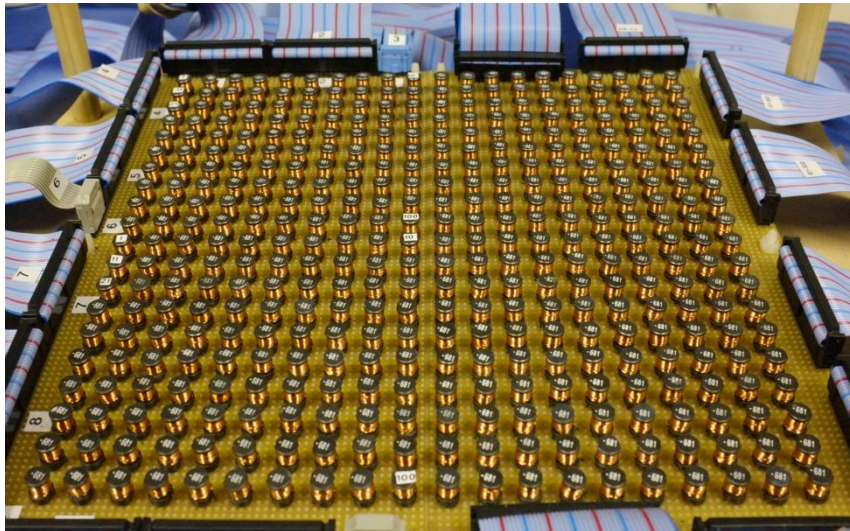


16/32-channel system for low-resolution imaging of brain oedema





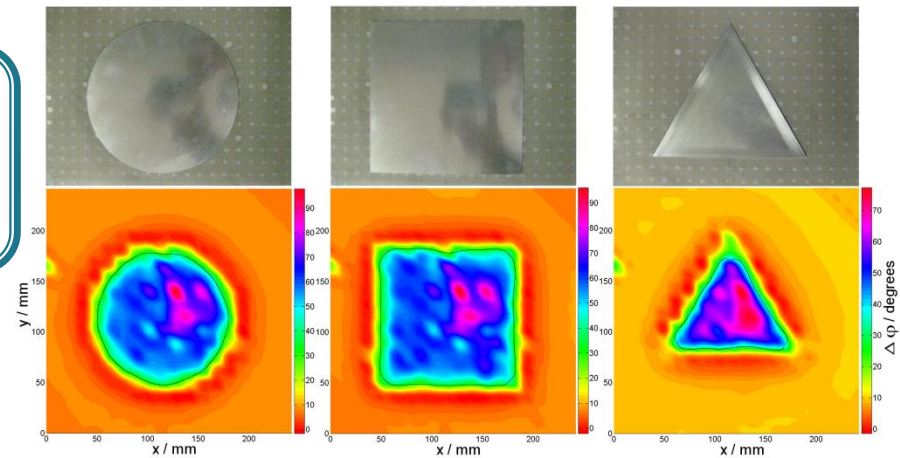
In-vivo image of the human head



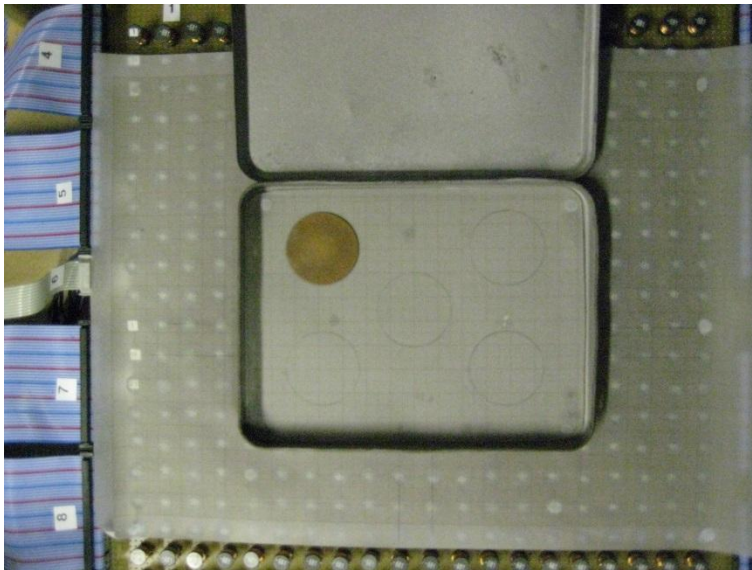
Planar geometry



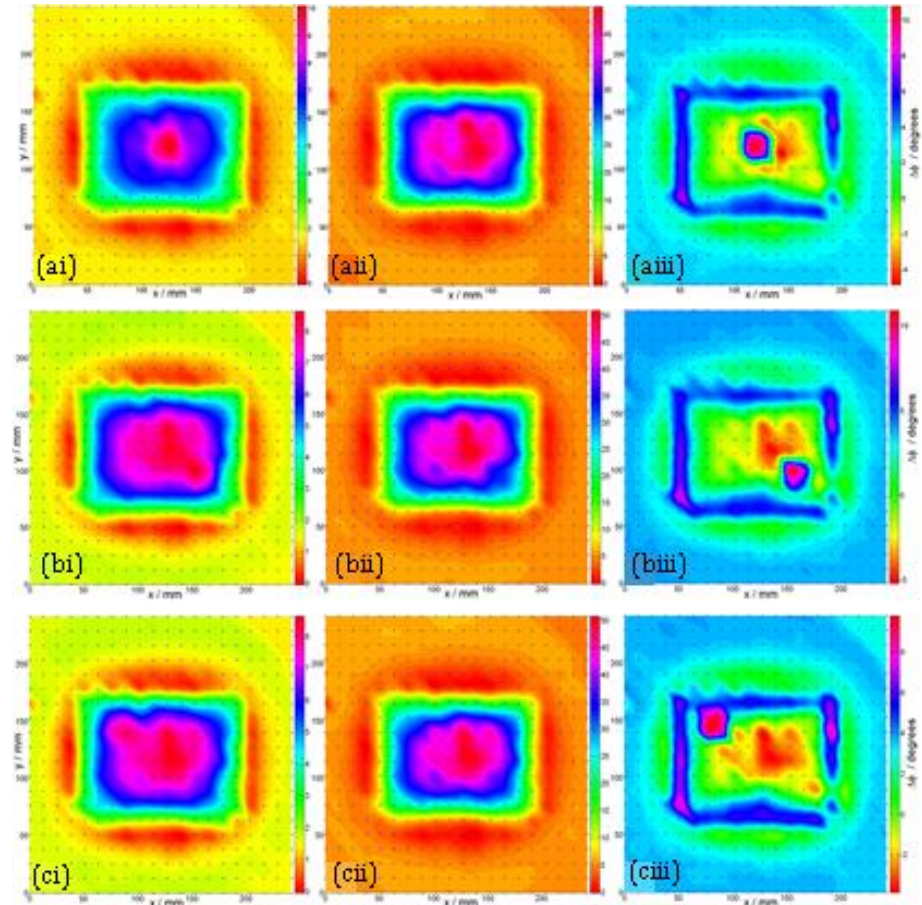
No solution of the inverse problem required

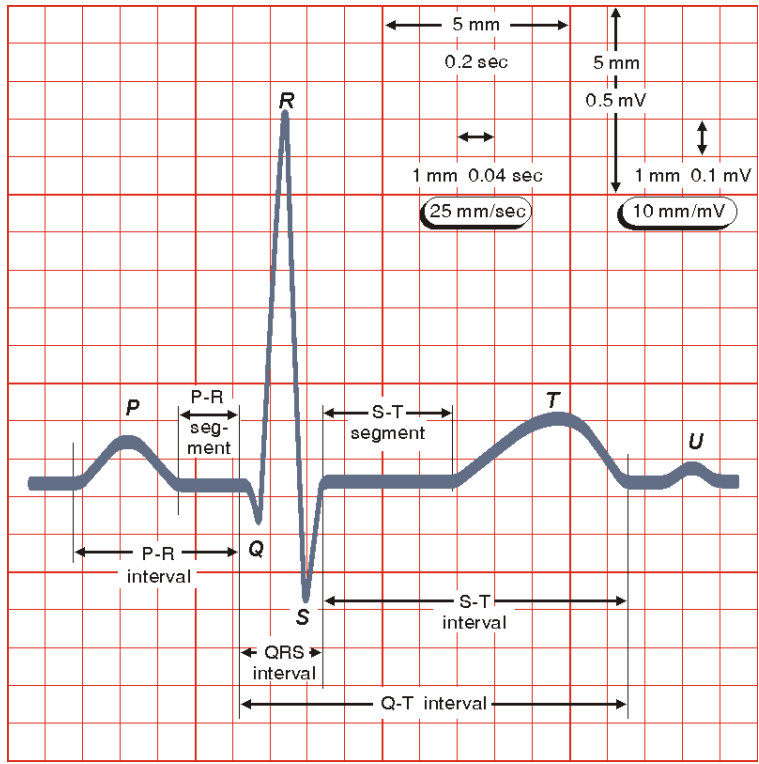


MIT for Cargo screening



The use of dual frequencies allows imaging through metallic screens

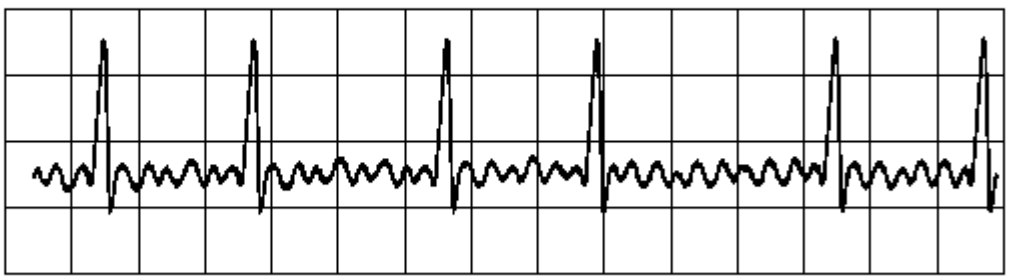
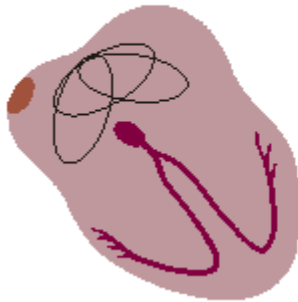




It affects **3-5%** of the population over 70
Main complication: **increase risk of stroke**

ATRIAL FIBRILLATION

Impuses have chaotic, random pathways in atria



Baseline irregular, ventricular response irregular

Causes

Atrial fibrillation occurs when abnormal electrical impulses suddenly start firing in the atria. These impulses override the heart's natural pacemaker, which can no longer control the rhythm of the heart. This causes you to have a highly irregular pulse rate.

The cause is **not fully understood...**



Treatment

medication to prevent a stroke
medication to control the heart rate or rhythm
... controlled electric shock to restore normal rhythm
cather ablation, to prevent atrial fibrillation from occurring
having a pacemaker fitted...



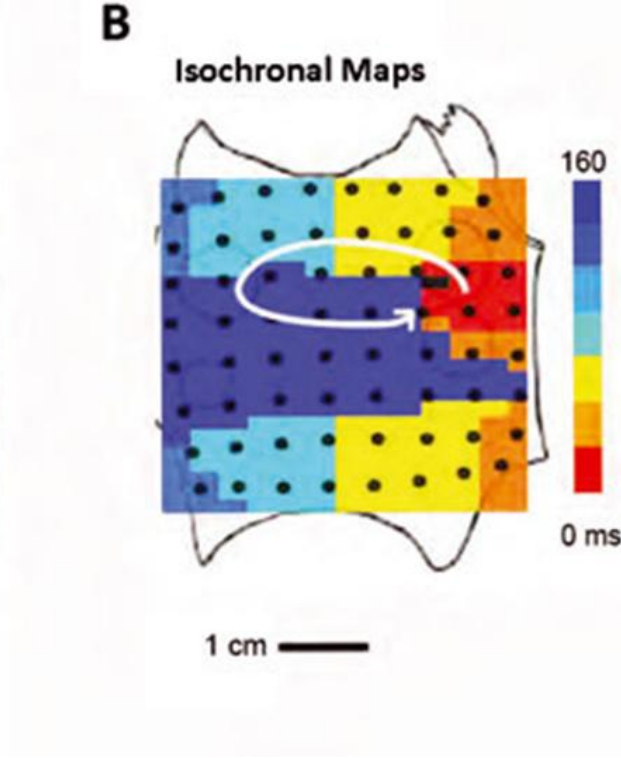
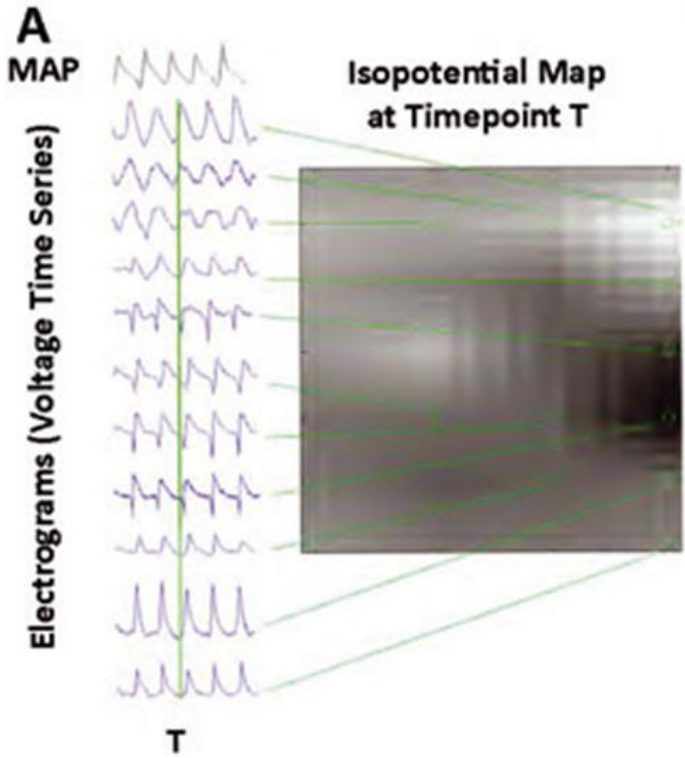
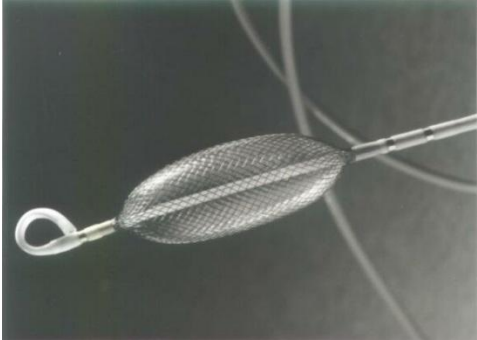


Rotors: rotational activity around a centre

Hypothesis: **rotors** activate rapidly enough to cause disorganized AF

Rotors are the target of RF ablation

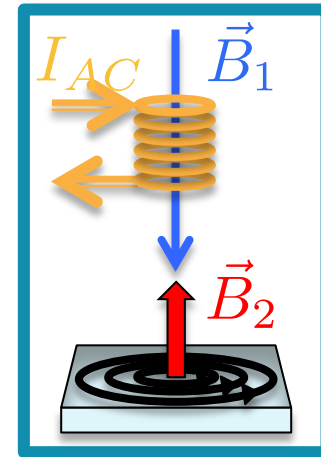
64 pole catheter for cardiac mapping



Map of activation times

Cardiac mapping using MIT

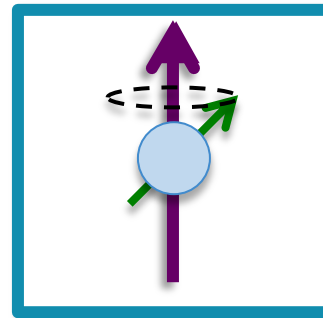
identification of zones of anomalous conductivity



Requirements:

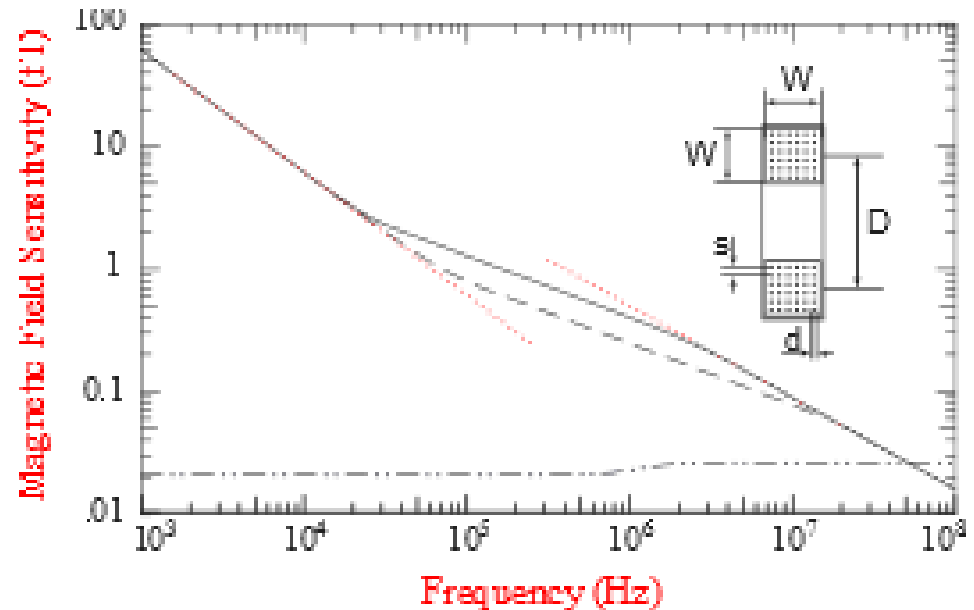
extreme sensitivity

resolution



- ▶ Potential for miniaturization

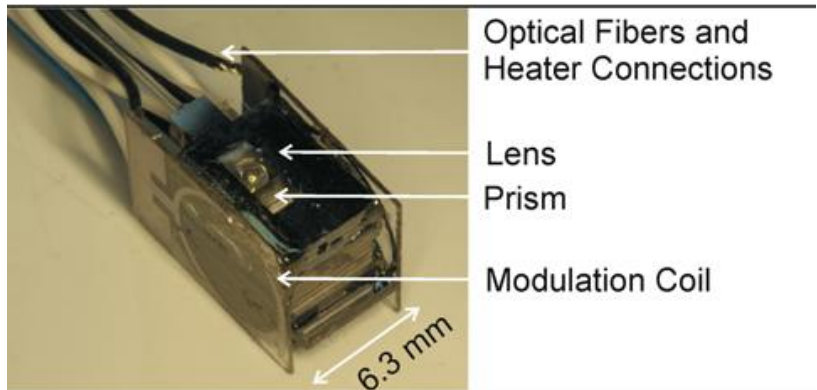
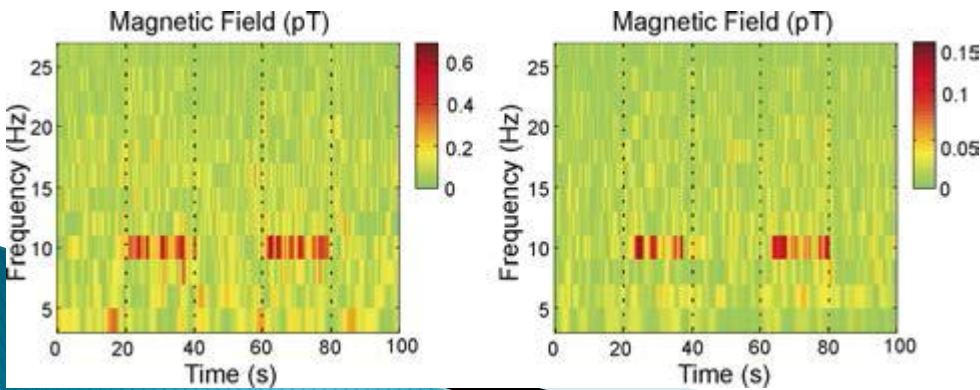
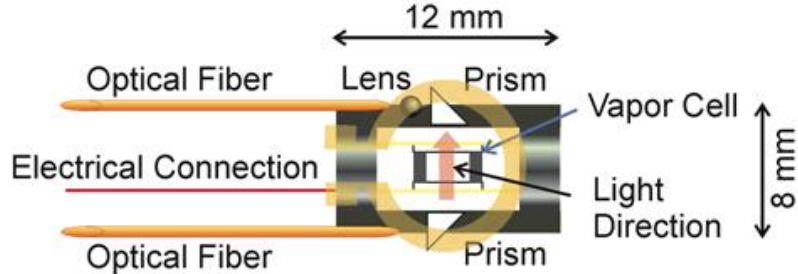
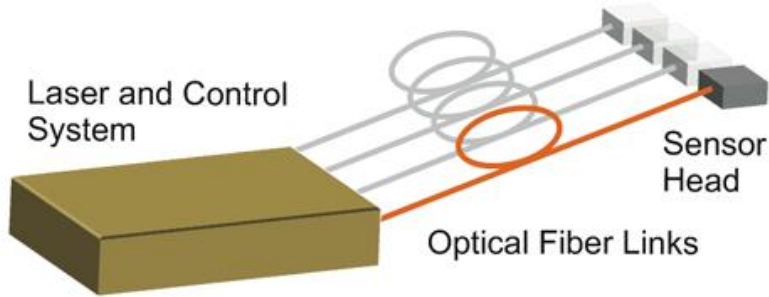
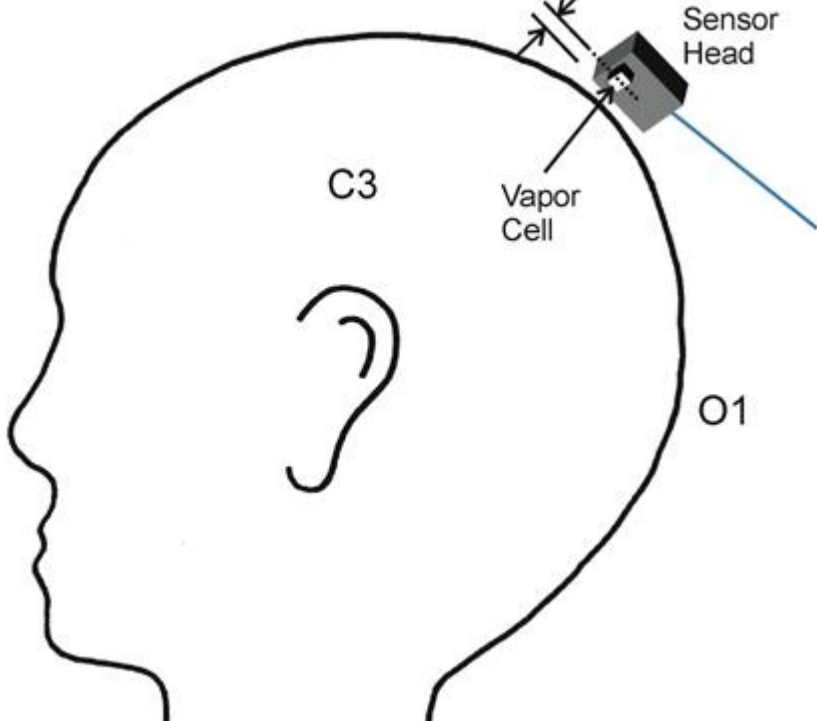
- ▶ Extreme sensitivity



- ▶ Room temperature operation

- ▶ Resolution

Distance between sensor center and skull: < 4 mm

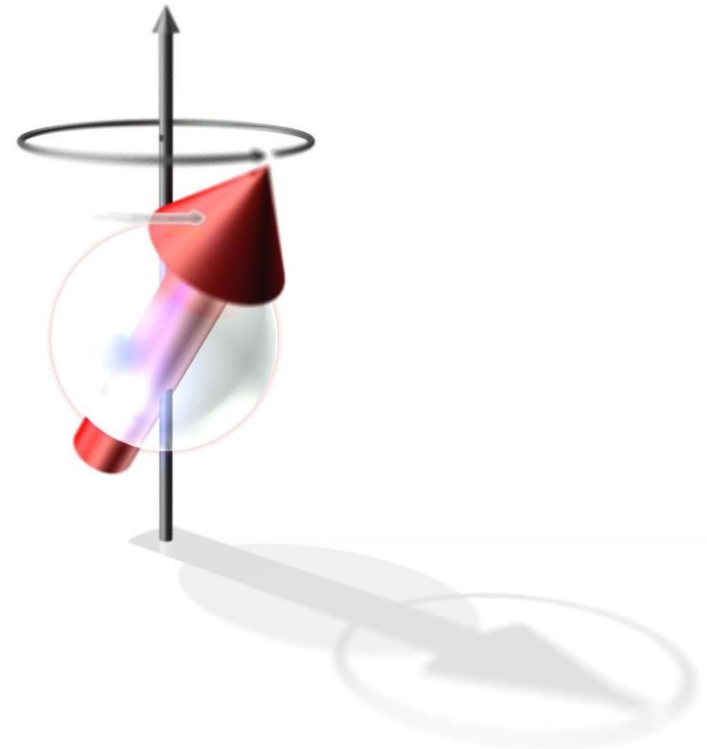


Precession of a spin
in a magnetic field
at the Larmor frequency

$$\omega = \gamma B$$

Preparation of the spin
(optical pumping)

Detection of the Larmor
precession
(via an optical probe)



De-polarizing collision with the walls of the glass cell

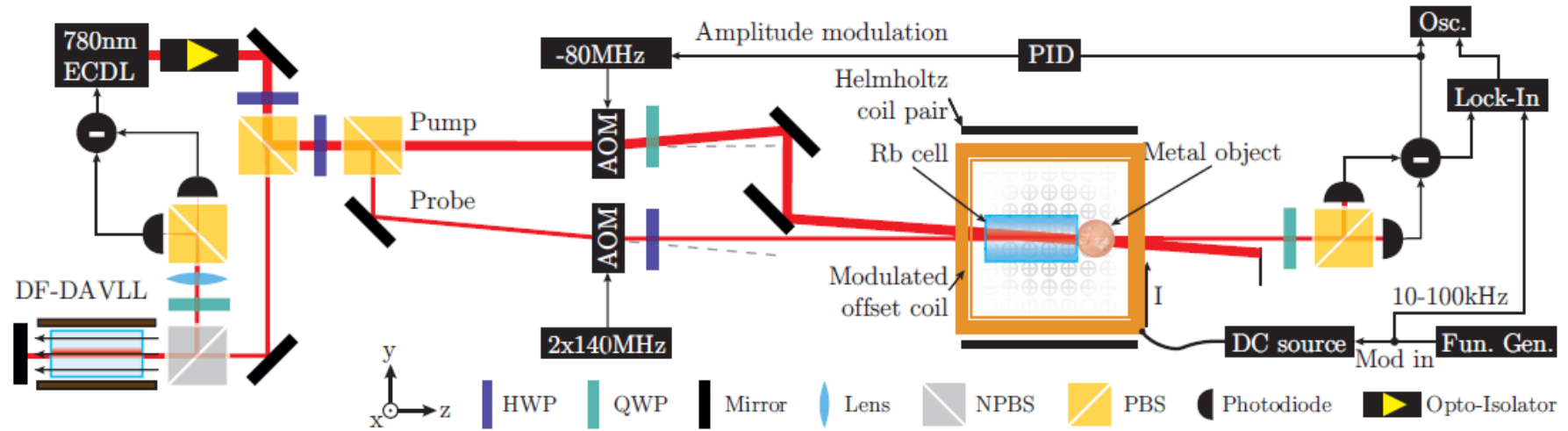
Solution: coating

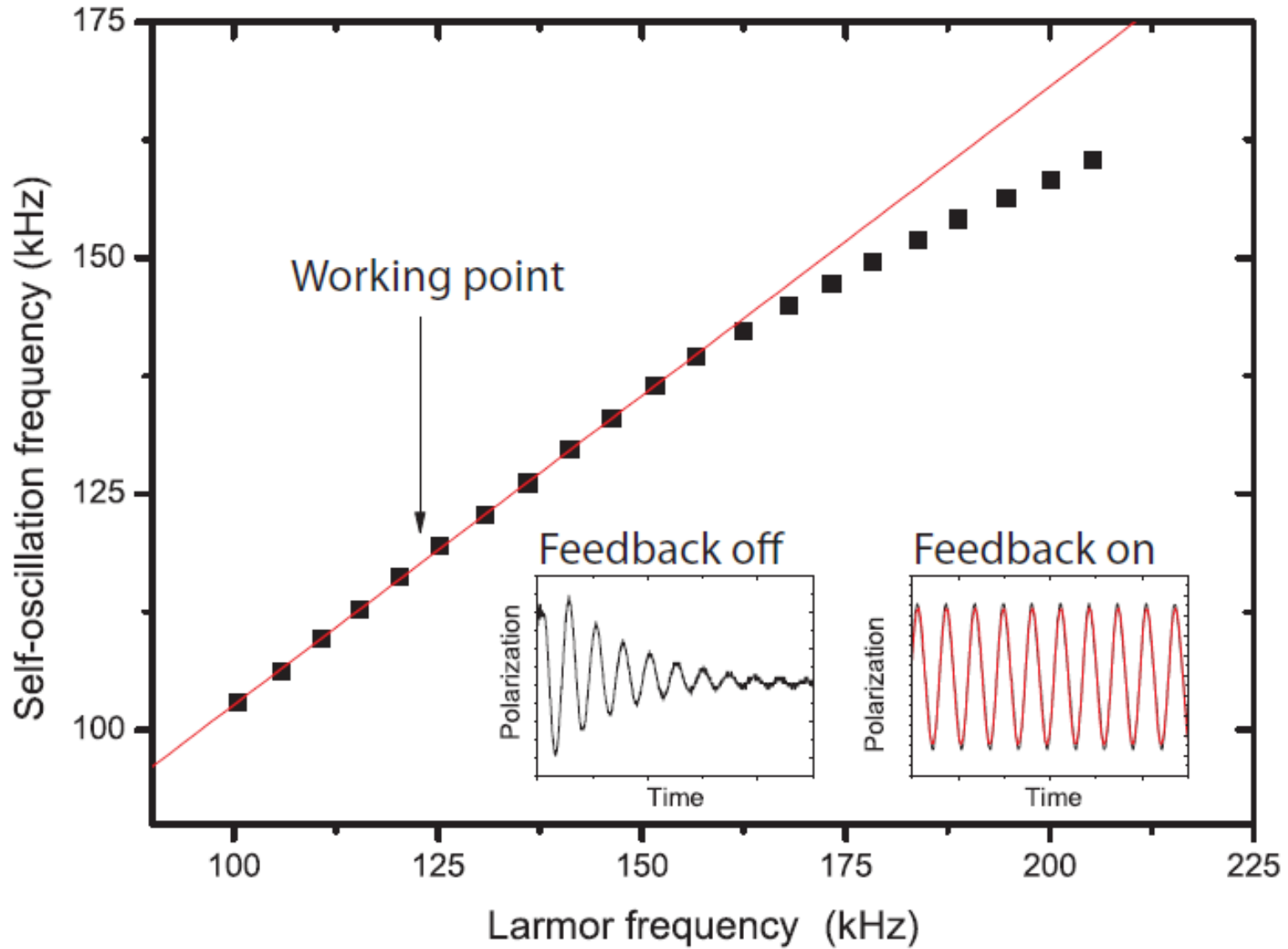
Short interaction time with the laser field

Solution: buffer gas

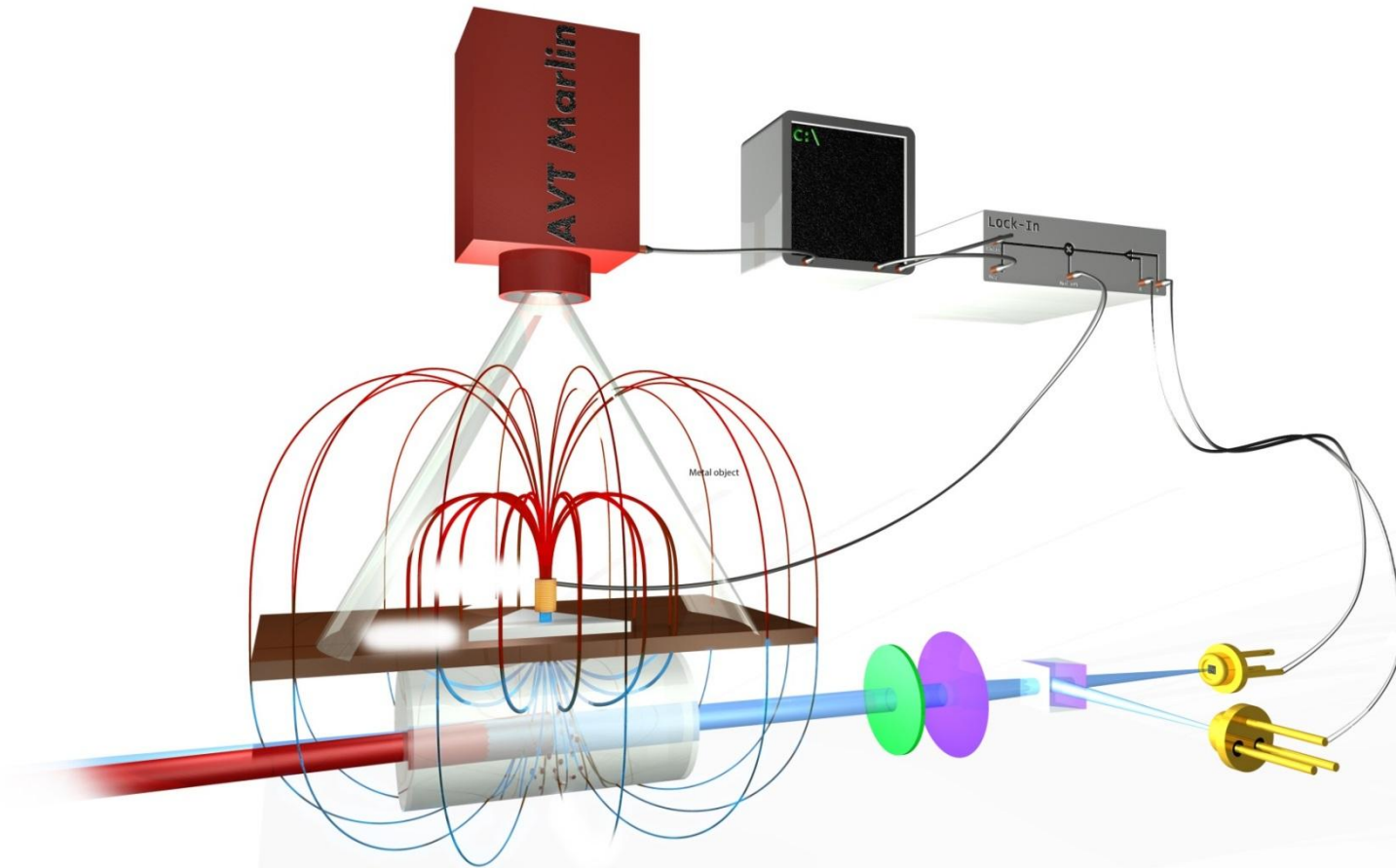
Alternative/complementary approach: re-polarize the atoms by optical pumping

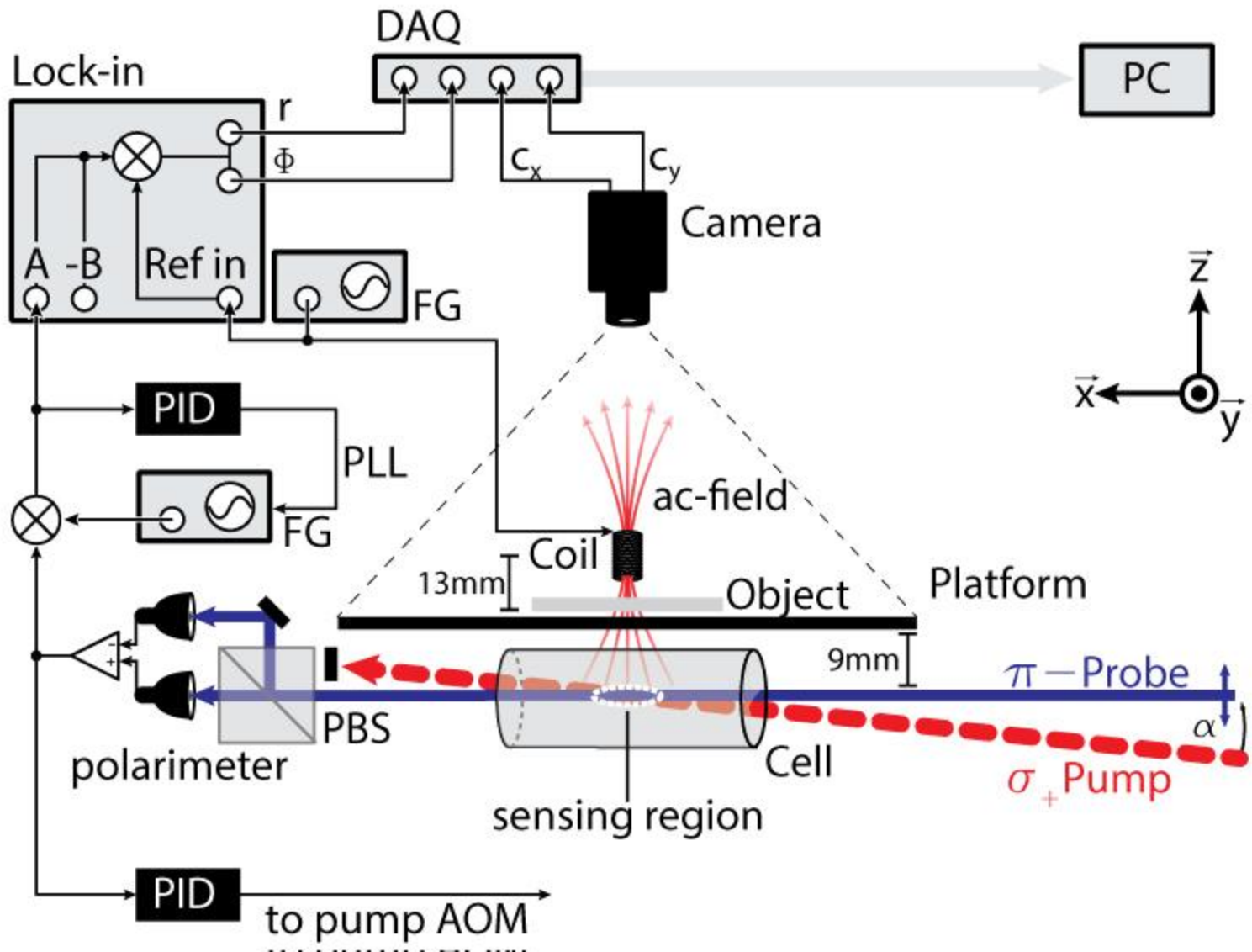
Optical pumping pulse synchronized with the Larmor precession

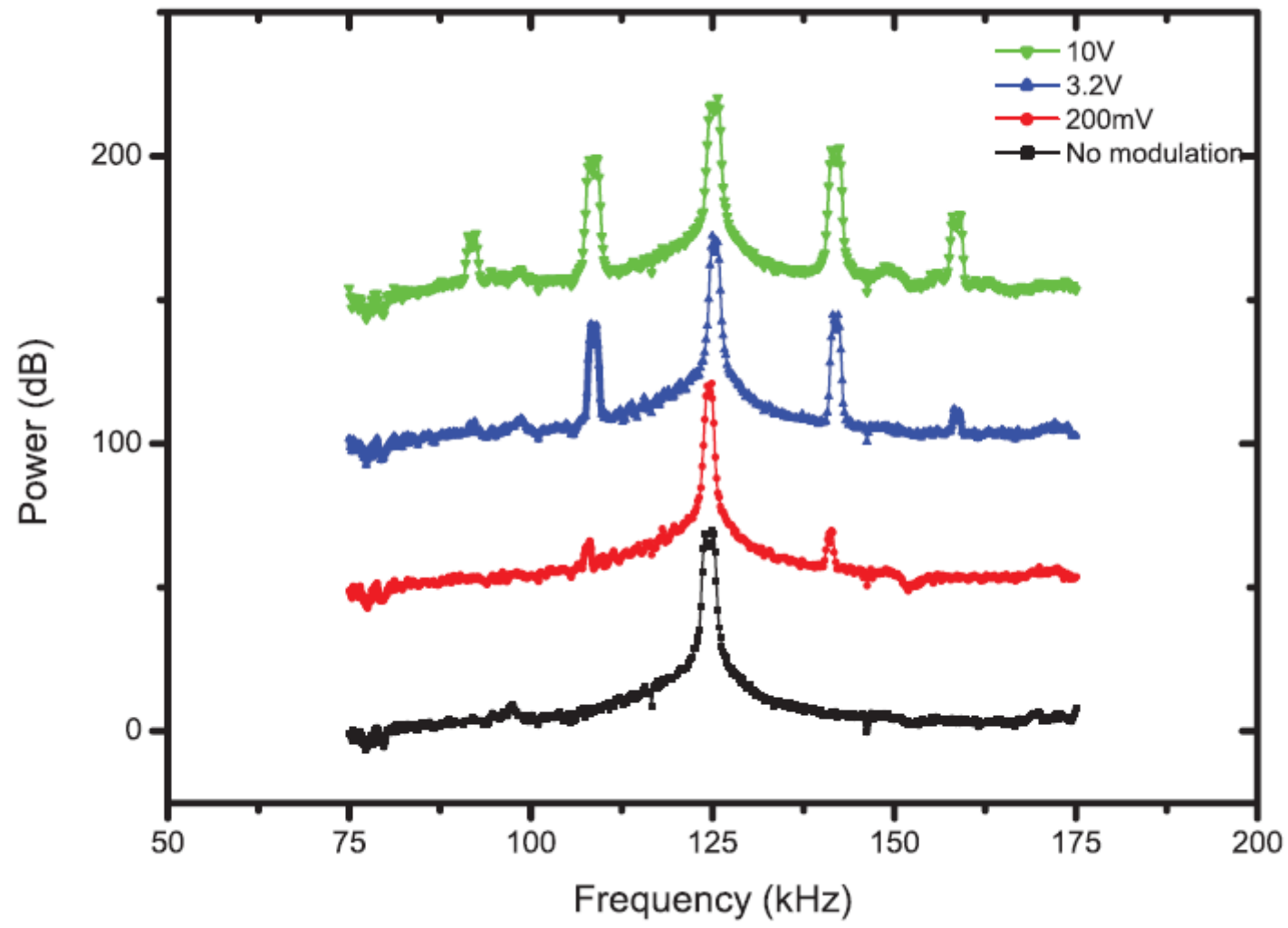


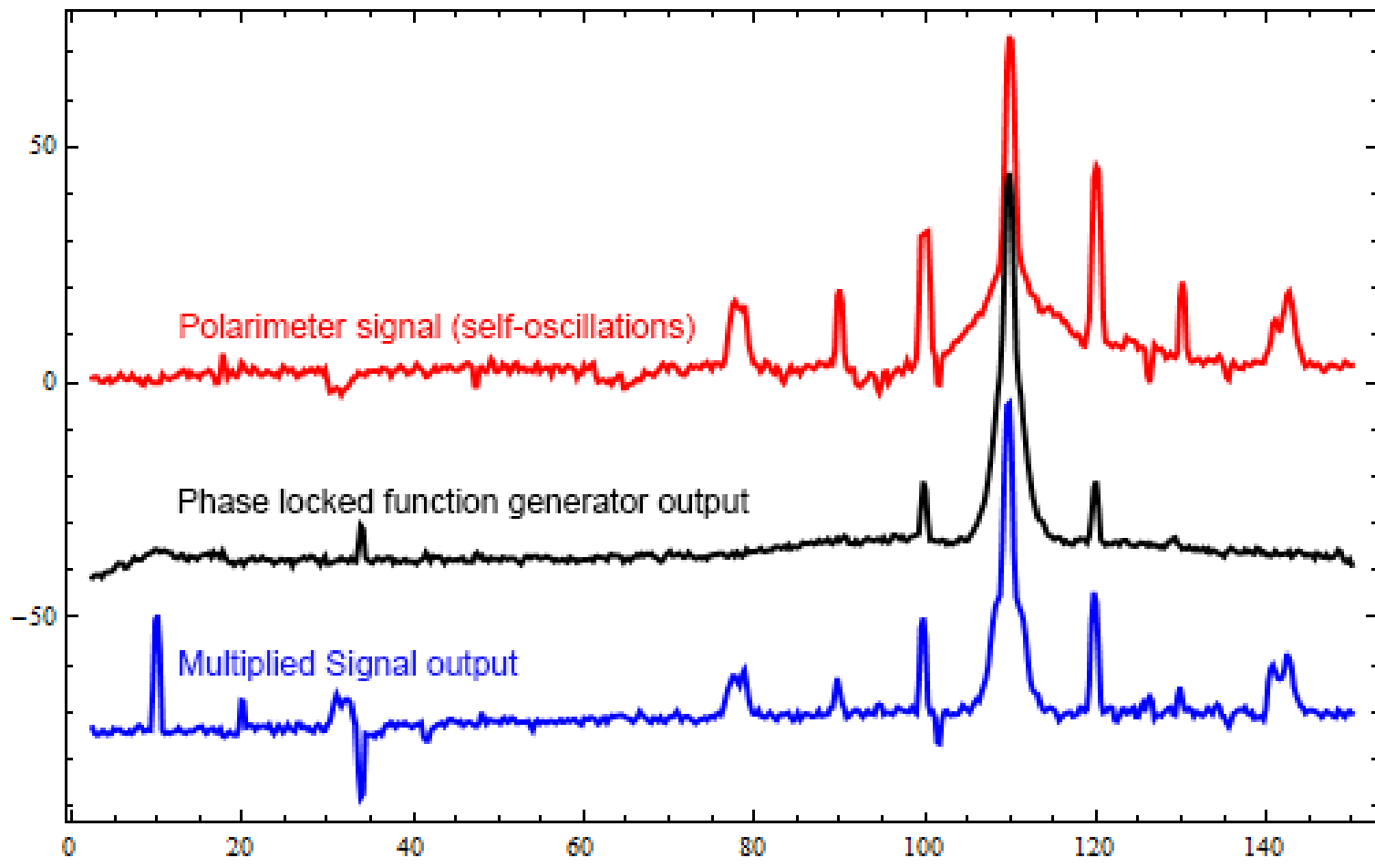


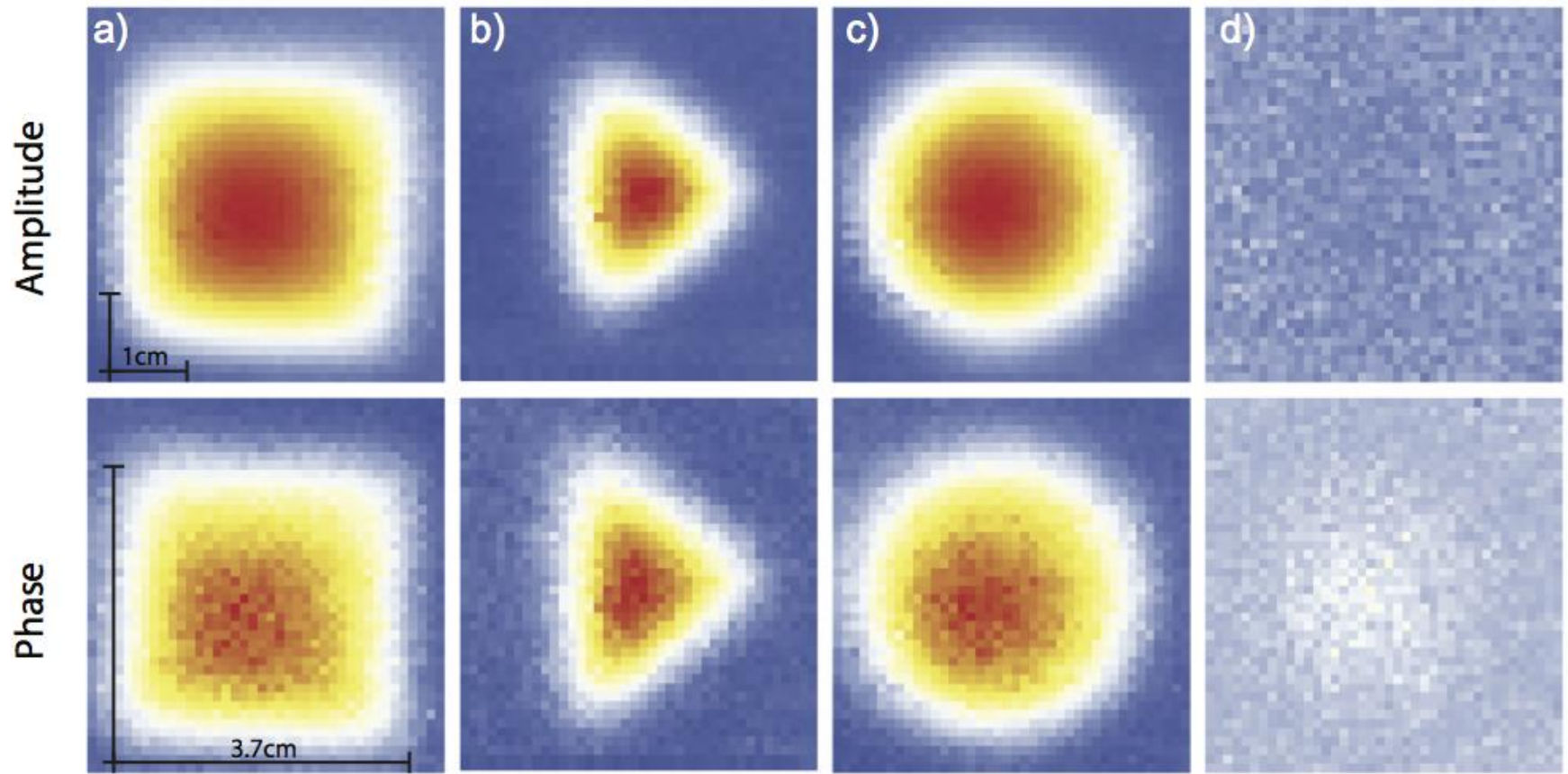
MIT with Atomic Magnetometers

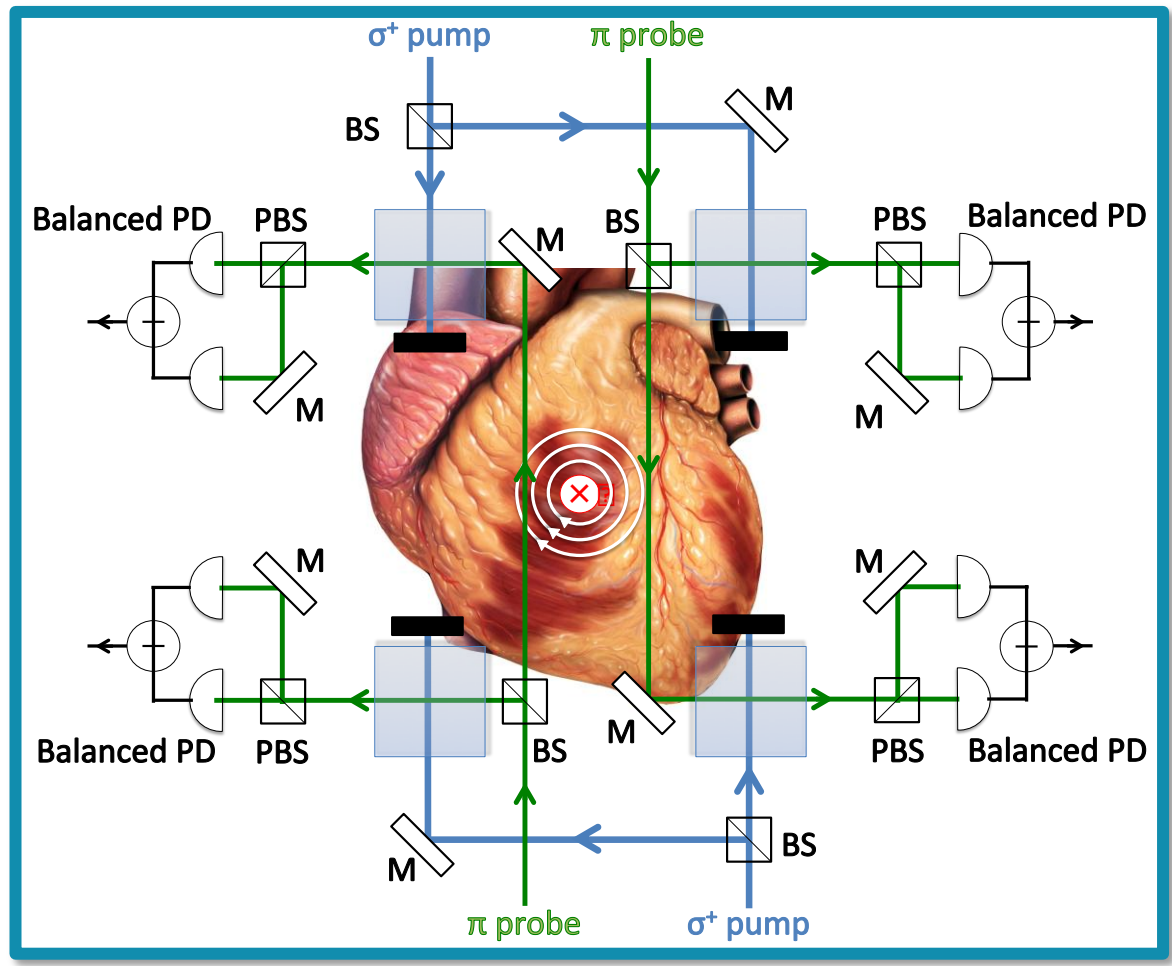


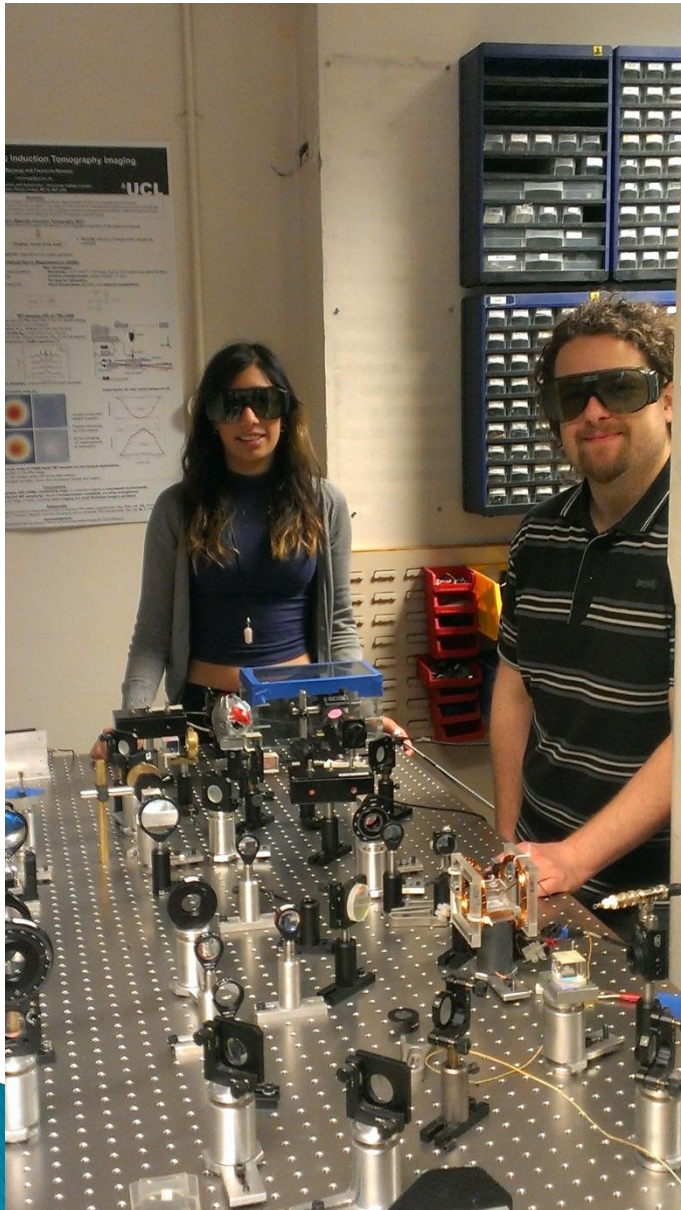












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Jenelle Rajroop (NPL/UCL)

EPSRC

Engineering and Physical Sciences
Research Council



[dstl]

NPL
National Physical Laboratory

Innovate UK
Technology Strategy Board

THALES

wellcometrust

- A. Wickenbrock, et al, APL 103, 243503 (2013)
- A. Wickenbrock et al, Opt. Lett. **39**, 6367 (2014)
- L. Marmugi and FR, submitted.

- ▶ Principles of Magnetic Induction Tomography
- ▶ “Magnetic images” are conductivity maps
- ▶ Atomic magnetometers are the ideal sensor
- ▶ Applications in medicine