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Optically excited and optically probed high frequency acoustic transducers

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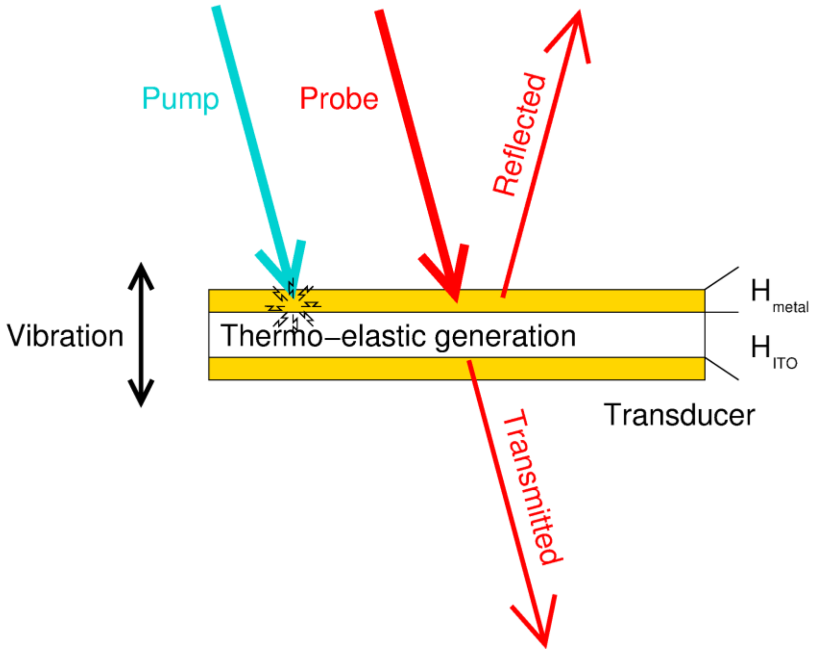
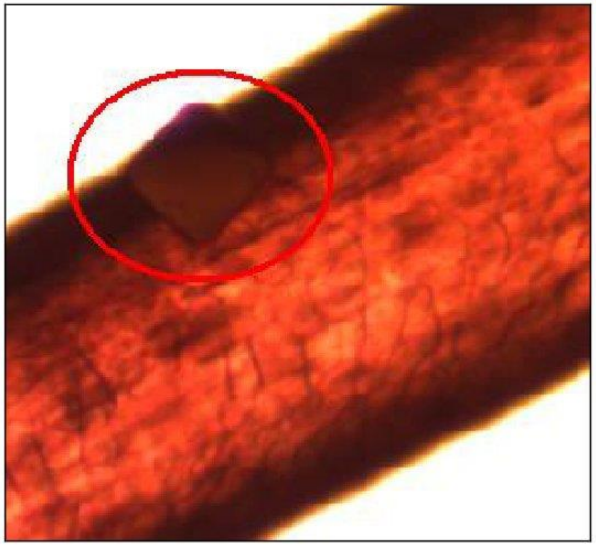
Introduction

- High frequency ultrasound gives access to wavelengths shorter than visible light
- Challenges to excite waves and read out information when the devices get very small
- Laser ultrasound technique can generate very high frequency waves without need to be in physical contact

High frequency transducers



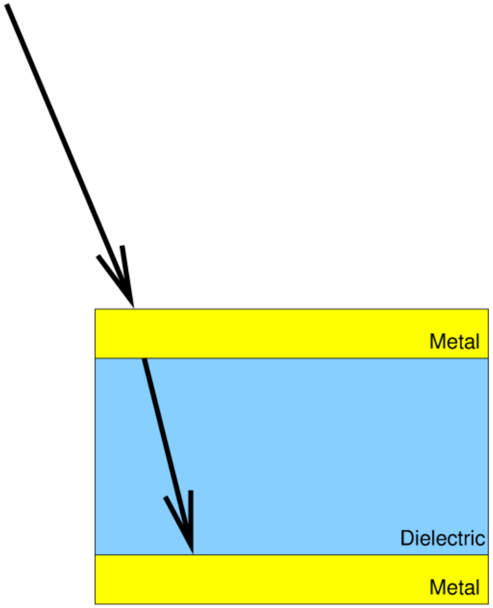


Not fussy → something optically & elastically resonant

Transducer design

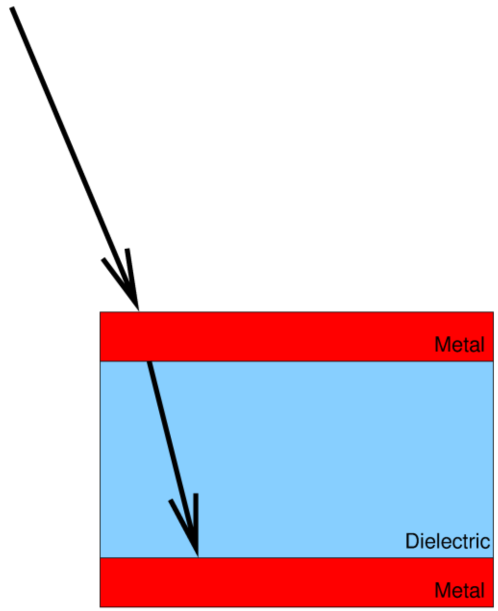
Generation of ultrasound

Transducer design



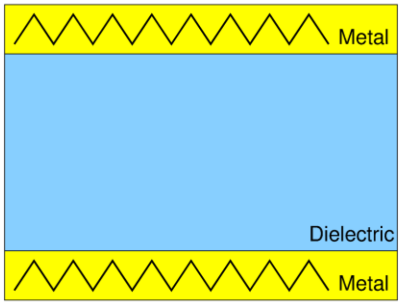
Pulse

Transducer design



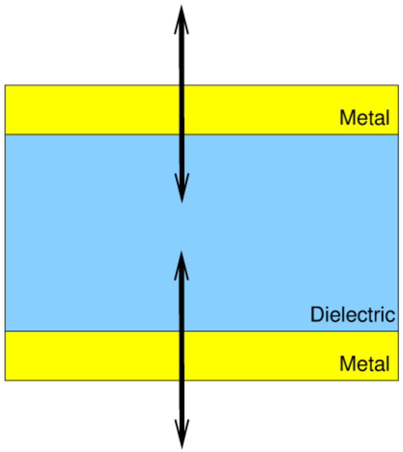
Pulse → heat

Transducer design



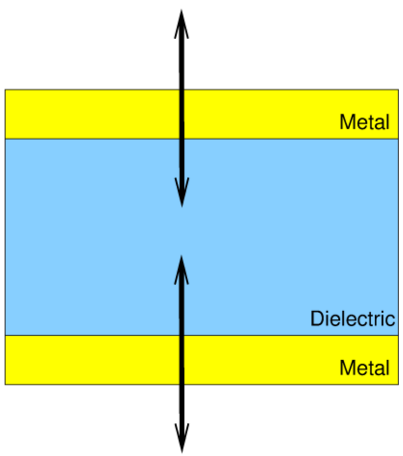
Pulse → heat → stress

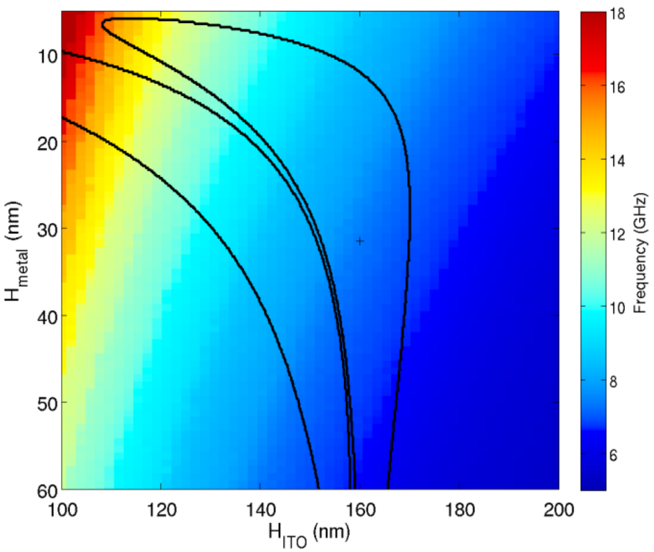
Transducer design



Pulse → heat → stress → ultrasound

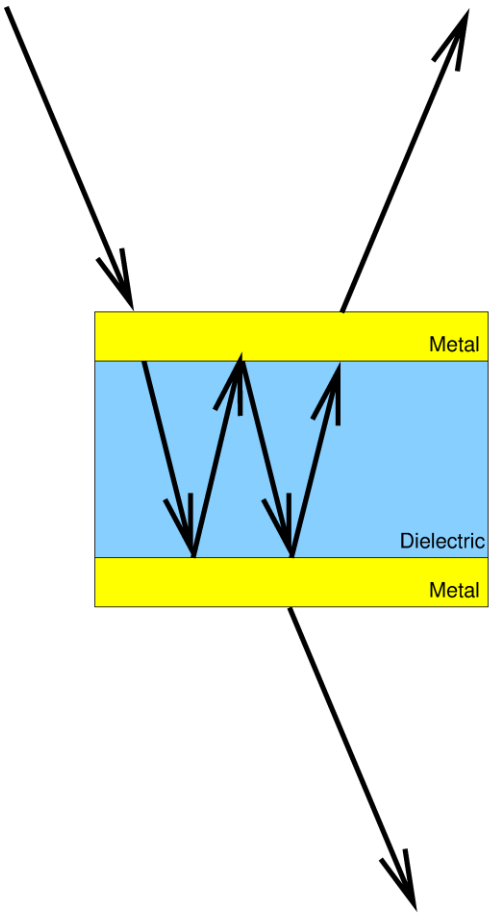
Transducer design

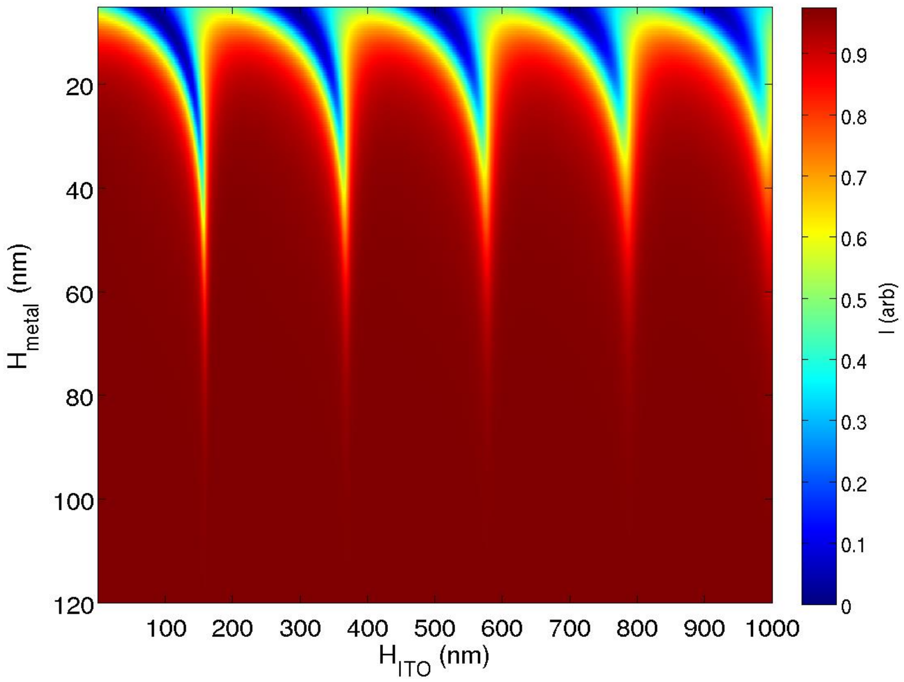




Tune structure → f

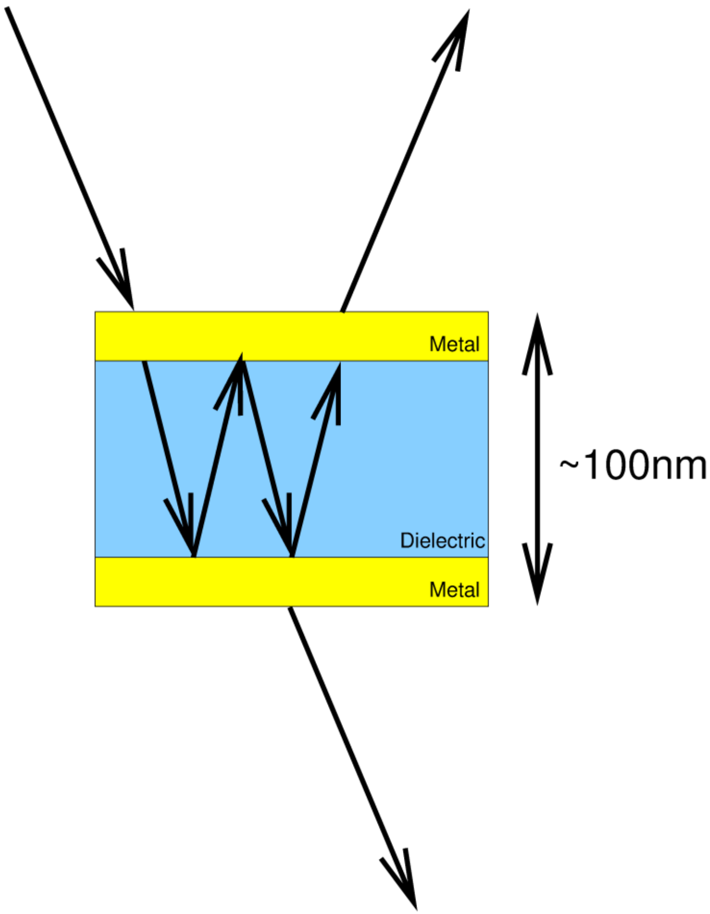
Transducer design

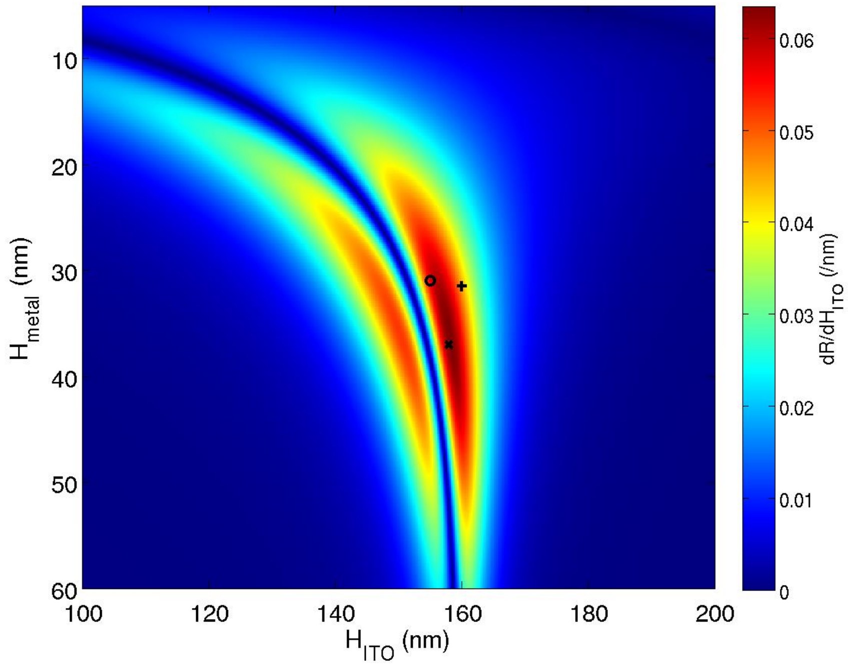




Pulse → resonance → dips / peaks

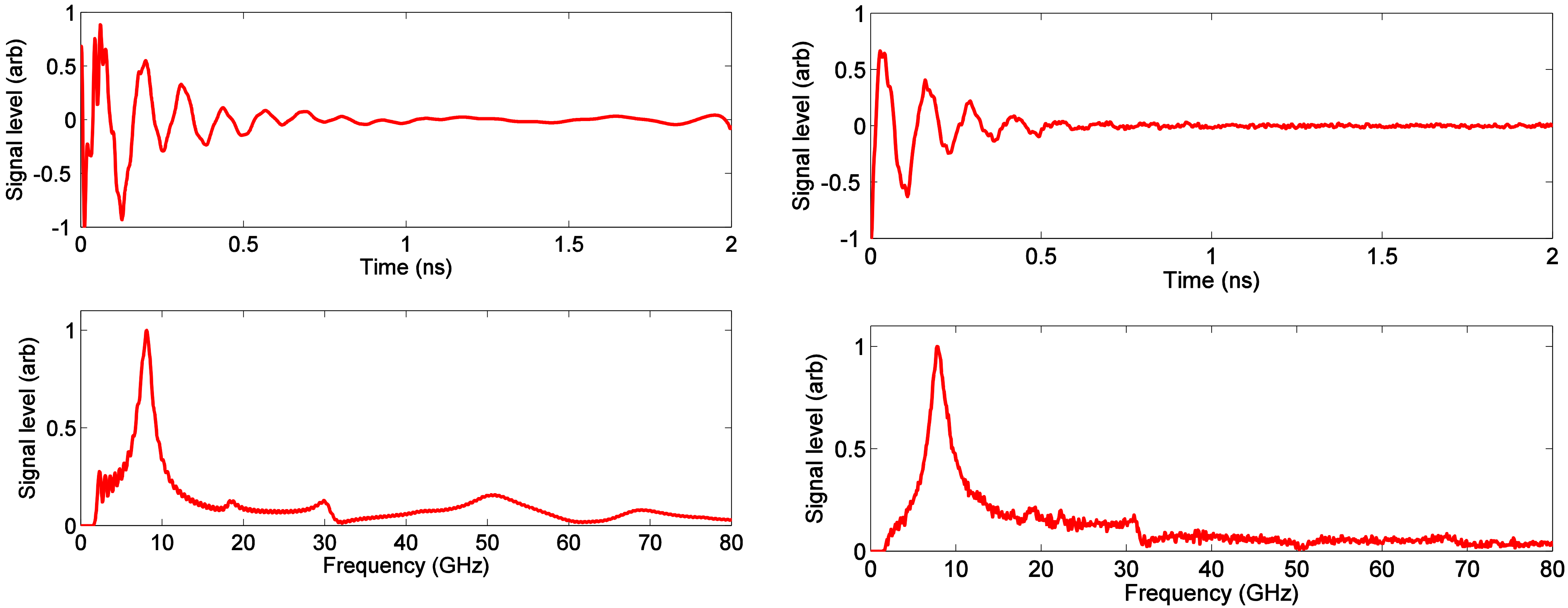
Transducer design





resonance + ultrasound → modulation → signal

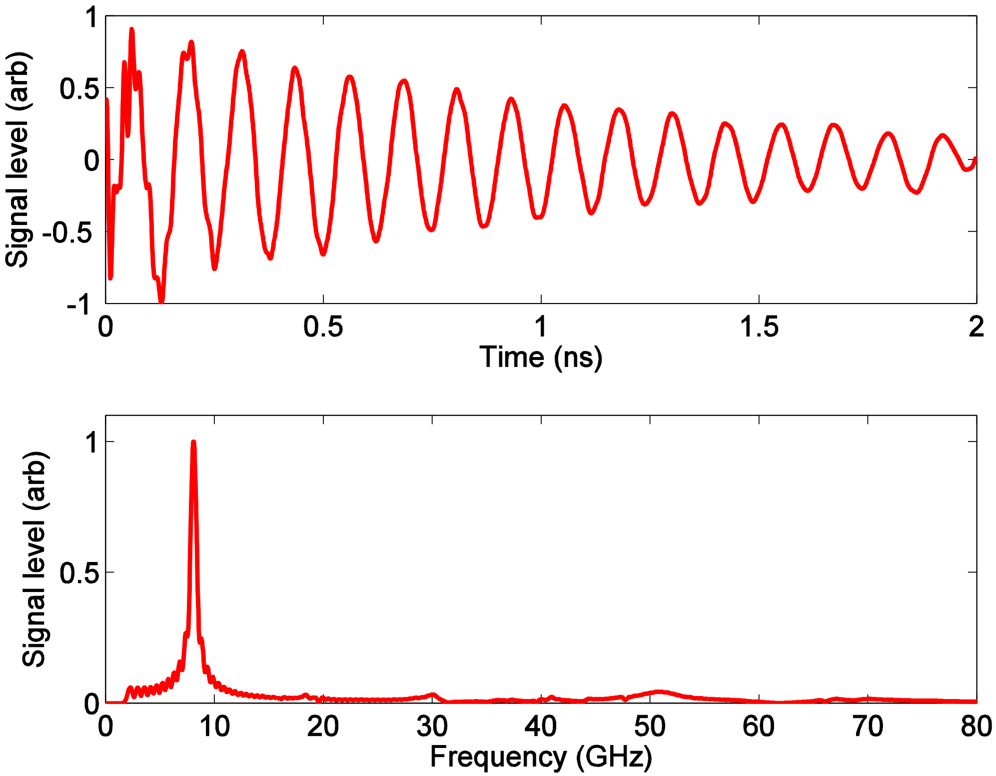
Au:ITO:Au on glass (31:160:32 nm)



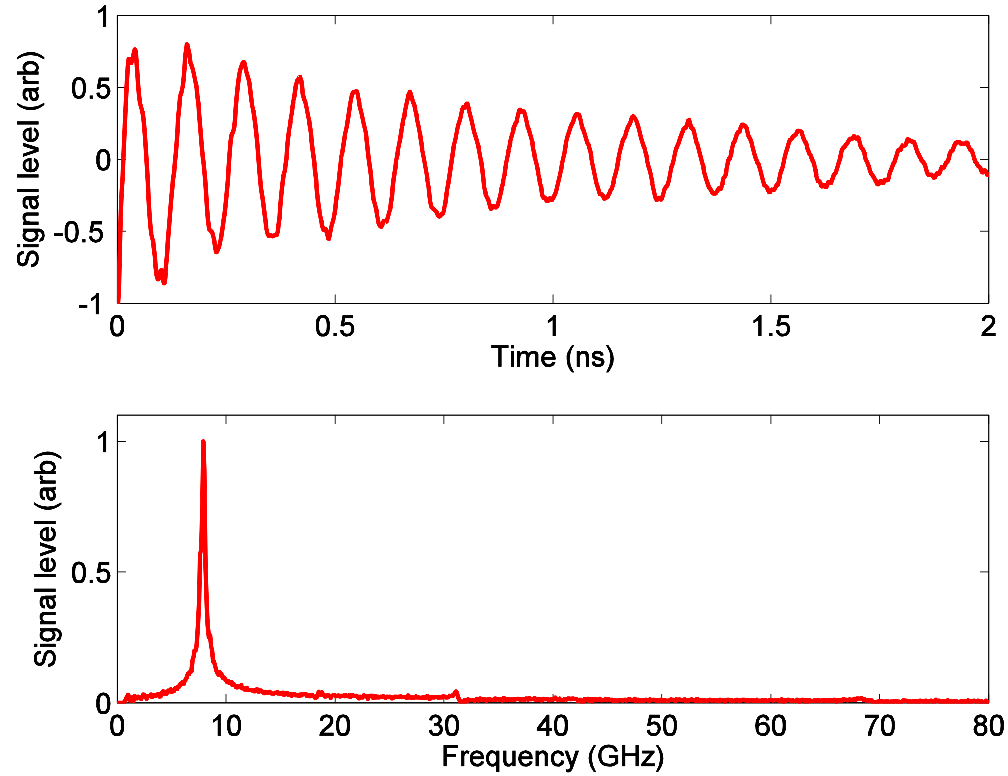
Simulation

Experiment

Au:ITO:Au on polymer on glass (31:160:32 nm)

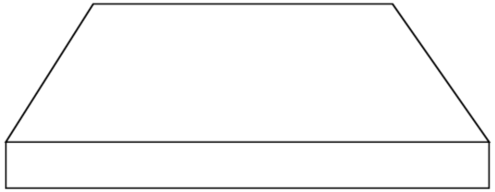


Simulation



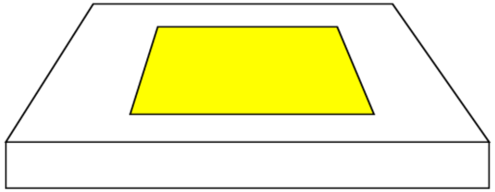
Experiment

Protein sensing



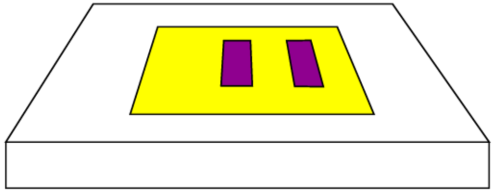
Protein imaging / sensing

Protein sensing



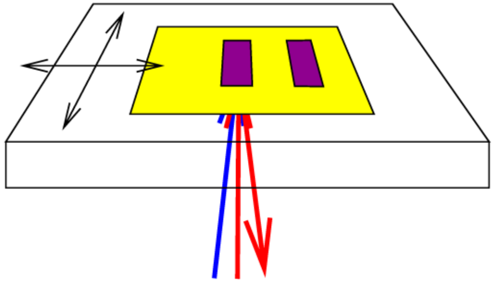
Deposit transducers

Protein sensing



Print protein (bovine serum albumin ~66kDaMW)

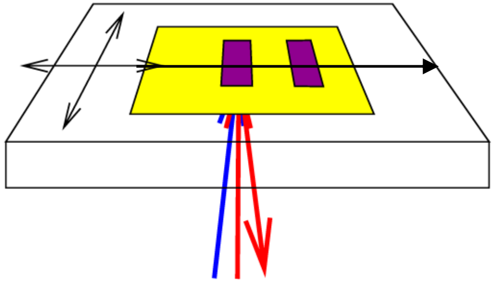
Protein sensing

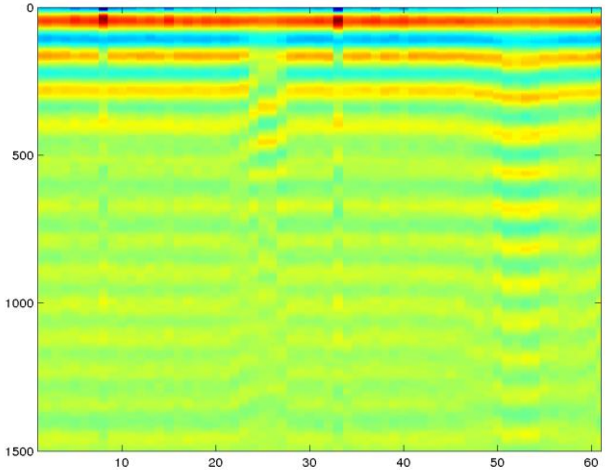


Probe protein ultrasonically from below

Scan sample

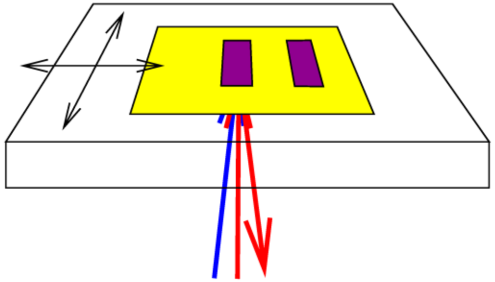
Protein sensing





Protein shifts frequency by mass-loading top surface

Protein sensing



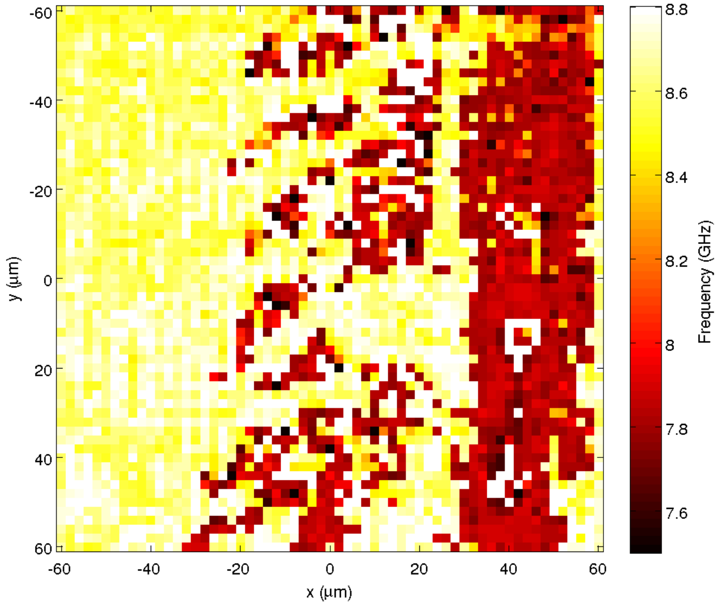
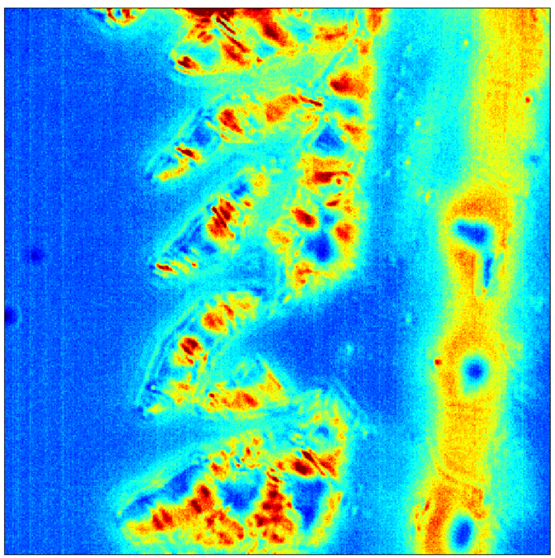
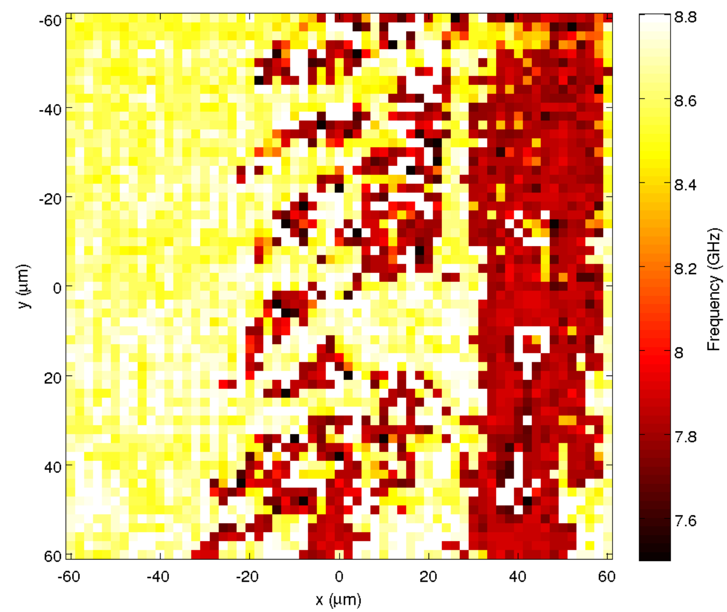


Image protein by plotting f-shift

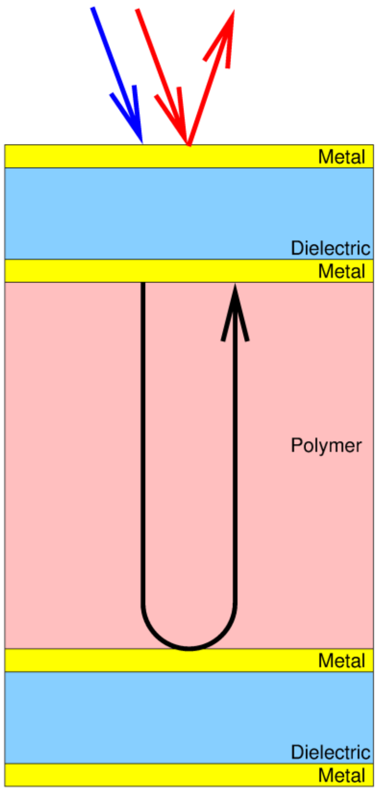
Protein sensing





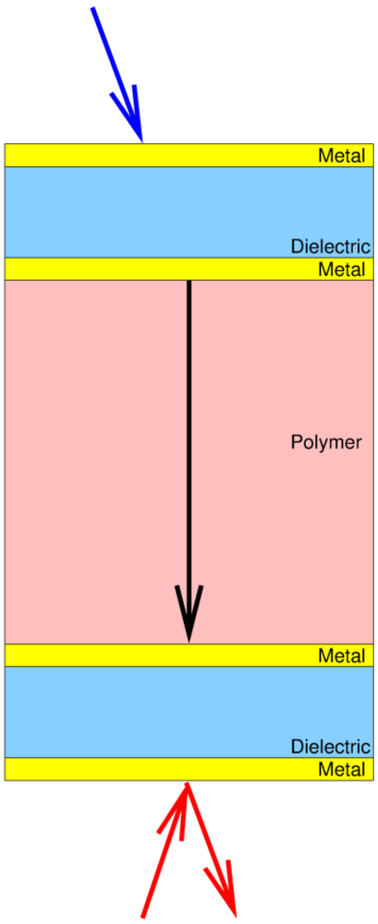
Comparison with optical micrograph from top surface

Pulse-echo / pitch-catch



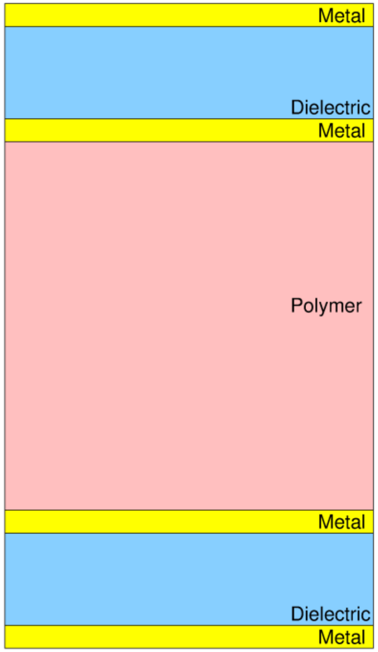
Use in pulse-echo mode

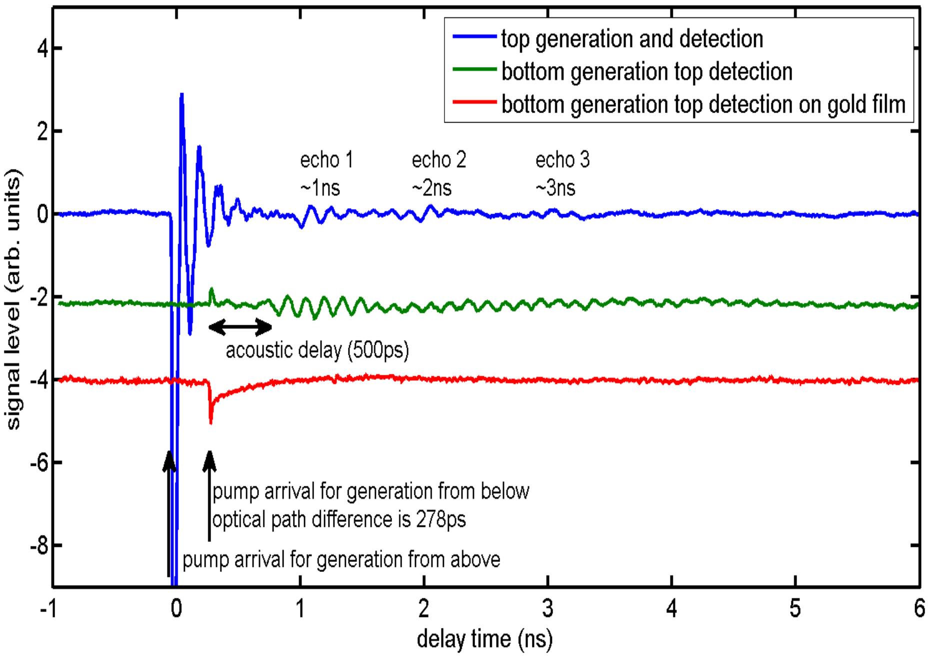
Pulse-echo / pitch-catch



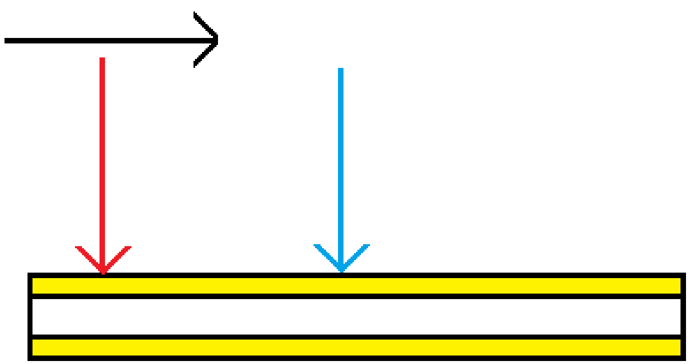
Use in pitch-catch mode

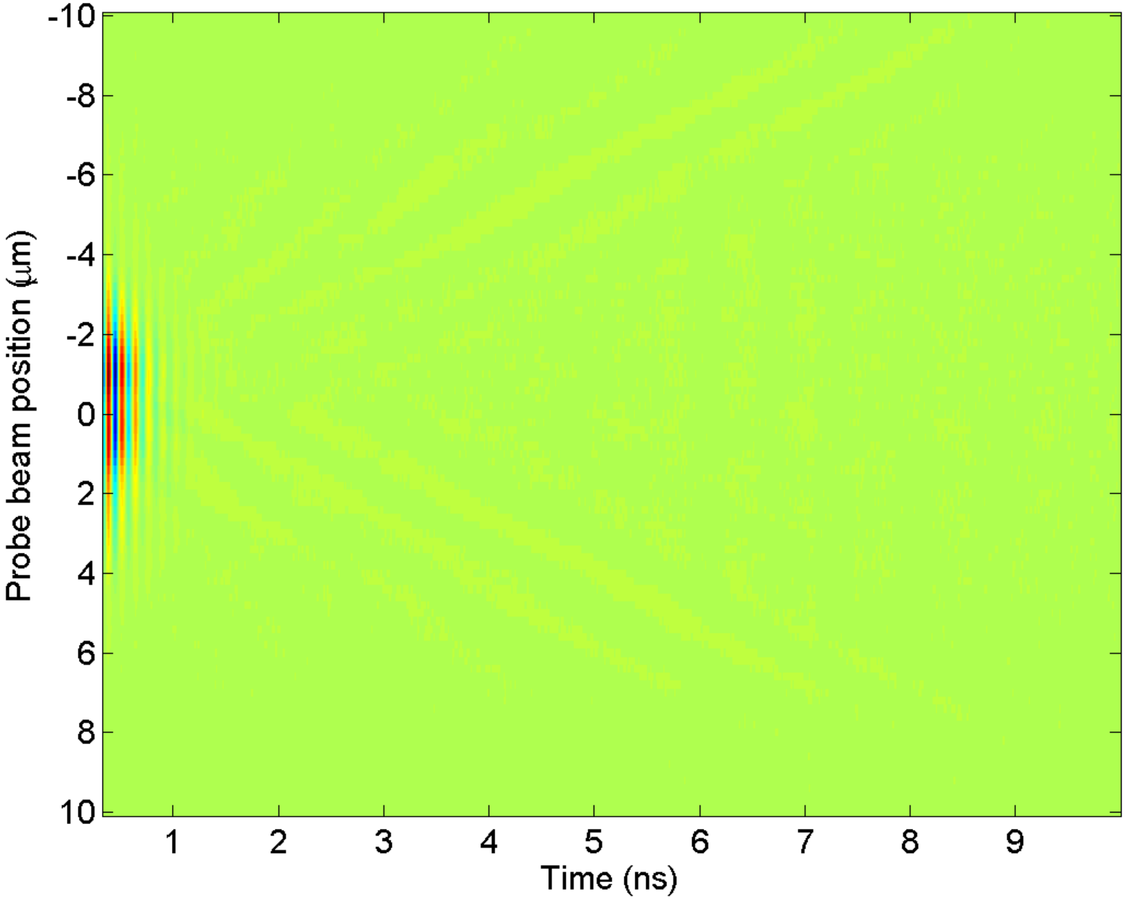
Pulse-echo / pitch catch

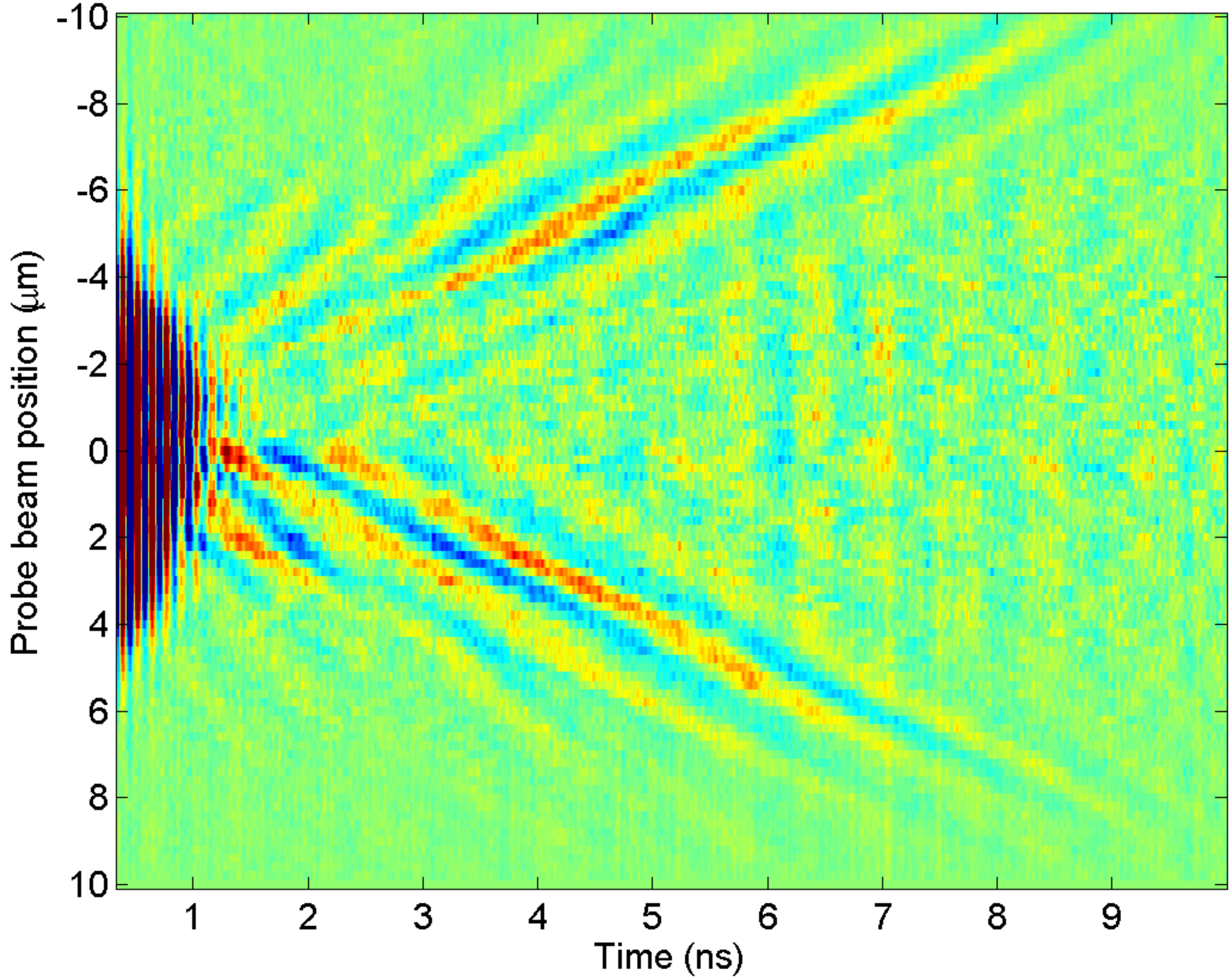




Other modes …

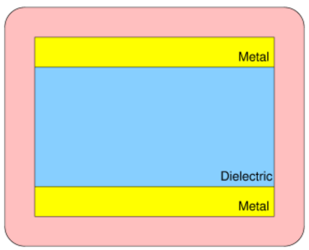




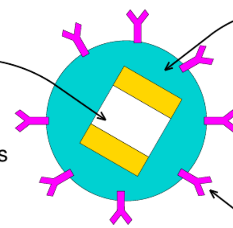


-10
-8
-6
-4
-2
0
2
4
6
8
10
Probe beam position (μm)
1
2
3
4
5
6
7
8
9
Time (ns)

Where we are headed…

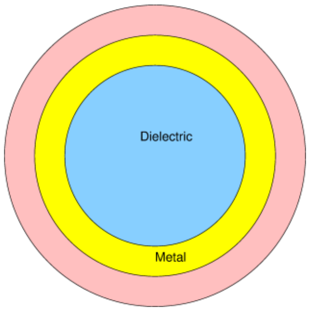


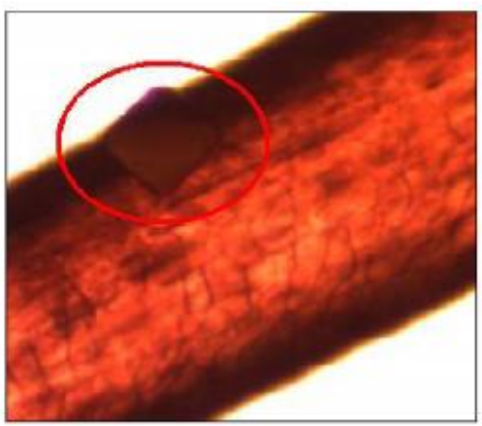
Bar coding
- internal structure
- optically engineered
- switchable properties
- bridging
- addressing

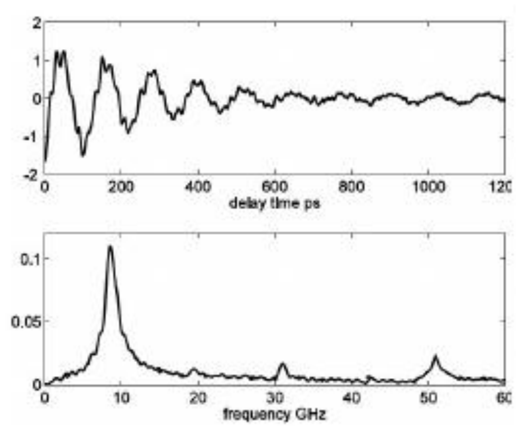


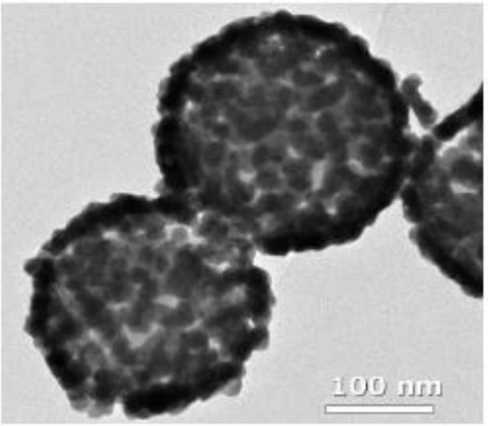
Active payload
- drug / DNA / signals
- disruptable core
- targeted /controlled release

Functionalisation
- sensing
- location + delivery
- interface









Conclusion

We are interested in ultrasonics at the micro / nano scale
Picosecond lasers + transducers → SNR → imaging
Presented basic experiments show the transducers work
Applications to chemical sensing and cell imaging

Next:
P-C/P-E cell imaging
Higher resolution

The University of Nottingham
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Acknowledgements

Funders:
EPSRC Platform Grant EP/G061661/1
EPSRC Challenging Engineering EP/K021877/1
RR Aeroengines

Laboratory:
Matt, Fernando, Leo,
Teti, Victoria, Steve,
Kevin, Rikesh

CONACYT
Consejo Nacional de Ciencia y Tecnología

Finally...

Thanks for listening...

Any questions?