Imaging Around Corners
With Ultrasound

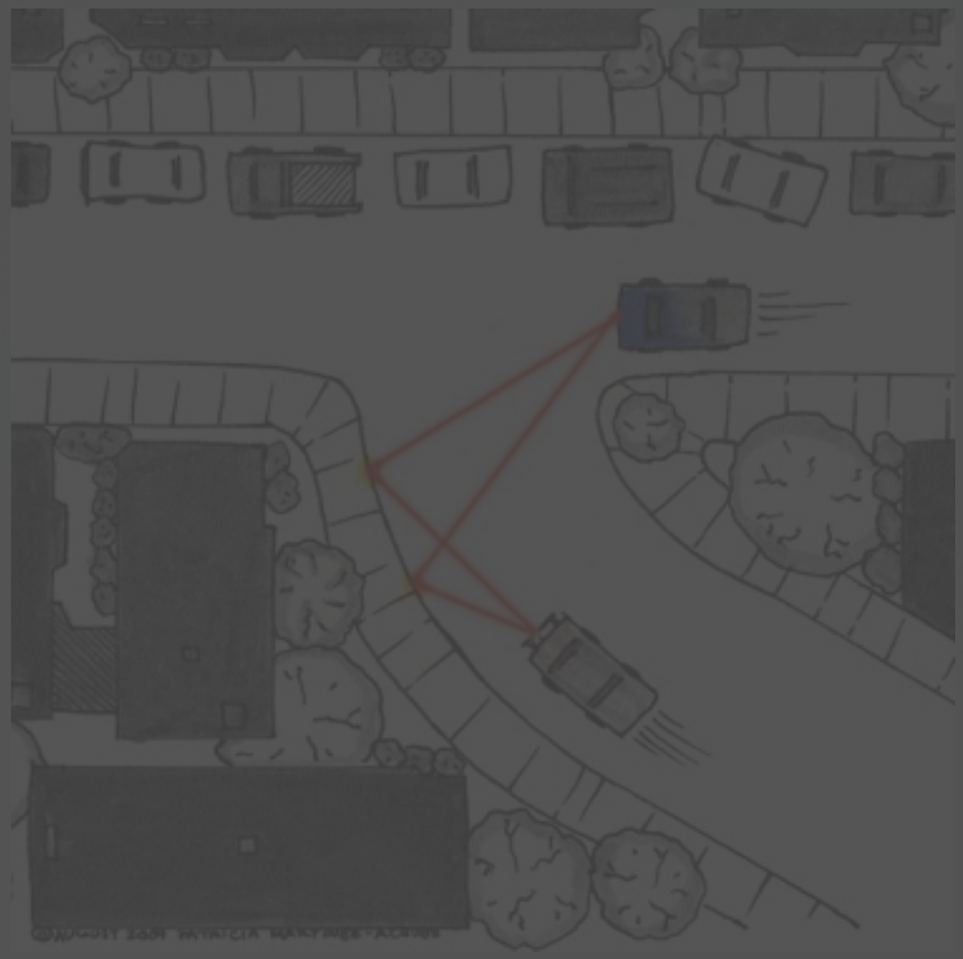
Biyeun Buczyk

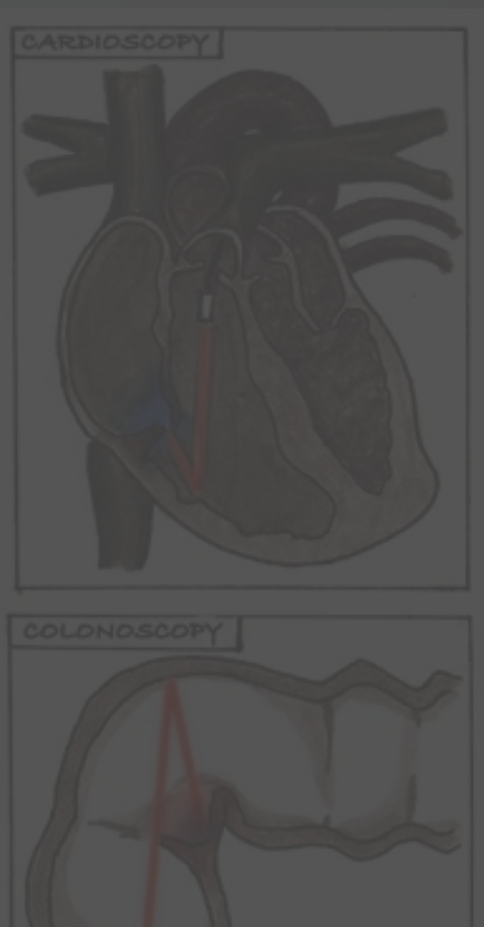
Hallway Ambush

Hallway Ambush

The hallway is deserted. The office...too quiet.

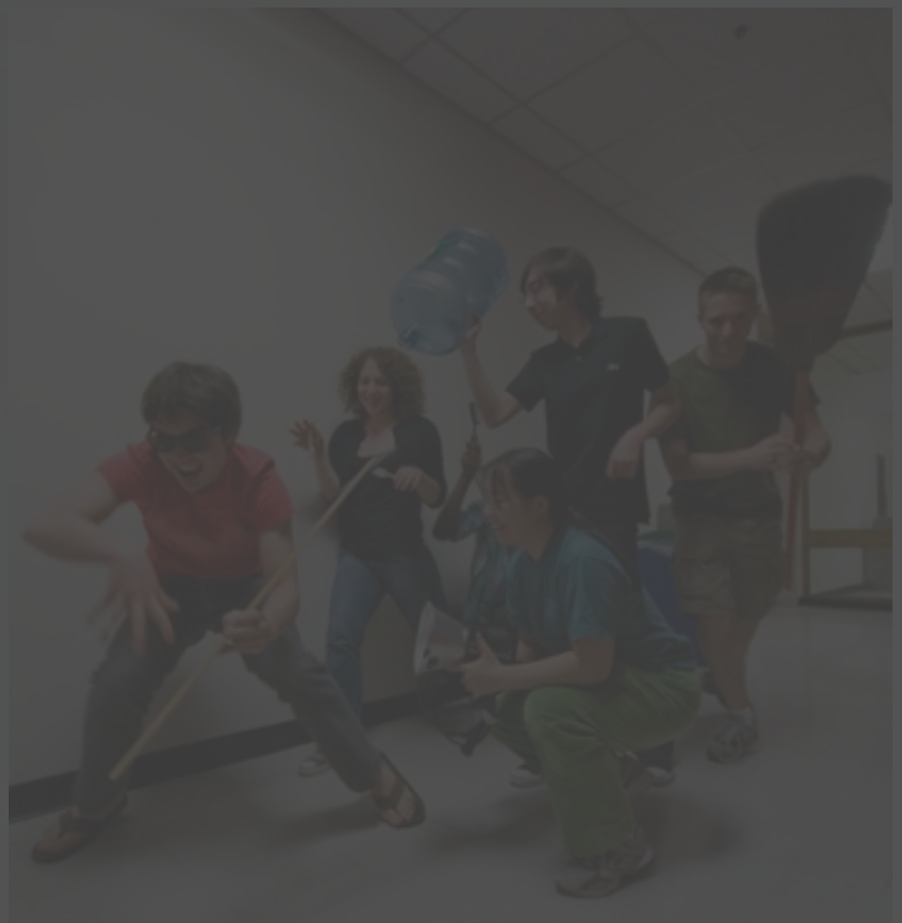
Ambush avoidance: Turn the wall into a ‘mirror.’

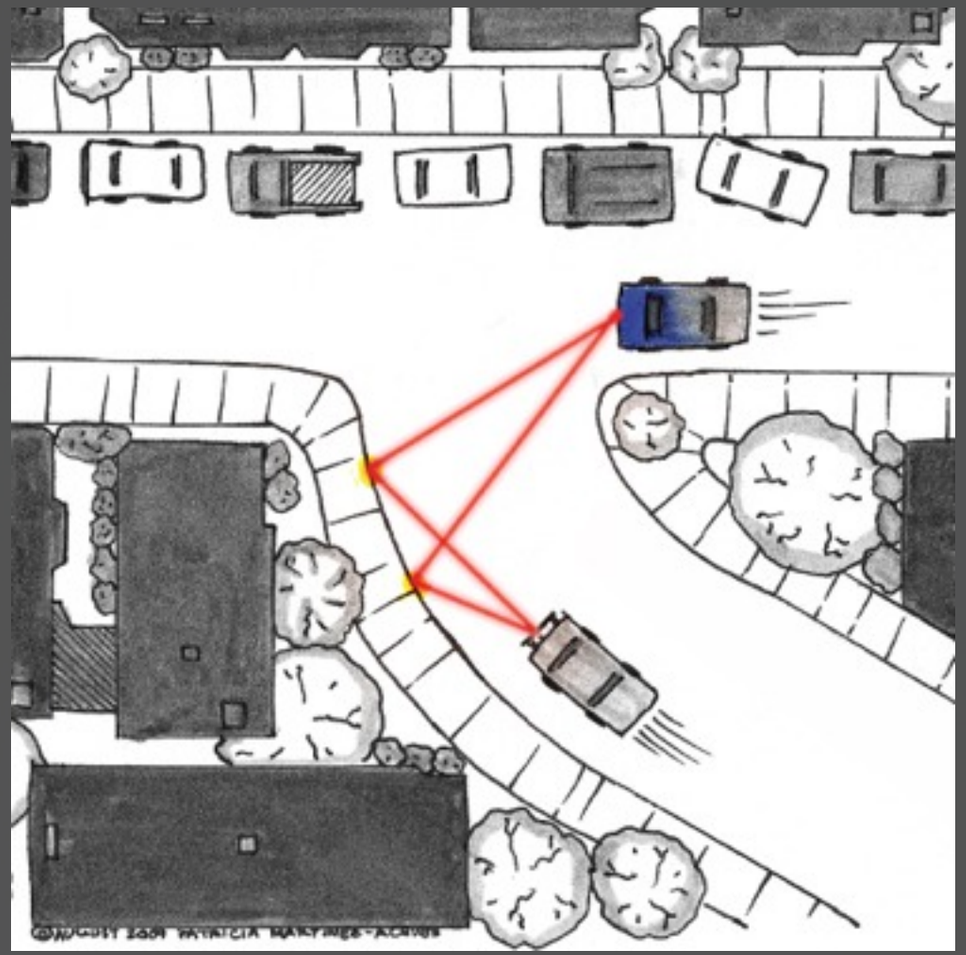


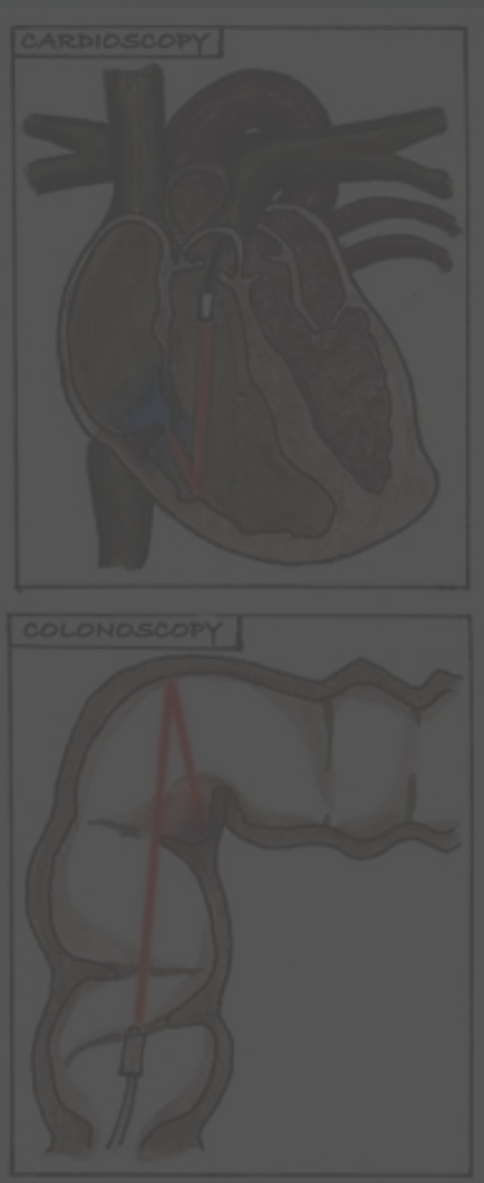


Femtosecond Transient Imaging

A. Kirmani,
T. Hutchison, J. Davis,
R. Raskar







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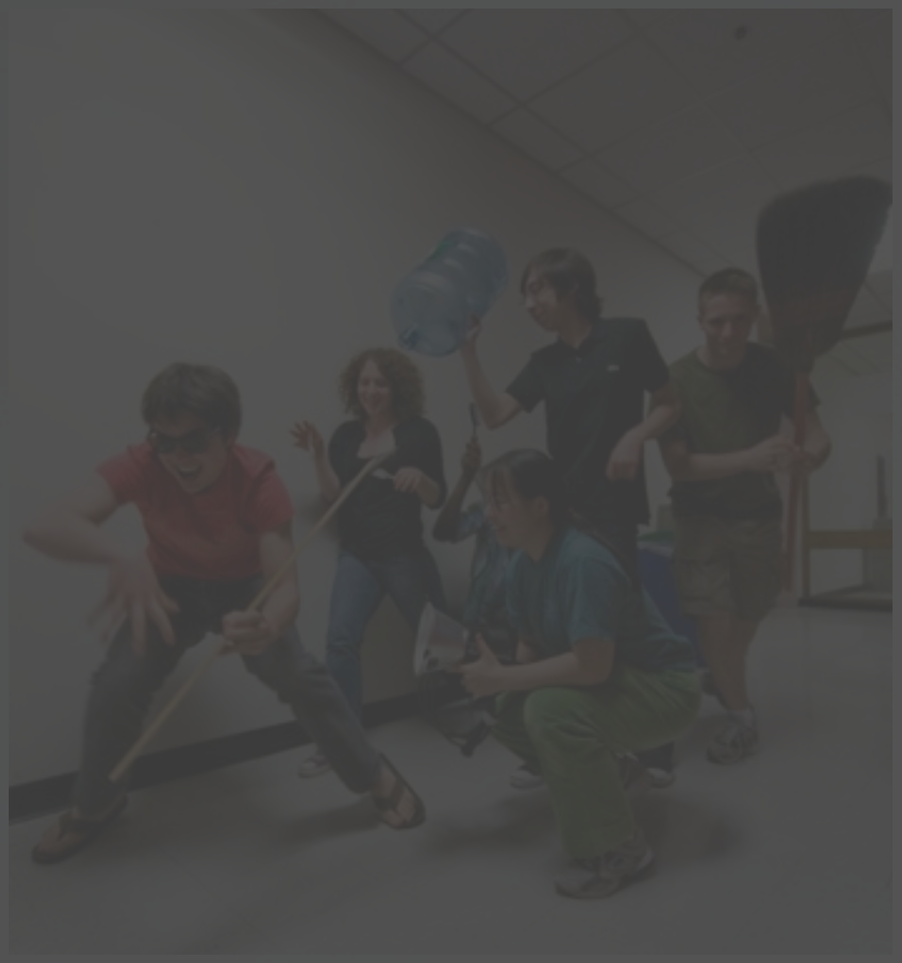

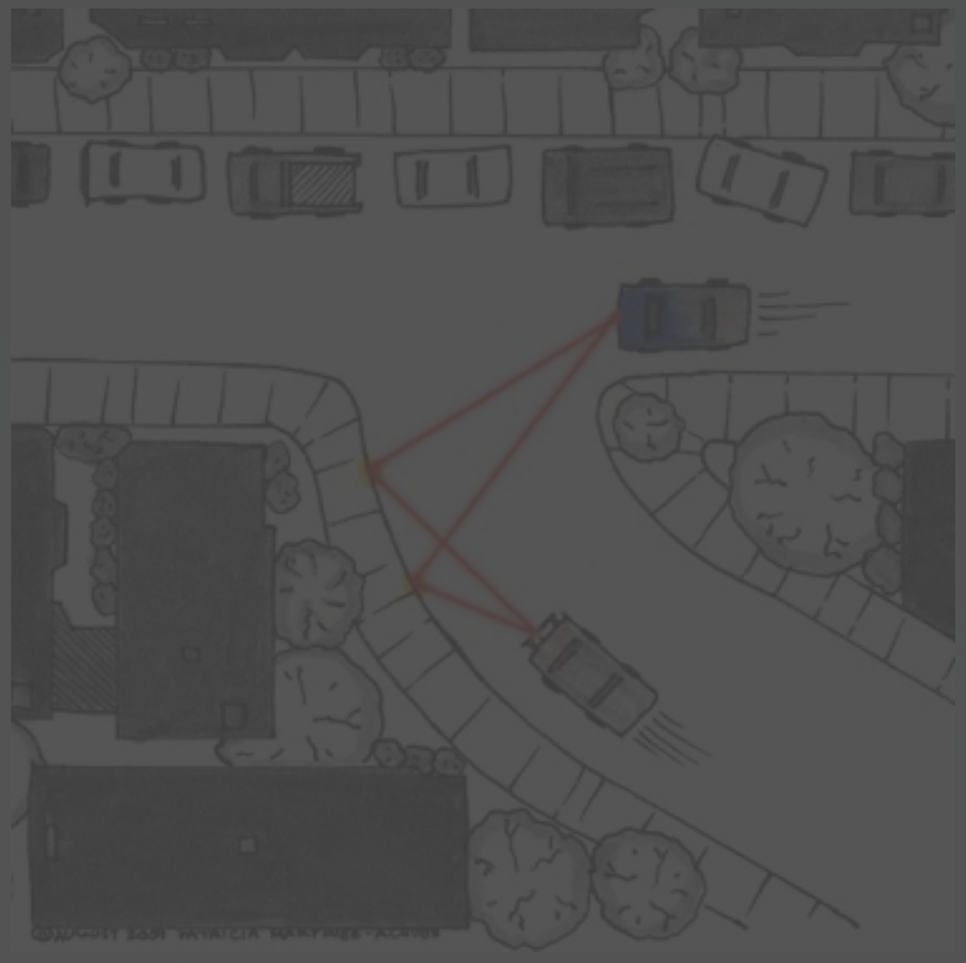

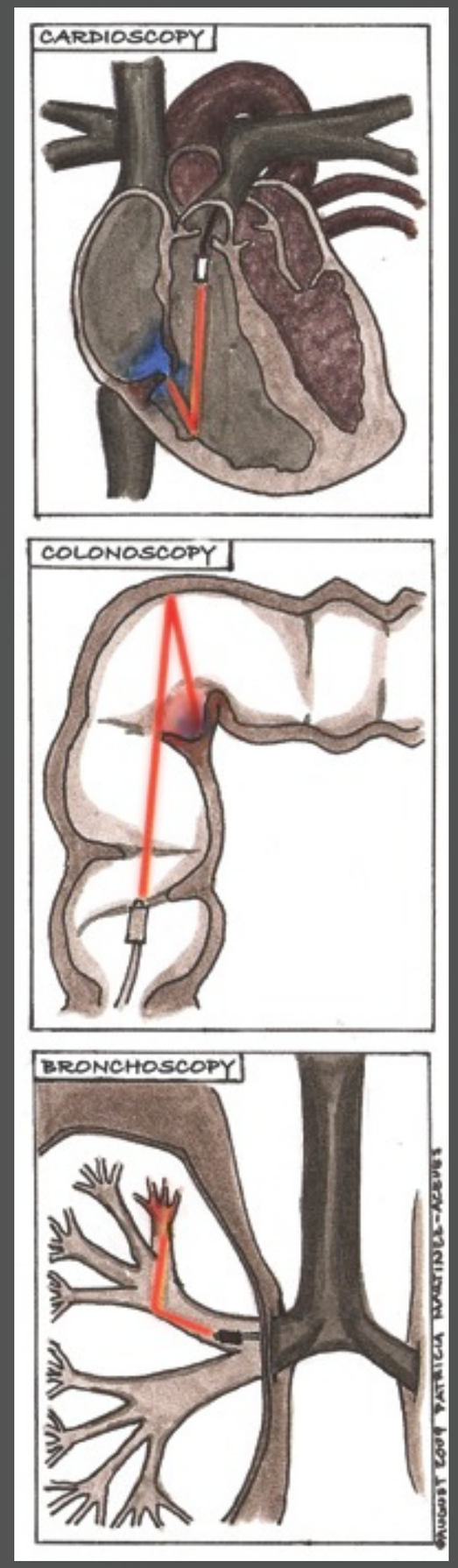

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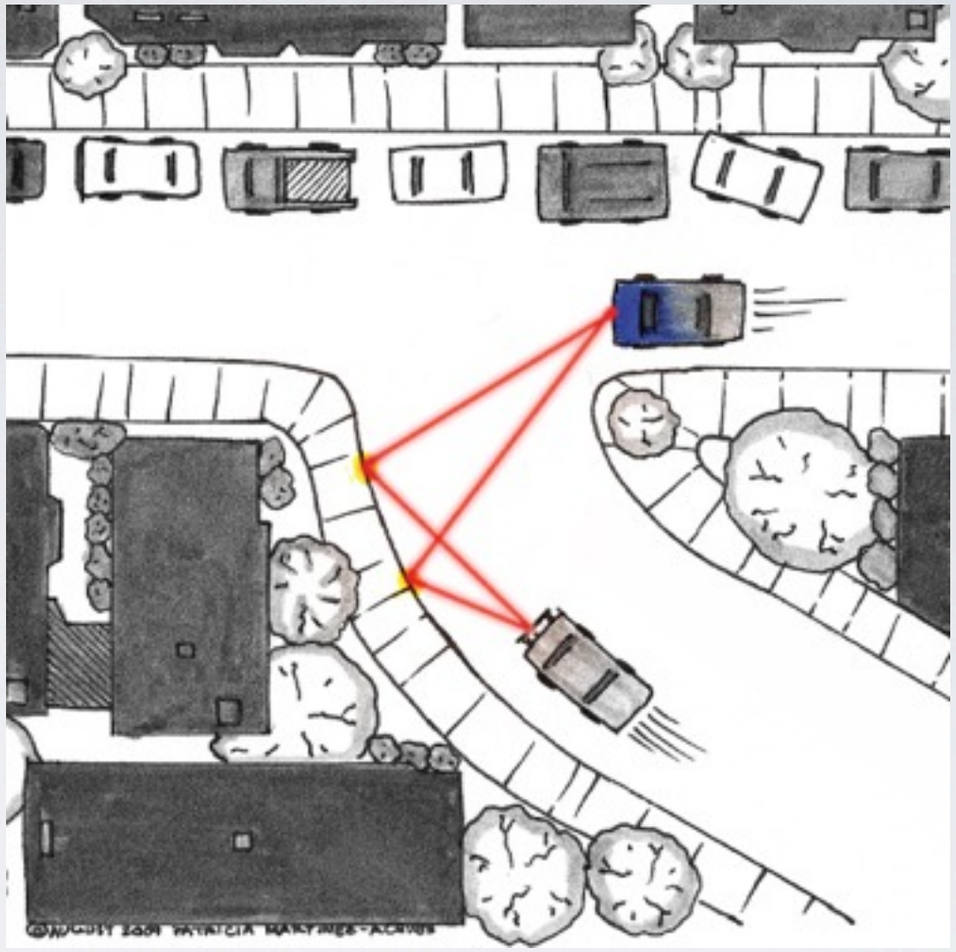

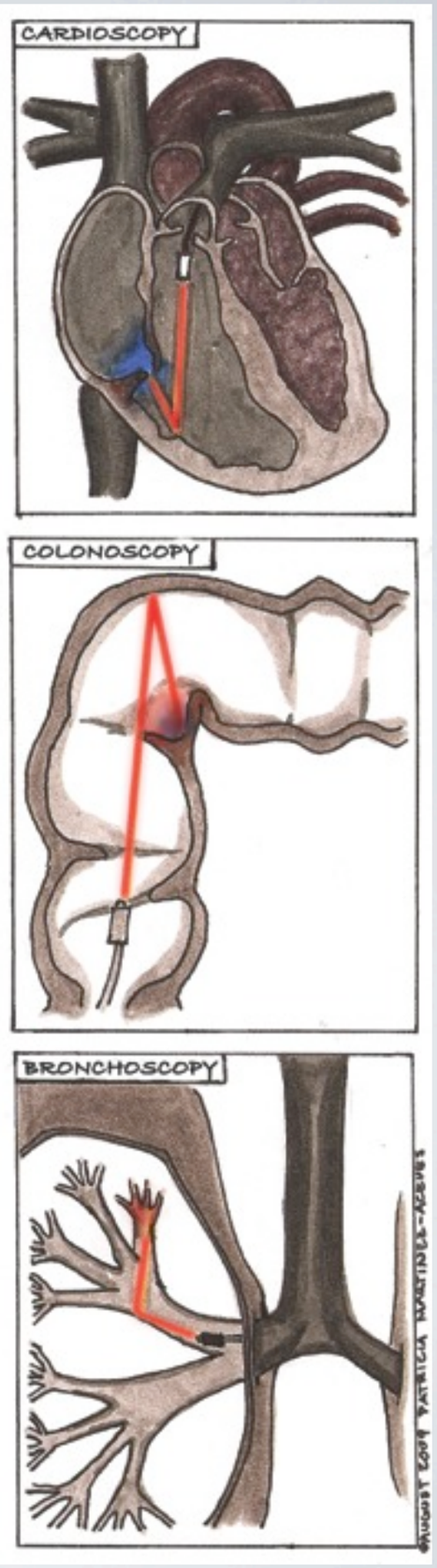

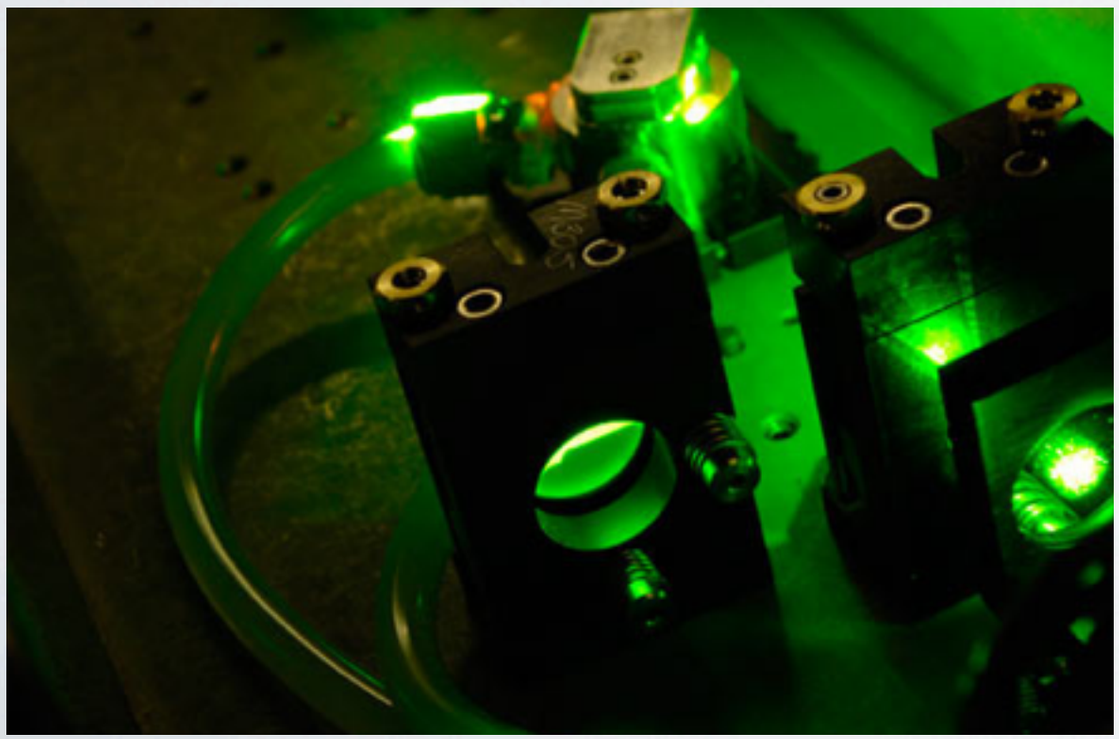

Femtosecond Transient Imaging

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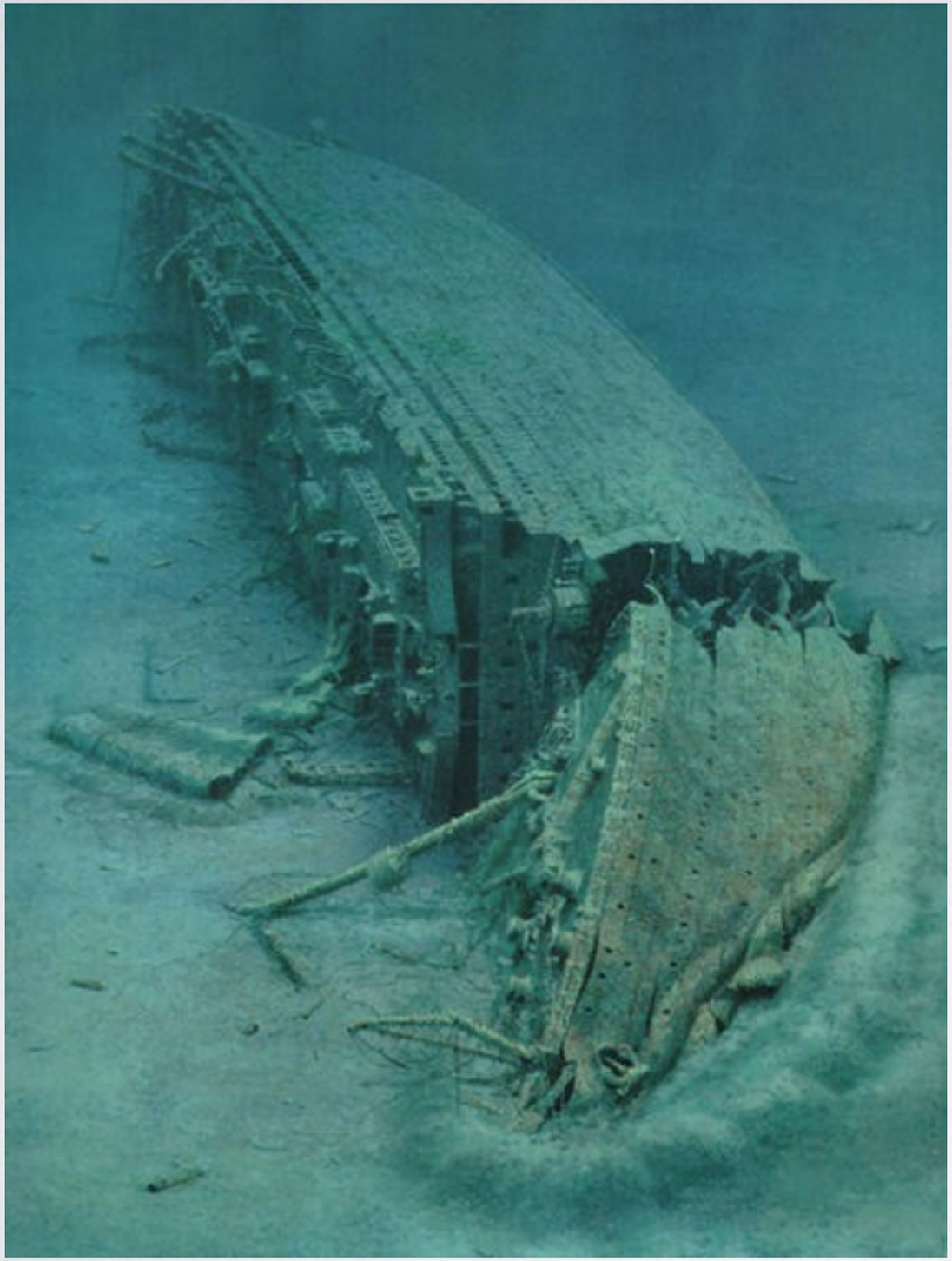


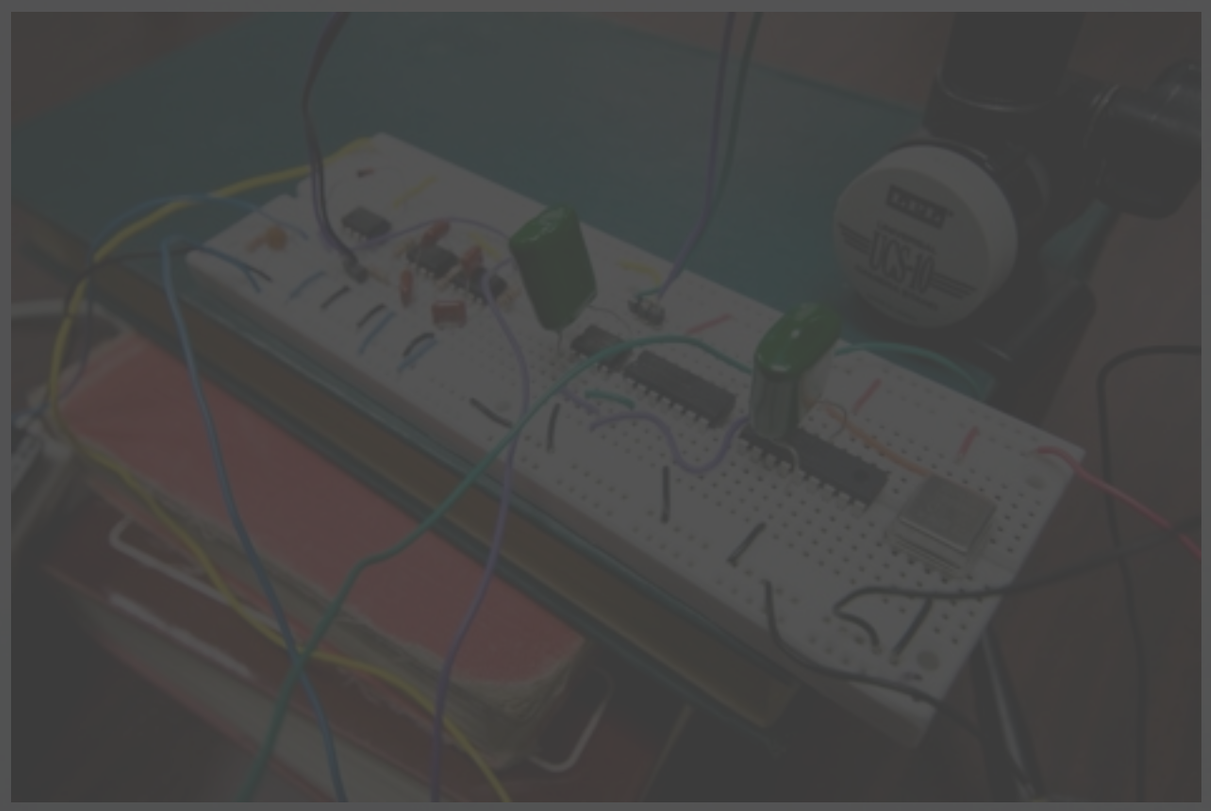
Photo by Ken Marschall

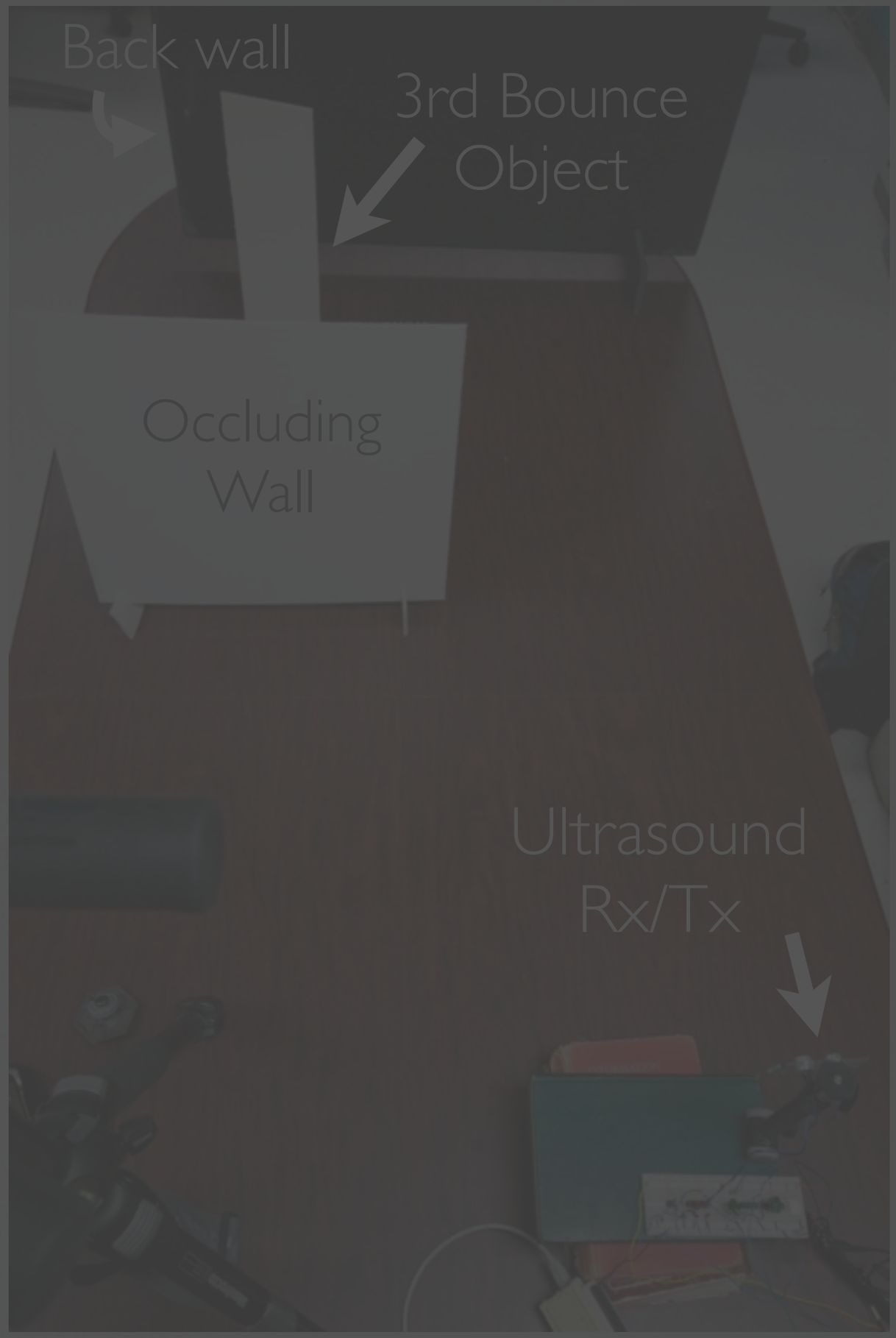
Ultrasound Transient Imaging

- Image underwater
- Eye safe
- Body safe
- More intensity, less power input

The Setup

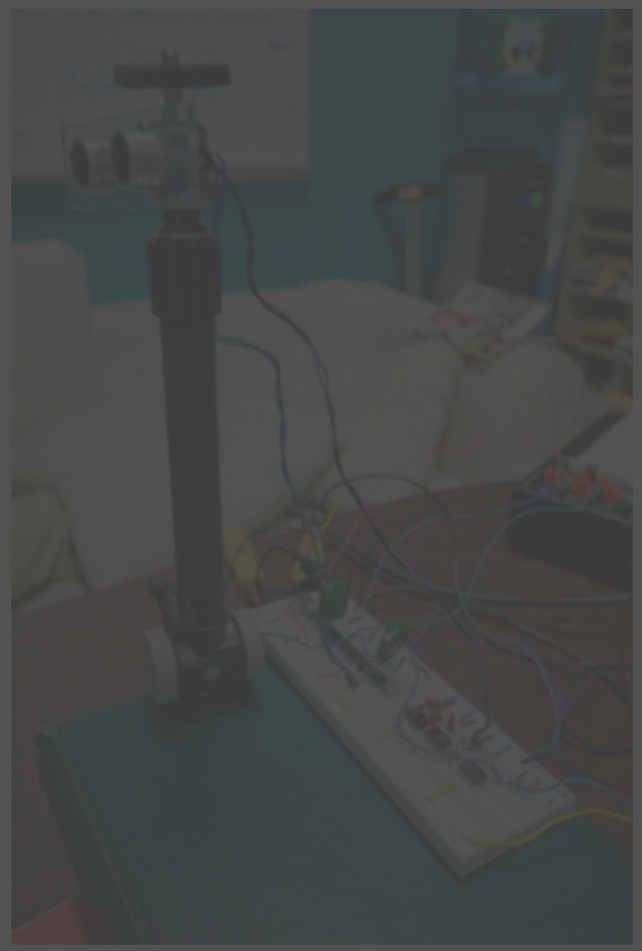
40 kHz transducers

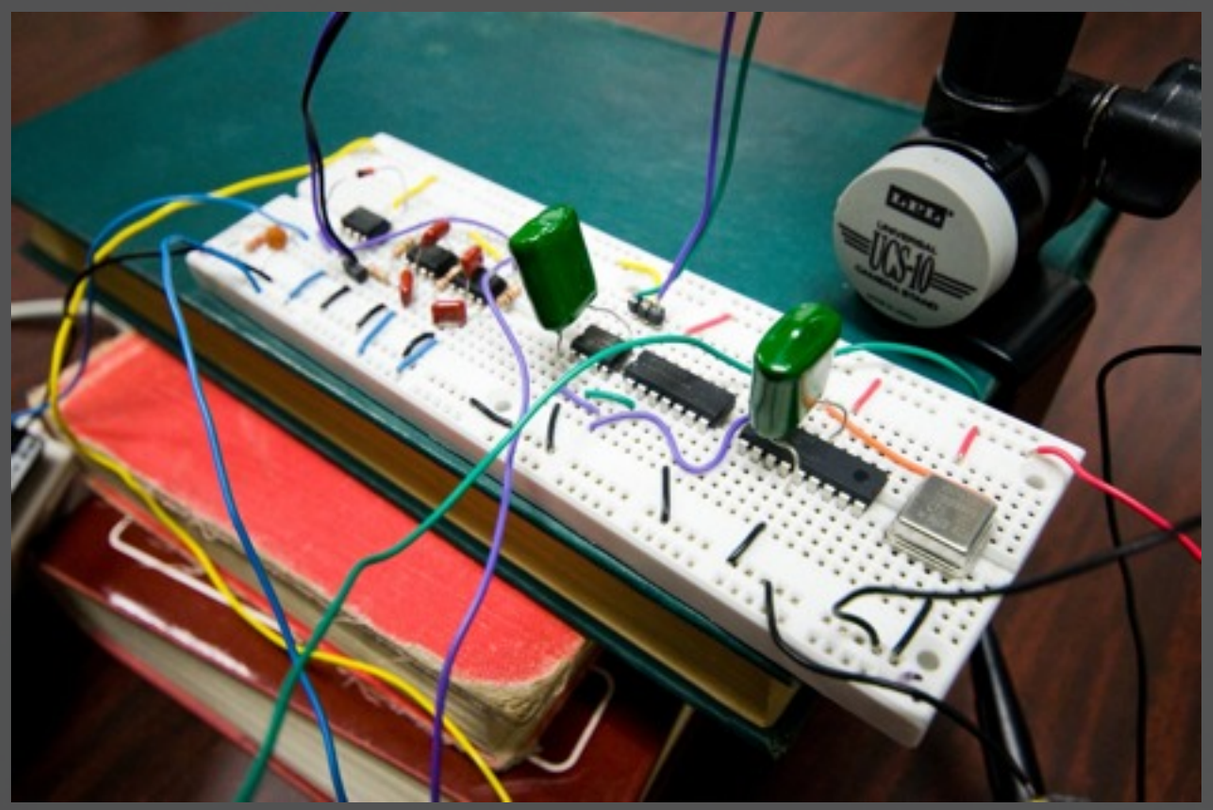


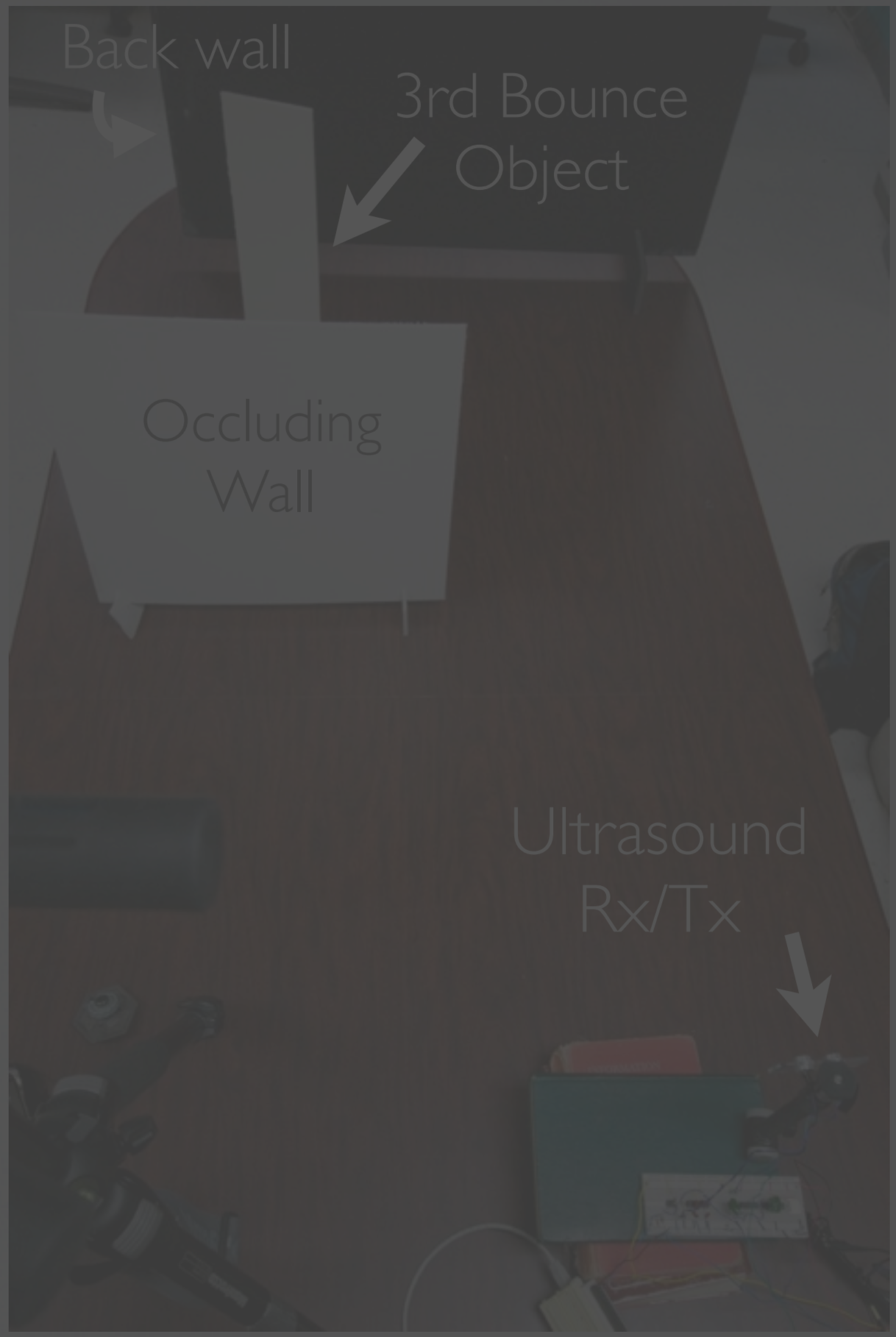


The Setup

40 kHz transducers







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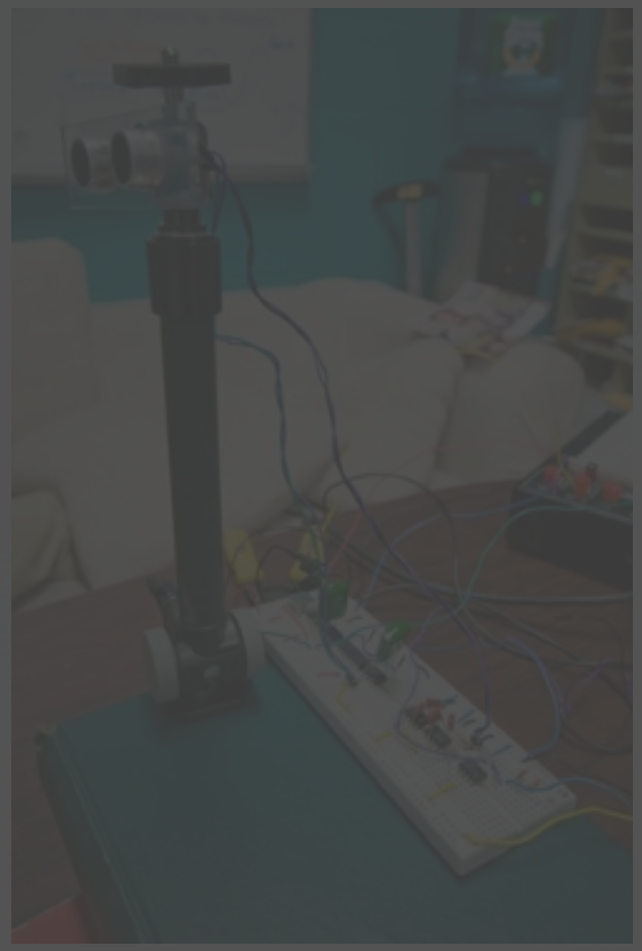
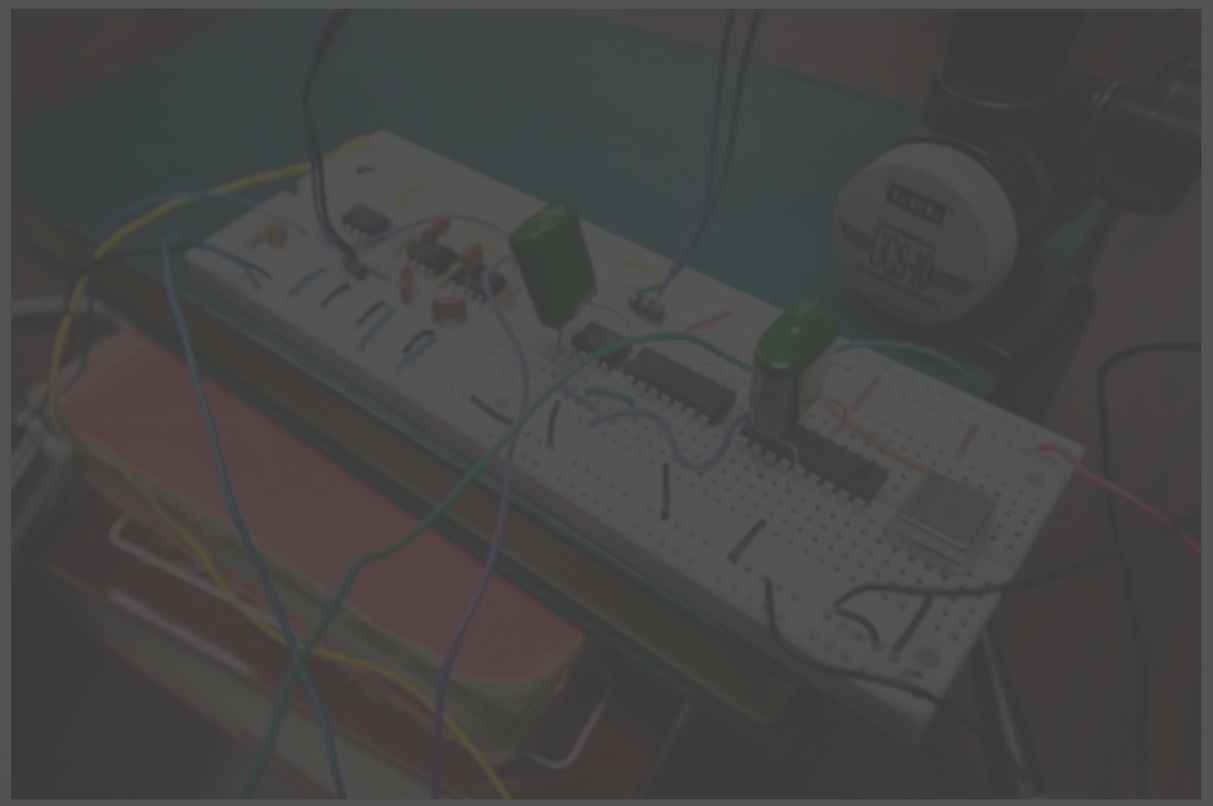
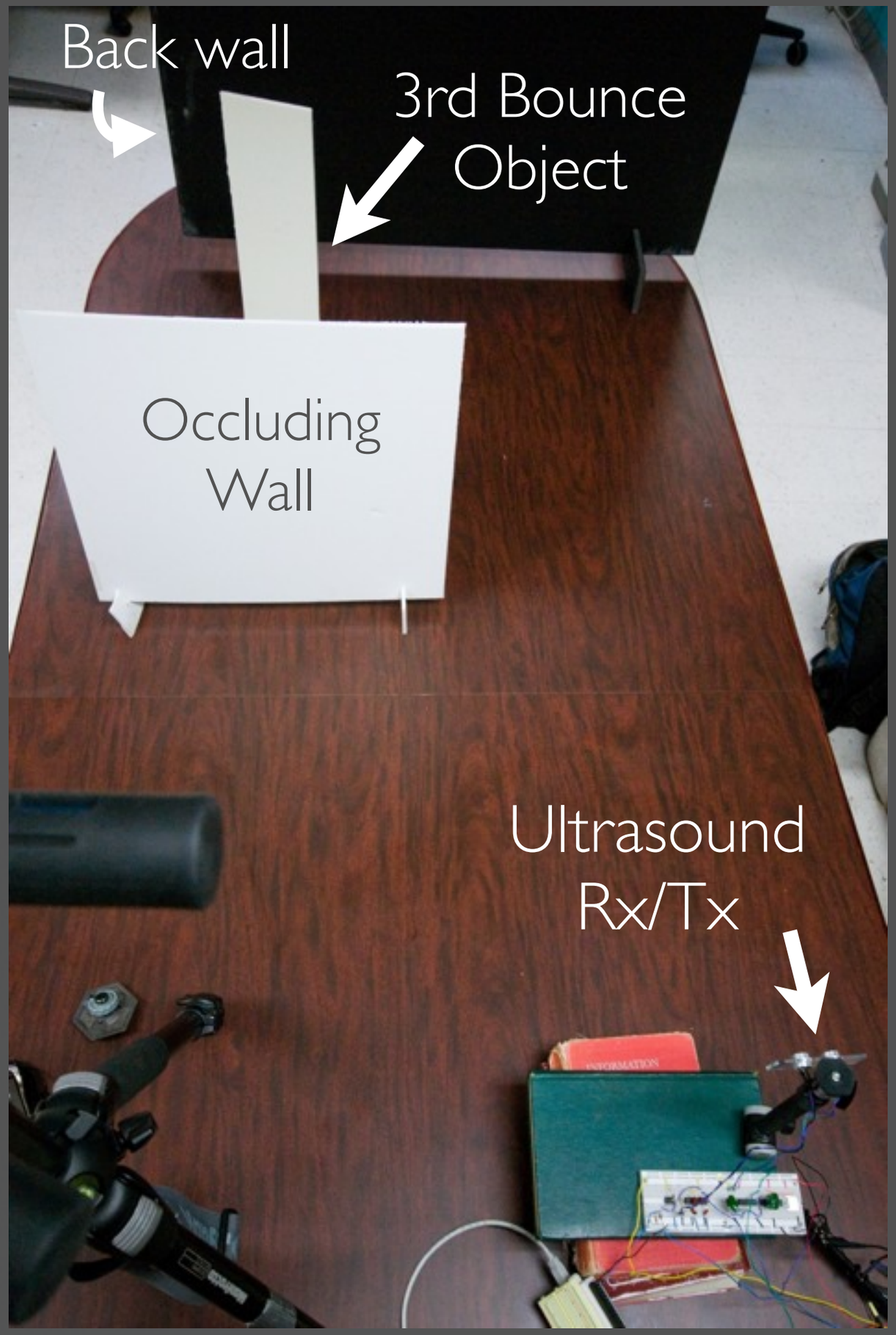
40 kHz transducers

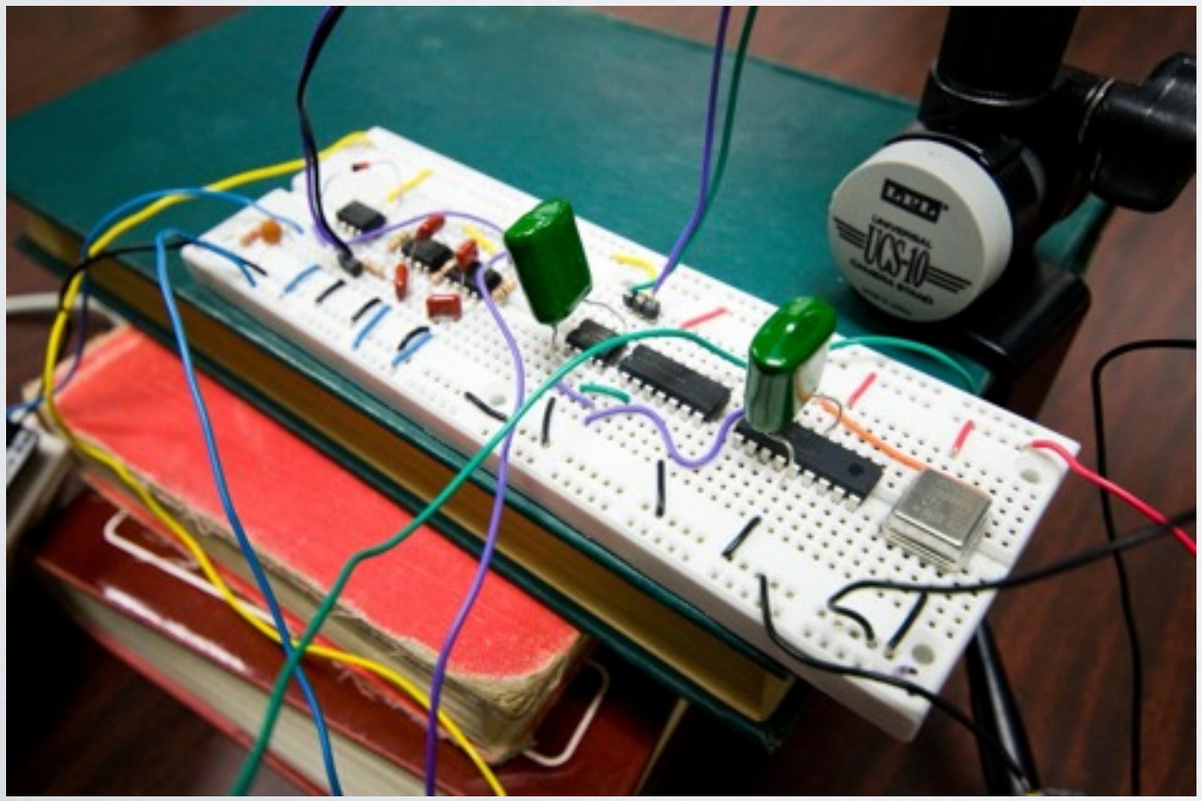


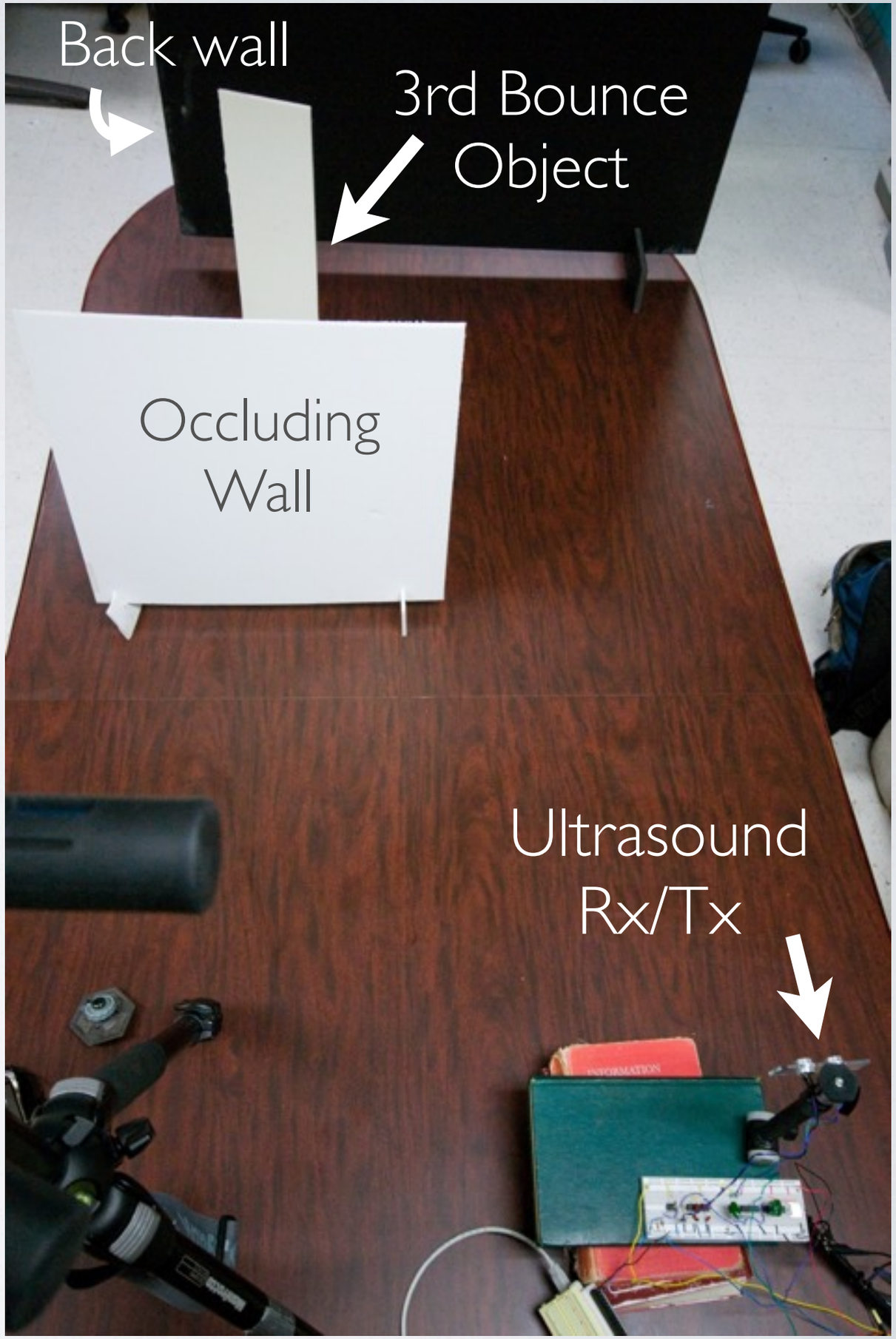




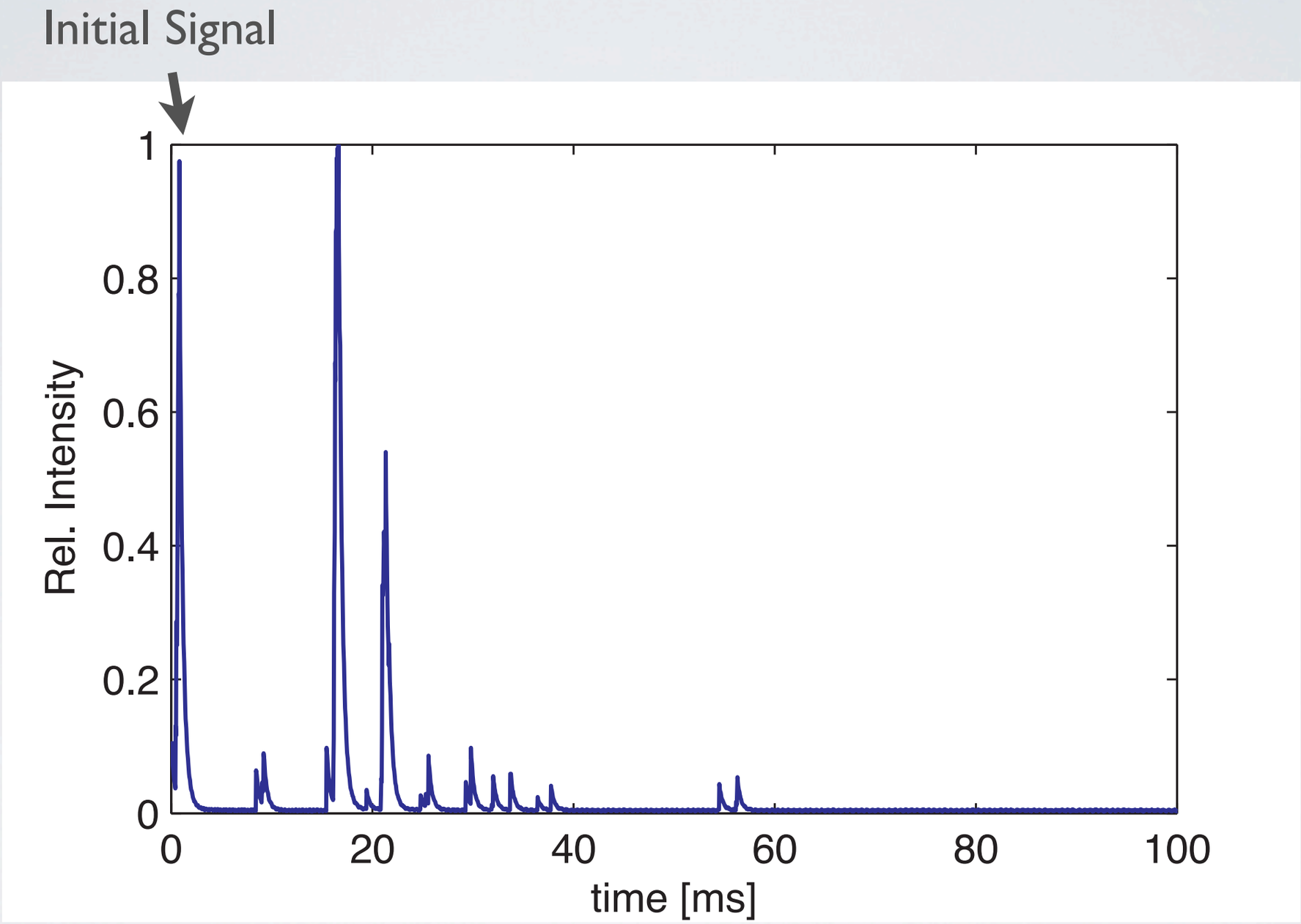
The Setup

40 kHz transducers



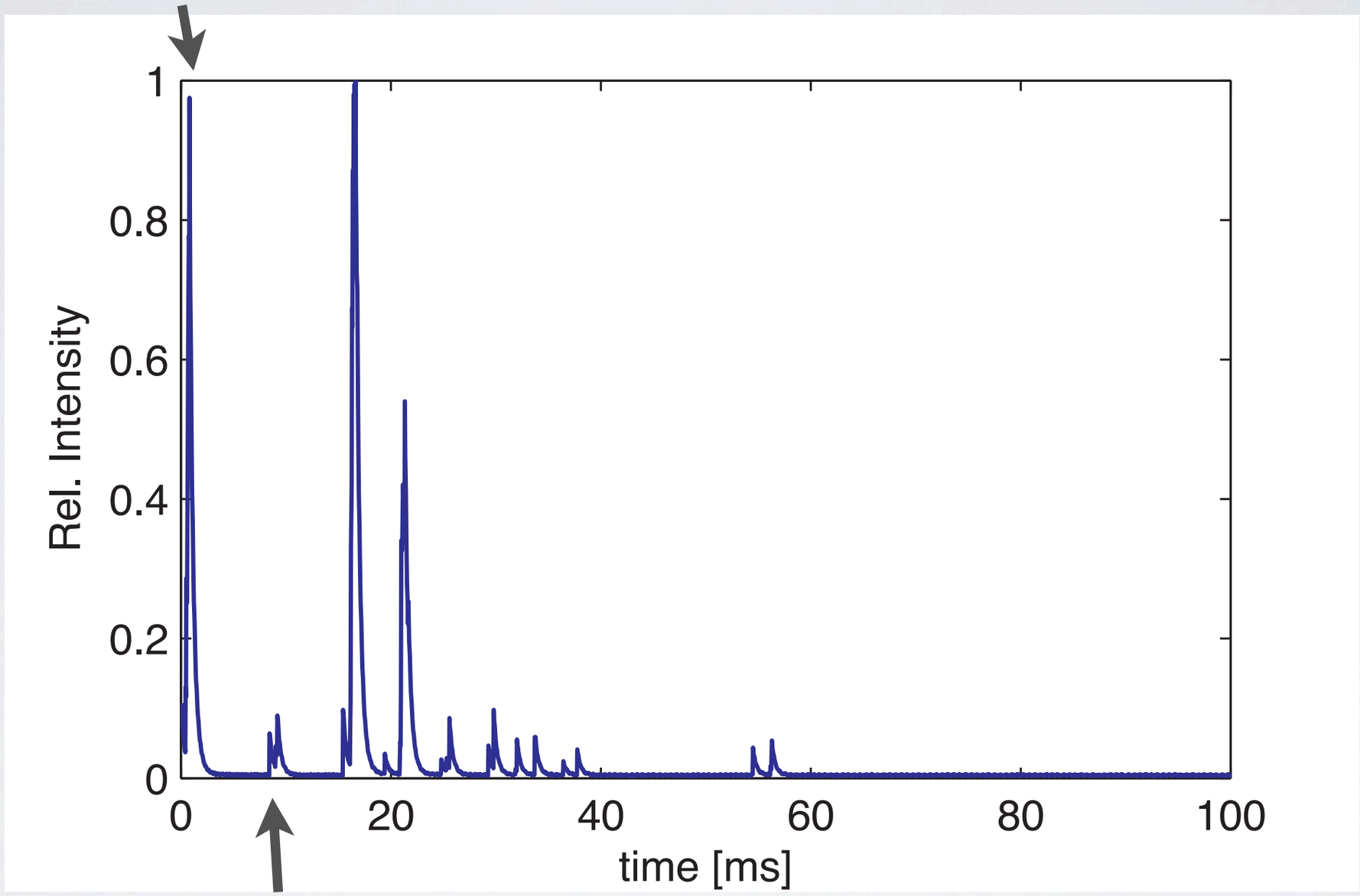


Data


Initial Signal
1
0.8
0.6
0.4
0.2
0
Rel. Intensity
0
20
40
60
80
100
time [ms]

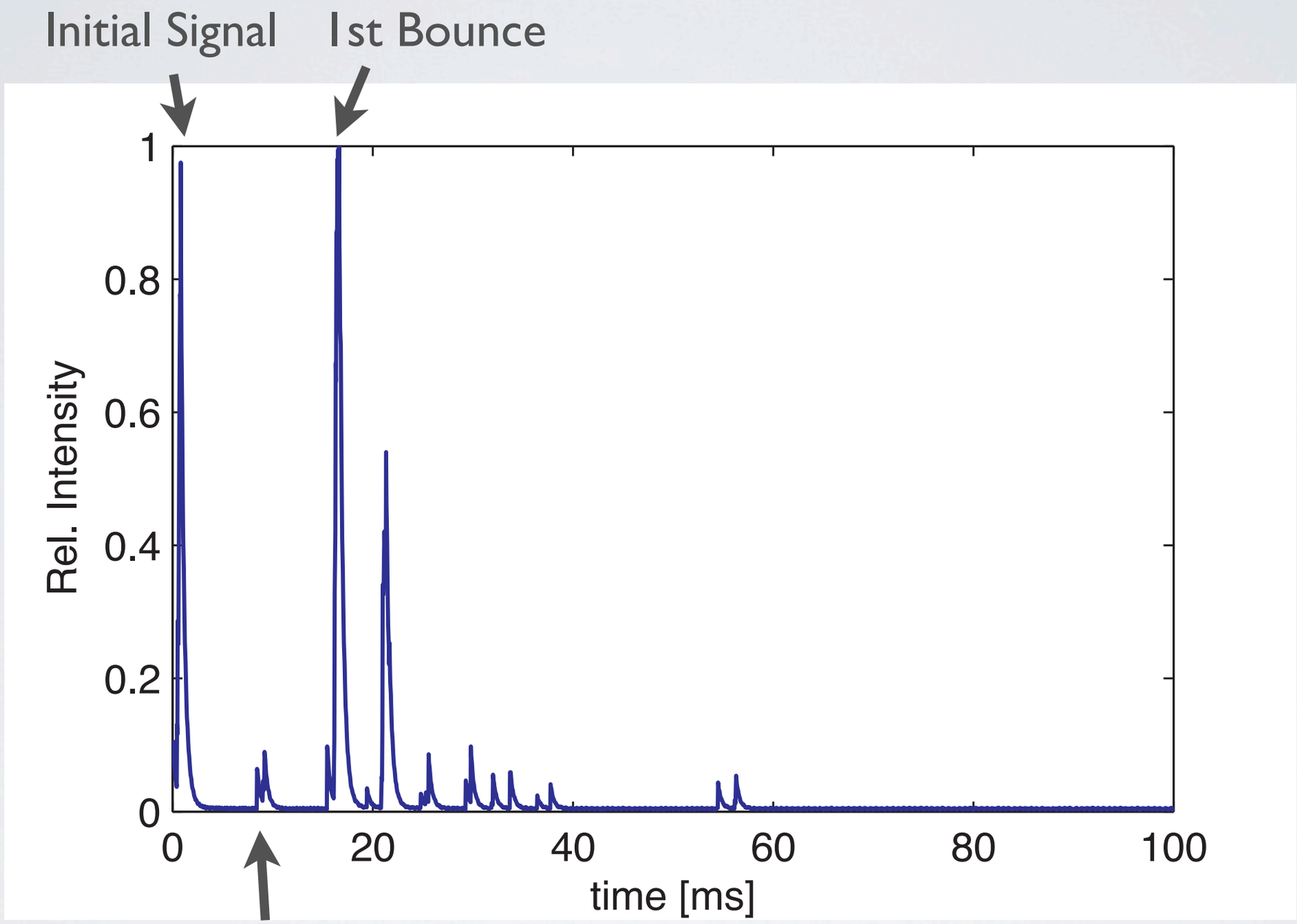
Data

Initial Signal



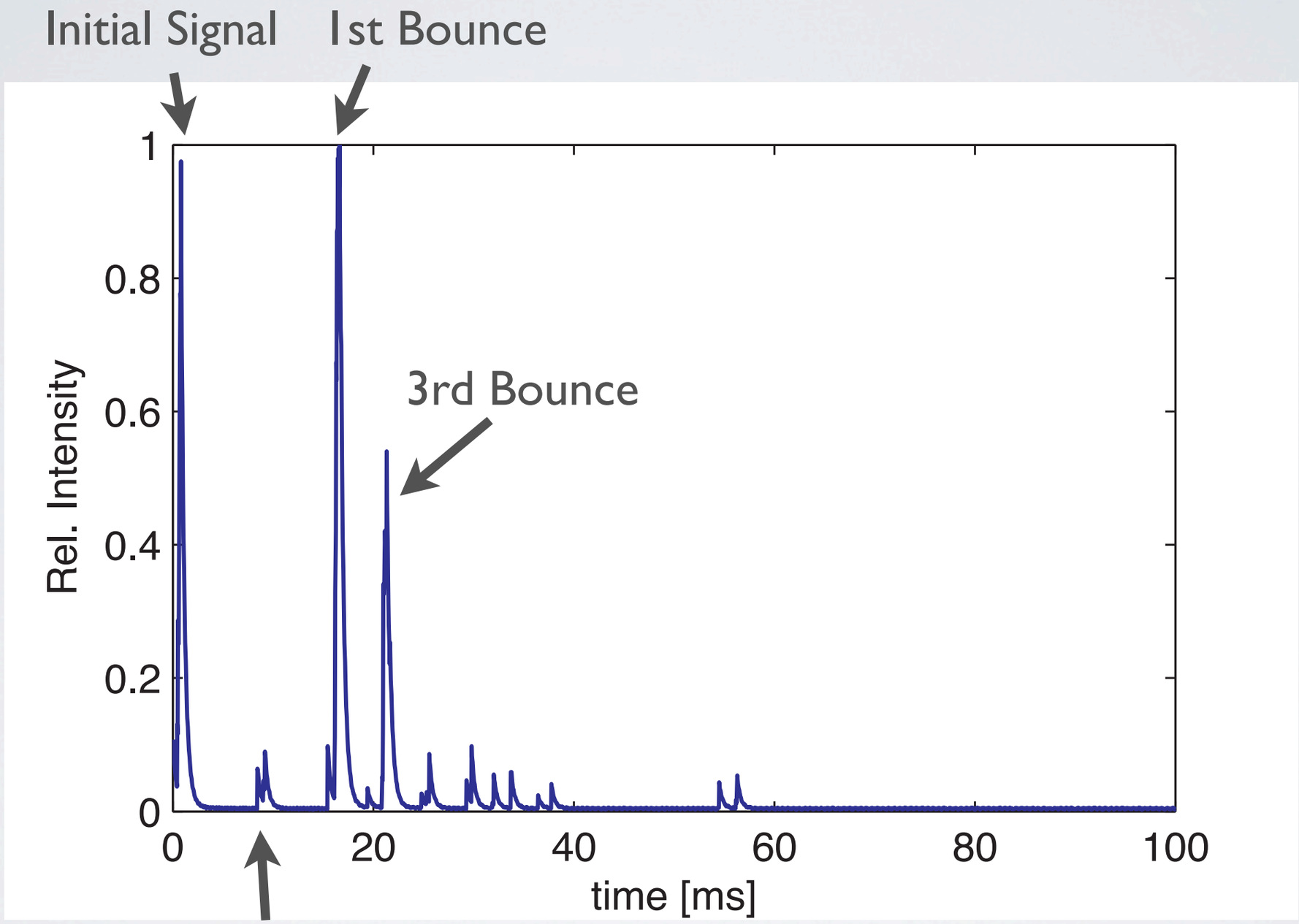
Back of occluding wall

Data



Back of occluding wall

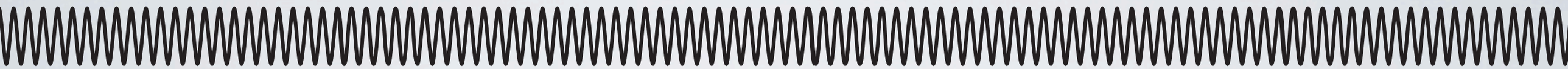
Data



Back of occluding wall

Light

$\lambda \sim 7 \times 10^{-9}$ m

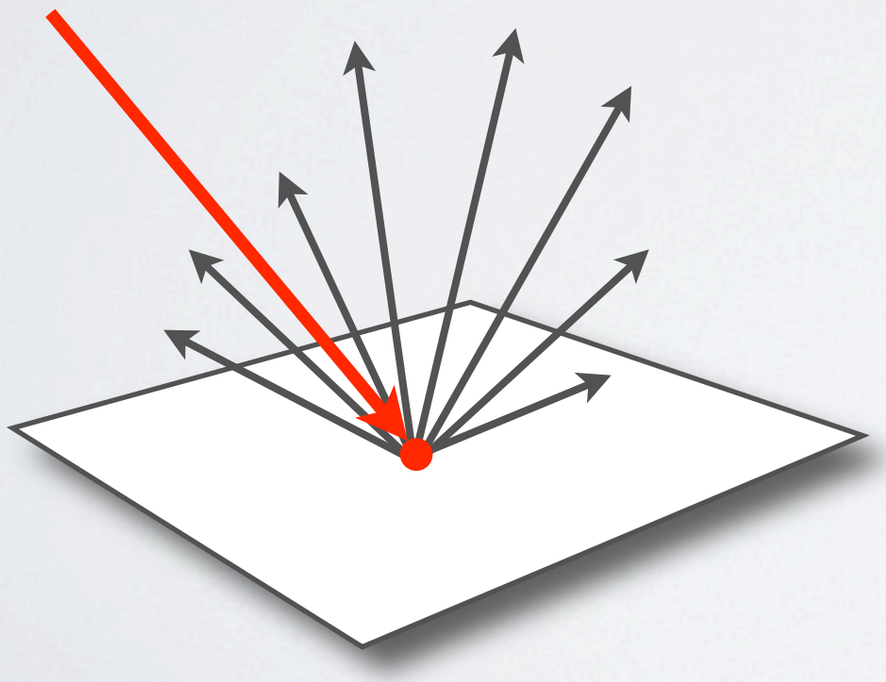


Ultrasound

$\lambda \sim 8 \times 10^{-3}$ m

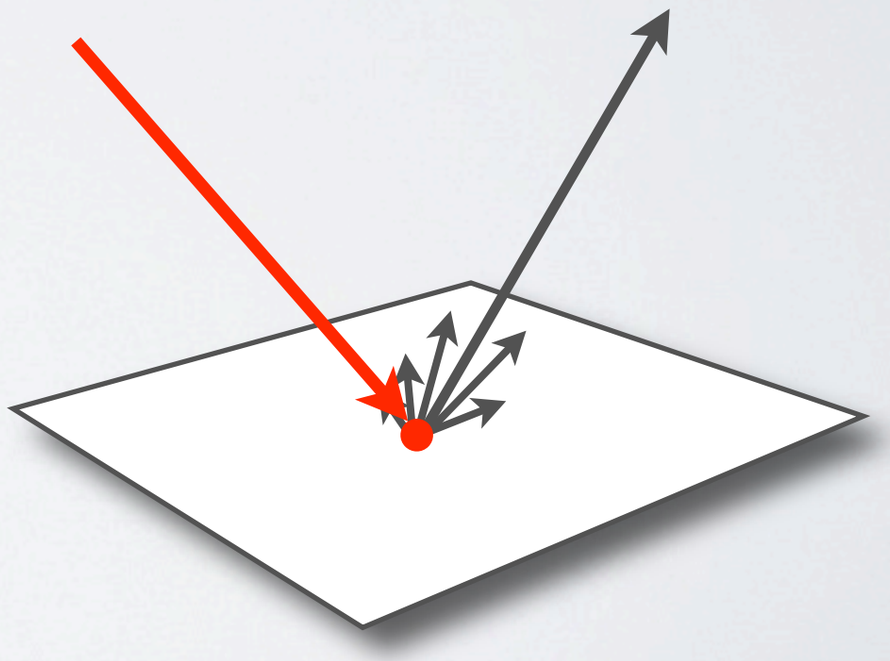
Light

- Most materials have a significant diffuse component.
- Intensity attenuates quickly.



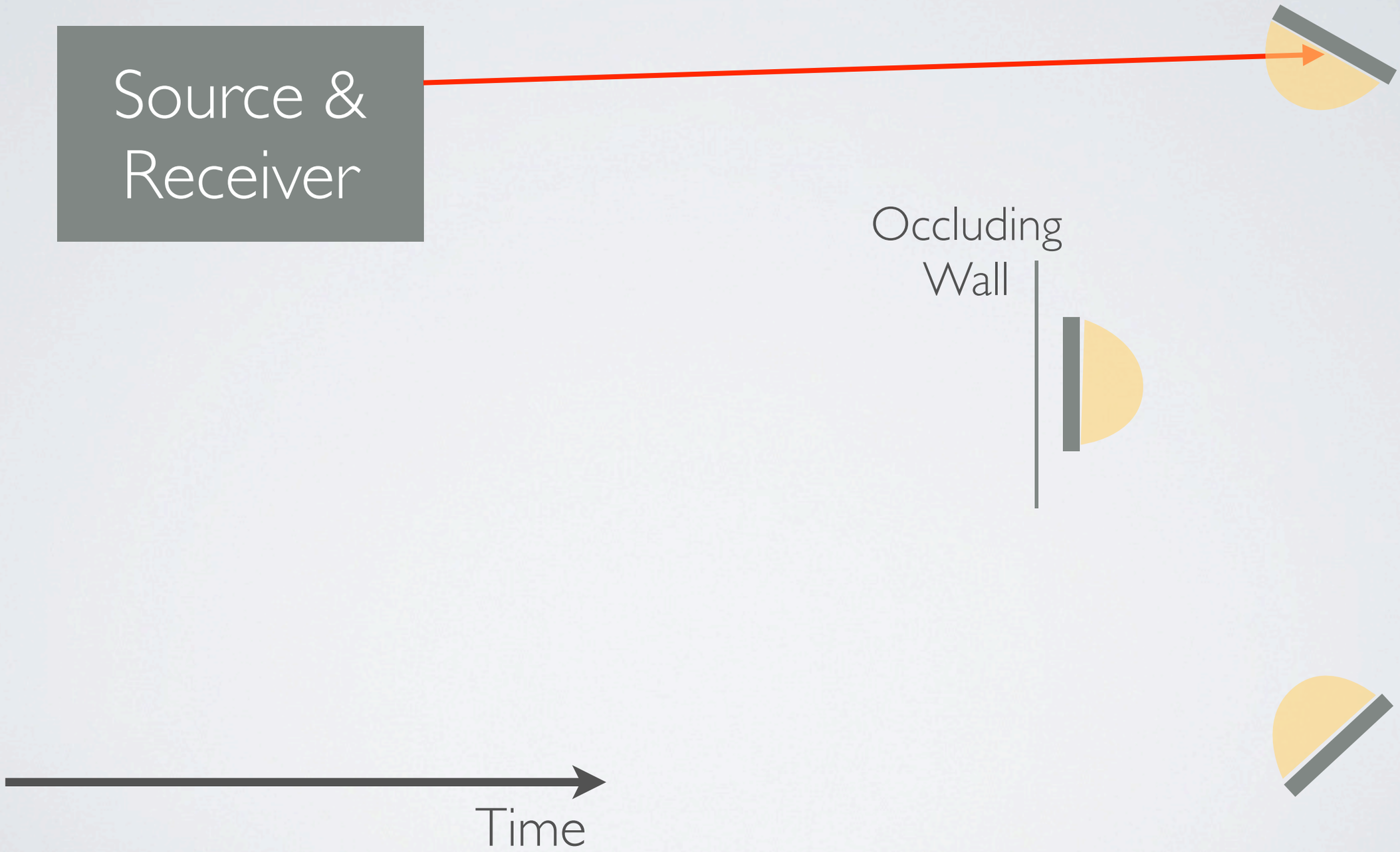
Ultrasound

- Most materials have a significant specular component.
- Theoretically, intensity is mostly maintained.

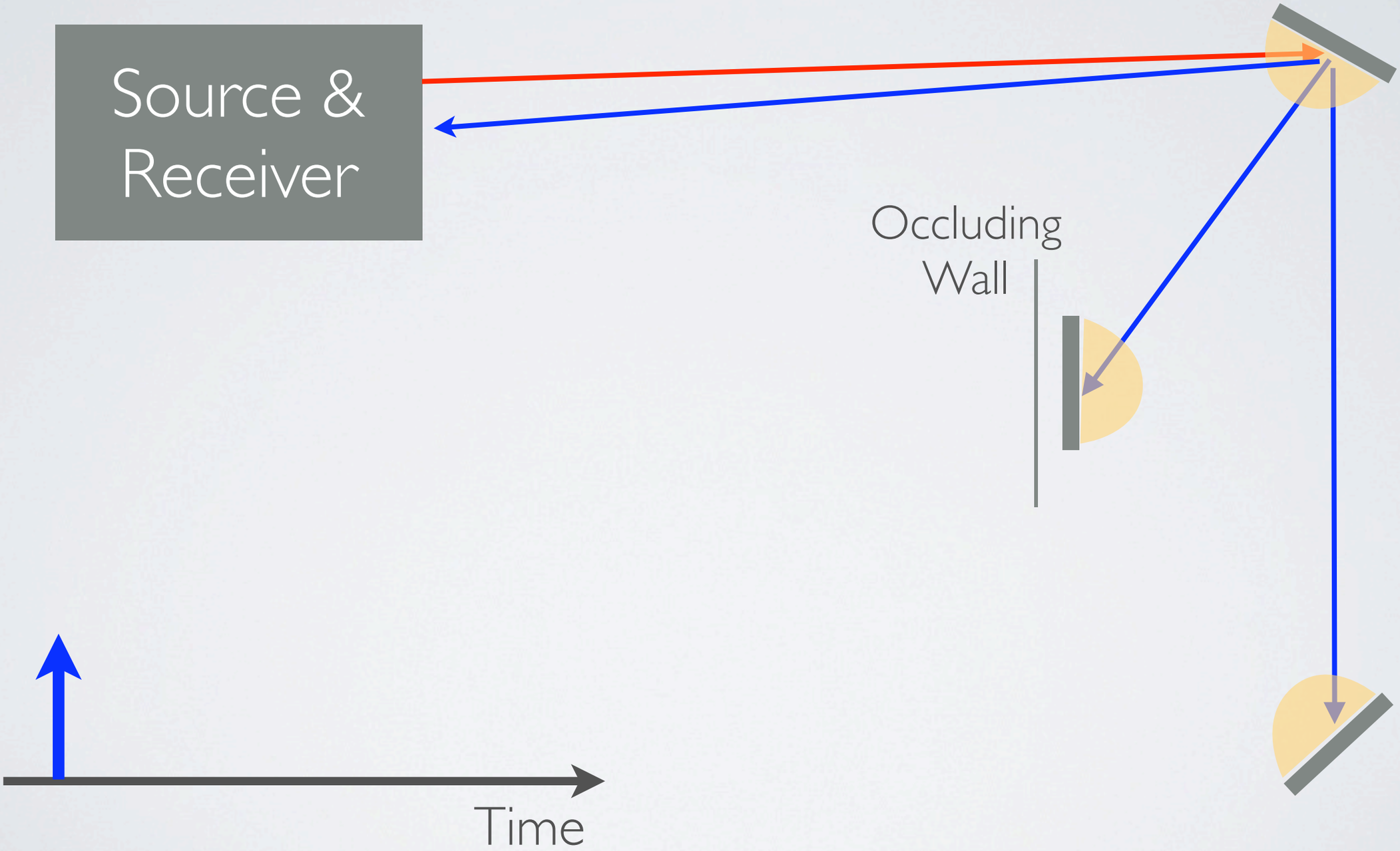


How do we reconstruct the geometry?

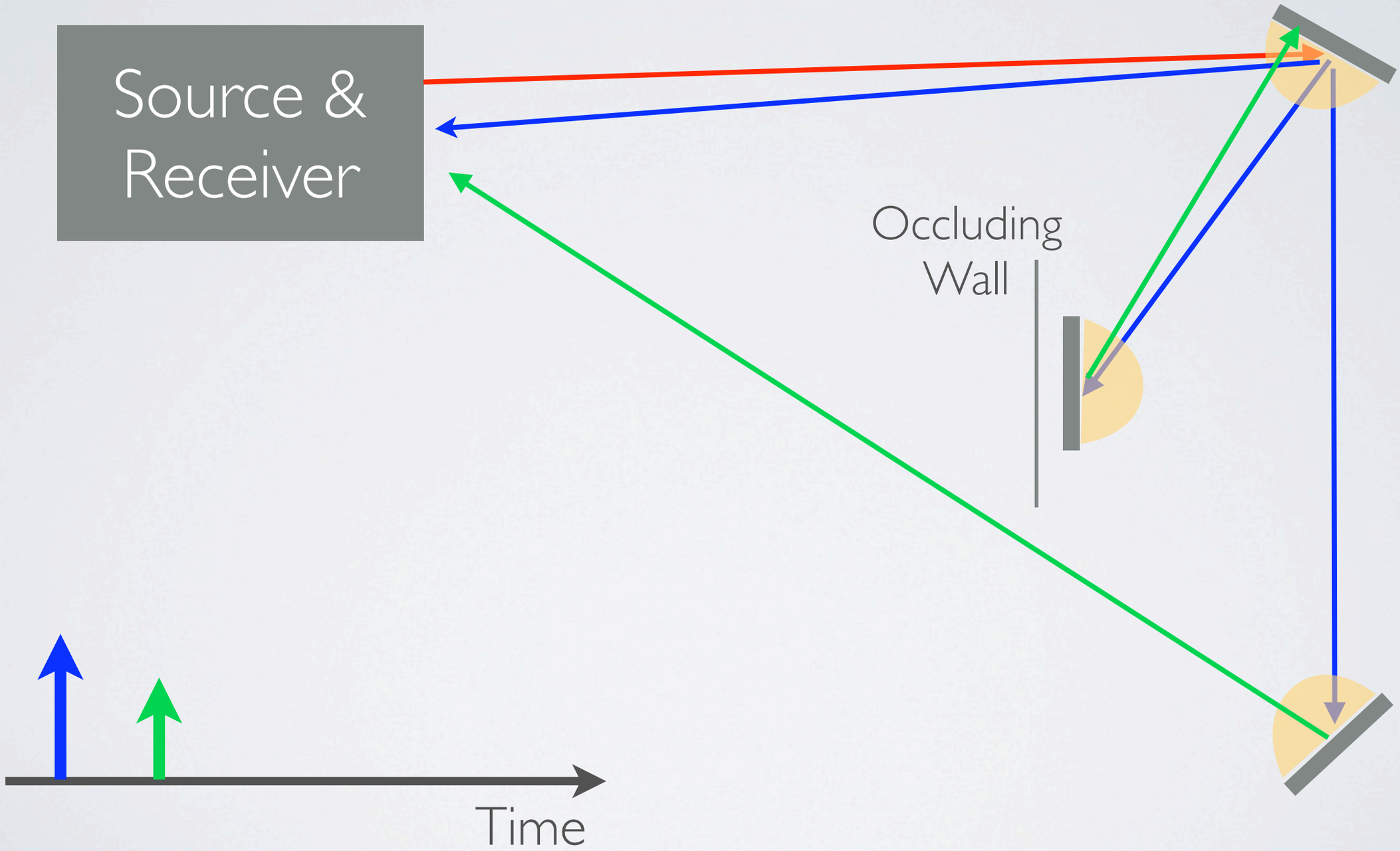
Femtosecond Geometry



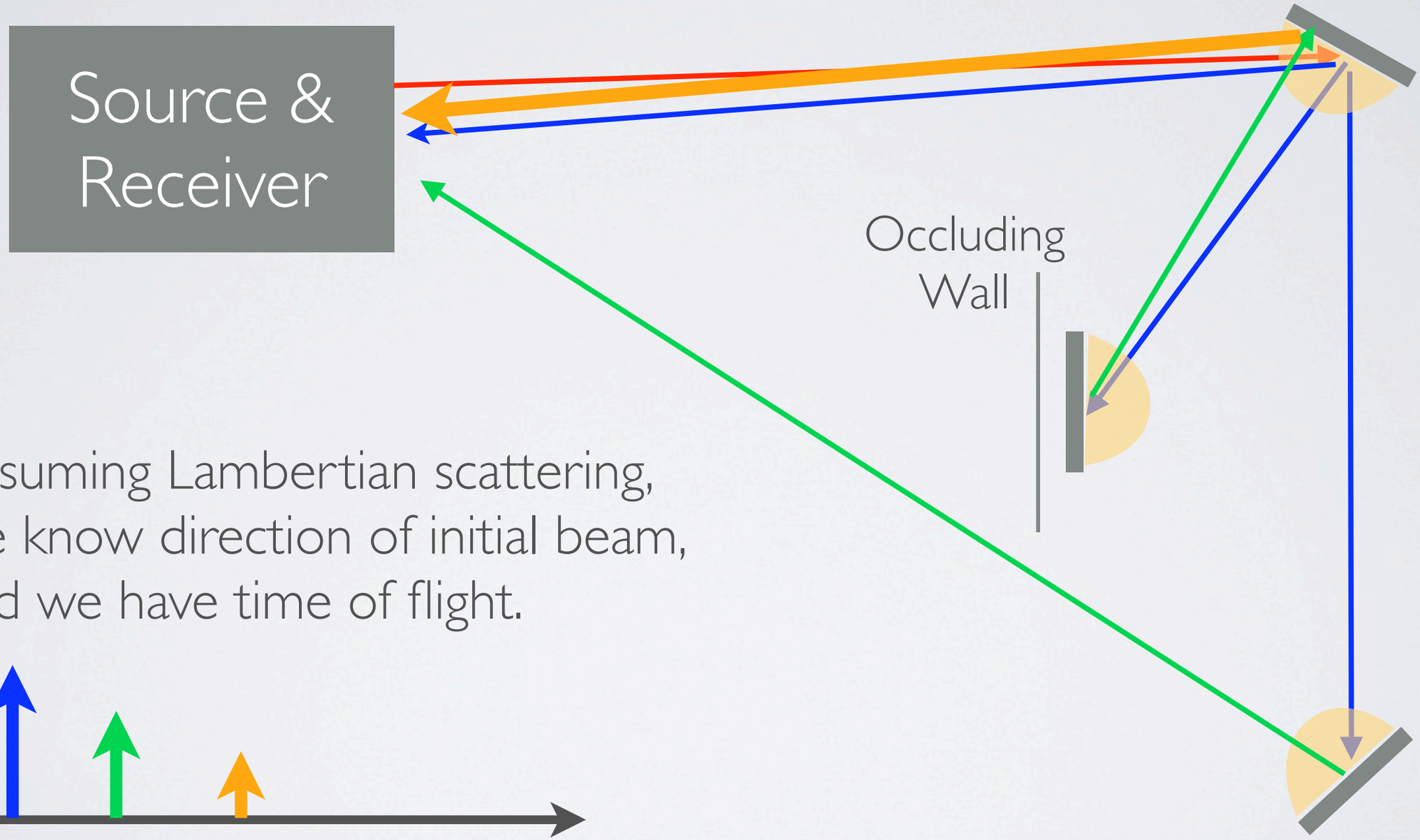
Femtosecond Geometry



Femtosecond Geometry

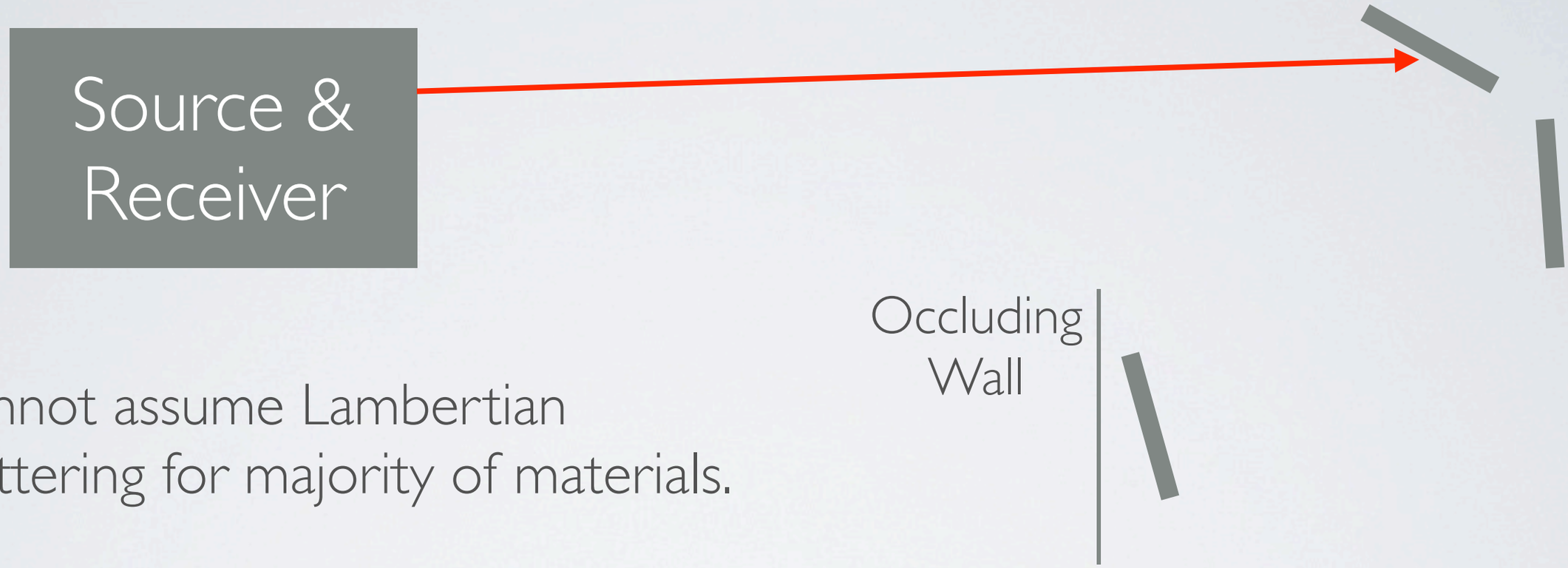


Femtosecond Geometry

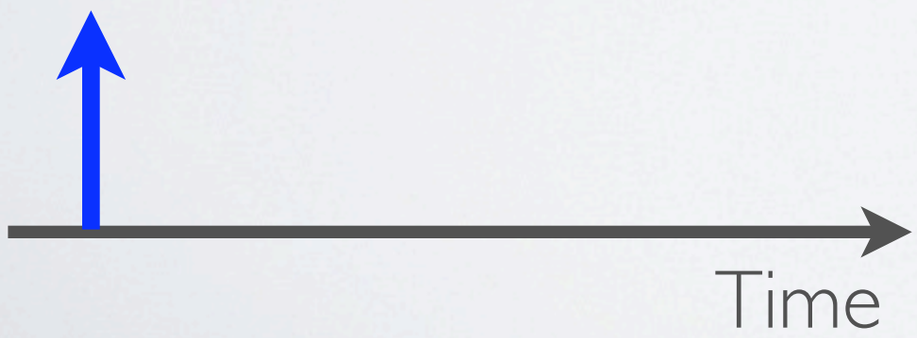


Assuming Lambertian scattering,
we know direction of initial beam,
and we have time of flight.

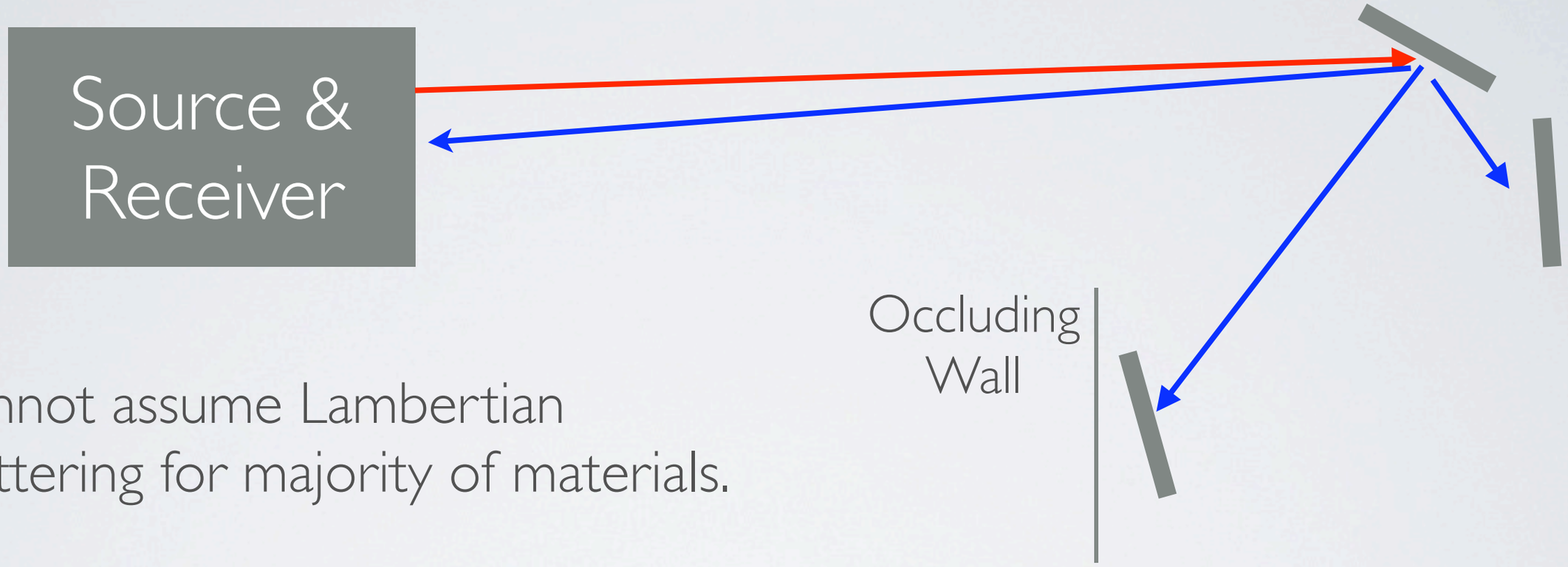
Ultrasound Geometry



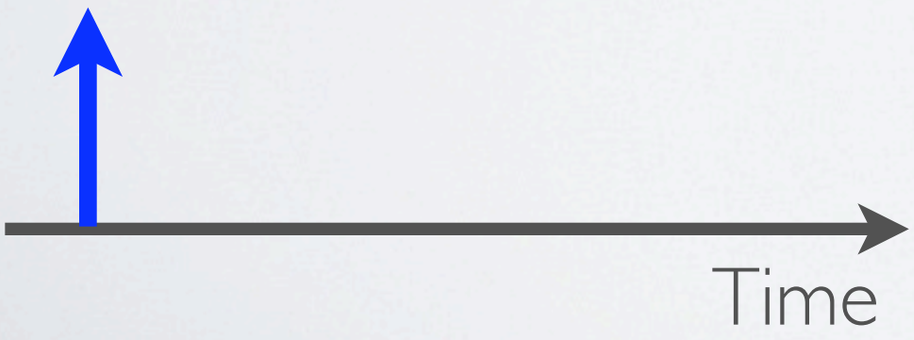
Cannot assume Lambertian scattering for majority of materials.



Ultrasound Geometry

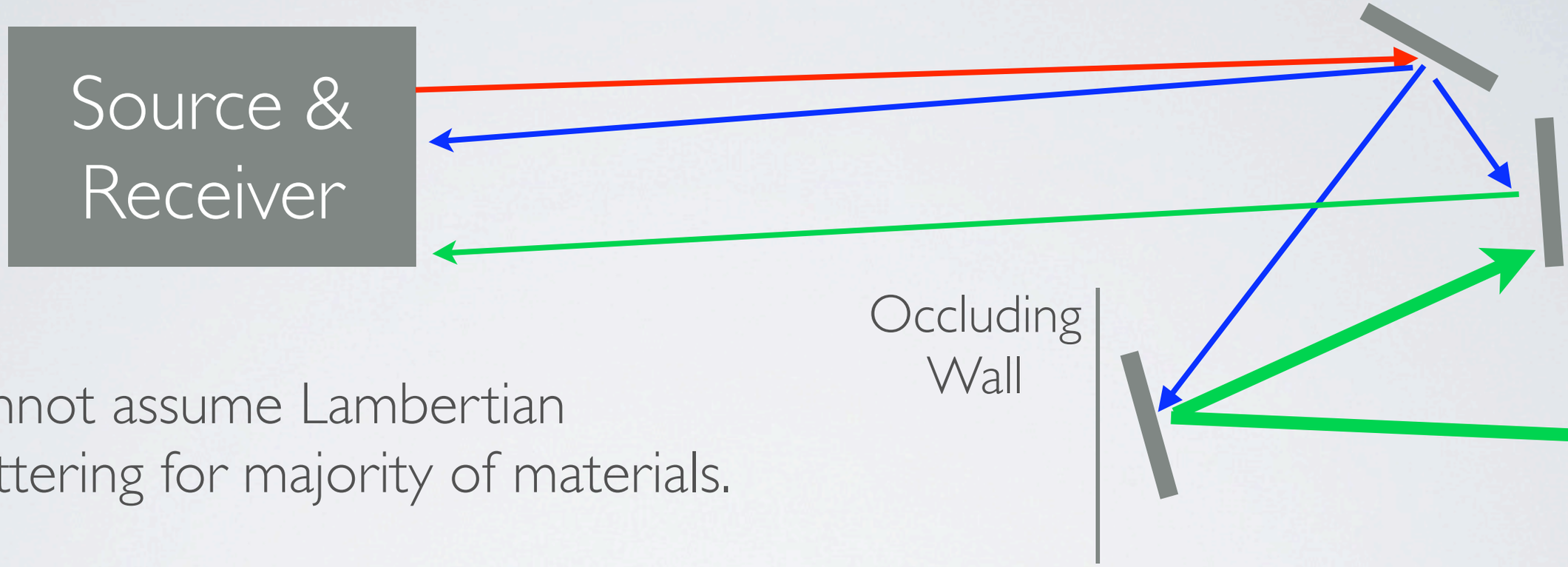


Cannot assume Lambertian scattering for majority of materials.



More diffuse scattering in nature (tree bark, rocks, etc.)

Ultrasound Geometry



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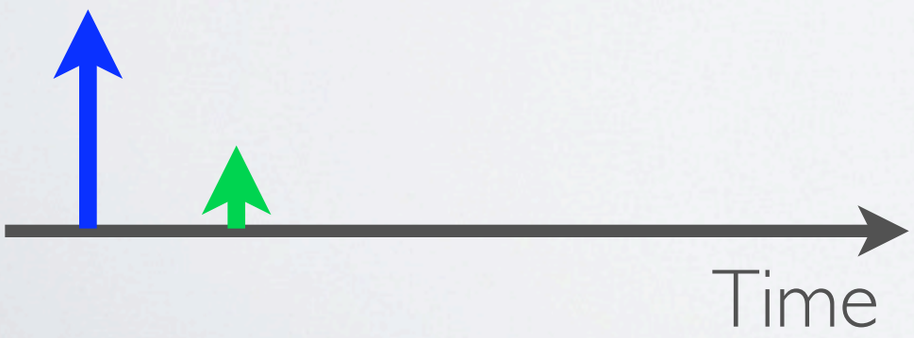
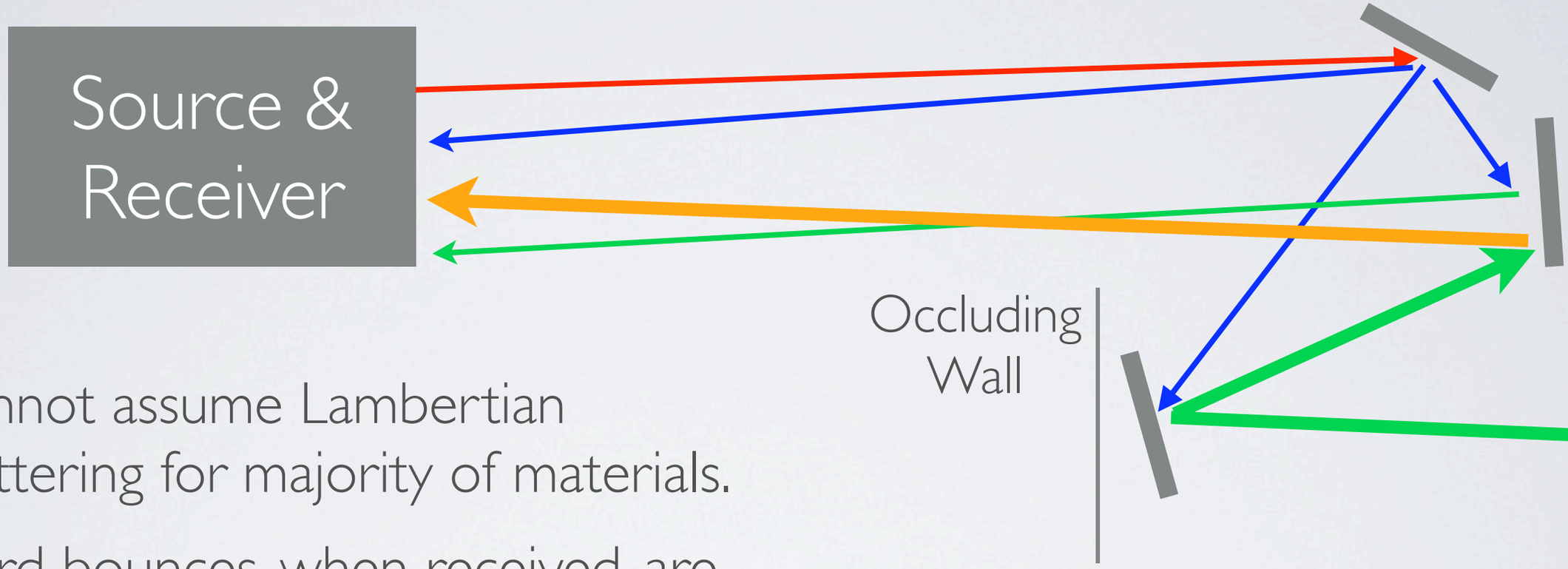


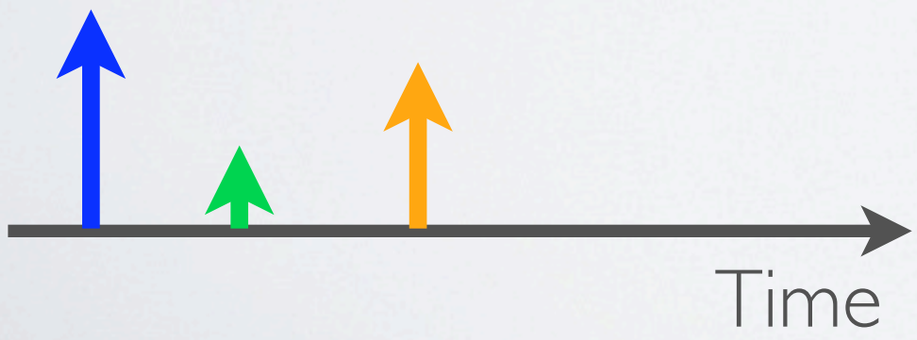
More diffuse scattering in nature (tree bark, rocks, etc.)

Ultrasound Geometry



Cannot assume Lambertian scattering for majority of materials.

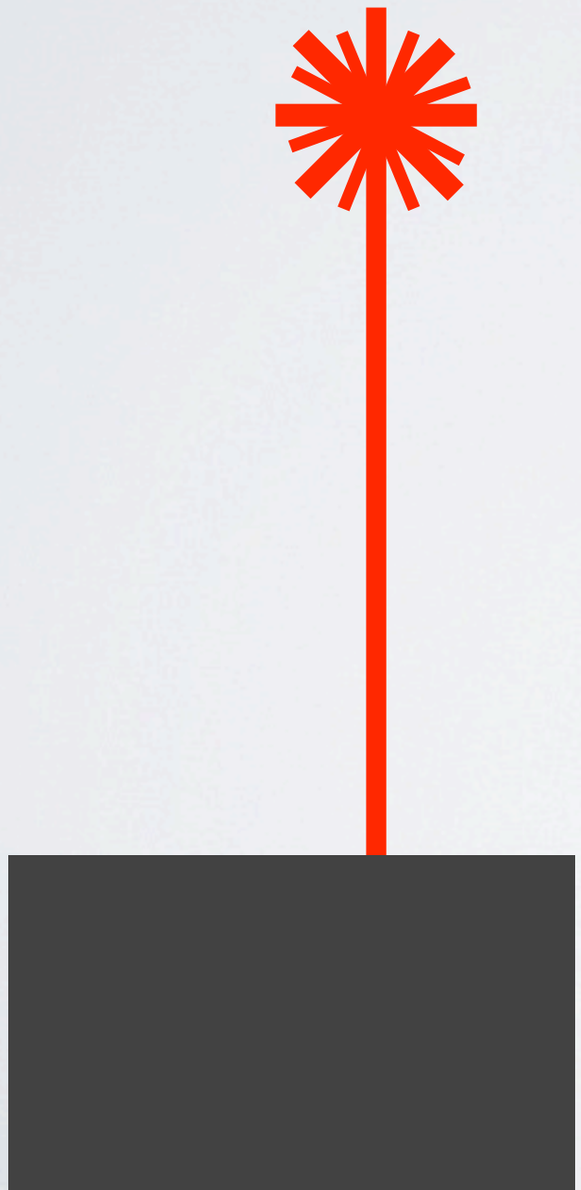
Third bounces, when received, are strong.



More diffuse scattering in nature (tree bark, rocks, etc.)

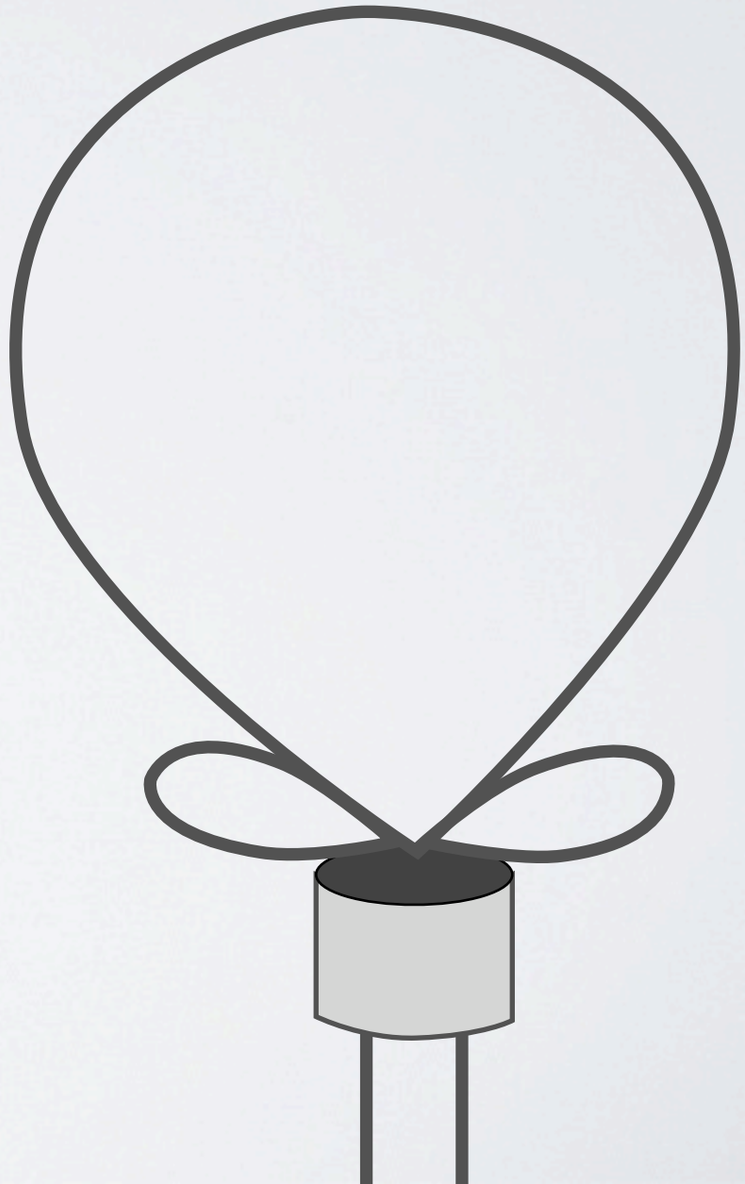
Femtosecond Laser

- Collimated and easily focused

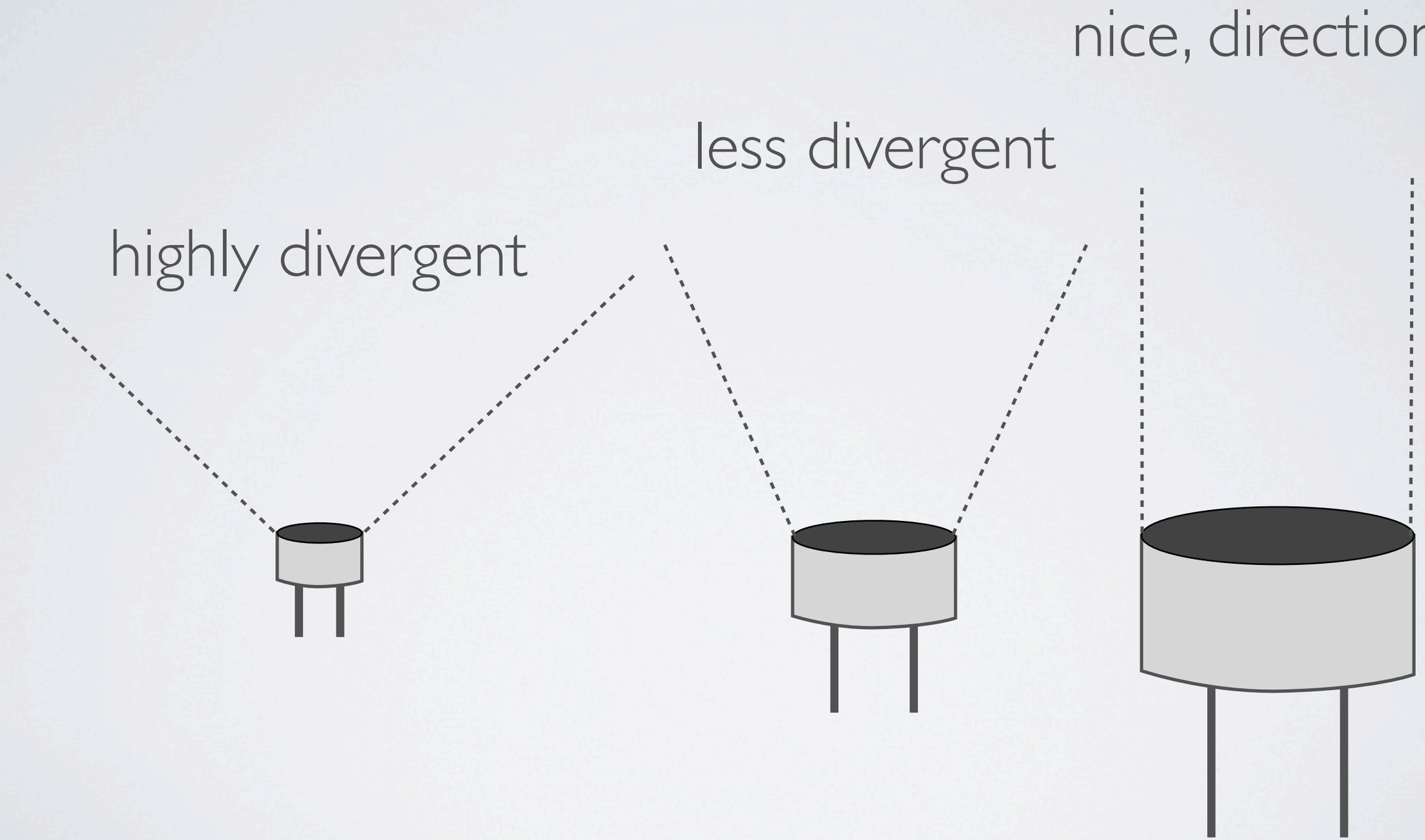


Ultrasonic Transducer

- Single transducer has wide beamwidth and not focusable alone



Diameter vs. Divergence

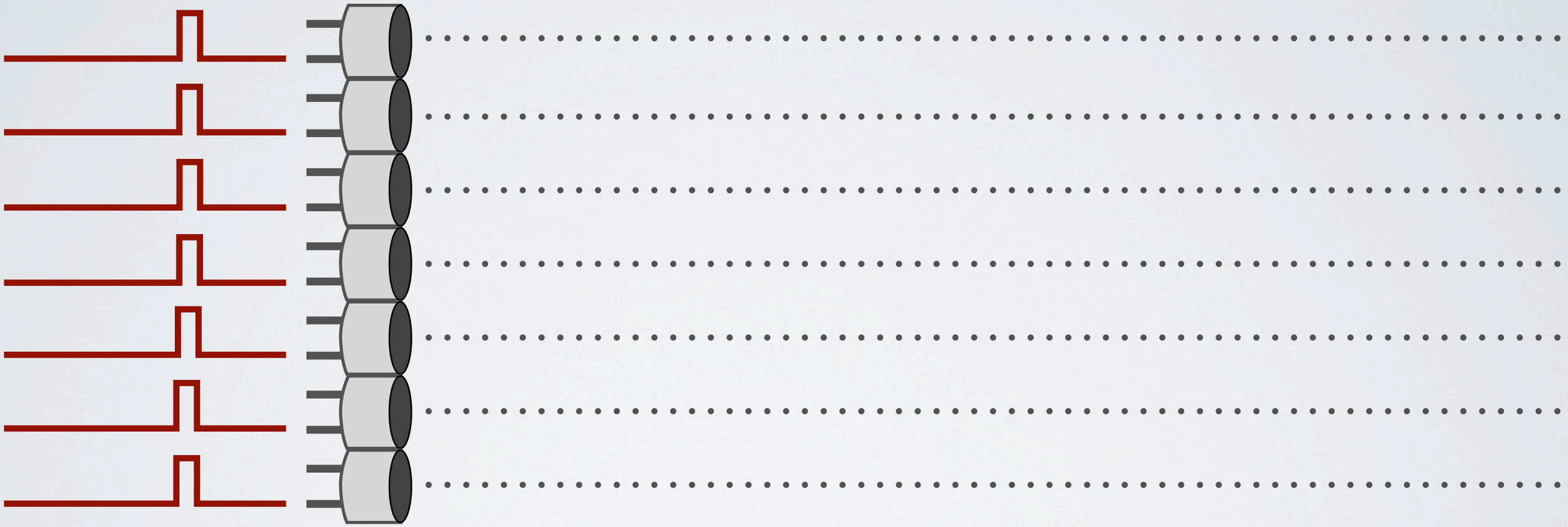


Cost = Angular Resolution

Beam too wide.

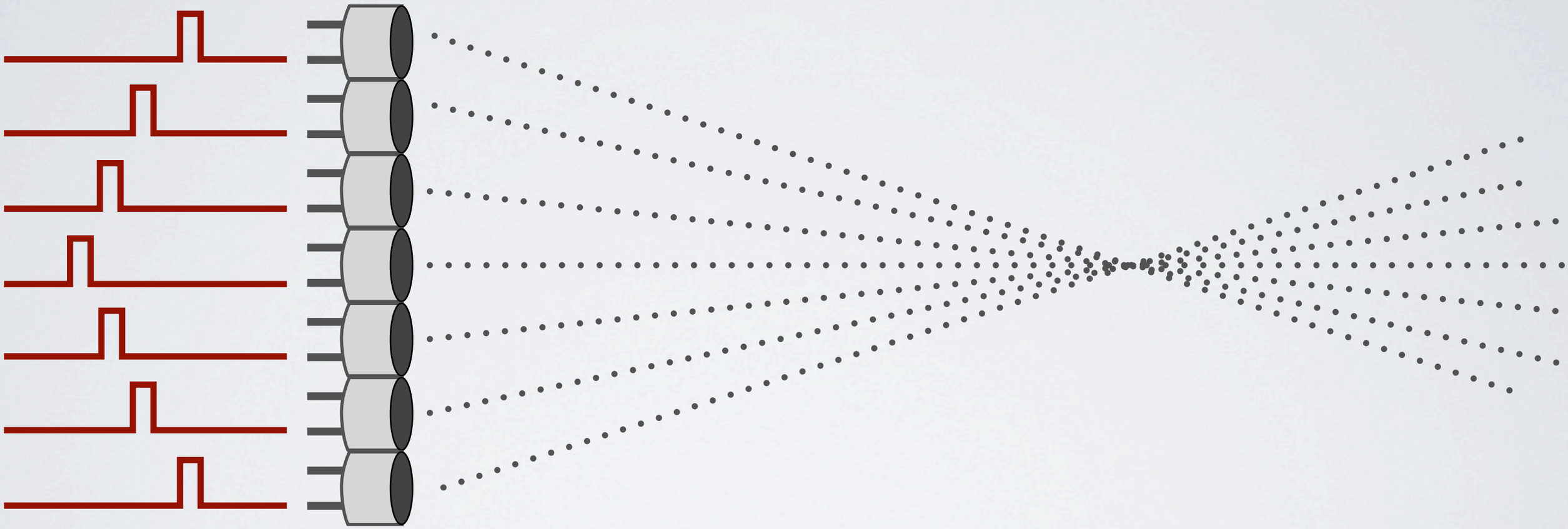
Phased Array

Synchronous



Phased Array

Focused



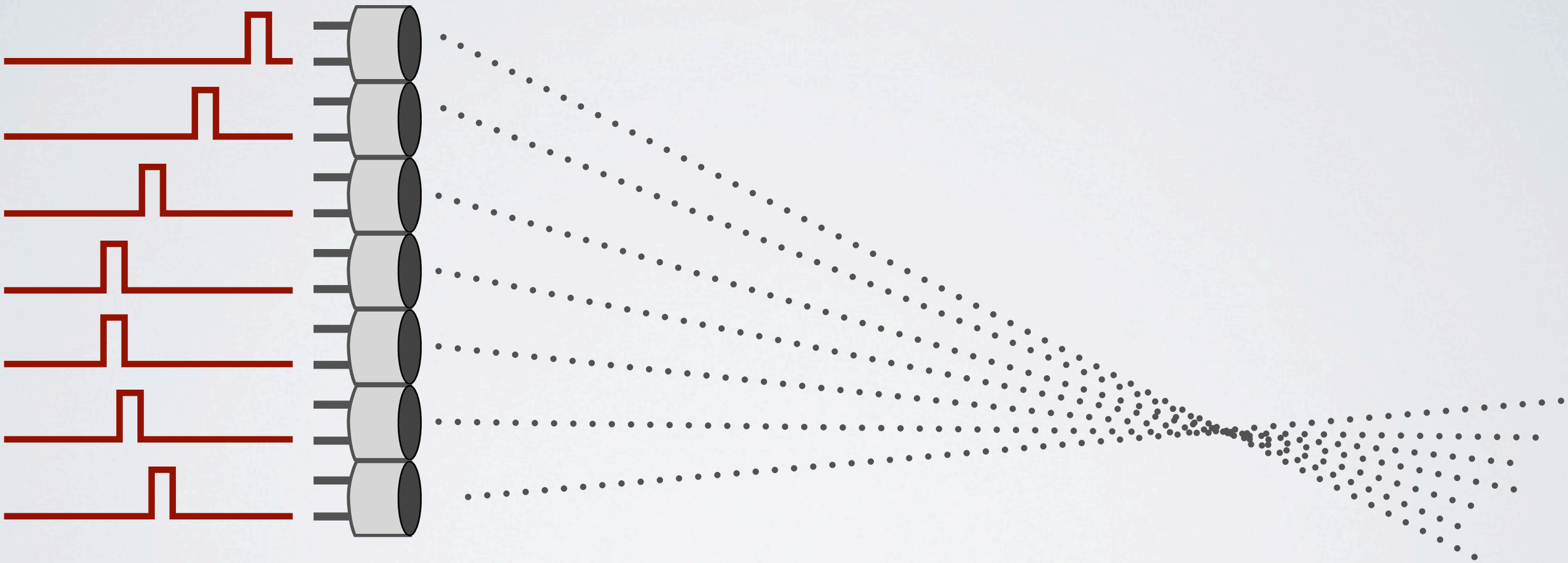
Focus as far as $(L_{Array})^2/\lambda$

Phased Array

Steered

Phased Array

Focused & Steered



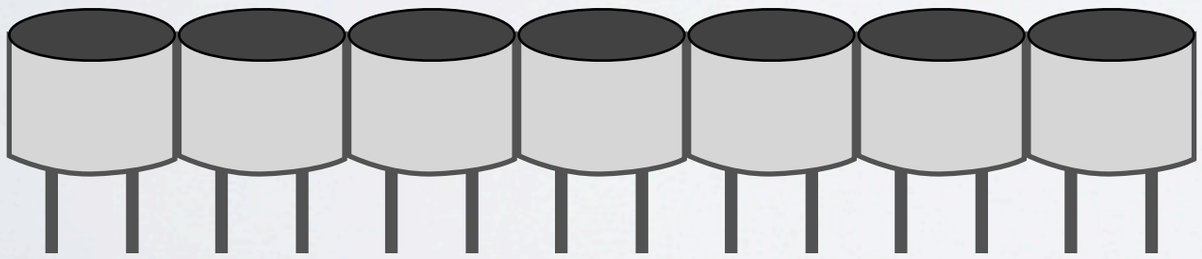
Phased arrays in air:
Difficult to manufacture.

40 kHz $\lambda \sim 8.5$ mm

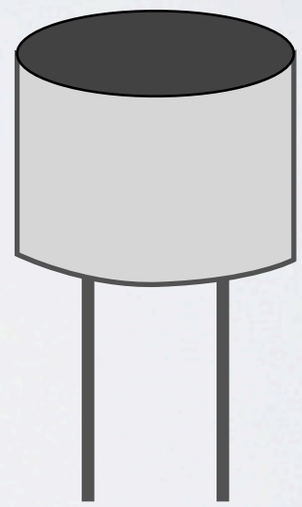
100 kHz $\lambda \sim 3.4$ mm

1 MHz $\lambda \sim 0.34$ mm

$\lambda/2 \rightarrow$ Nyquist



16 mm

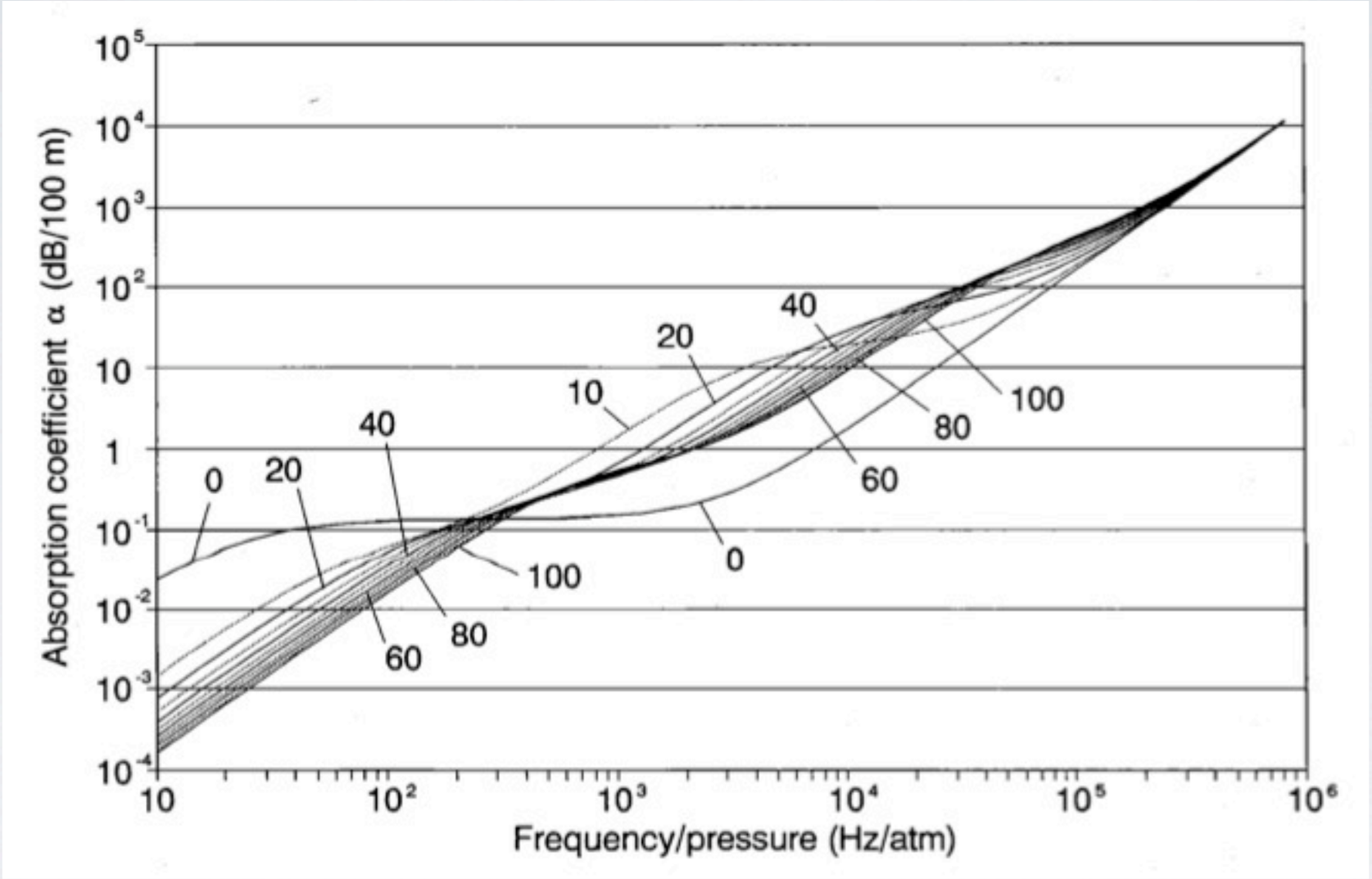


But wait! Higher frequency, smaller beamwidth.

No need for an array...

Atmospheric Absorption of Sound

Air = high acoustic impedance mismatch



H. E. Bass, et. al.

Dependent on humidity, atmospheric pressure, and temperature.

In this room...

40 kHz	1.32 dB/m
100 kHz	3.31 dB/m
1 MHz	163.83 dB/m

Water: Lower impedance mismatch.
Ideal for ultrasound.

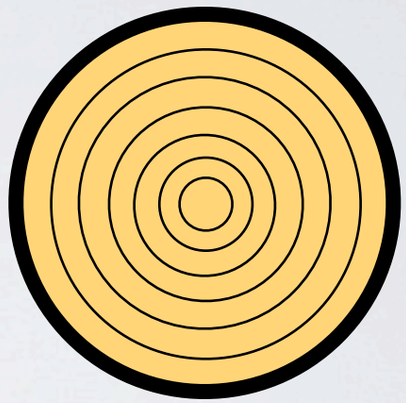
Speed of sound is faster in water.

40 kHz	$\lambda \sim 3.7$ cm
100 kHz	$\lambda \sim 1.5$ cm
1 MHz	$\lambda \sim 1.5$ mm

What does the future hold?

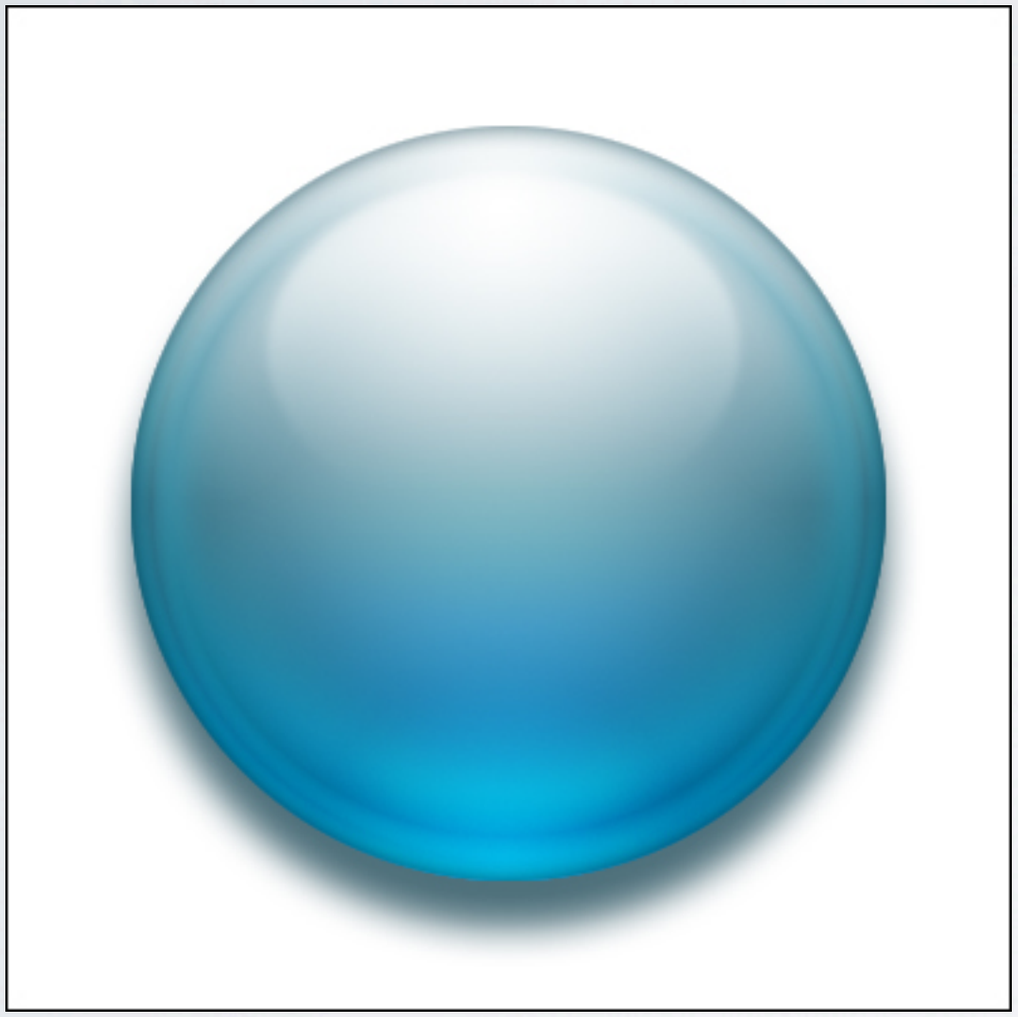
Looking around the corner in air

- Circular piezoelectric stack
- Combine ultrasound with lasers...best of both worlds.



Carry out experiments in water

Where could this go?



- From one place, know entire geometry of the scene, even hidden objects
- 3D reconstruction
- High-speed 3D capture

Questions