VISTA Visual Sensing Theory & Applications Laboratory

Computer Science Department

Technion Israel Institute of Technology

and to hear
Learning to see at the age of AI

Alex Bronstein, ISTA & Technion

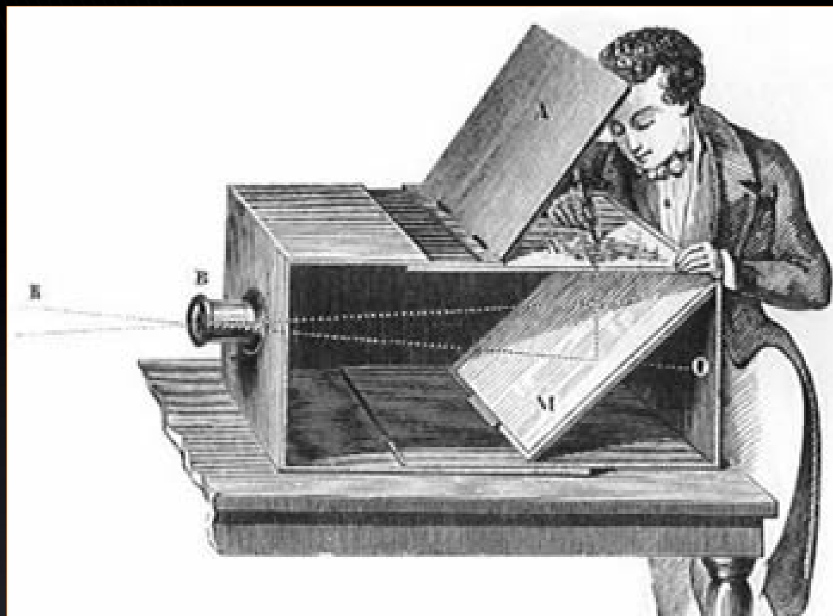
The world as we see it

Human imaging system

Communicating with pictures

Oldest cave paintings (about 37000 years ago)

Capturing light



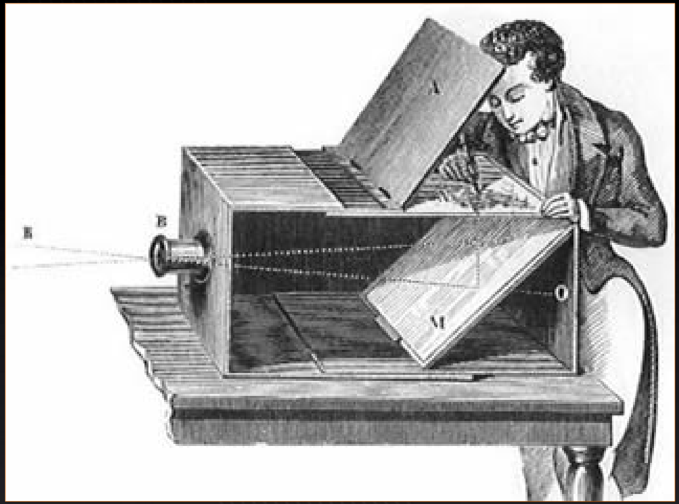
Camera obscura: Earliest written records ca. 500 BCE (China, Greece)

Widespread in Europe by 1700

Making it persistent

One of the earliest photographs (ca 1826; T_{exp}=6h)

Didn’t we travel a long way?



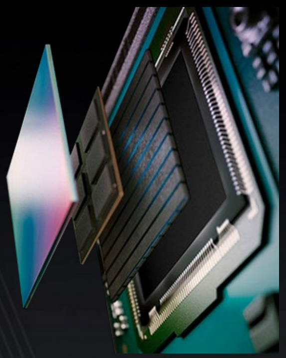
Camera obscura (late 1600)

Canon Mark VI (2017)

Apple iPhone XS (2019)

Conventional imaging

optics



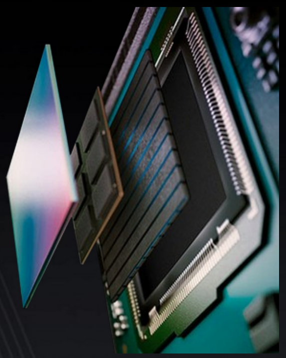
sensor

beholder

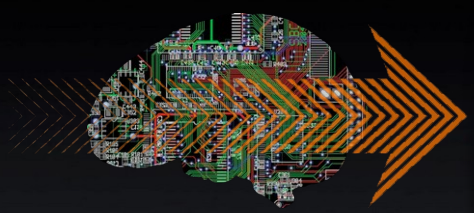
Conventional camera: raw image is directly intelligible

Computational imaging

crazy optics



crazy sensor

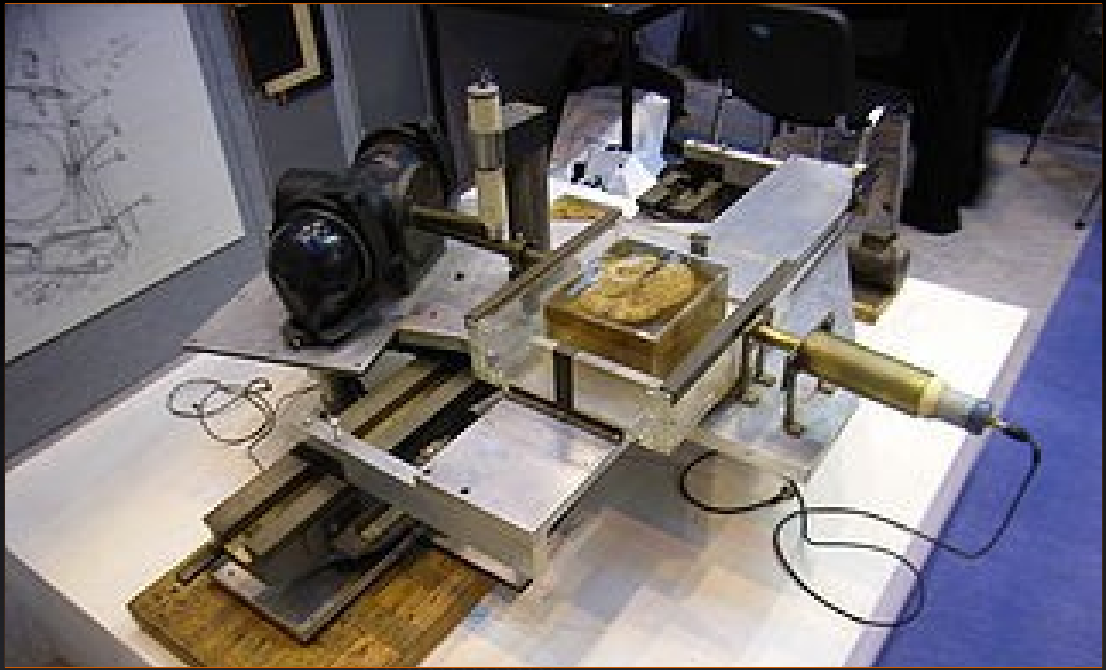


digital processor

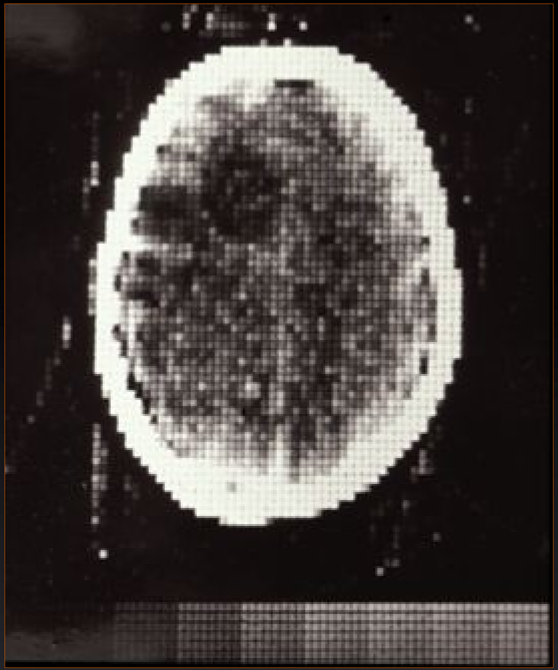
beholder

Computational camera: image is intelligible after processing

What you see is not what you get



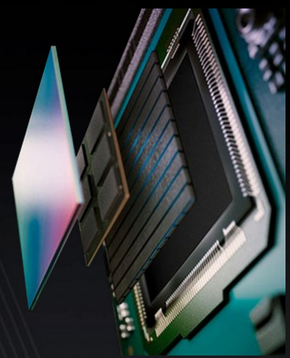
First CT scanner (Hounsfield&McLeod Cormack, 1971)



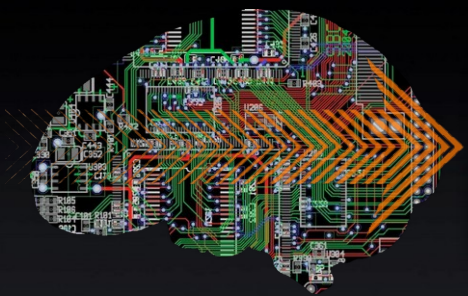
First CT image

Computational imaging

optics



sensor



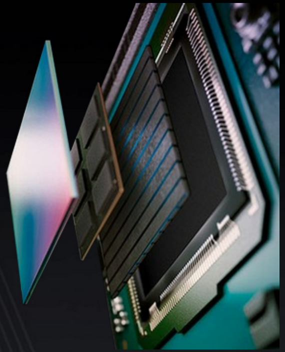
digital processor

beholder

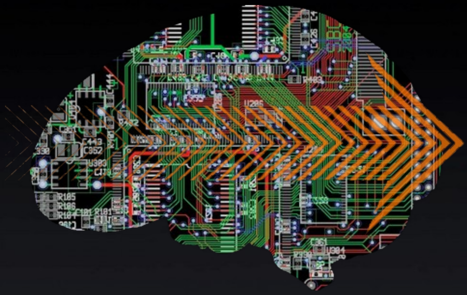
Computational camera: image is intelligible after processing

Not for your eyes only

optics



sensor

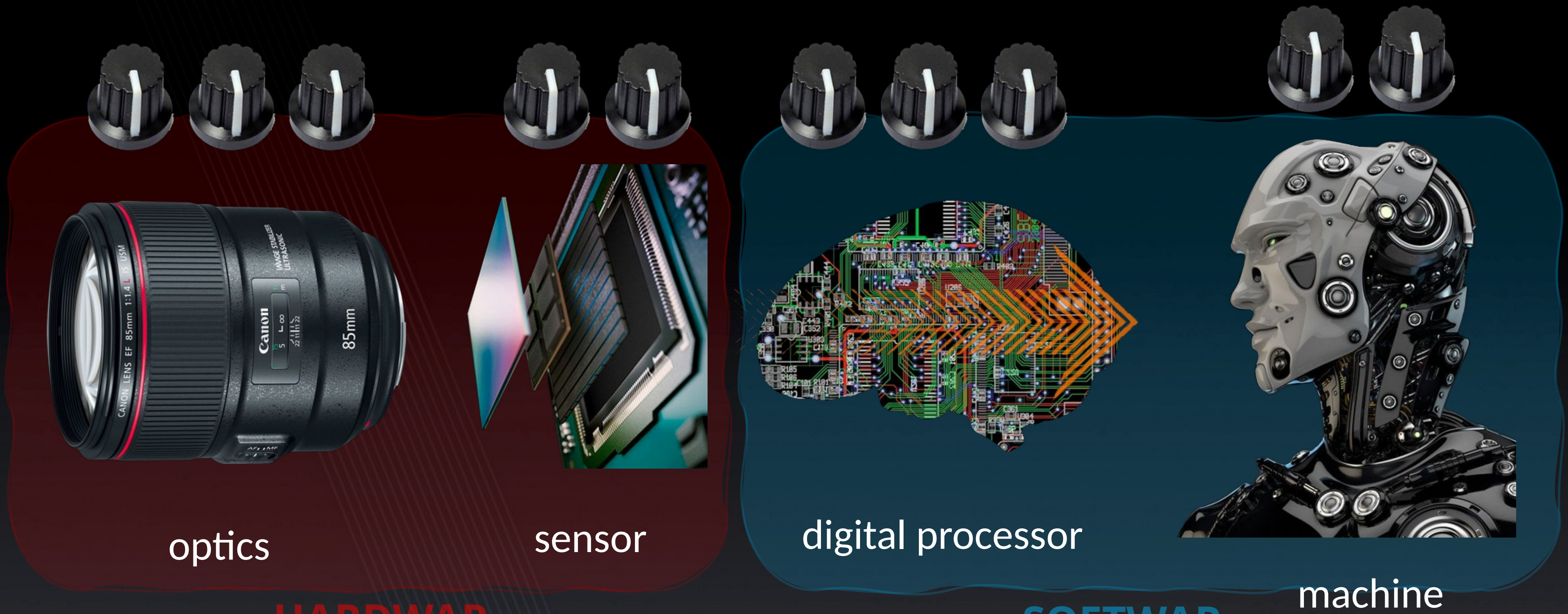


digital processor

machine

Do we need an image at all?

Learning to see



HARDWARE

SOFTWARE

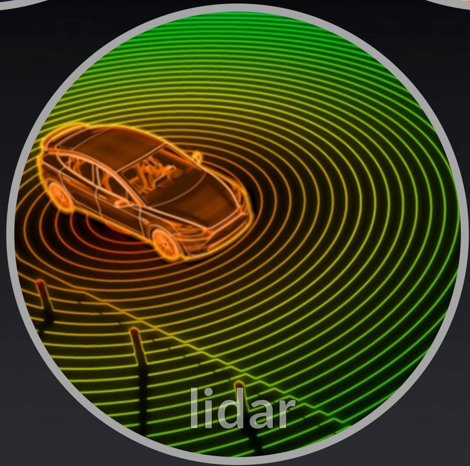
Learned camera: all stages are tuned for a specific end task


optical
imaging


acoustic
imaging


MRI


radar


lidar

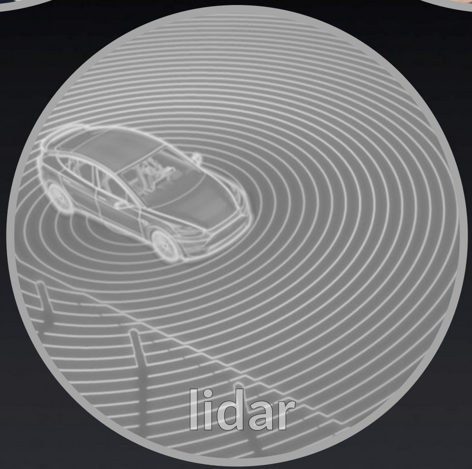

quantum
light sources


optical
imaging


acoustic
imaging

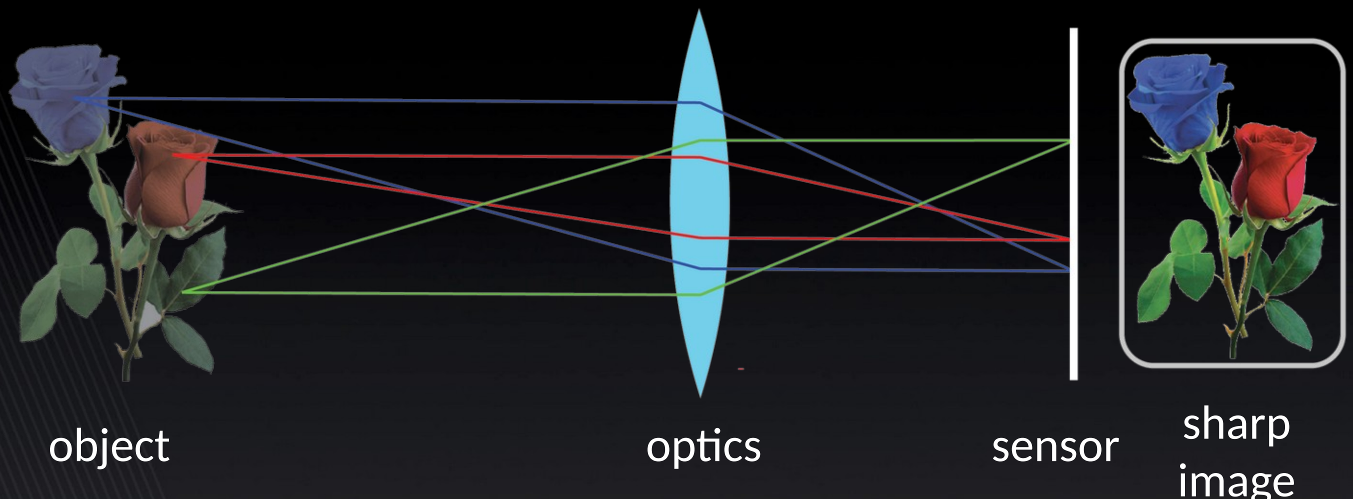

MRI


radar


lidar

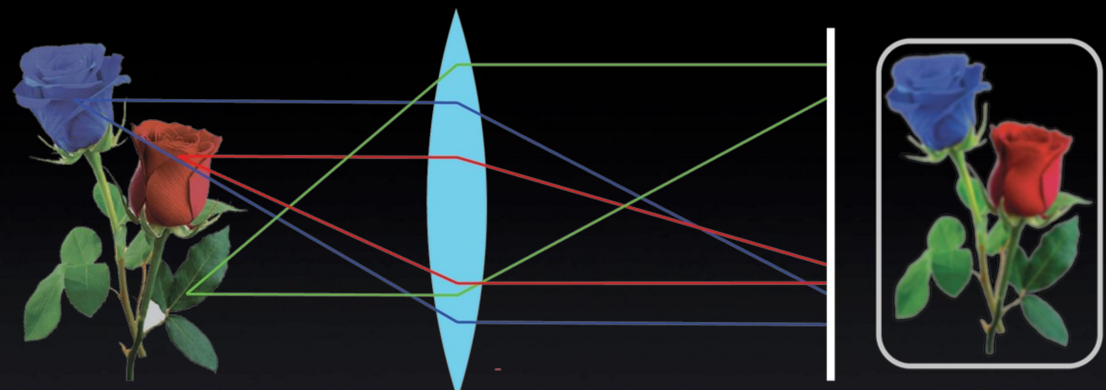

quantum
light sources

Putting everything in focus



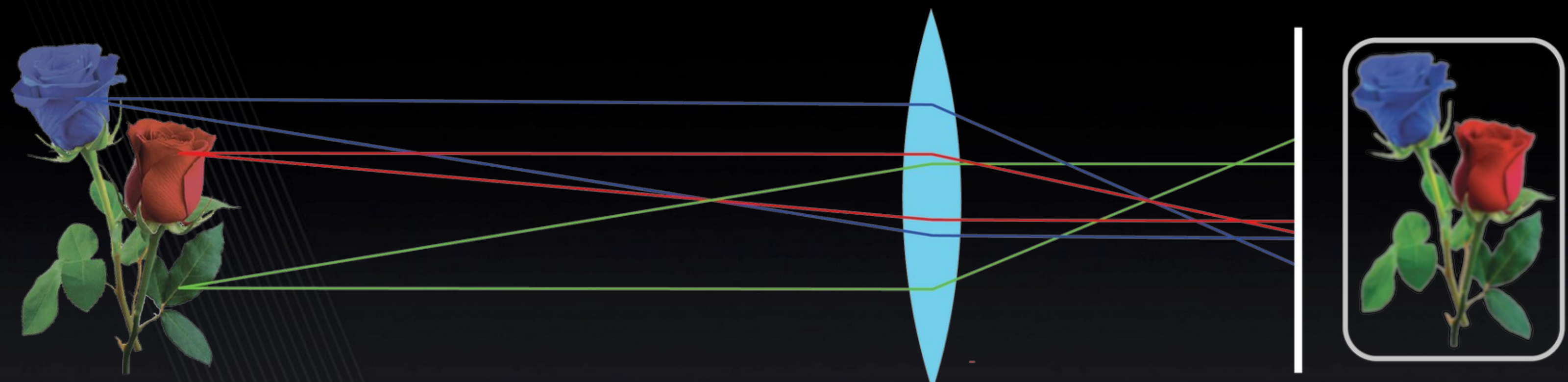
Conventional camera focused on an object

Putting everything in focus



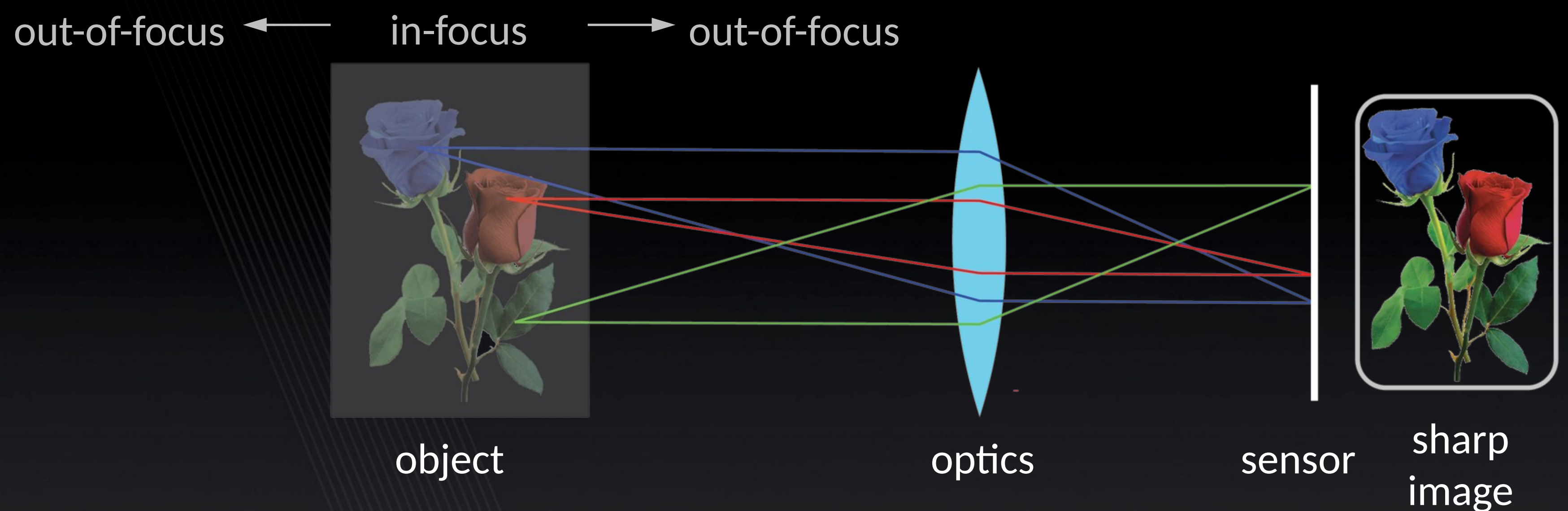
Conventional camera suffering from far-sightedness

Putting everything in focus



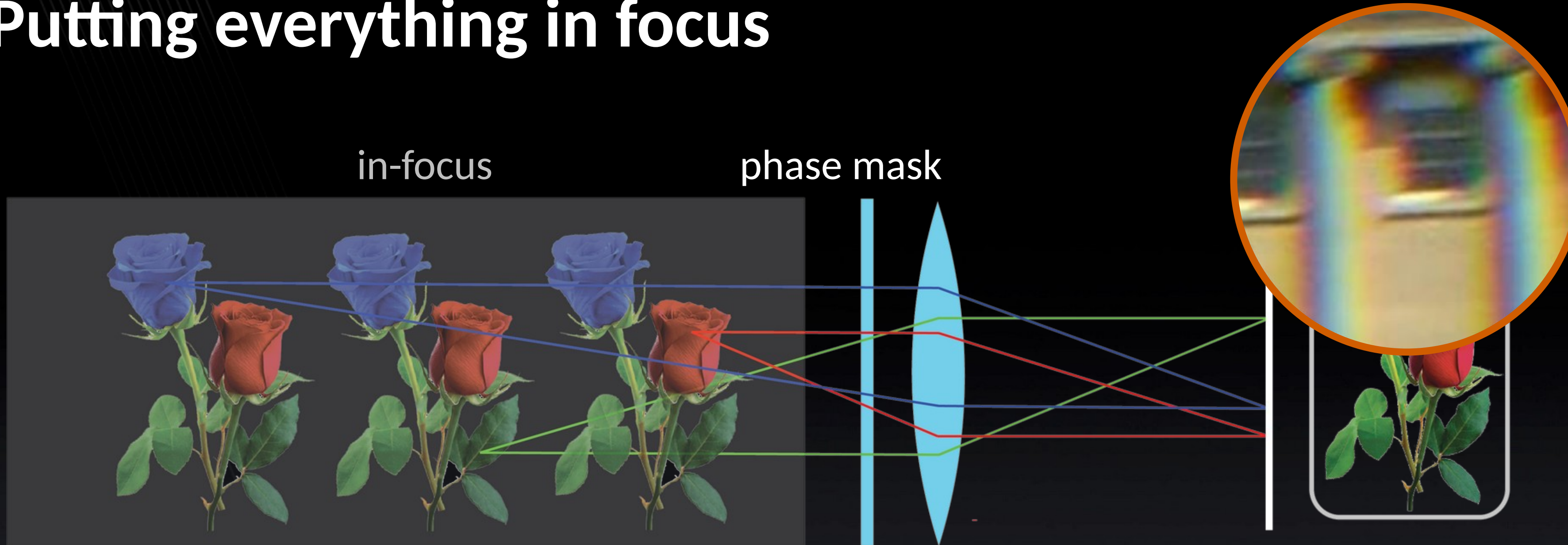
Conventional camera suffering from short-sightedness

Putting everything in focus



Conventional camera with narrow depth-of-field

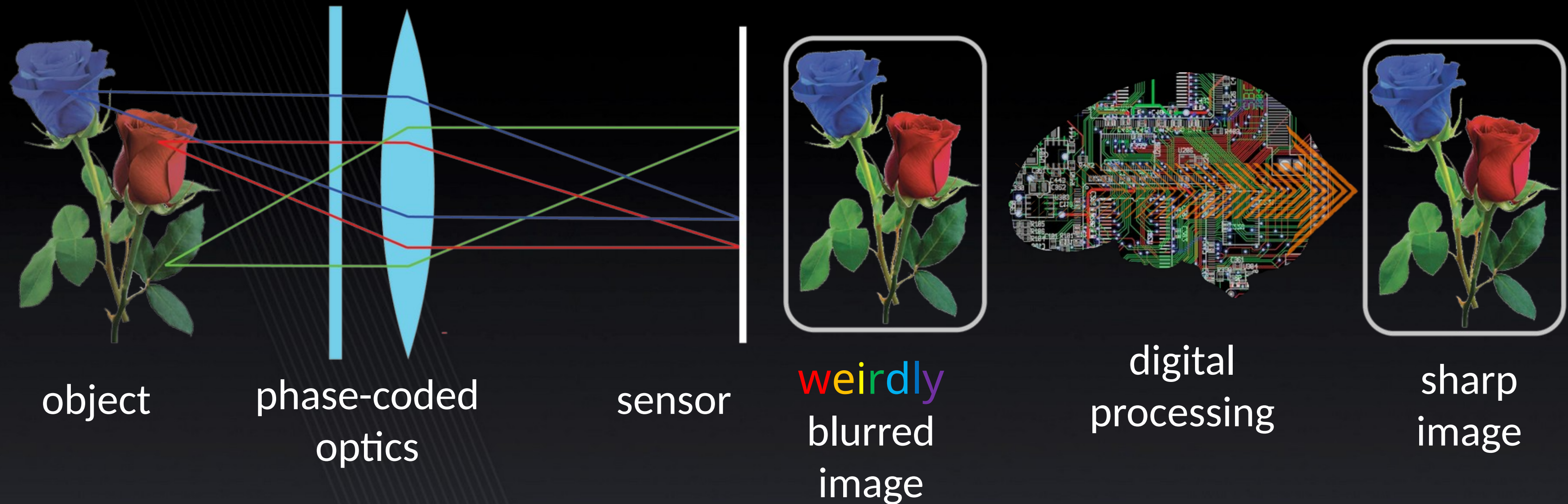
Putting everything in focus



Phase-coded aperture camera has a wider depth-of-field

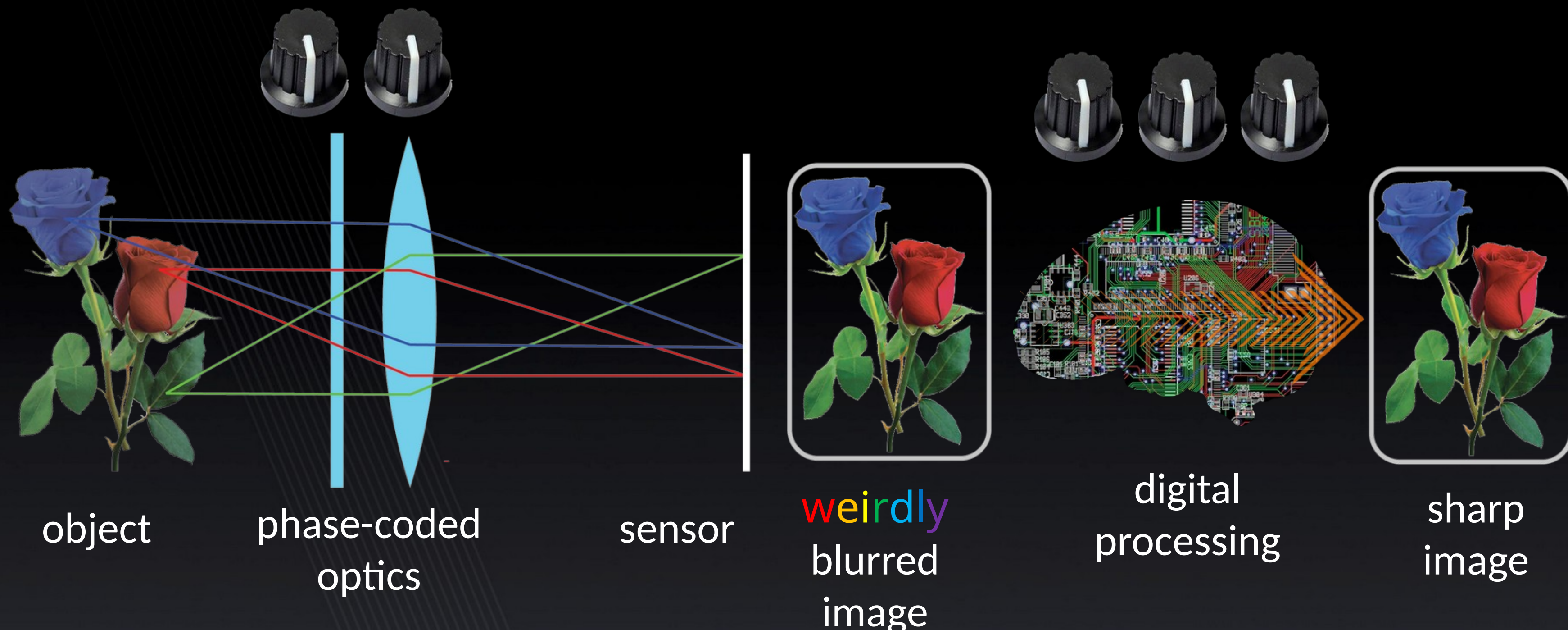
Haim, B, Marom, OSA 2015

Putting everything in focus



Haim, B, Marom, OSA 2015

Putting everything in focus



Haim, B, Marom, OSA 2015

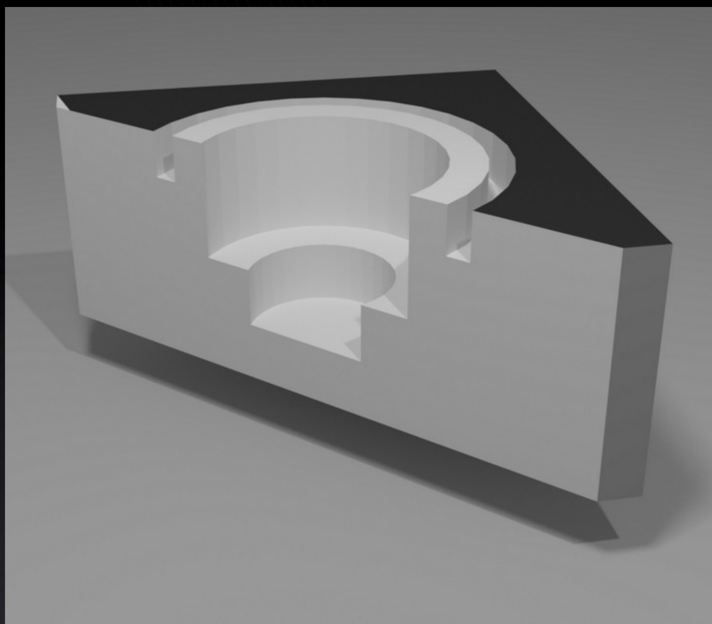
Computational extended depth-of-field imaging

Blurred clear aperture image

Sharp image reconstructed computationally from phase coding

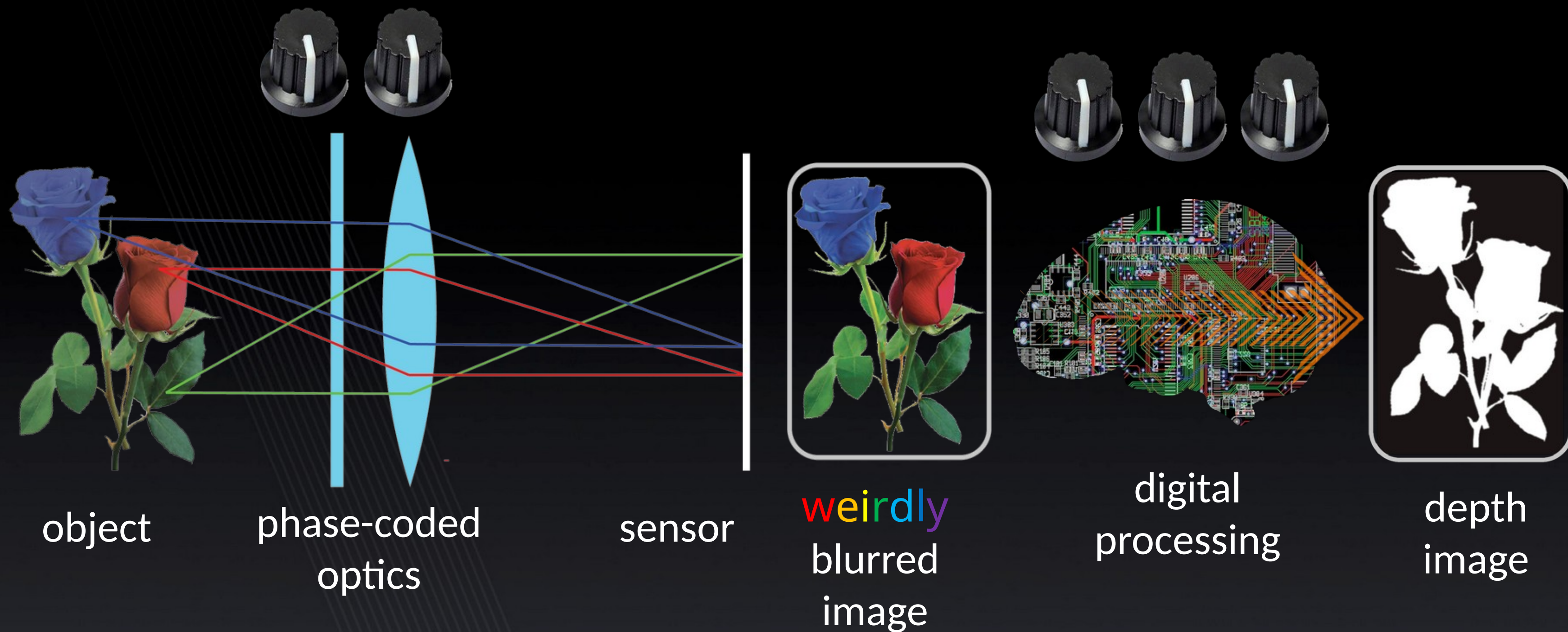
Haim, B, Marom, OSA 2015

Mask off



Haim et al., IEEE TCI 2018 · Winner of the OSA grand challenge

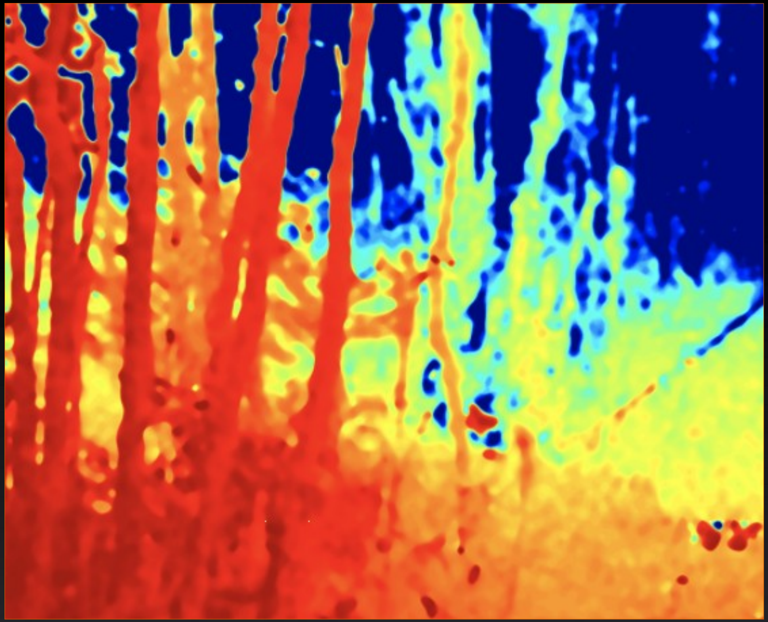
Seeing depth



Haim et al., IEEE TCI 2018 · Winner of the OSA grand challenge

Seeing depth

Regular image



Depth image

Haim et al., IEEE TCI 2018 · Winner of the OSA grand challenge


planet earth

Planet Earth 2.0

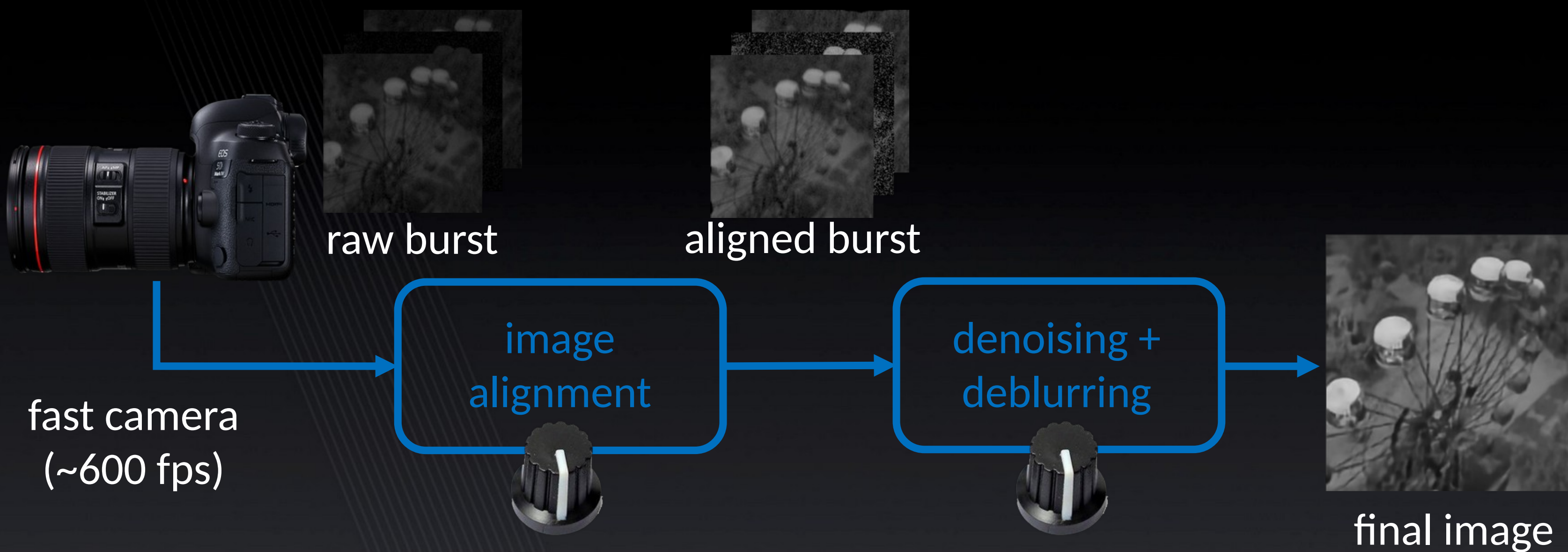
Airborne stabilized camera (2005)

...today

Gimbal

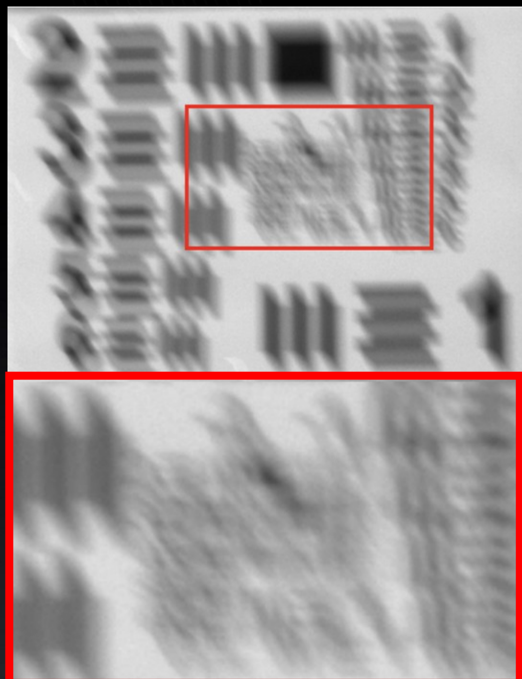
- Weight
- Power
- $$$

Digital gimbal

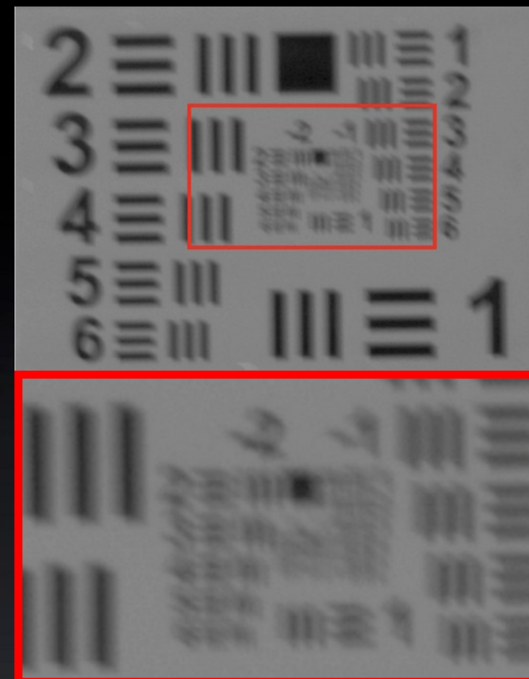


Dahari, Jacoby, B, CVPR 2020

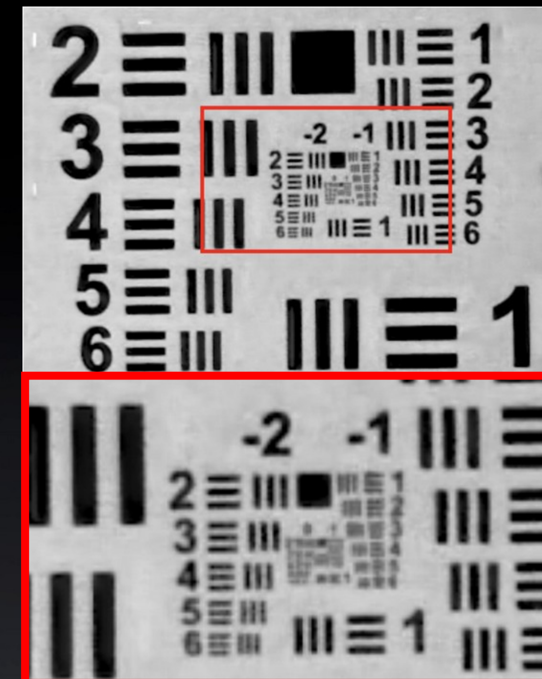
Digital gimbal



full exposure (5ms)



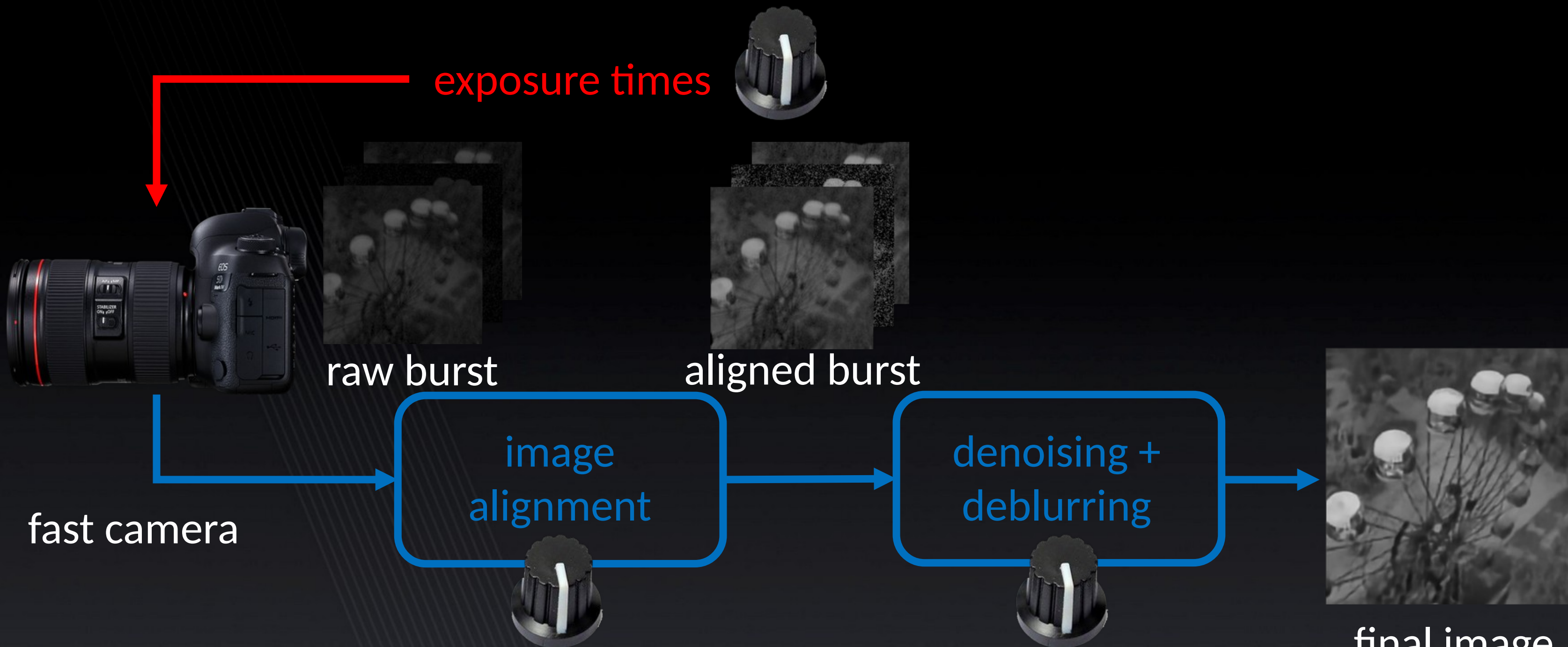
burst (1.16ms)



Digital Gimbal

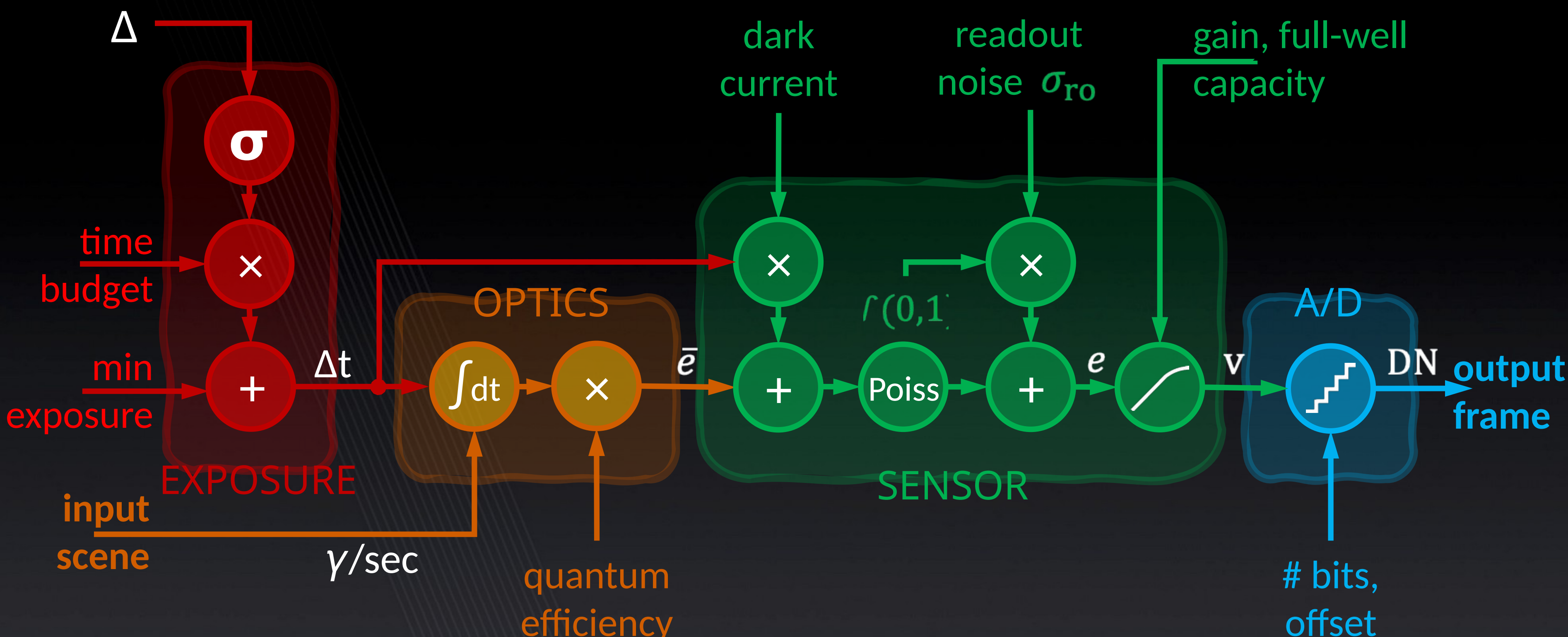
Dahari, Jacoby, B, CVPR 2020

Digital gimbal



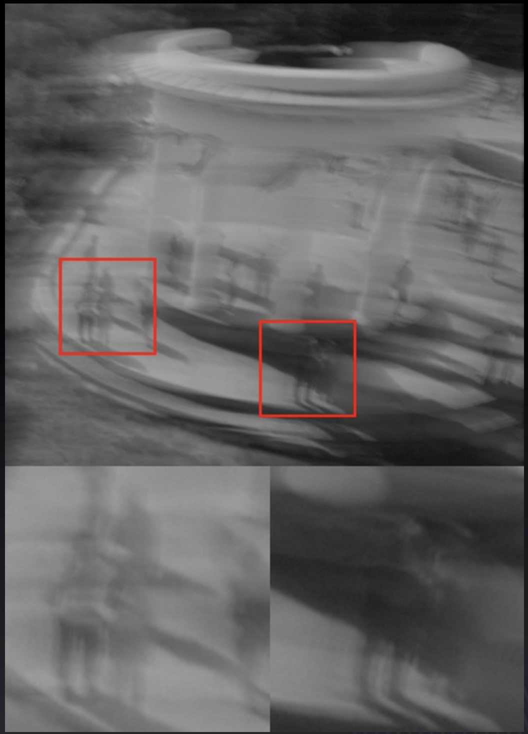
Dahari, Jacoby, B, CVPR 2020

Differentiable camera model



Dahari, Jacoby, B, CVPR 2020

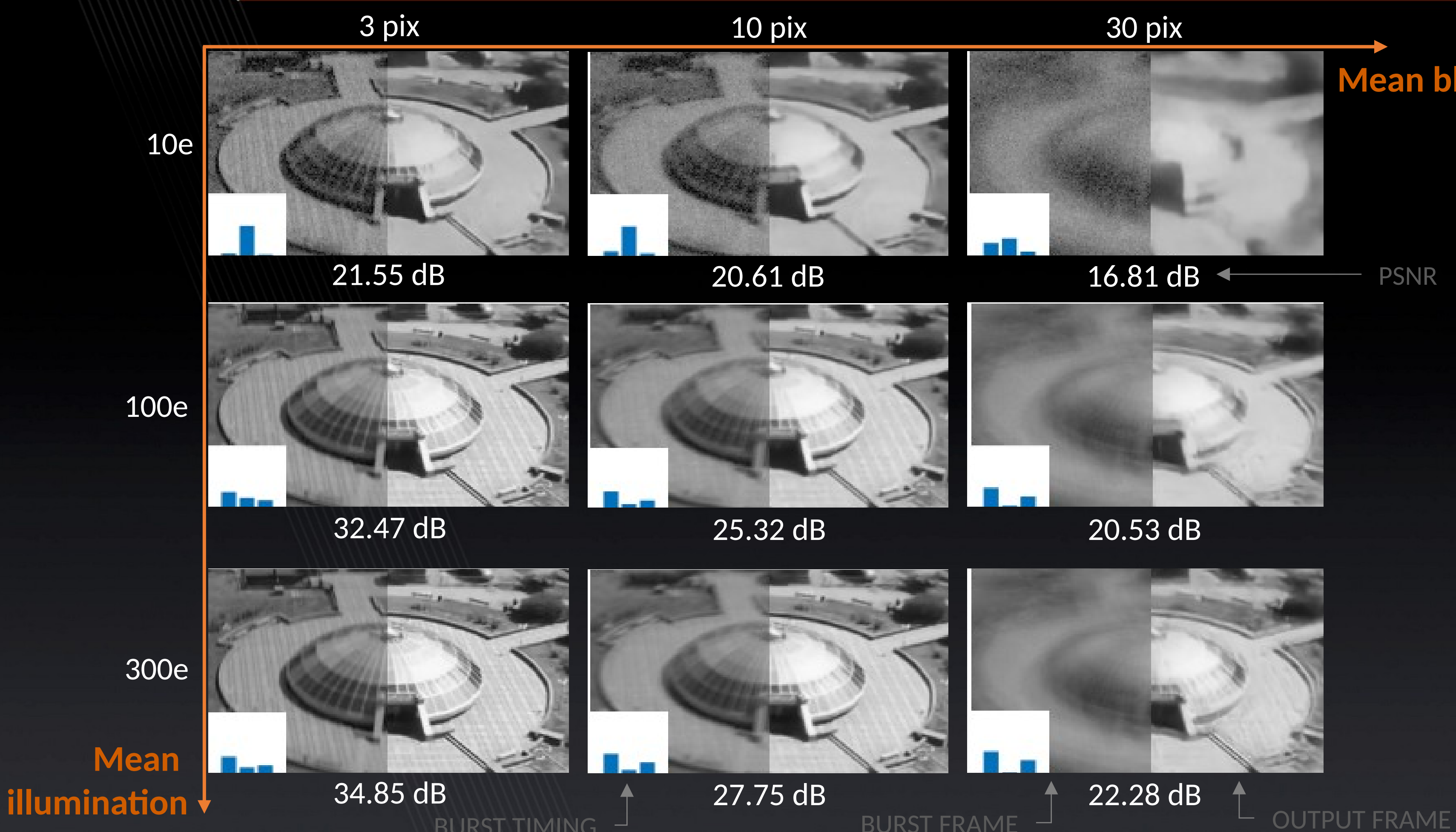
Digital gimbal

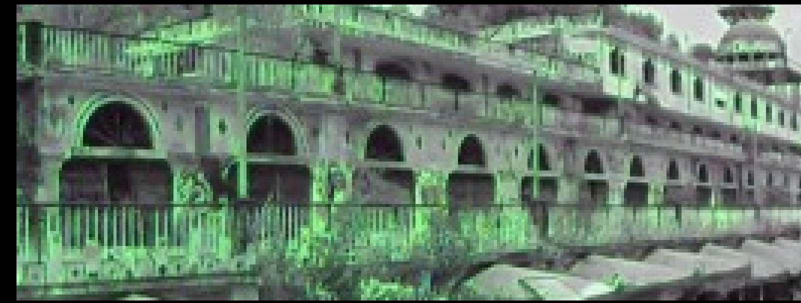
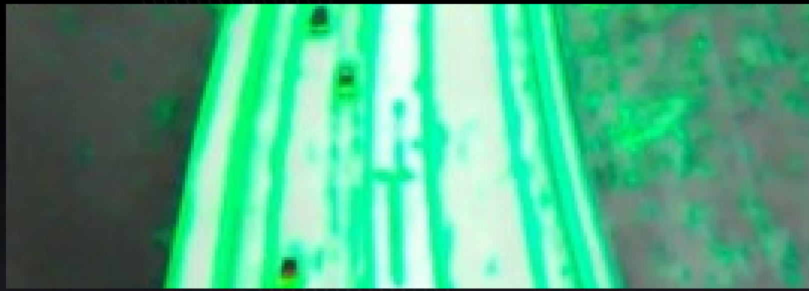

full exposure


Digital Gimbal


Digital Gimbal + **learned exposure**

Dahari, Jacoby, B, CVPR 2020


3 pix
10 pix
30 pix
Mean blur
10e
21.55 dB
20.61 dB
16.81 dB
PSNR
100e
32.47 dB
25.32 dB
20.53 dB
300e
34.85 dB
27.75 dB
22.28 dB
Mean illumination
BURST TIMING
BURST FRAME
OUTPUT FRAME


Uniform exposures

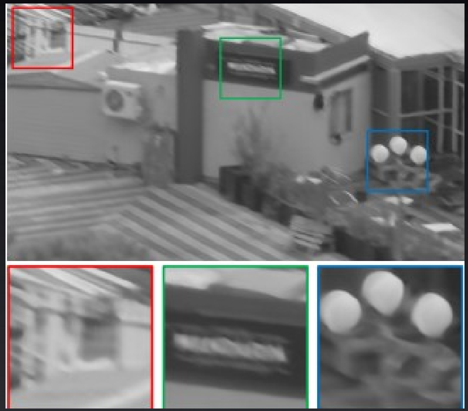
Learned exposures

Dahari, Jacoby, B, CVPR 2020

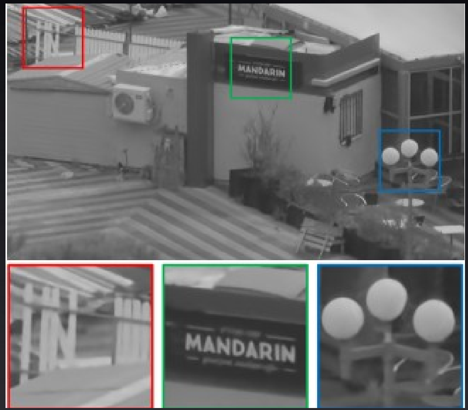
Acquisition setup

Full exposure

DeblurGAN v2



Kernel prediction net



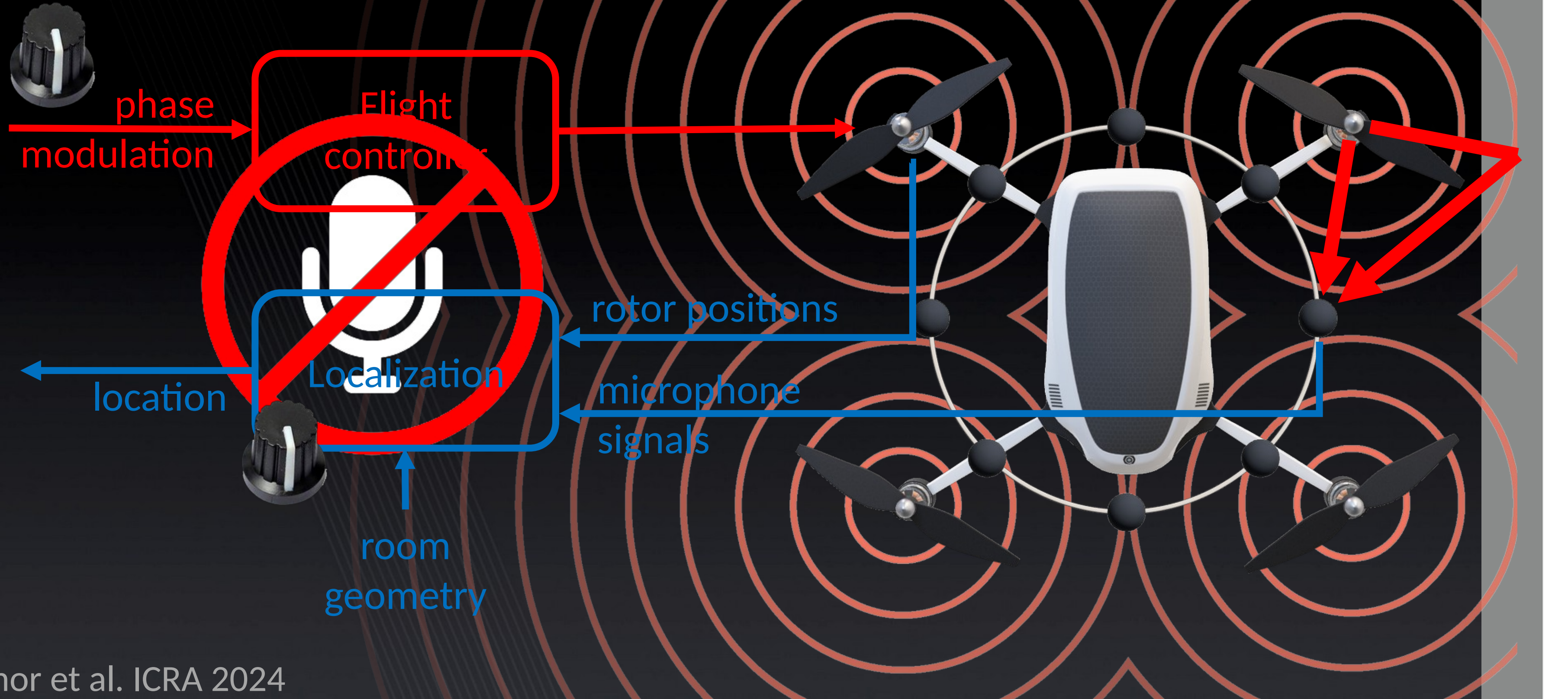
Digital Gimbal

Dahari, Jacoby, B, CVPR 2020

Endowing drones with ears

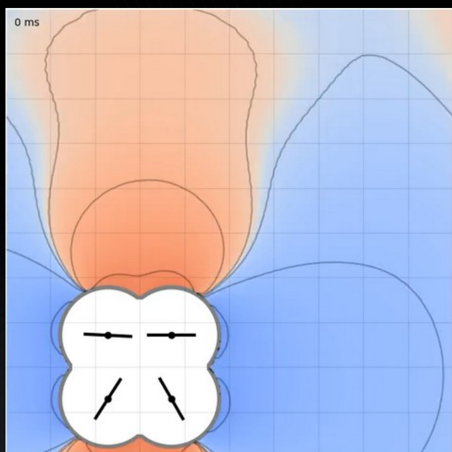
Shor et al. ICRA 2024

Endowing drones with ears

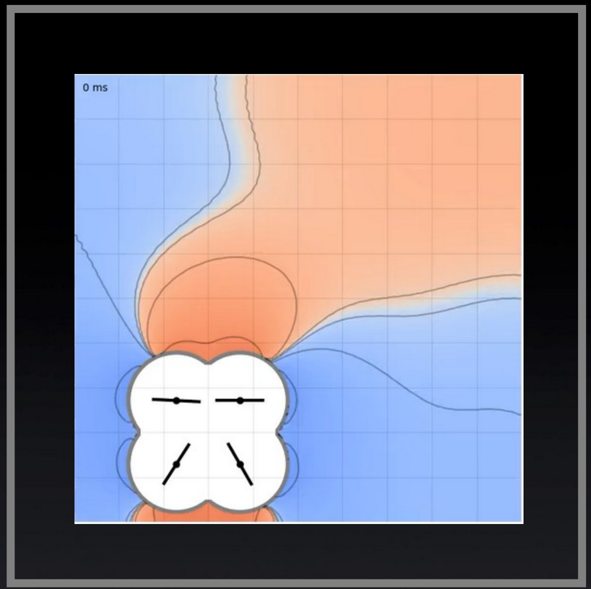


Shor et al. ICRA 2024

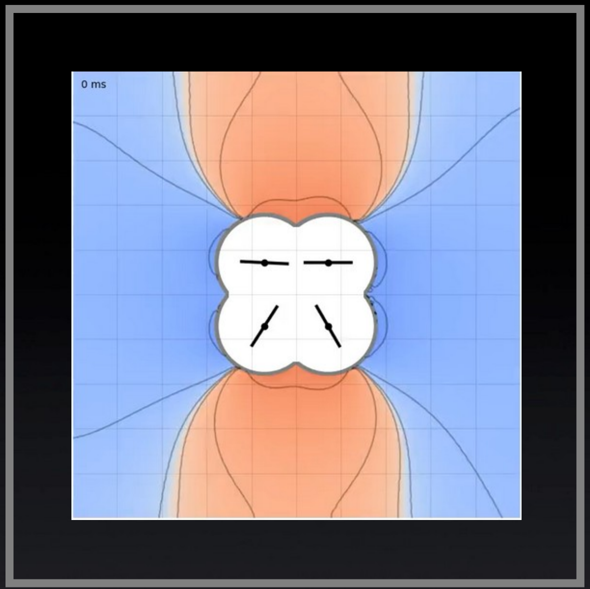
Can you hear the shape of the room?



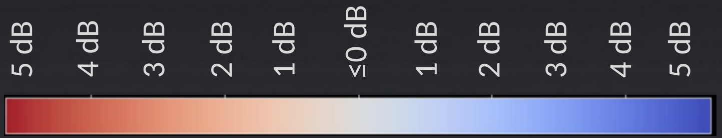
free space



in a room

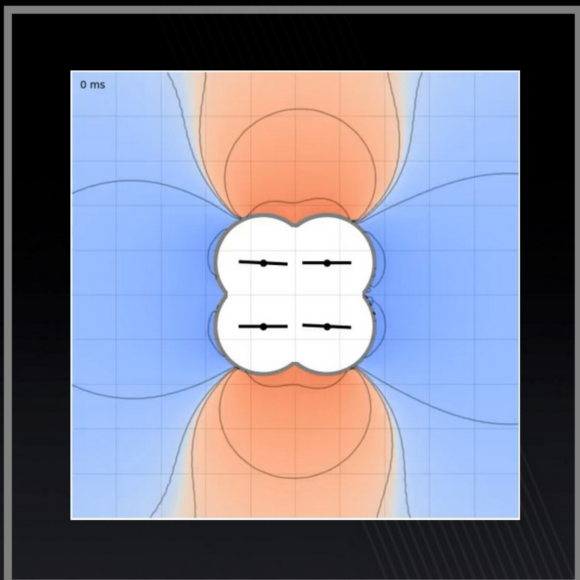


in a room

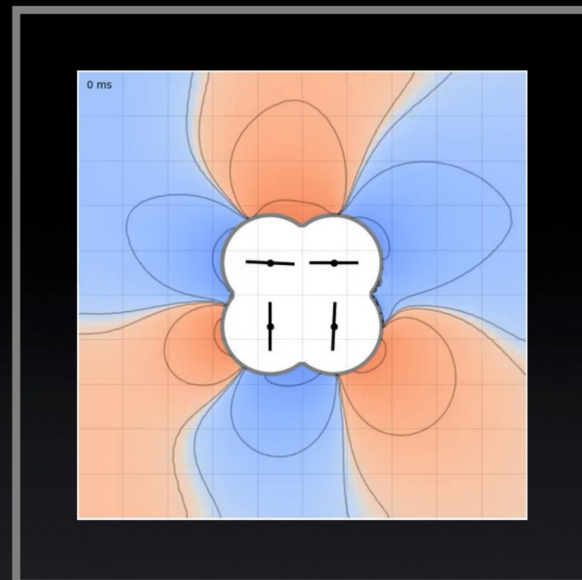


Shor et al. ICRA 2024

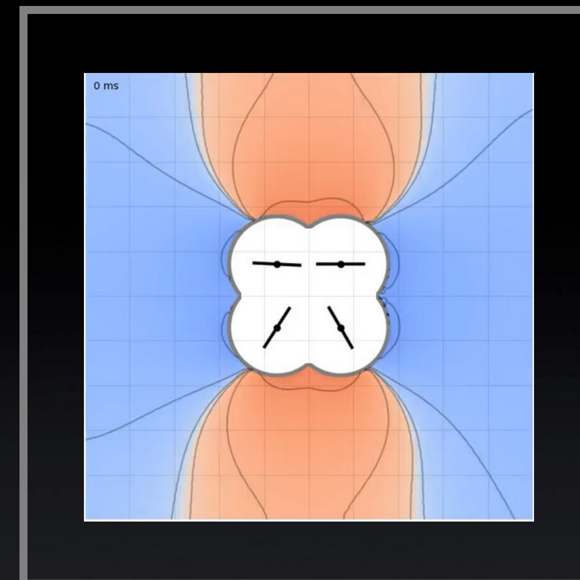
Can you hear the shape of the room?



zero phase modulation



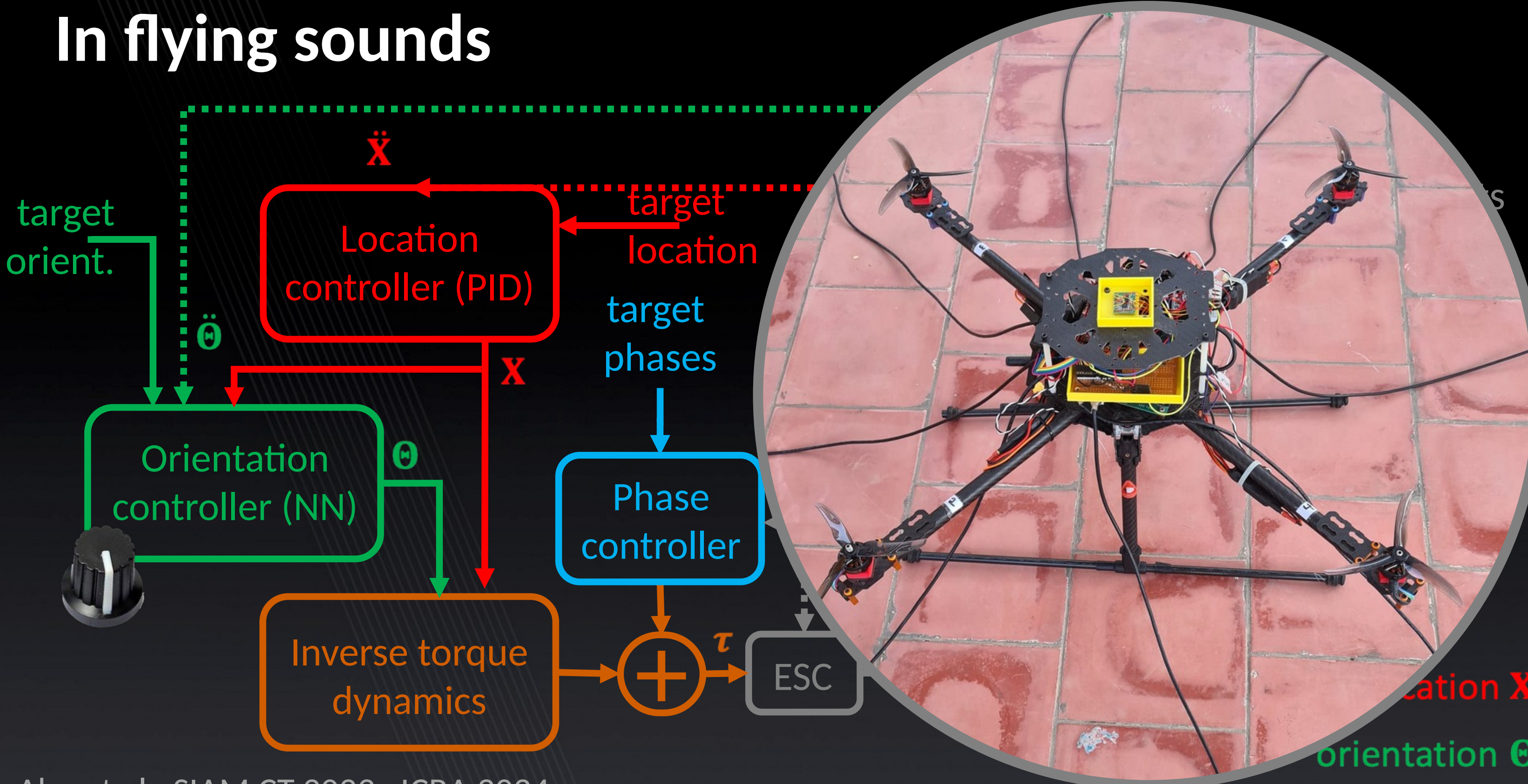
fixed phase offset



time-varying phase modulation

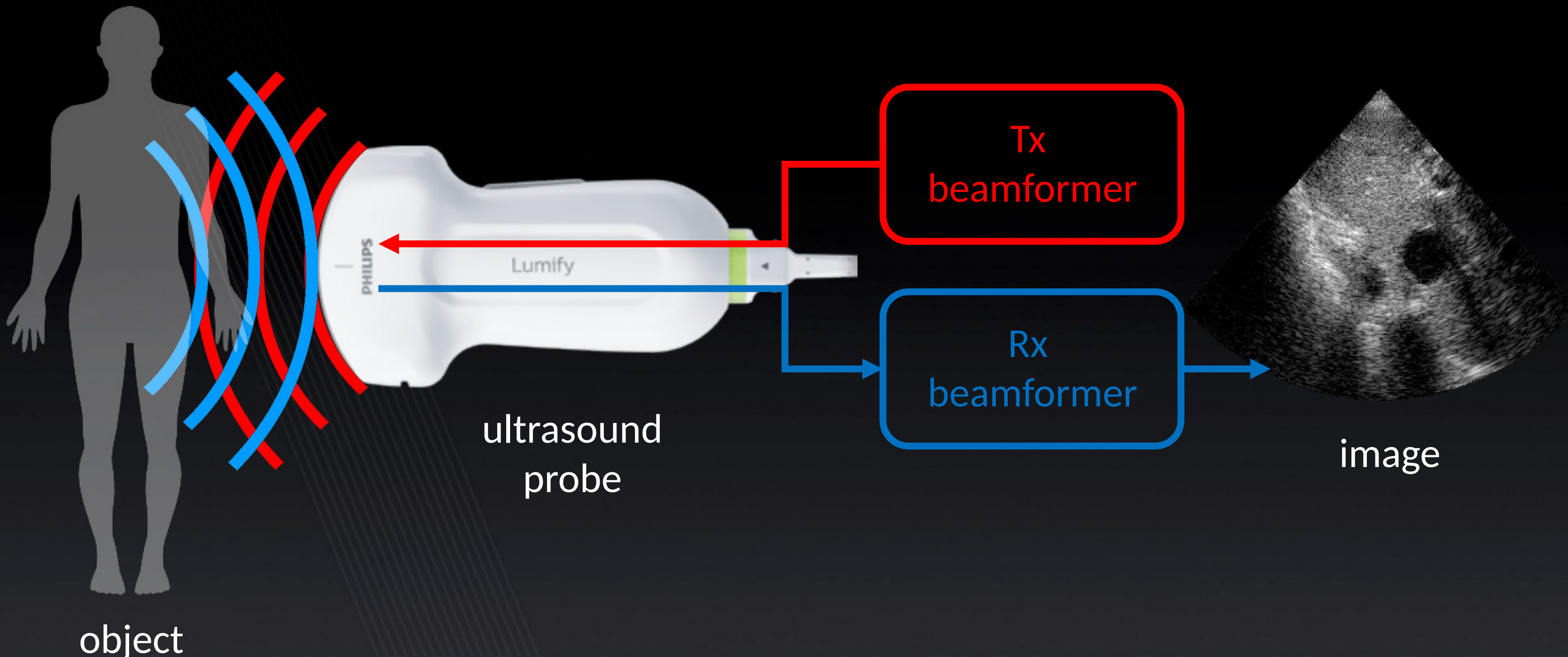
Shor et al. ICRA 2024

In flying sounds

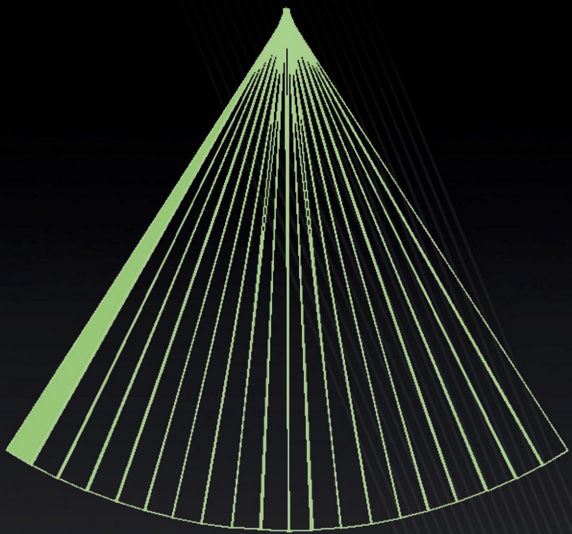


Abu et al., SIAM CT 2023 · ICRA 2024

Learning to hear inside the body

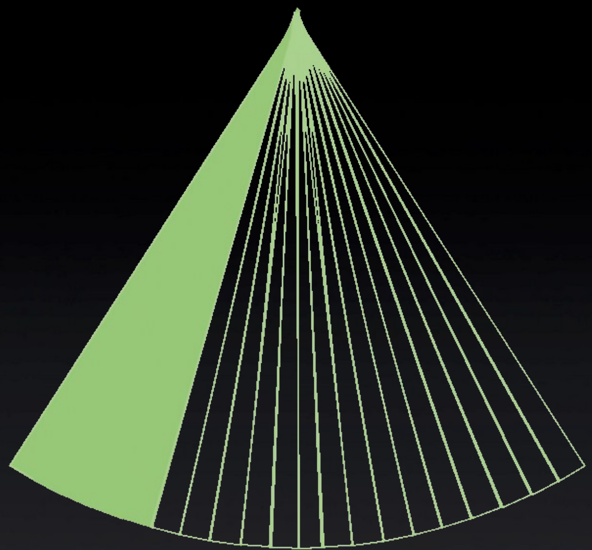


Learning to hear inside the body

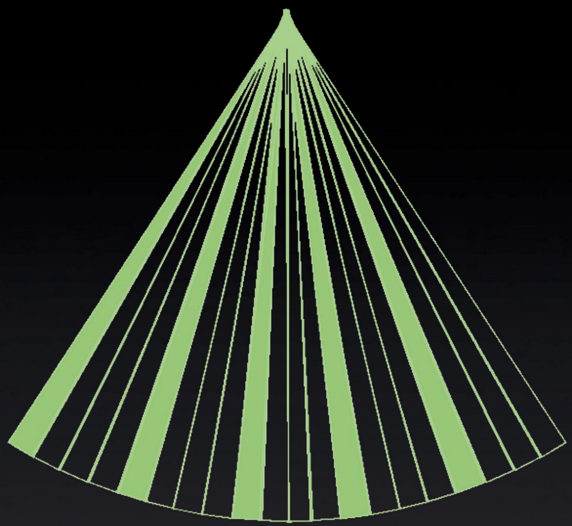


single-line acquisition

SLOW!



multi-line acquisition



multi-line transmission

Learning to hear inside the body

single-line acquisition

SLOW!

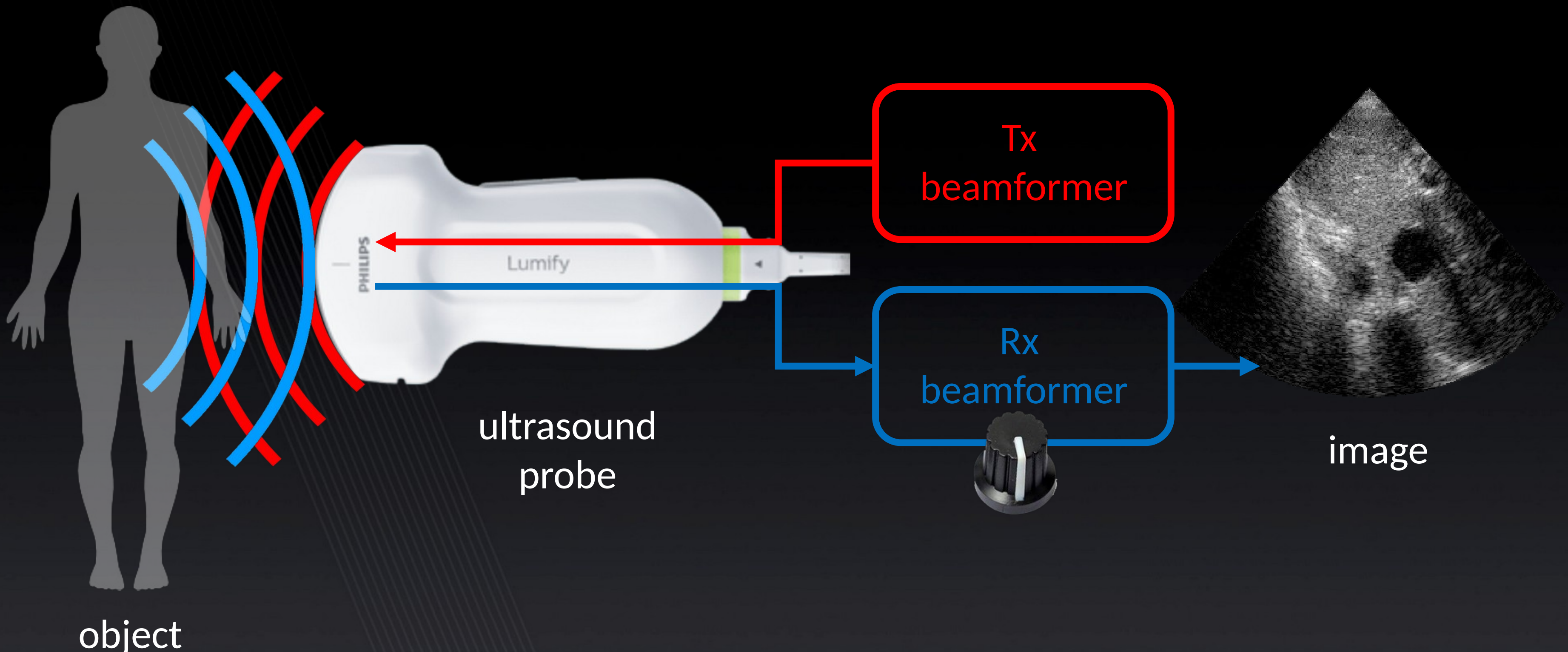
multi-line acquisition

LOW RESOLUTION

multi-line transmission

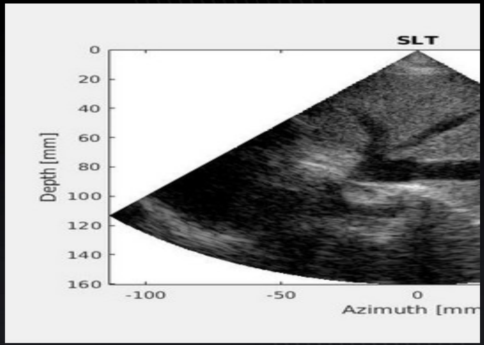
LOW CONTRAST

Learning to hear inside the body

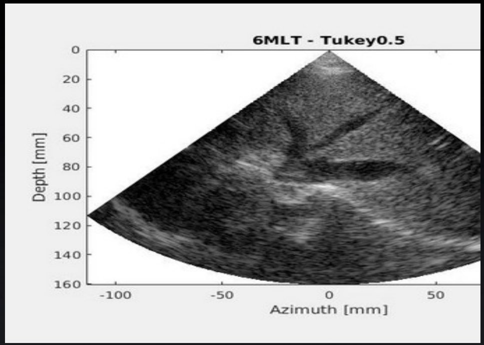


Senouf et al., MICCAI 2018; MLMIR 2018

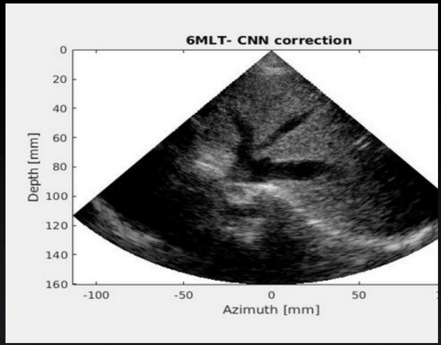
End-to-end beamforming learning in US



single-line
acquisition



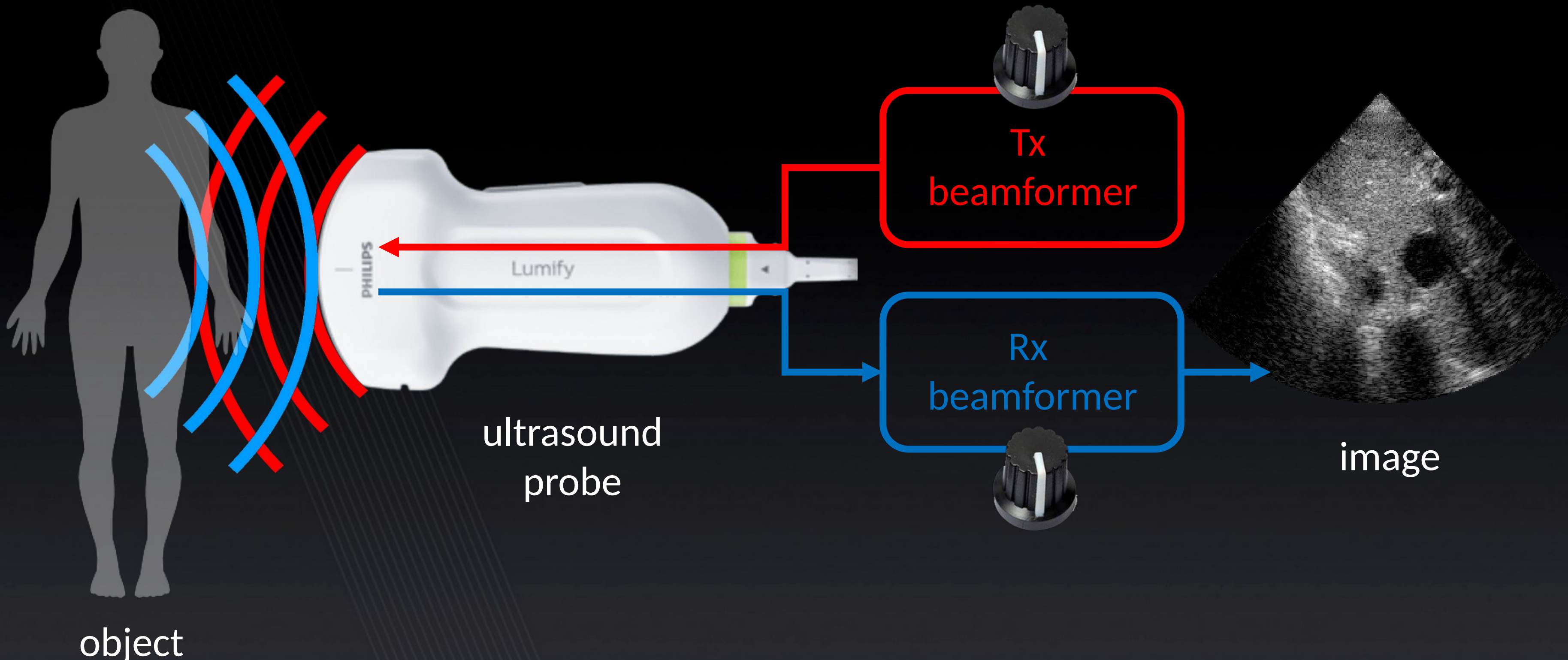
x6 multi-line
transmission



x6 learned
Rx beamforming

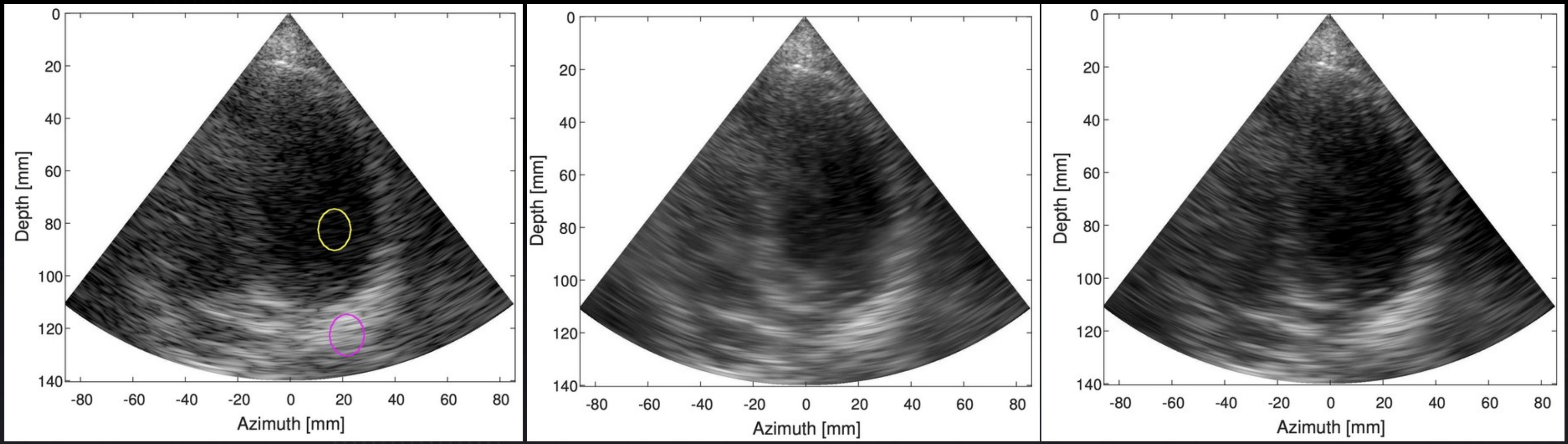
Senouf et al., MICCAI 2018; MLMIR 2018

Learning to hear inside the body



Vedula et al., MIDL 2019

End-to-end beamforming learning in US



single-line acquisition

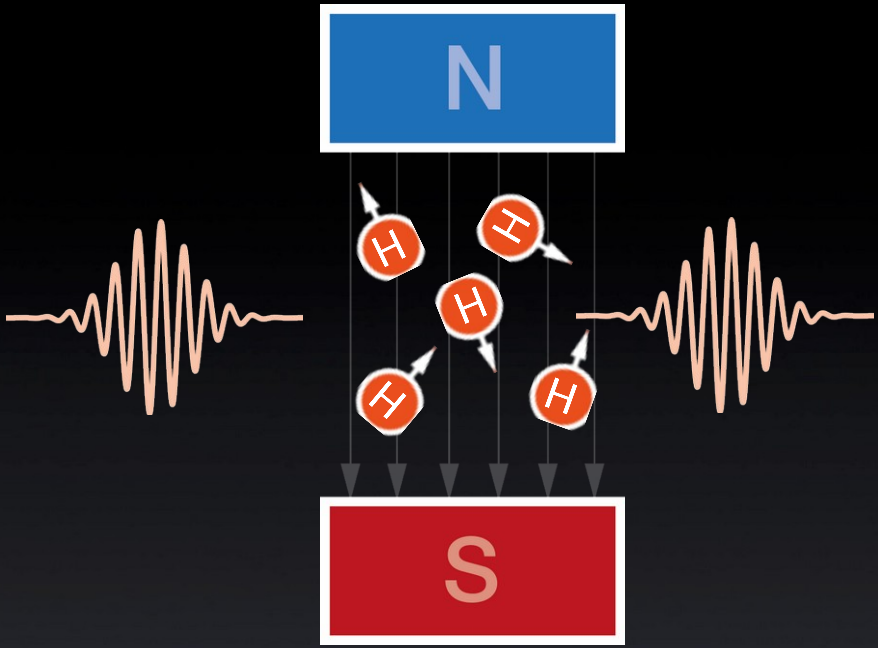
x20 multi-line acquisition

x20 learned Rx+Tx beamforming

Vedula et al., MIDL 2019

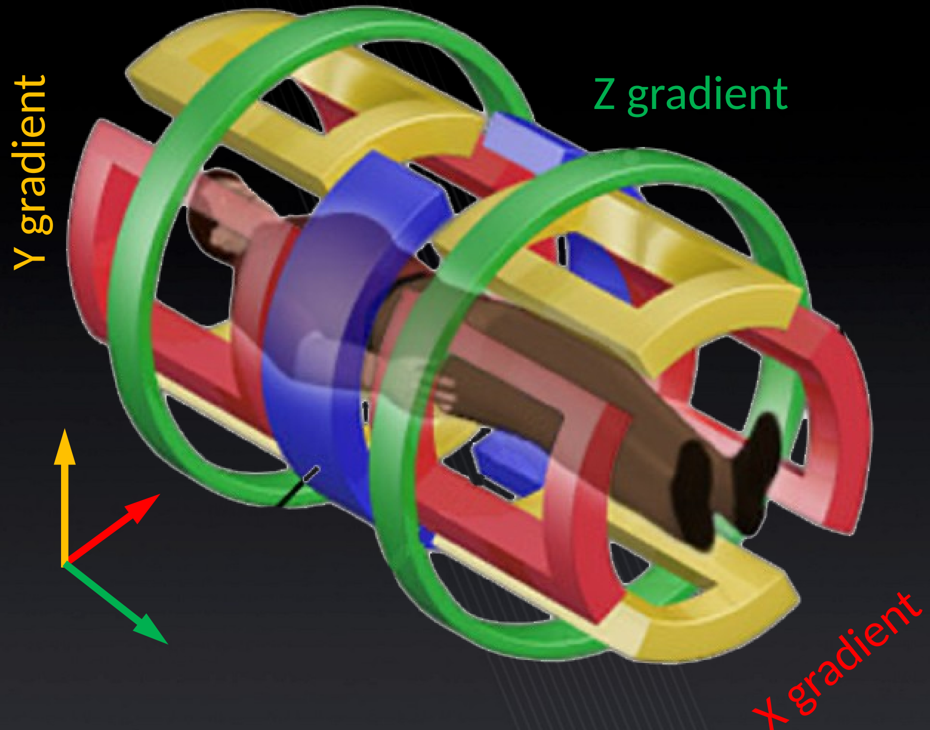
Learning to see inside the body

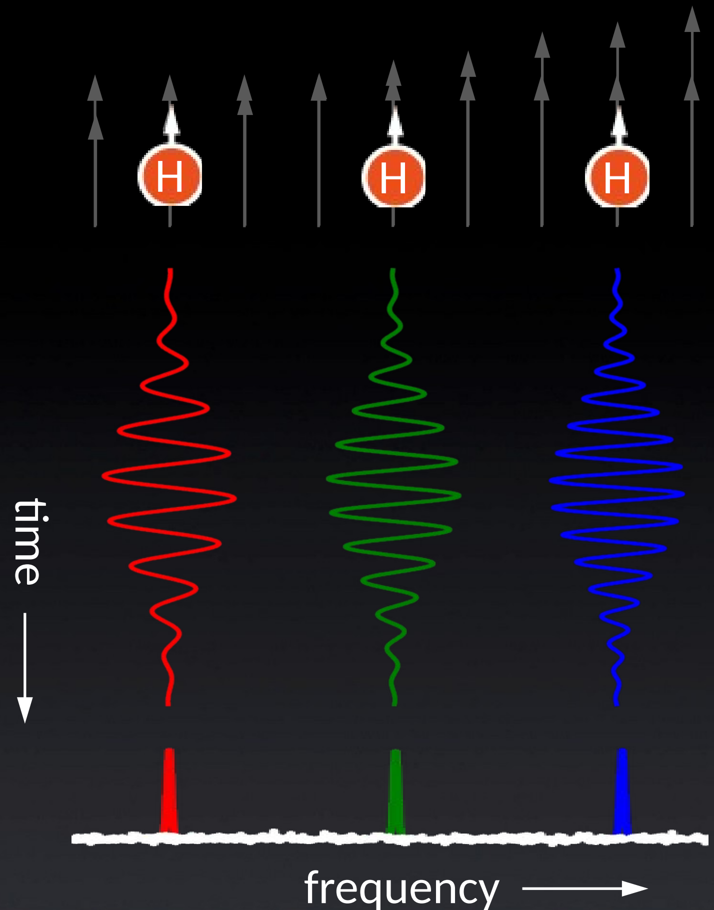
magnetic resonance imaging (MRI)



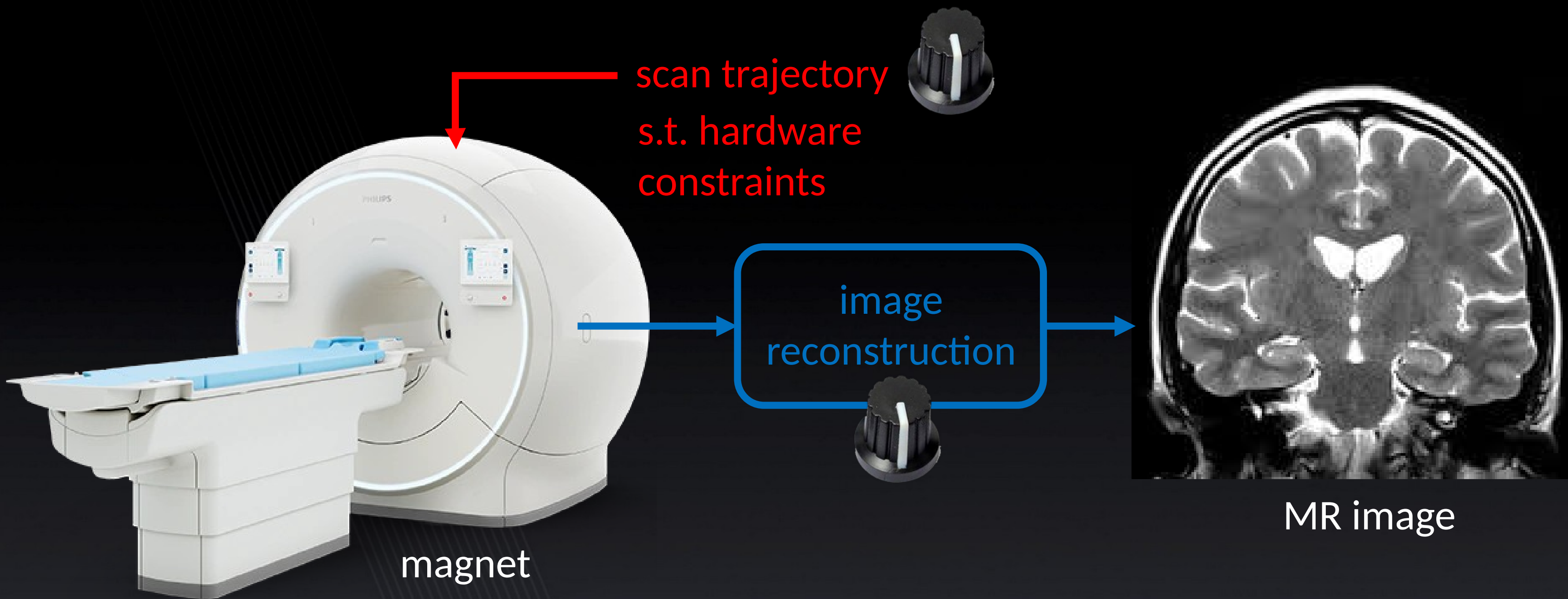
nuclear magnetic resonance

The working of MRI

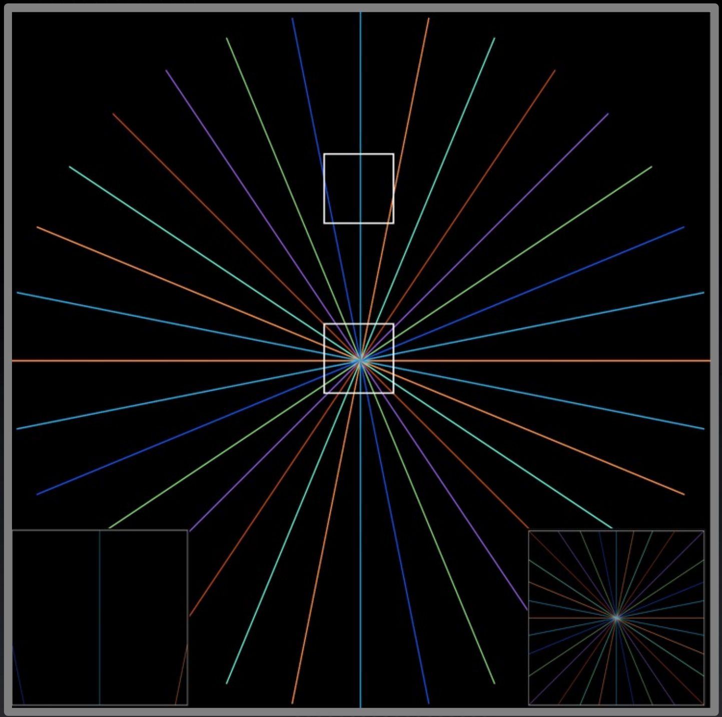




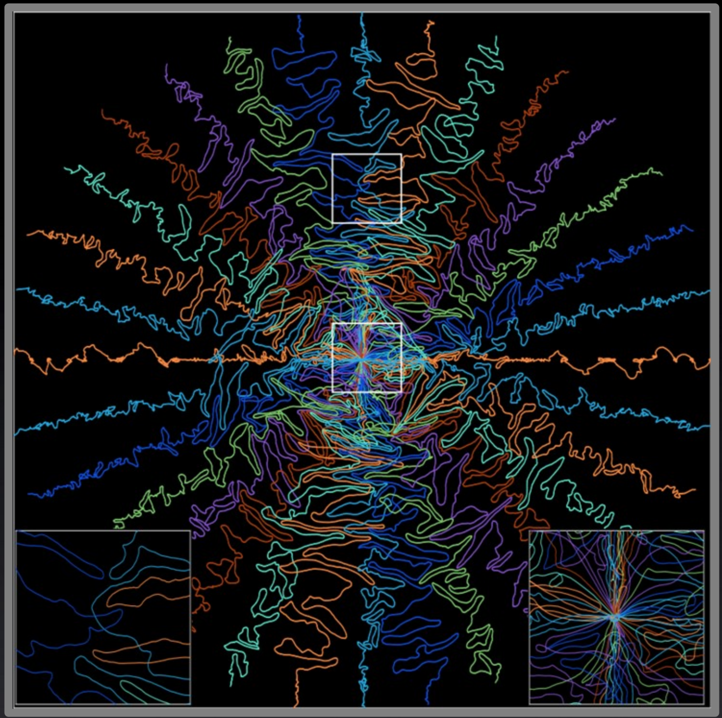
Learning to see inside the body



Learning to scan



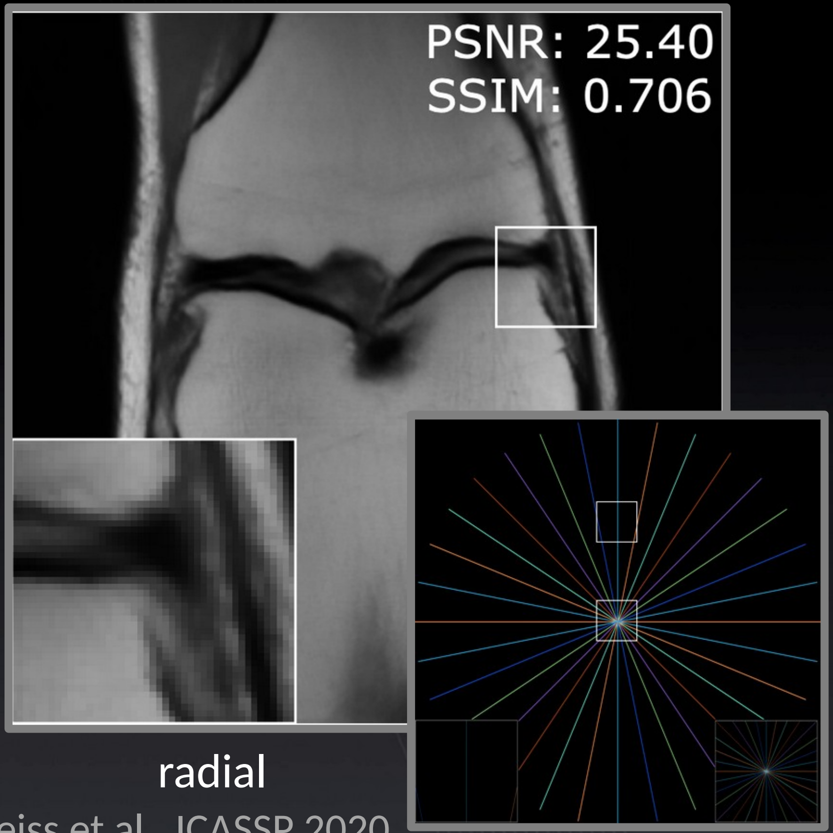
radial scan (16 shots)



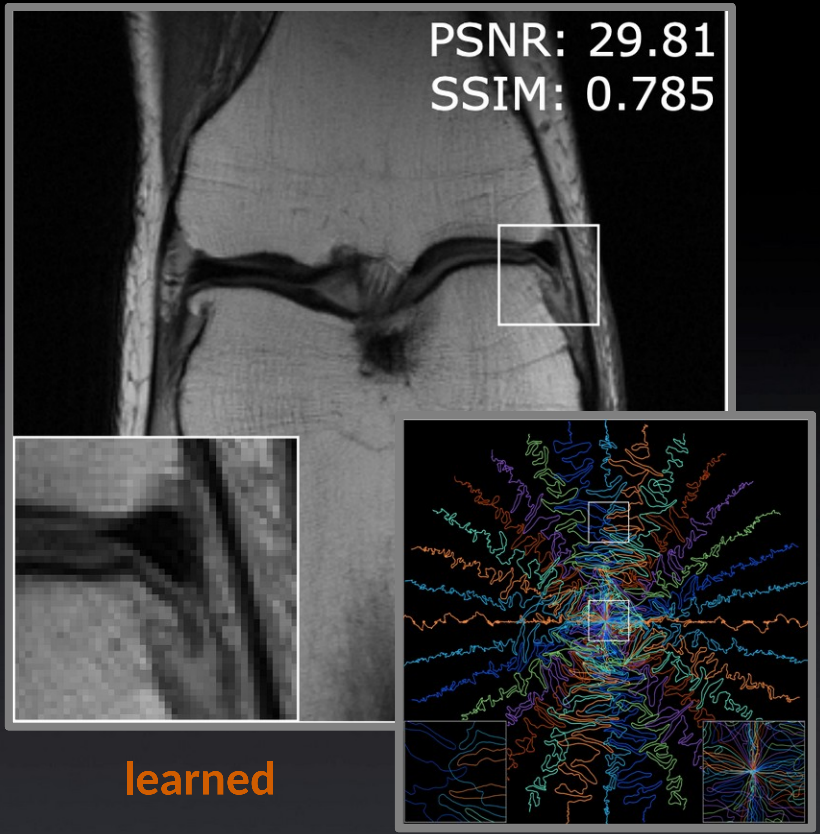
learned scan (16 shots)

Weiss et al., ICASSP 2020; MELBA 2021

Learning to scan



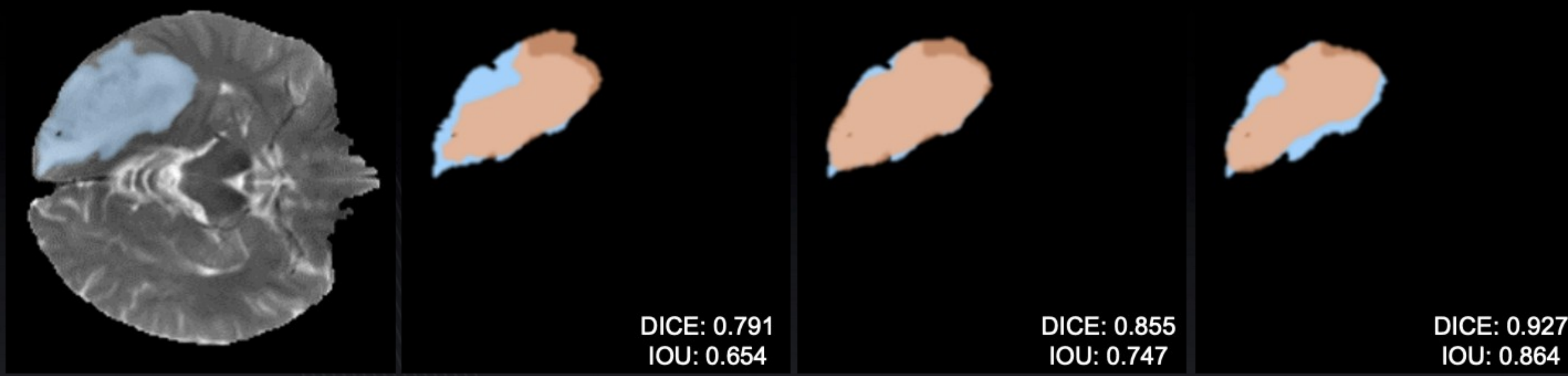
radial



learned

Weiss et al., ICASSP 2020

Learning to segment images



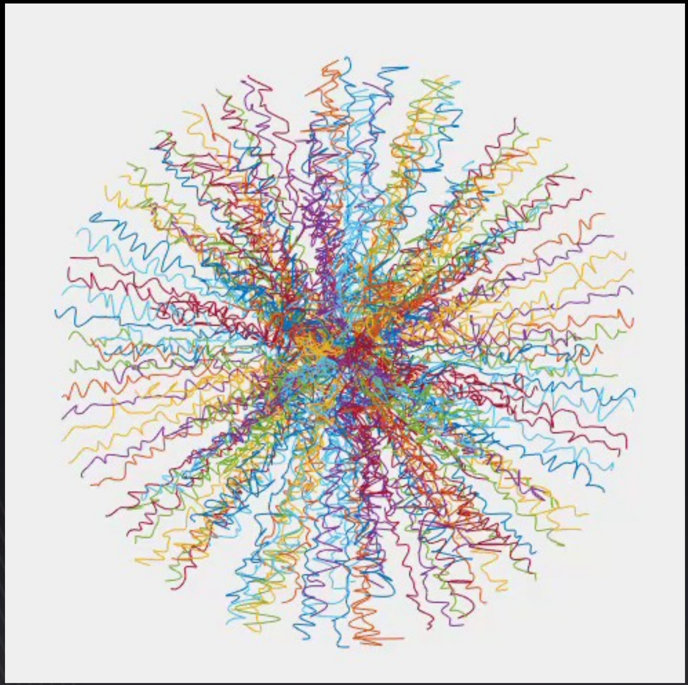
fixed

learned for **reconstruction**

learned for **segmentation**

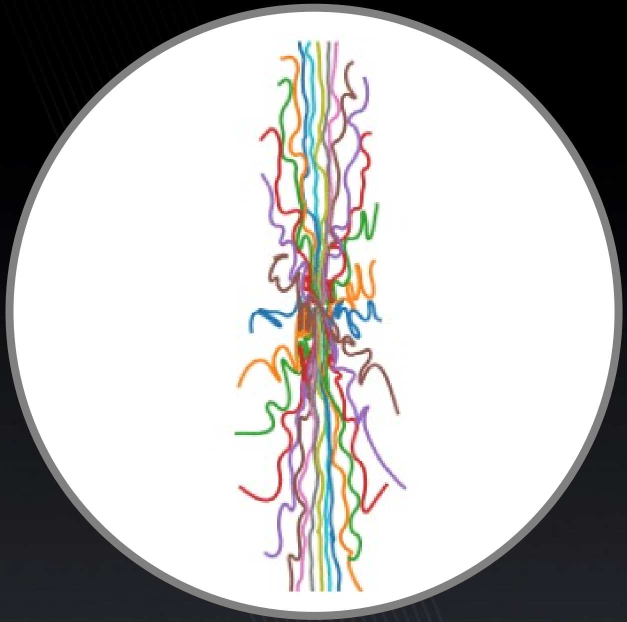
Weiss et al., ICASSP 2020; MELBA 2021

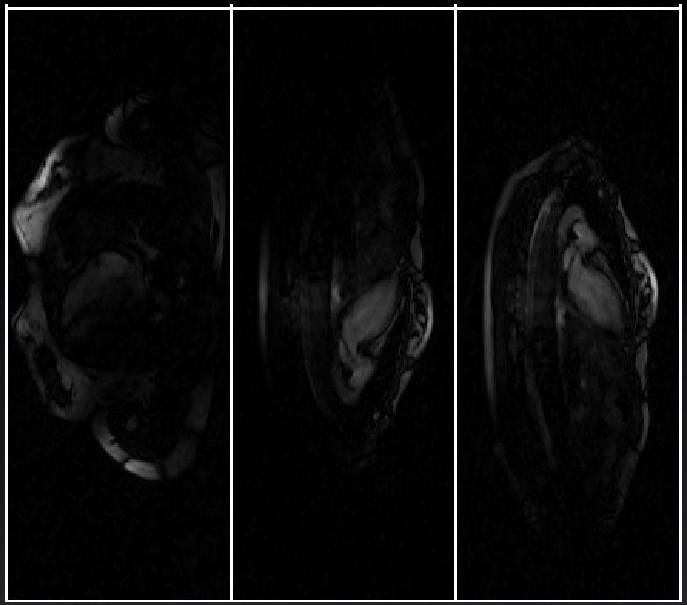
Extending to 3D



Ackerman et al., MICCAI’20

Extending to dynamic MRI

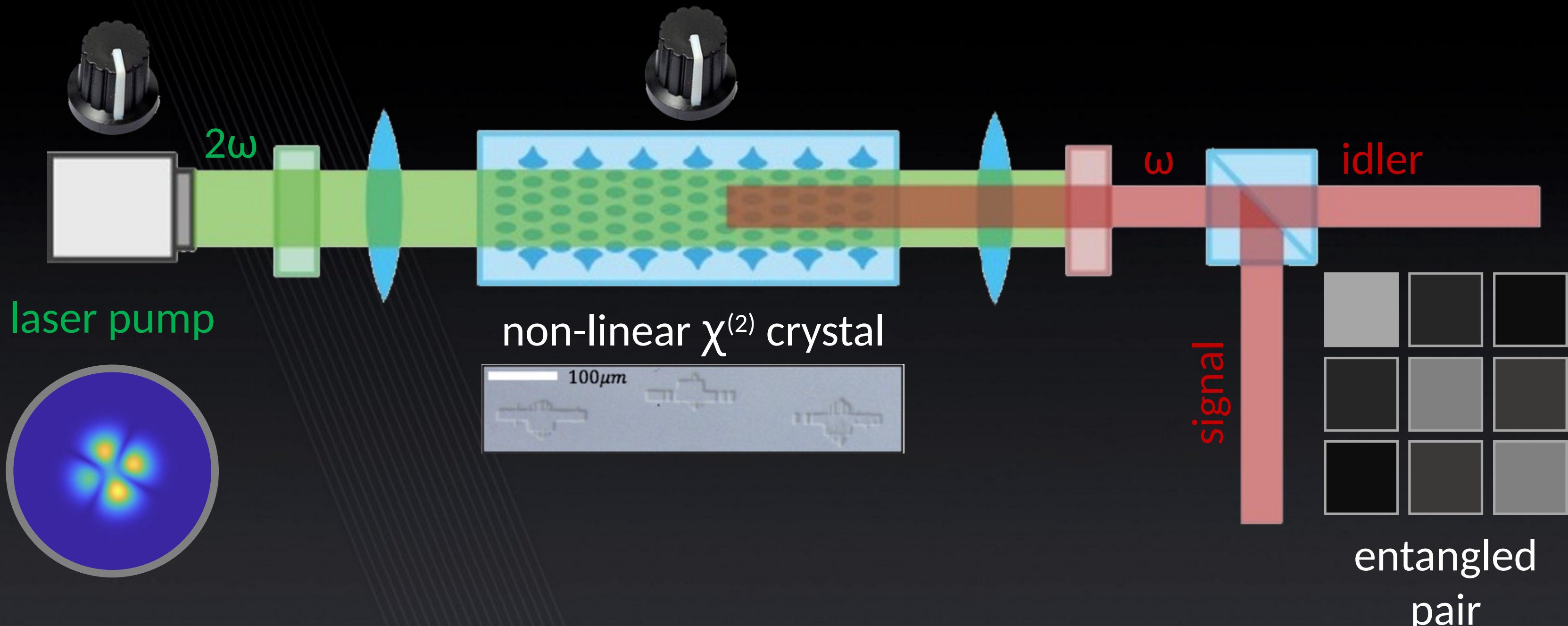




Shor et al., MICCAI'23

Learning to entangle light

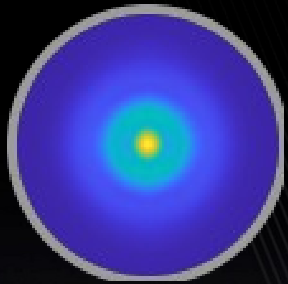
spontaneous parametric down conversion (SPDC)



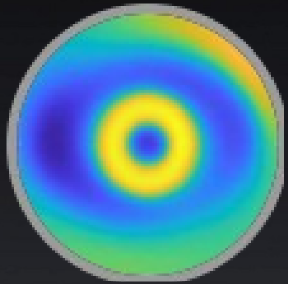
Rozenberg et al., Optica 2020; ICLR 2023

Learning to entangle light

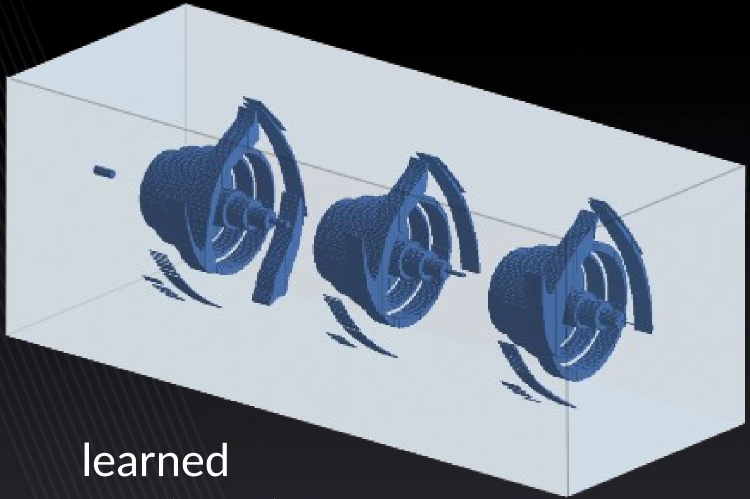
learned pump



intensity

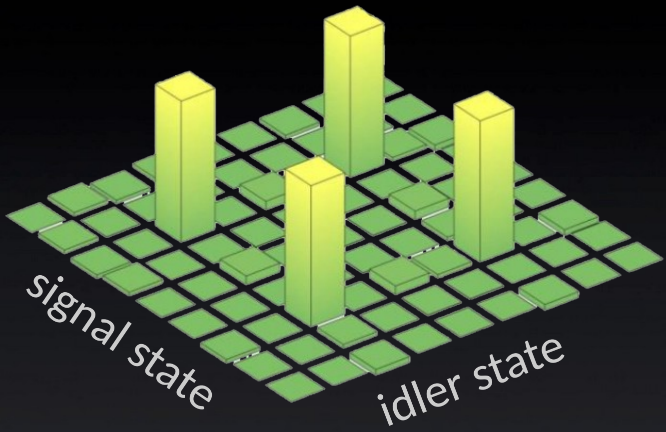


phase



learned
crystal (z×20)

two-photon
density matrix



Rozenberg et al., Optica 2020; ICLR 2023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