Evaluation of lateral and axial resolution of pixel-based beamformers in Photoacoustic Tomography using a linear US probe

Irene Pi-Martín, Alejandro Cebrecos, Juan José García-Garrigós, Noé Jiménez, Francisco Camarena

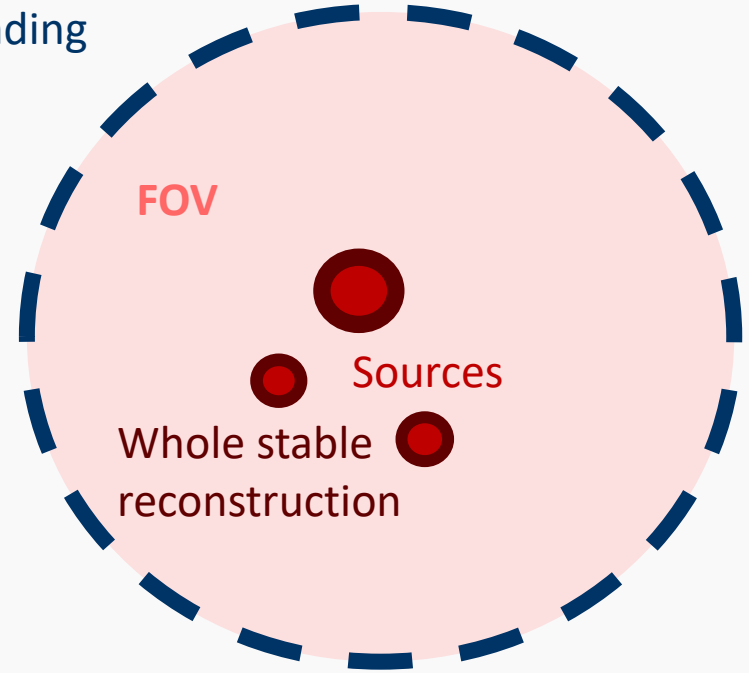
Universitat Politècnica de València / CSIC, Instituto de Instrumentación para Imagen Molecular (I3M), València, Spain

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International Ultrasonics Symposium
Venice, Italy || October 10-13, 2022

Introduction

Background and motivation

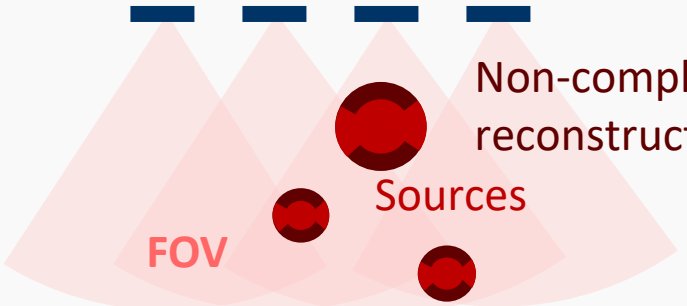
Array surrounding the source



☑ Able to record all angular components

☒ Expensive

Linear array



☑ Cheap, simple and portable

☒ Missing angular components → Complex beamformers

Introduction

Objectives

- **Characterisation of the system resolution:**
  - Quantify it with 3D simulations
  - Experimental quantification.

- **Choice** of the most **suitable beamformer depending on** various **limitations** of the linear **probe**.

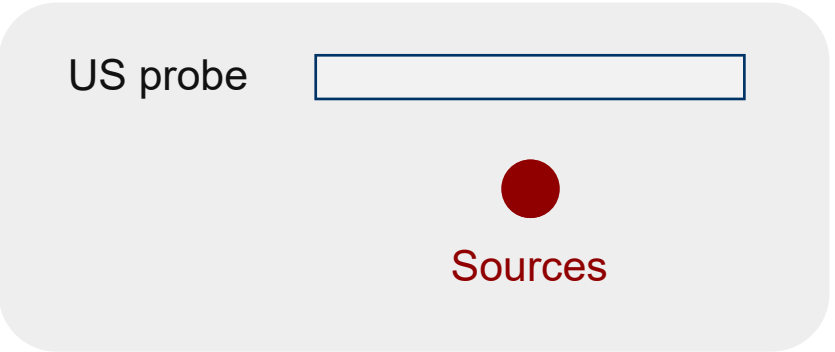
  - Evaluate the effect of the
    - Field of view (FOV)
    - Frequency response

  - Compare the resolution of a PA tomography system using:
    - Linear ultrasound probe
    - Pixel-based beamformers

Methods

Simulations

- 3D numerical simulations
- 2 independent sources
- 1 linear US array



Simulated conditions:

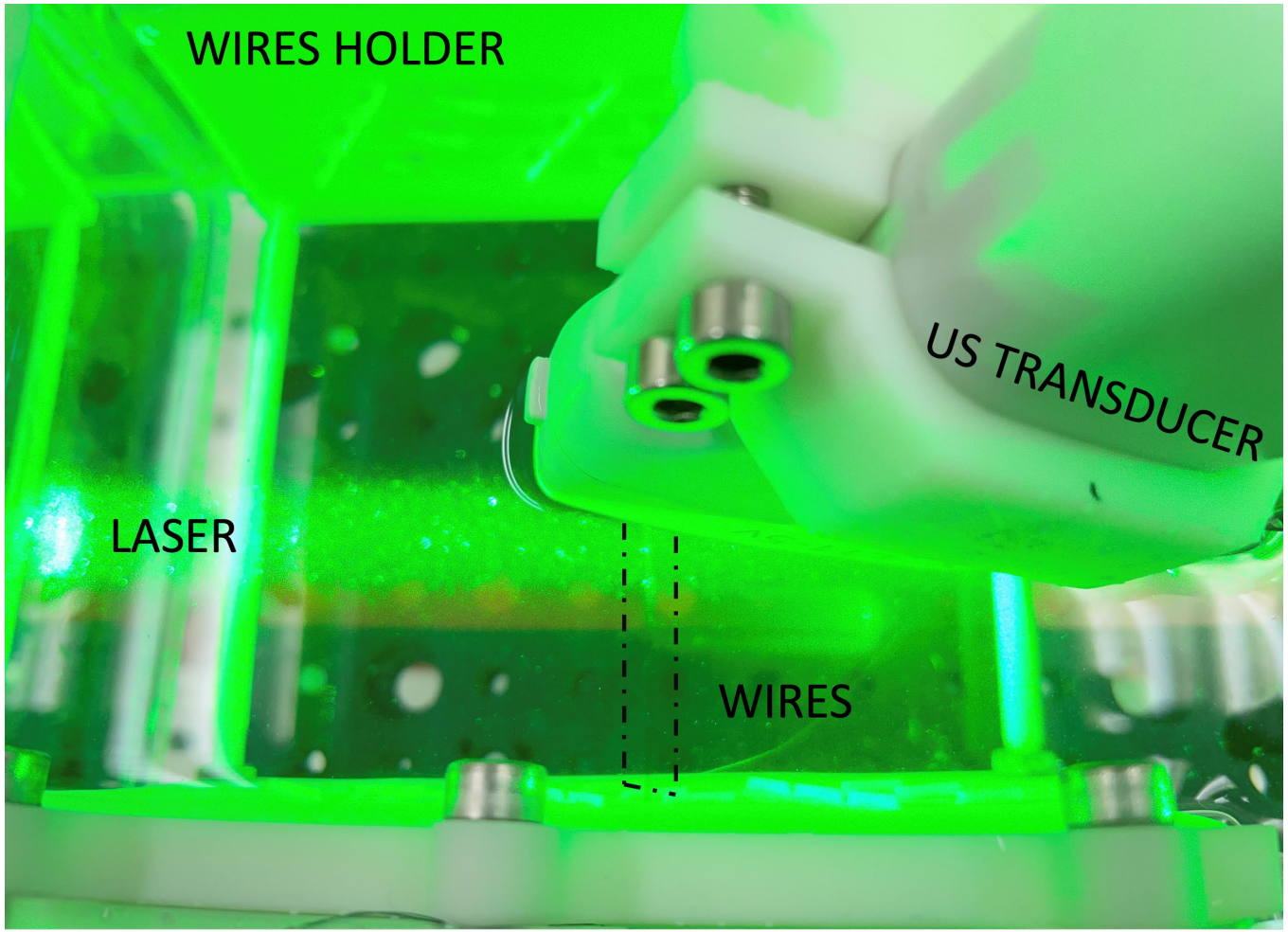
- **Cond. 1:** Omnidirectional sensor, freq. response up to 15.2 MHz.
- **Cond. 2:** Cond. 1 + frequency response limited to fc = 7.6 MHz and 77% bandwidth.
- **Cond. 3:** Cond. 1 + probe directivity limited to 0.5 rad.
- **Cond. 4:** Cond. 2 + Cond. 3 (realistic conditions).

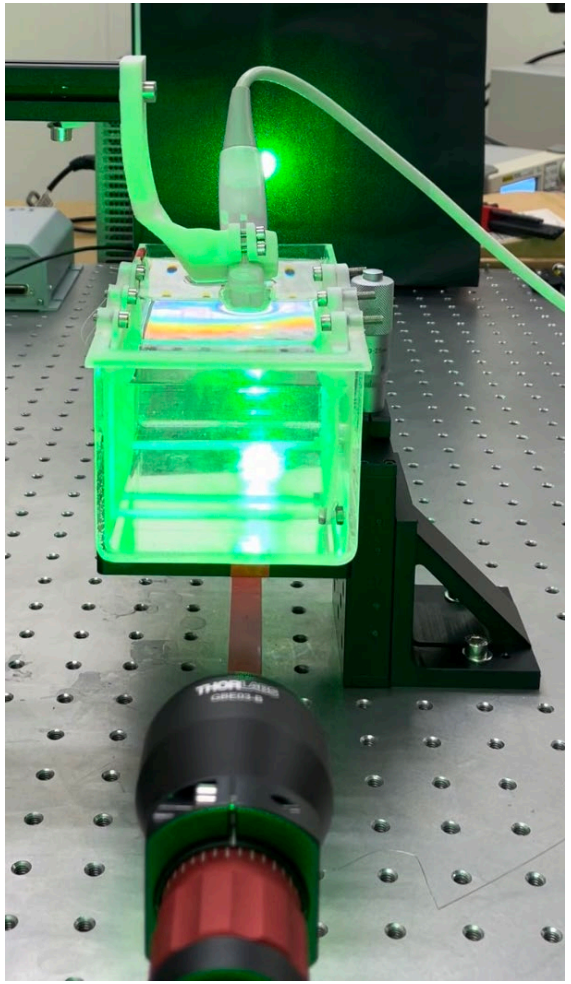
MATLAB®

k-Wave
A MATLAB toolbox for the time-domain simulation of acoustic wave fields

Methods

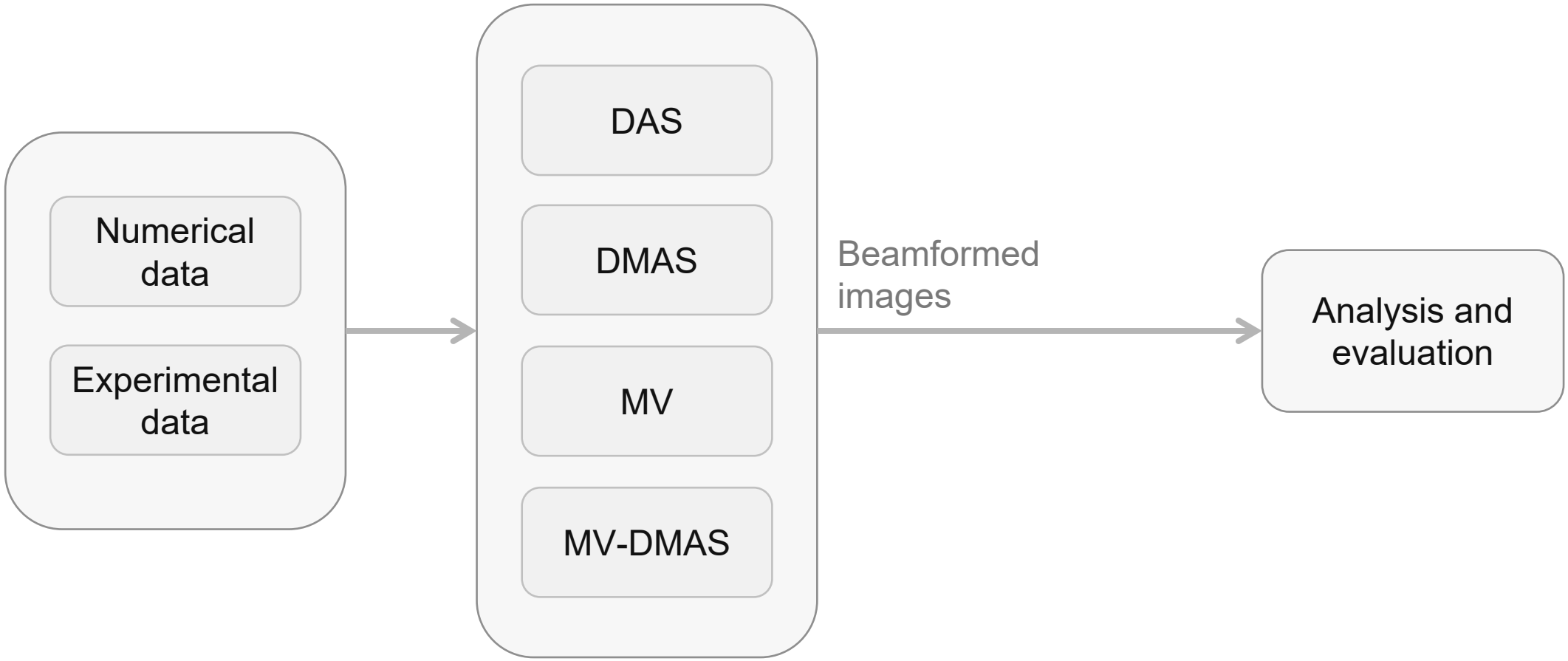
Experiments





Methods

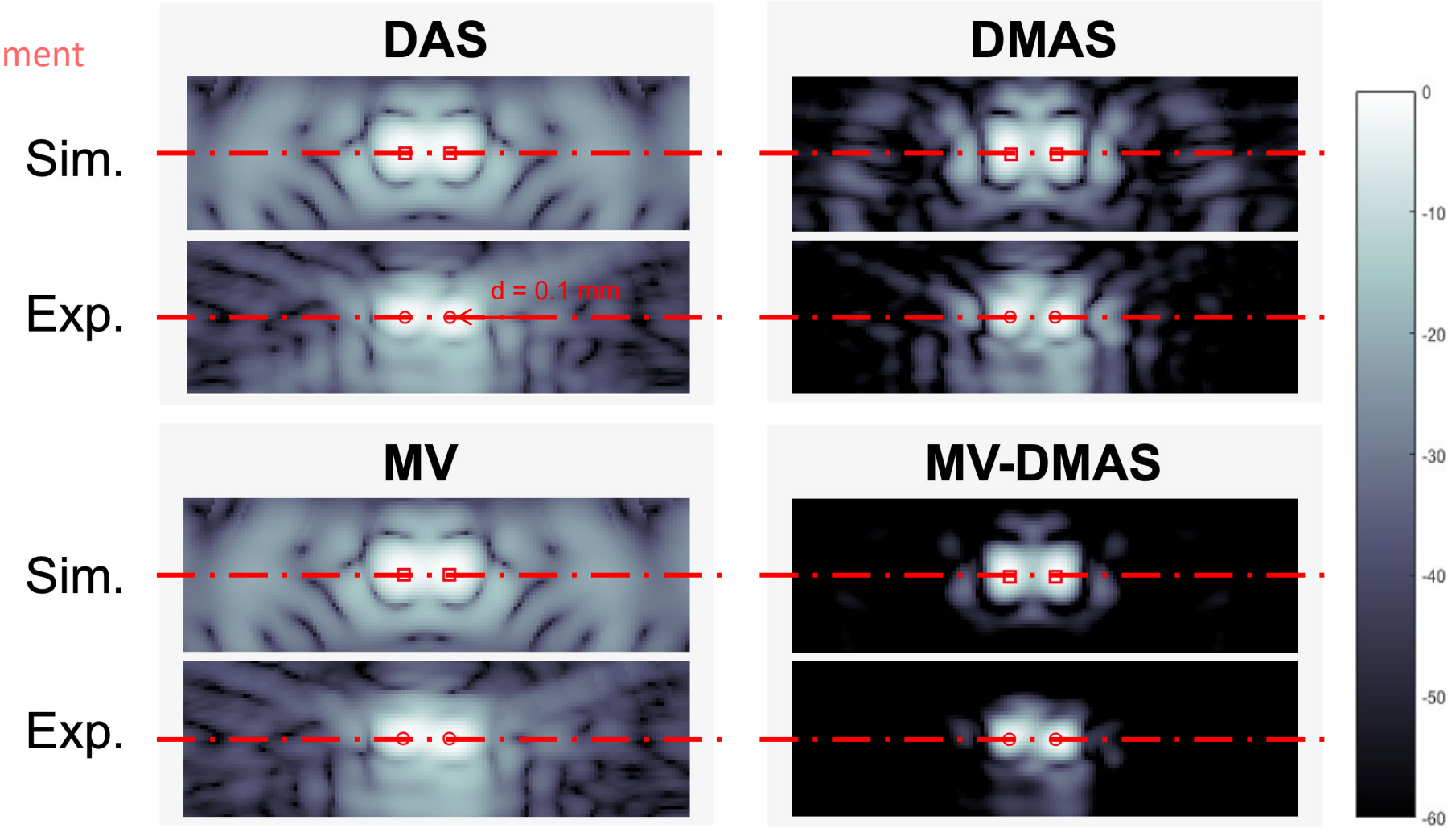
Data post processing



Results

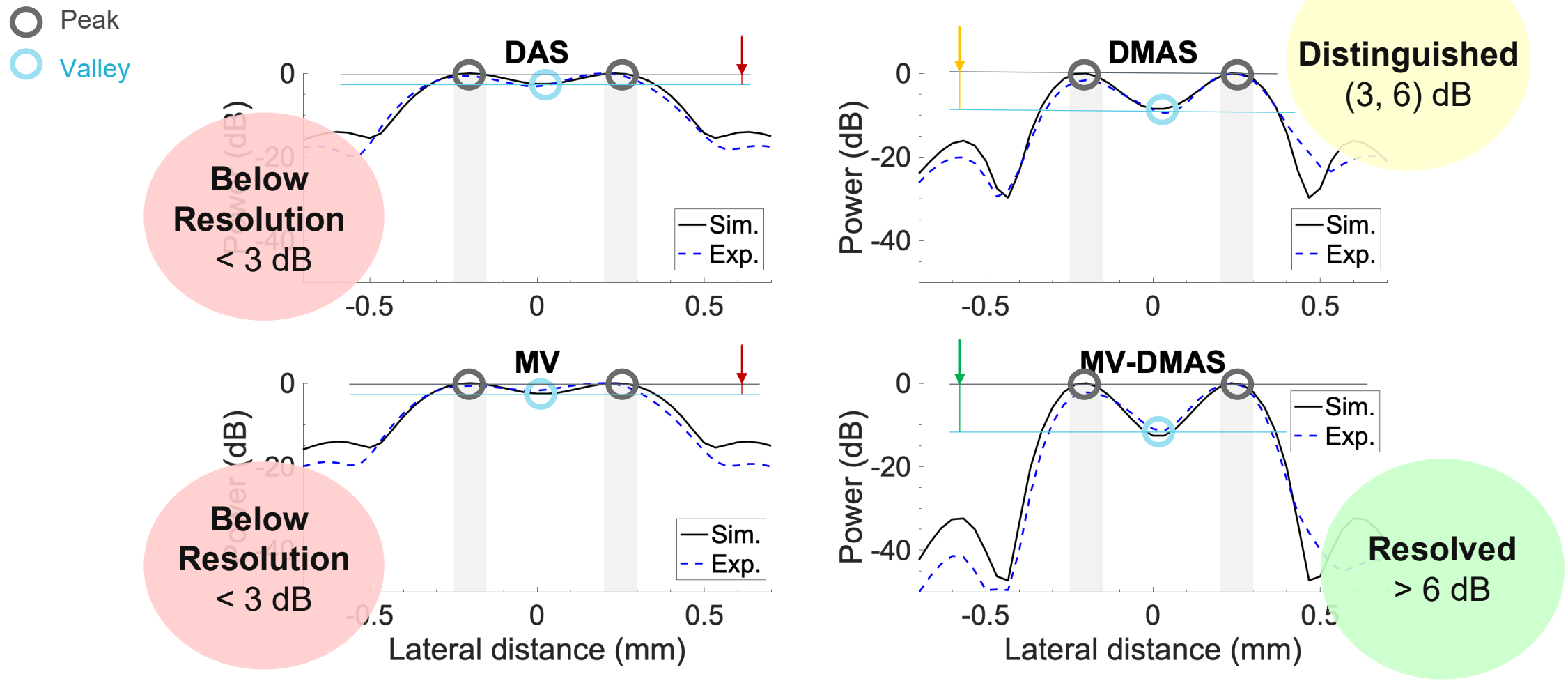
Beamformed images

- [x] Sim. & Exp. agreement
- [x] SNR improve



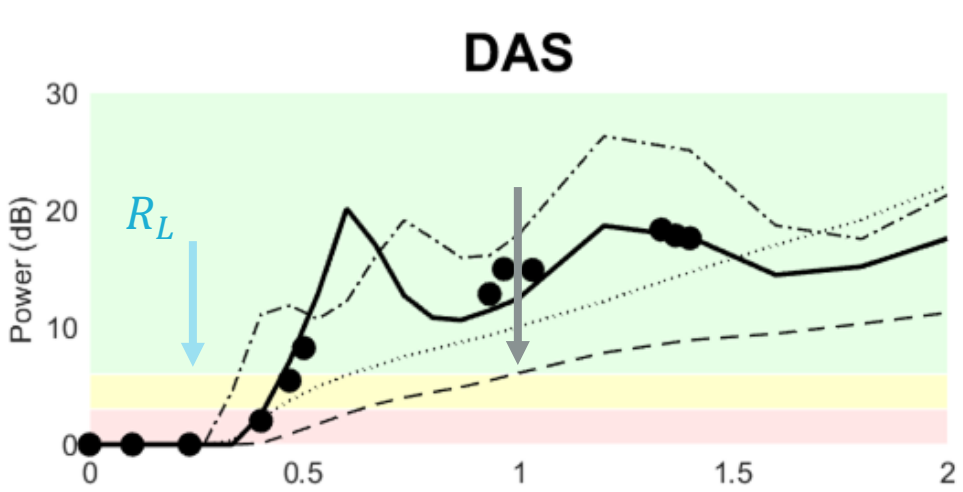
Results

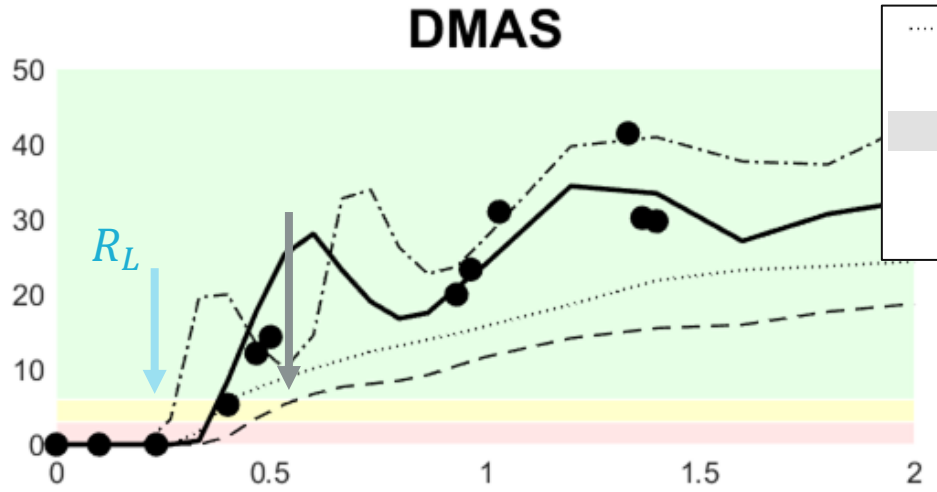
Lateral profiles

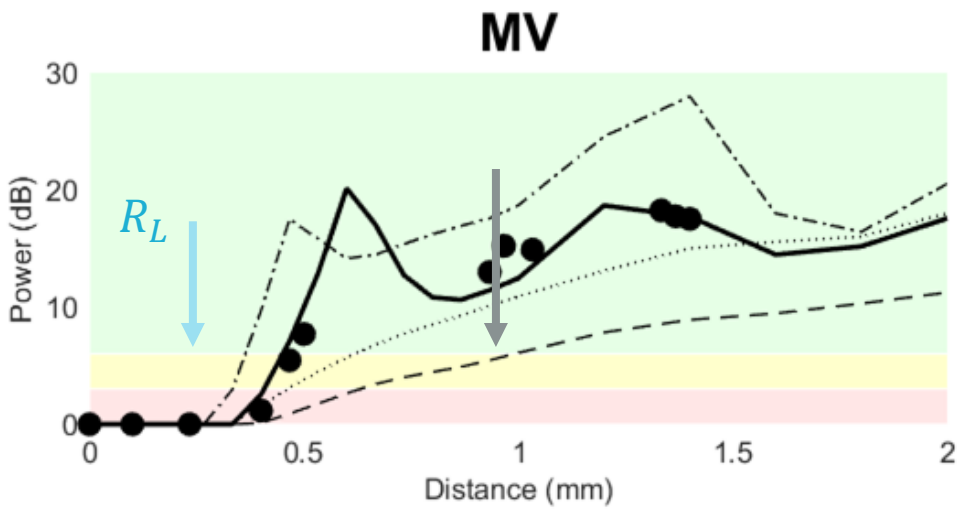


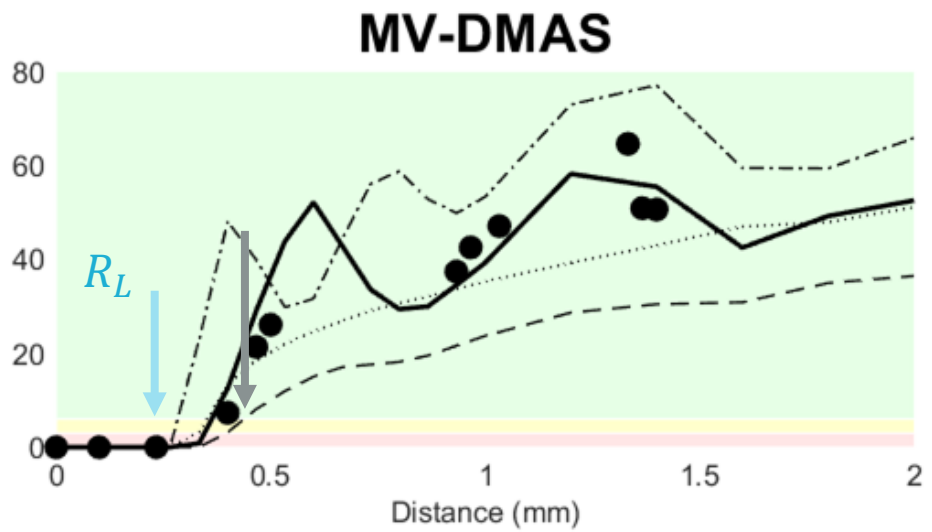
Results

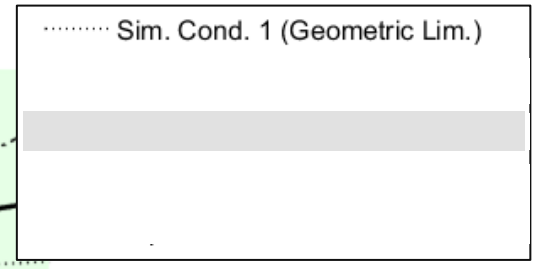
Lateral resolution. Peak-valley distance (PV).









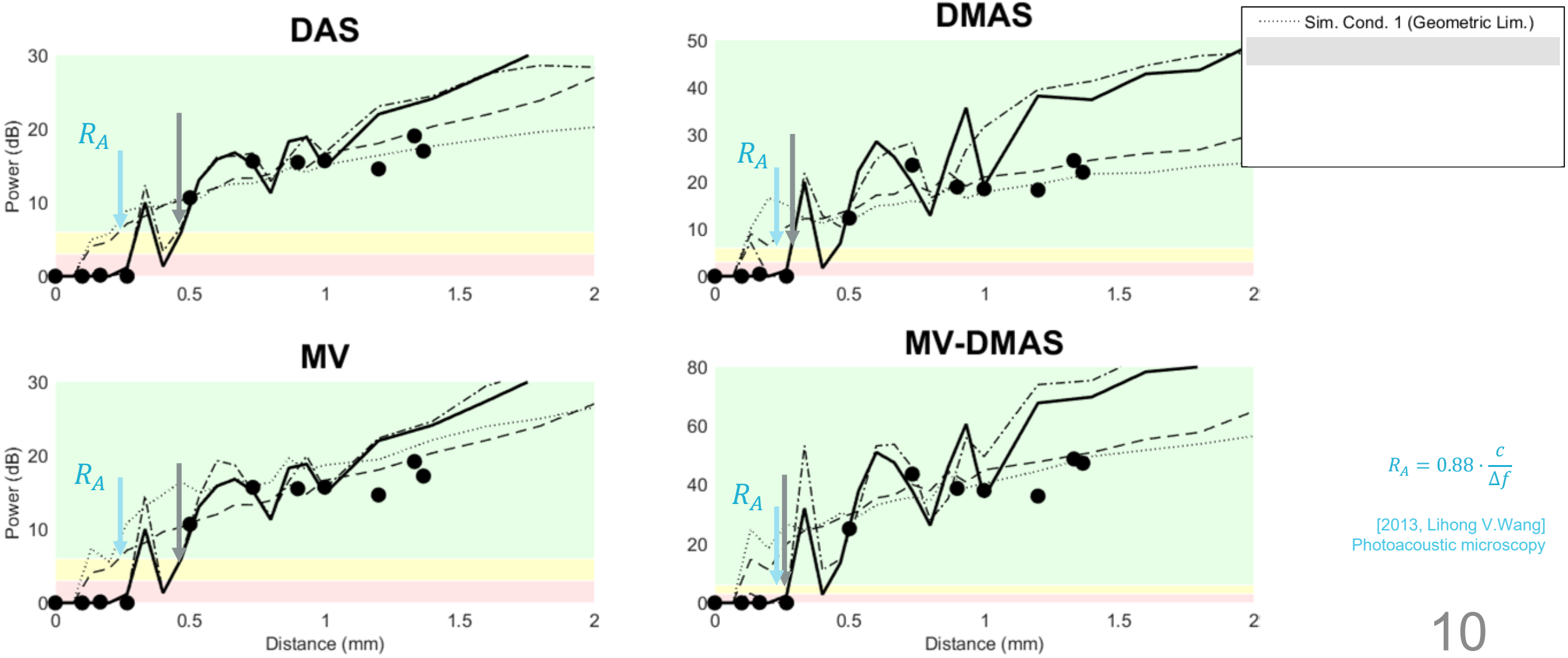


$$R_L = 0.71 \cdot \frac{c}{NA \cdot f_c}$$

[2013, Lihong V.Wang]
Photoacoustic microscopy

Results

Axial resolution. Peak-valley distance (PV).



$$R_A = 0.88 \cdot \frac{c}{\Delta f}$$

[2013, Lihong V.Wang]
Photoacoustic microscopy

Results

Resolution limit (PV > 6 dB)

$$R_L = 0.71 \cdot \frac{c}{NA \cdot f_c}$$

[2013, Lihong V.Wang]
Photoacoustic microscopy

Lateral	DAS (mm)	DMAS (mm)	MV (mm)	MV-DMAS (mm)	Theoretical (mm)
Numerics	0.451	0.379	0.448	0.362	0.21
Experiments	0.473	0.406	0.474	0.369	

Table 1. Lateral numerical, experimental and theoretical resolution.

$$R_A = 0.88 \cdot \frac{c}{\Delta f}$$

[2013, Lihong V.Wang]
Photoacoustic microscopy

Axial					
Numerics	0.303	0.284	0.302	0.275	0.23
Experiments	0.395	0.380	0.396	0.322	

Table 2. Axial numerical, experimental and theoretical resolution.

Conclusions

Simulations

Experiments



Results

Lateral resolution ⟷ FOV

Axial resolution ⟷ Frequency

Advanced algorithms compensate linear probes with reduced angular spectrum **limitations**.

DAS

DMAS

MV

MV-DMAS

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- No…Jim…nez
- Francisco Camarena

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