Fast Focusing Methods For Ultrasonic Imaging

Ewen Carcreff⋆, Gavin Dao•, Dominique Braconnier⋆

⋆ The Phased Array Company, 9365 Allen Rd., West Chester, Ohio, USA
• Advanced OEM Solutions, 8044 Montgomery Rd. 700, Cincinnati, Ohio, USA
ewen.carcreff@thephasedarraycompany.com

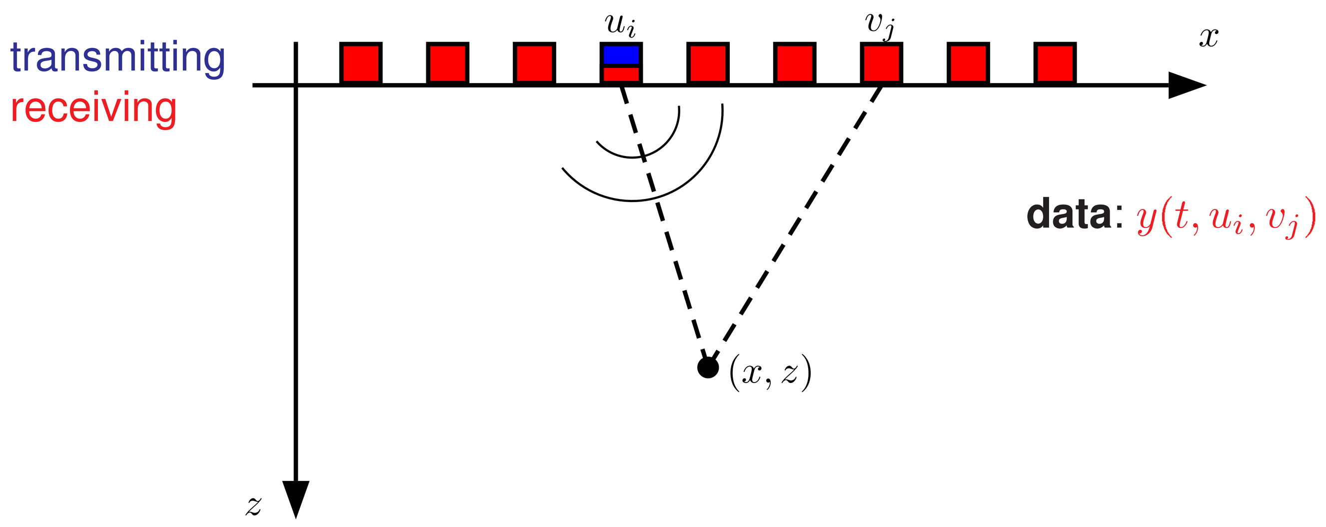
1 - Introduction

This work deals with advanced and fast imaging techniques using phased array probes for non destructive evaluation or medical imaging. These methods employ a large amount of summations in order to focus at each pixel of the reconstruction image, which often represent a prohibitive computational cost. We present two acceleration methods, *i.e.* GPU computation and a migration approach. The GPU computing uses massively parallel computations. The migration approach works in the wavenumber domain and permits a significant improvement in terms of image quality. In this paper, we demonstrate the benefits of these techniques with experimental data captured from an aluminum block containing artificial flaws.

2 - Imaging techniques

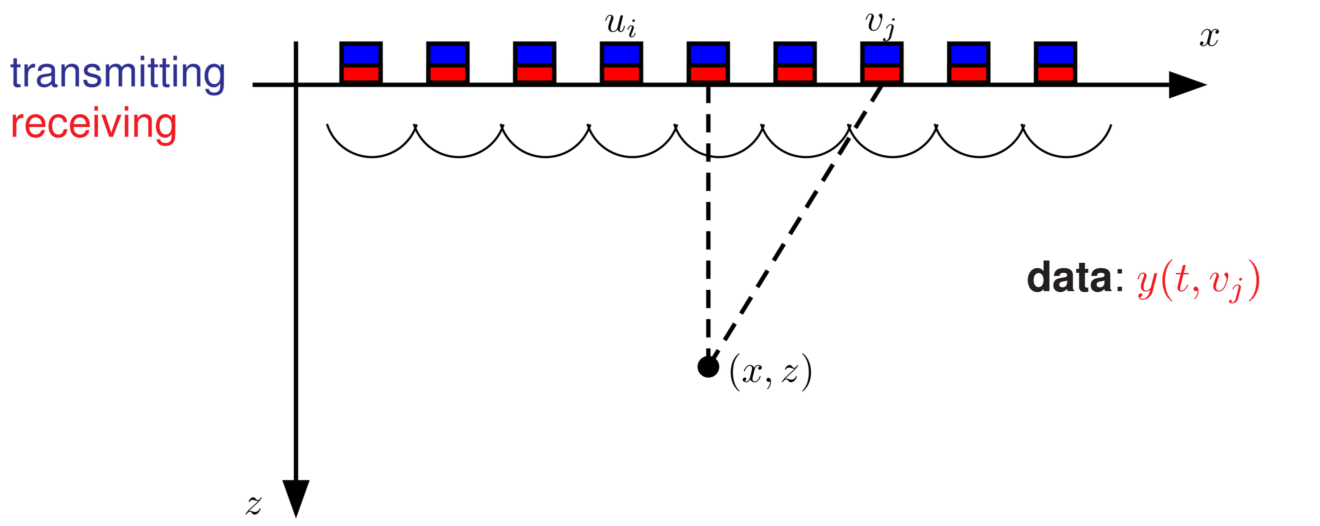
Principle: data: Y $\Longrightarrow$ estimation of the object: O

- **Total Focusing Method (TFM):**



Reconstruction: $O(x,z) = \sum_{i=1}^{N}\sum_{j=1}^{N} y\left(\frac{\sqrt{(x-u_i)^2+z^2}+\sqrt{(x-v_j)^2+z^2}}{c}, u_i, v_j\right)$

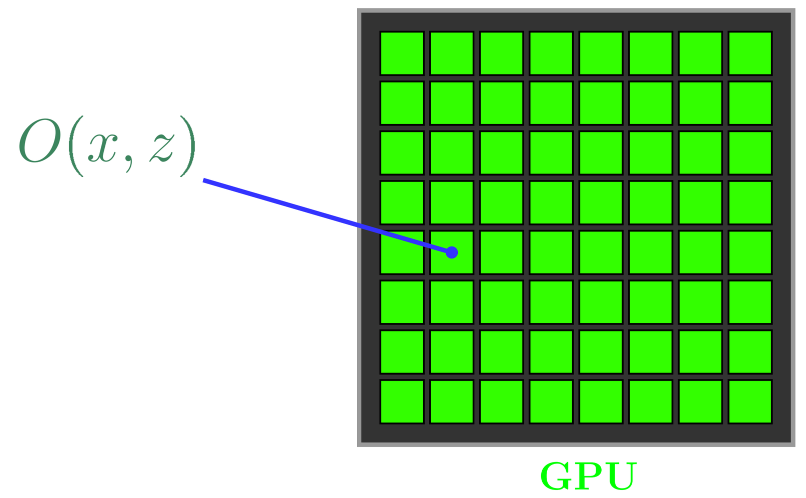
- **Advanced Focusing Method (AFM) with full insonification:**



Reconstruction: $O(x,z) = \sum_{j=1}^{N} y\left(\frac{z+\sqrt{(x-v_j)^2+z^2}}{c}, v_j\right)$

3 - GPU computation

Each pixel $O(x,z)$ can be computed in parallel in a Graphics Processing Unit (GPU)

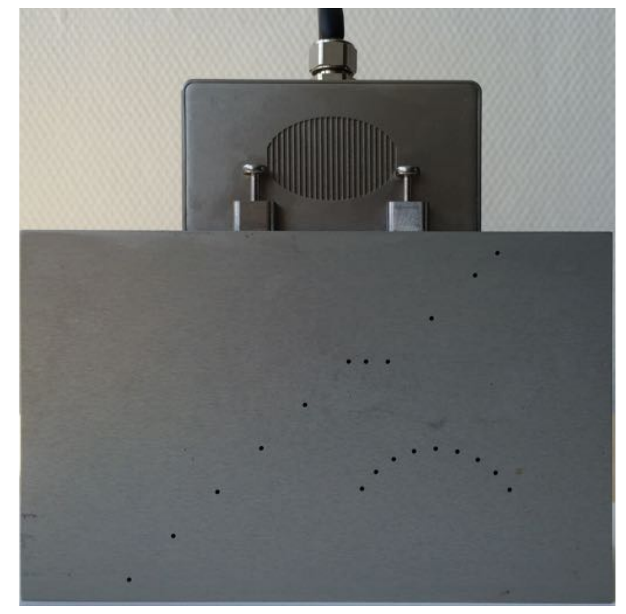


$\Longrightarrow$ **For TFM, 1500-4000 times faster than CPU processing !**

4 - Experimental results

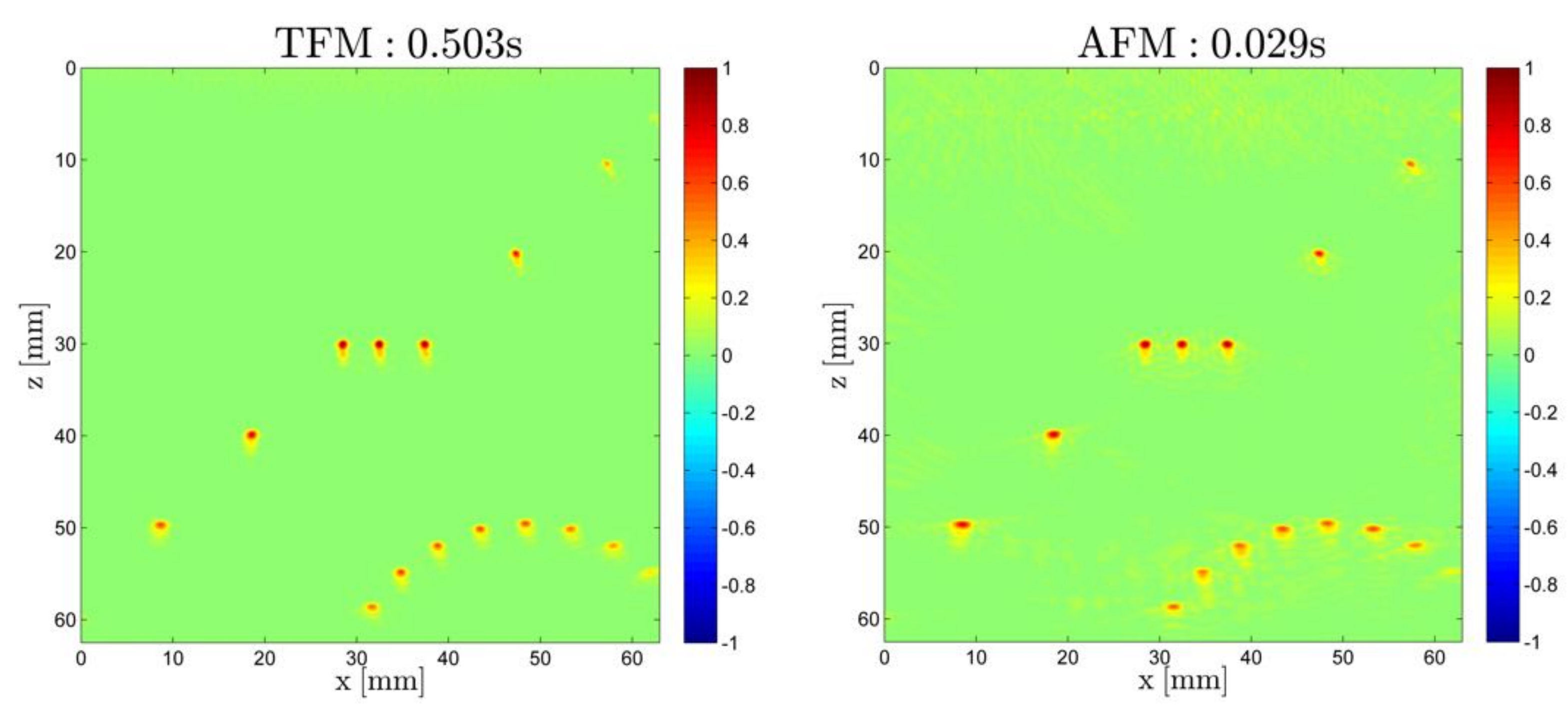
- **Experimental apparatus:**

64-elements-PA instrument from AOS NDT with fast acquisition (150 MB/s)



5 MHz, 64-elements-probe Aluminum block containing ∅ 1 mm SDH

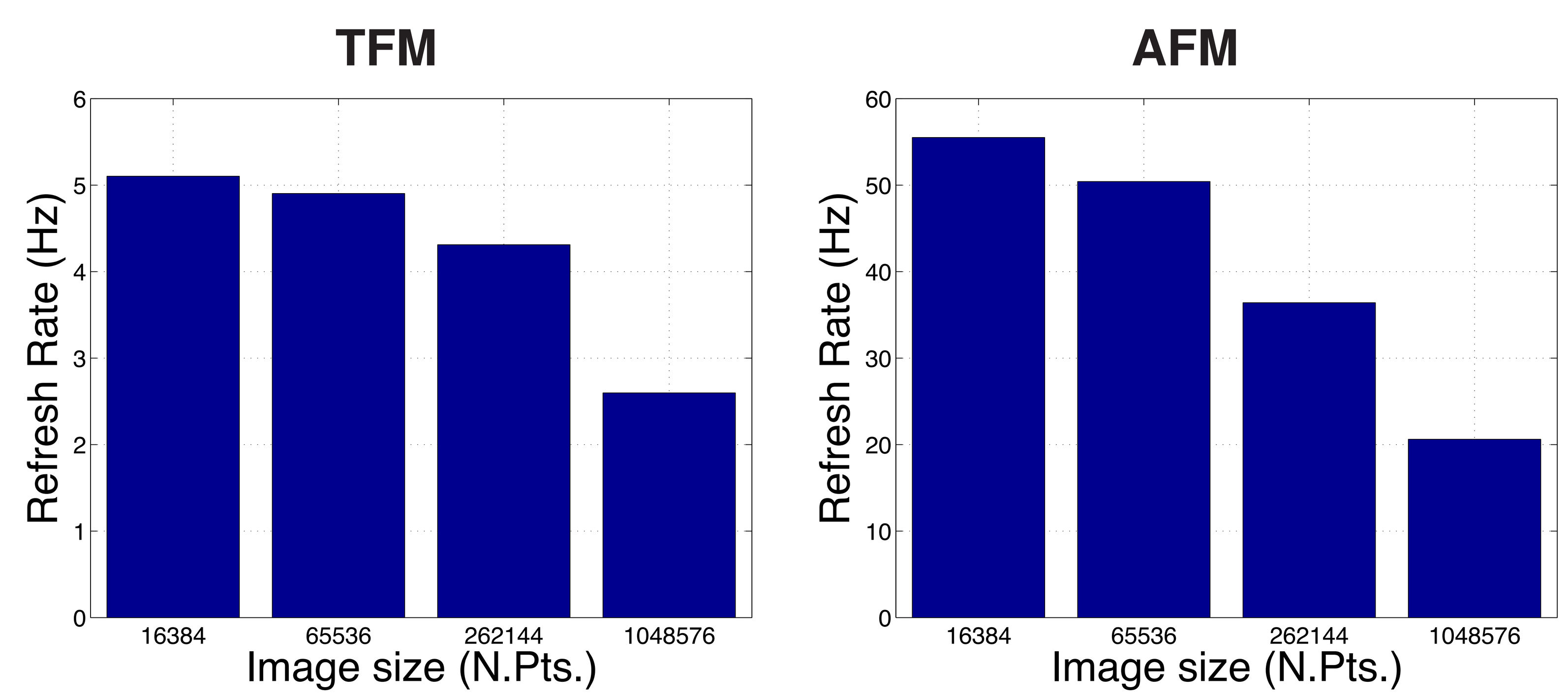
- **TFM and AFM by GPU (for 5 M points):**



- **Merits and drawbacks:**

	TFM	AFM
☺	resolution flexible	fast SNR
☹	lot of data slow processing	resolution specific cases

- **Real-time imaging performances for 64 elements:**

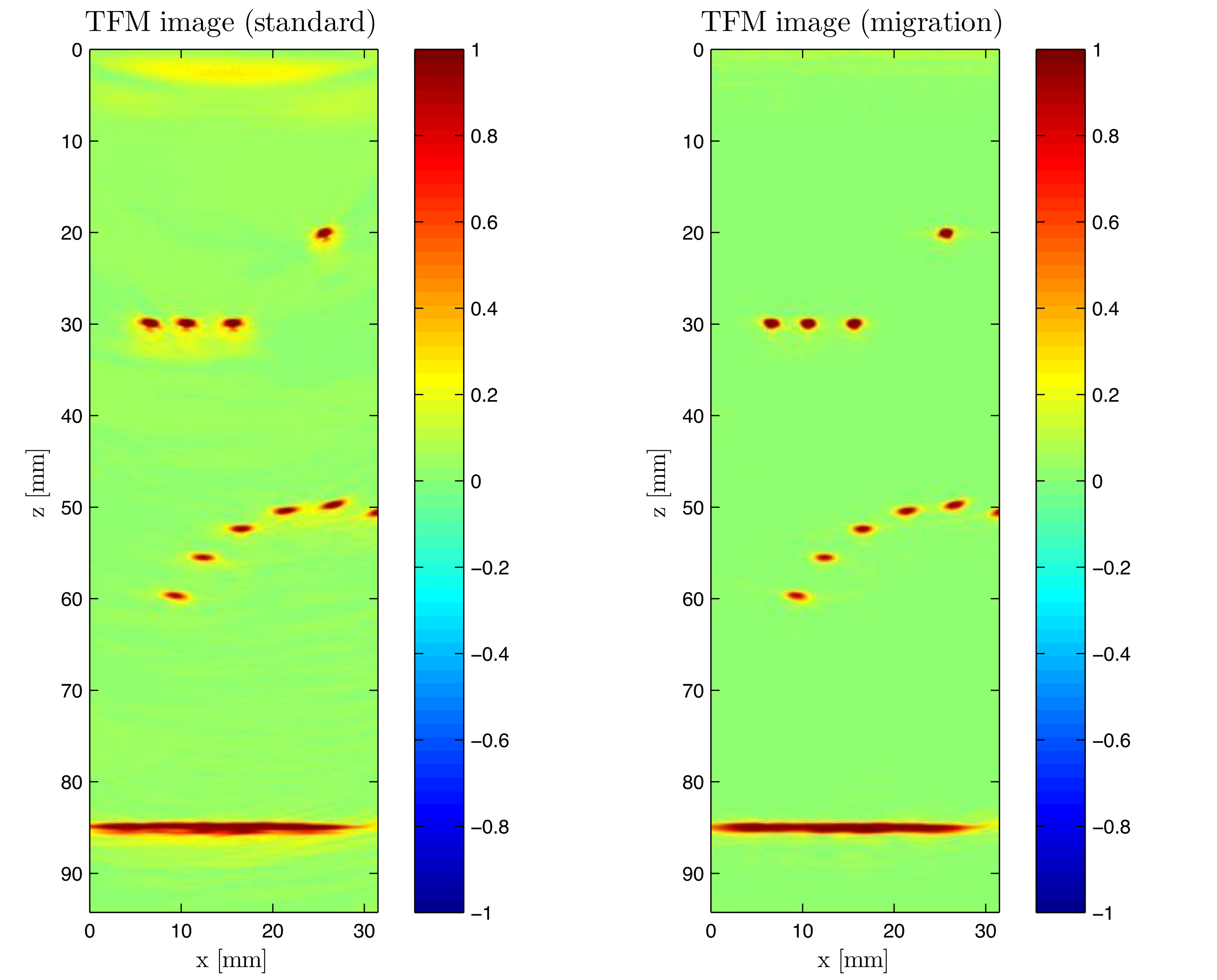


5 - Migration

- **Principle:** mapping in the wavenumber domain

$$y(t,u) \Longrightarrow Y(f,k_u) \Longrightarrow Y(k_z,k_x) \Longrightarrow O(x,z)$$

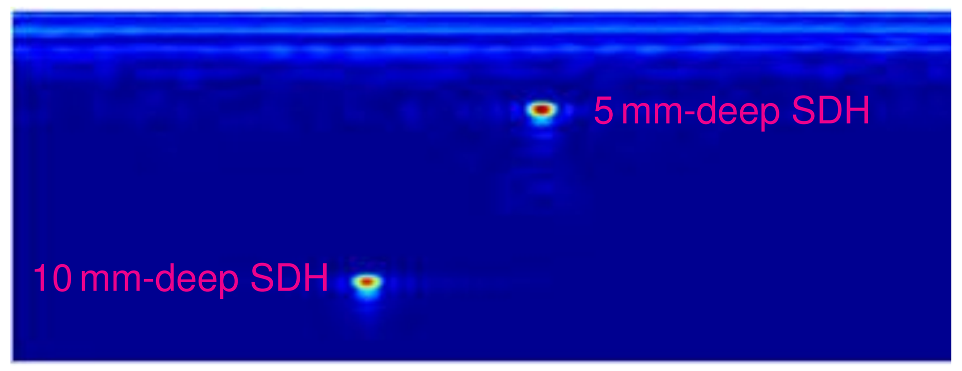
- **Experimental results:**



- **Advantages:** SNR, near surface imaging, CPU speed, available for TFM and AFM

size	std.	mig.
0.19 M	91.3	12.3
0.38 M	177.8	12.2
0.77 M	353.3	12.6
1.54 M	719.1	14.0

CPU time (s)



Near-surface imaging with migration TFM

6 - References

[1] M. Karaman, P.-C. Li, and M. O'Donnell. Synthetic aperture imaging for small scale systems, *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 42, num. 3, p. 429–442, May 1995.

[2] G. Montaldo, M. Tanter, J. Bercoff, N. Benech, and M. Fink. Coherent plane-wave compounding for very high frame rate ultrasonography and transient elastography, *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 56, num. 3, p. 489–506, March 2009.

[3] A. J. Hunter, B. W. Drinkwater, and P. D. Wilcox. The wavenumber algorithm for full-matrix imaging using an ultrasonic array. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 55, num. 11, p. 2450–2462, November 2008.

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