

Plateformes ouvertes et techniques d'imagerie avancées pour le contrôle non destructif par ultrasons multi-éléments

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	OCCOCCCC	Super-resolution	Additive manufacturing	Nonlinear	Conclusion



- 2 Ultrasound solutions
- Super-resolution imaging
- 4 Adaptive inspection of parts from additive manufacturing
- Closed crack characterization by nonlinear imaging

6 Conclusion

Introduction ●○○○○	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion OO
Outline					

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Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 00000000000000000	Conclusion OO
The Co	mpany				

• Two main locations :



Nantes (France)



West-Chester (Ohio, USA)

- Representatives : Europe, China, Japan, USA
- About 35 people

Introd	uction
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Iltrasound solutions

Super-resolution

dditive manufacturing

Nonlinear

Conclusion

Application fields

Nondestructive testing



Ultrasonic imaging



Material characterization





Ultrasound solutions

Super-resolution

dditive manufacturing

Nonlinear 0000000000000 Conclusion

Fields in NDT

Oil and Gas



Power generation



Transportation industry



Manufacturing



Heavy industry



Research



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Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing		

Activities of the company

- Activities :
 - Provide Ultrasound solutions
 - Software
 - Engineering
 - Studies
- Customers :
 - Labs, Universities
 - R&D centers
 - Integrators
 - Service companies

Introduction	Ultrasound solutions ●○○○○○○	Super-resolution	Additive manufacturing	Nonlinear 00000000000000000	Conclusion OO
Outline					

2 Ultrasound solutions

- Super-resolution imaging
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- 5 Closed crack characterization by nonlinear imaging
- 6 Conclusion

Ultrasound solutions

Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Ultrasound solutions



OEM solutions



Complete solutions

Introduction
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Ultrasound solutions

Super-resolution

dditive manufacturing

Nonlinear

Conclusion

OEM solutions



- From 16 to 2048 full parallel channels, high speed data streaming
- Integrable and small form factor
- Totally open and configurable
- Driver and software development kit (SDK) under **Windows** and **Linux** : Matlab, C++, Python, Labview, etc.



- Small form factor
- Totally open and configurable (idem OEM)
- Software included
- Arbitrary waveform generator (for Pioneer)
- All advanced imaging methods

Software	developmen	t kit (SDK)			
Introduction 00000	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 00000000000000000	Conclusion OO

- Perfect to develop specific and custom applications
- Full access to all parameters
- Direct access to raw data
- Numerous code examples
- Library available in C++, Python, Matlab, Labview, etc. (Windows and Linux)
- Technology is suitable for research, feasibility, prototype demonstration, industrialization (TRL 2 to 6)



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion OO
Open ir	naging platfo	rm <i>ARIA</i>			

- Real-time imaging using advanced methods (TFM, PWI, etc.)
- Fast acquisition (up to ~2000 frame/sec in PWI)
- Full access to raw data
- Openness in order to integrate specific computations
- Analysis tools for sizing and reporting





Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 00000000000000000	Conclusion OO
Software	e : TFM toolb	ох			

- Various functions for advanced imaging (TFM, PWI, etc.)
- Fast GPU implementations
- Usable from different environments (C++, Matlab, Python, etc.)
- Free of integration



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion
Outline					

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Super-resolution imaging

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6 Conclusion

 Introduction
 Ultrasound solutions
 Super-resolution
 Additive manufacturing
 Nonlinear
 Conclusion

 Super-resolution imaging

• Collaboration with :



Publication :

N. Laroche, E. Carcreff, S. Bourguignon, J. Idier, A. Duclos. "An Inverse Approach for Ultrasonic Imaging by Total Focusing Method for Close Reflectors Separation", IEEE IUS, October 2018, Kobe, Japan.

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion OO
Motivat	ion				

- Total Focusing Method (TFM) is becoming a standard in NDT
- Close flaws ~> overlapping





● Goal → Improve resolution of TFM

Iltrasound solutions

Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Principle of Total Focusing Method





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Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Principle of Total Focusing Method



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion OO
Principle of the inverse method					

- Work directly on raw data
- Development of algorithms based on inverse problems



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Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Results on two close flaws



- **Probe** : 32 elements (/128), 1.5 MHz, pitch 2 mm
- Material : Aluminum
- Wavelength : 4.2 mm

Results on two close flaws



 \sim Resolution up to $\lambda/4$

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing ●○○○○○	Nonlinear 0000000000000000	Conclusion OO
Outline					

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Introduction Ultrasound solutions Super-resolution Additive manufacturing Nonlinear Conclusion occosed of parts from additive manufacturing (AM)

Collaboration with :

Alexia Chabot Matthieu Rauch Jean-Yves Hascoët



Nantes France

Publication :

A. Chabot, N. Laroche, E. Carcreff, M. Rauch, J.Y. Hascoët, "Towards defect monitoring for metallic Additive Manufacturing components using Phased Array Ultrasonic Testing", Submitted to Journal of Intelligent Manufacturing, 2019.

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion OO		
Principle	Principle of Adaptive TFM						







Itrasound solutions

Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Inspection of a propeller with Adaptive TFM



Propeller made by WAAM

Inspection with water wedge

WAAM : Wire + Arc Additive Manufacturing

sound solutions

Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Inspection of a propeller with Adaptive TFM





Introduction 00000	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear ●○○○○○○○○○○○○○○	Conclusion
Outline					

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6 Conclusion

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear ○●○○○○○○○○○○○○○	Conclusion OO
Nonlinear imaging					

• Collaboration with :



Publication :

S. Haupert, Y. Ohara, E. Carcreff, G. Renaud. "Fundamental wave amplitude difference imaging for detection and characterization of embedded cracks", Ultrasonics, March 2019.

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear ○○●○○○○○○○○○○○	Conclusion OO
Motivation					

- Characterization of crack and crack growth is capital in industry
- Open part of cracks \rightsquigarrow Can be detected by conventional UT
- Closed part of cracks → Invisible to conventional UT (linear ultrasonics)
- Need of new tools for closed crack detection



 μCT image of a piece of steel

Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear	
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Introduction	Ultrasound solutions

Super-resolution

Additive manufacturing

Nonlinear

Conclusion



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Super-resolution

dditive manufacturing

Nonlinear

Conclusion



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Super-resolution

dditive manufacturing

Nonlinear

Conclusion





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Super-resolution

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Nonlinear

Conclusion





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Super-resolution

dditive manufacturing

Nonlinear

Conclusion



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Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear				

- Parallelepiped stainless steel AISI 304 (150x100x61mm)
- Crack obtained by thermal fatigue
- Probe 5 MHz, 64 elements, pitch 1 mm
- Inspection in contact from the top
- Crack length 24.2mm / depth 5.9mm



Nonlinear

Results from a thermal crack





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Super-resolution

Additive manufacturing

Nonlinear

Conclusion

Results from a thermal crack



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Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear	

Results from a mechanical fatigue crack

- Aluminum A7075 (170x30x40mm)
- Crack obtained by mechanical fatigue
- Probe 5 MHz, 128 elements, pitch 0.5 mm
- Inspection in contact from the top



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear	
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Results from a mechanical fatigue crack



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear	Conclusion OO
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Results from a mechanical fatigue crack



Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion
Outline					

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Introduction	Ultrasound solutions	Super-resolution	Additive manufacturing	Nonlinear 0000000000000000	Conclusion ○●
Conclusion					



- Presentation of open platforms
- Presentation of development kit and software
- ~> suitable for research, feasibility, industrialization (TRL 2 to 6)
- Presentation of 3 projects about advanced imaging
- Lots of further possibilities

THANK YOU!

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