

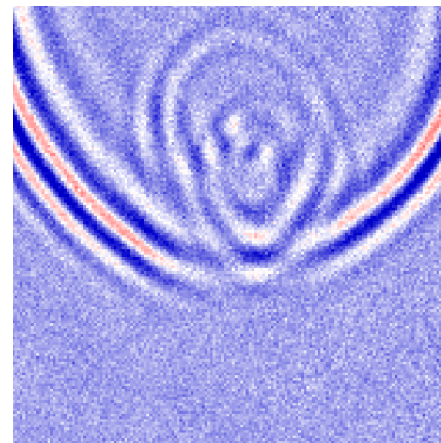
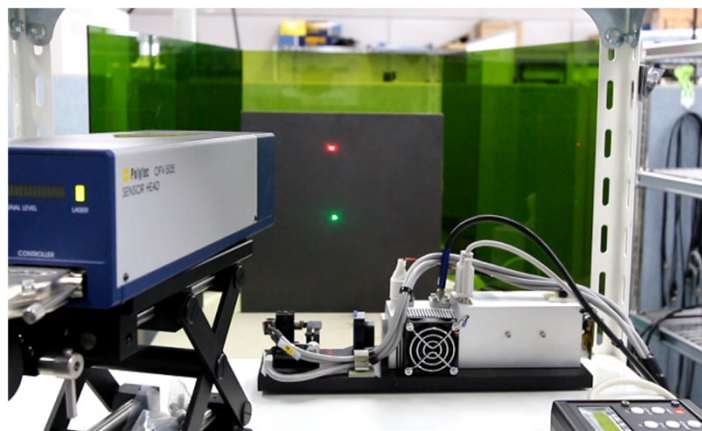
Non-destructive inspection by visualization of laser-induced ultrasonic waves

National Metrology Institute of Japan (NMIJ)
National Institute of Advanced Industrial Science and Technology (AIST)
Japan

Nobuyuki Toyama

Contents

- Background: ultrasonic inspection of structures
- Visualizing ultrasonic waves by pulsed laser scanning
- Examples for application to various structures
- Current R&D: Automatic diagnosis using AI, etc.



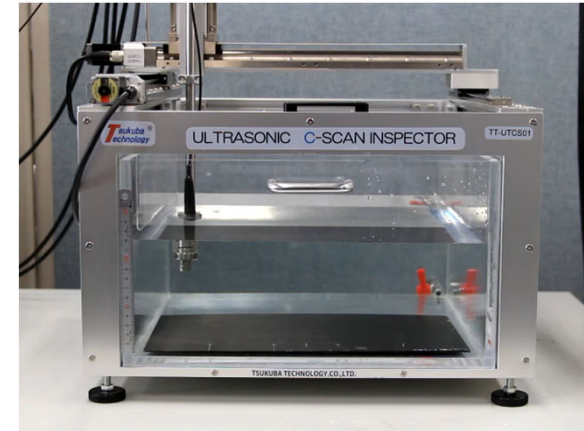
Problems in conventional ultrasonic testing



Ultrasonic probes and couplants



Manual UT

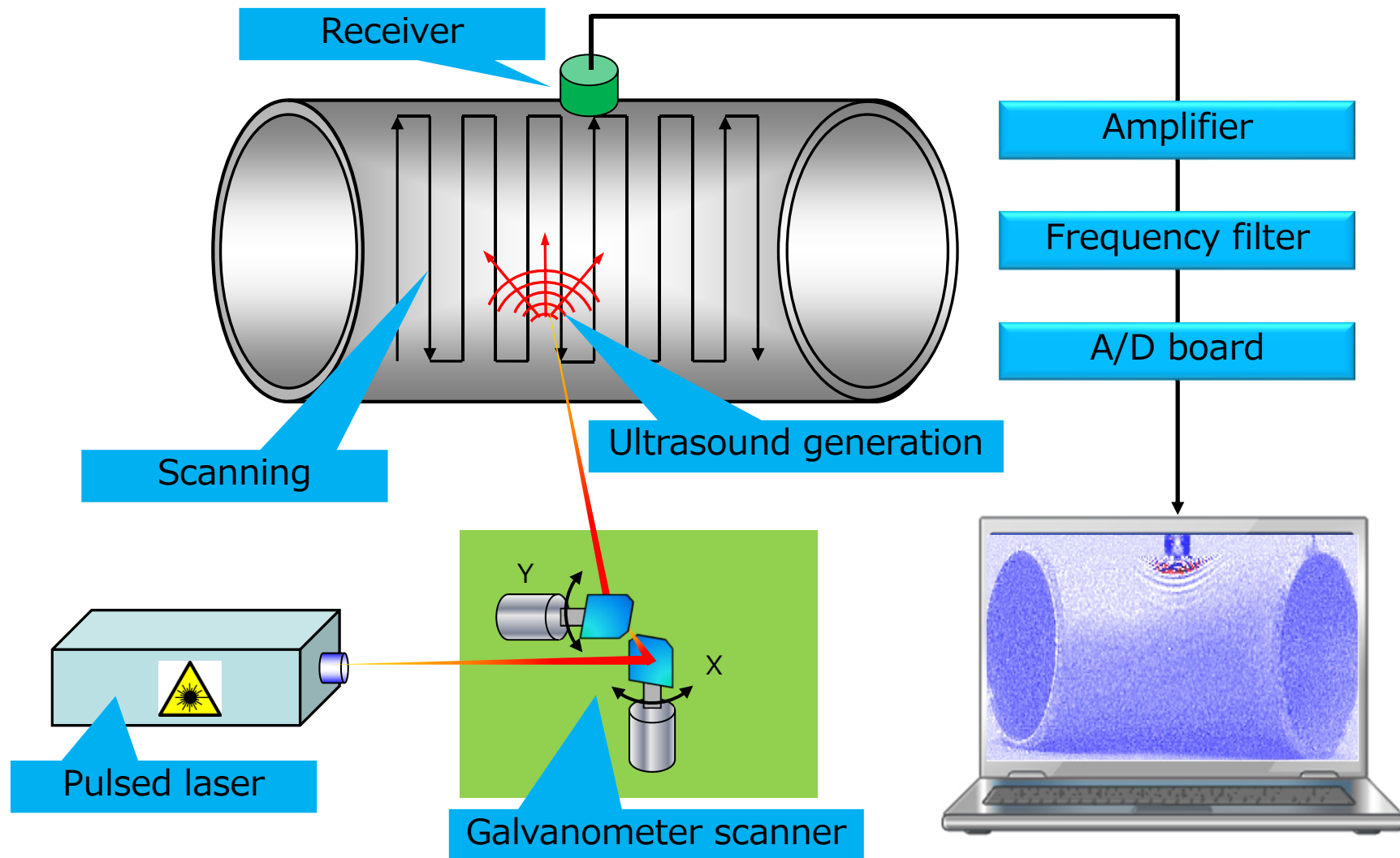


Immersion UT



- Difficulty for complex-shape objects
- Time-consuming
- Require a high level of expertise

Laser ultrasonic visualizing system



Japanese patent No.4595117, 2010

Visualization of wave propagation for NDT

Conventional visualization method

- Schlieren method : Only transparent object
- Photoelasticity method : Only transparent object
- Scanning receiving probe method : Only flat object

Not applicable to real structure components



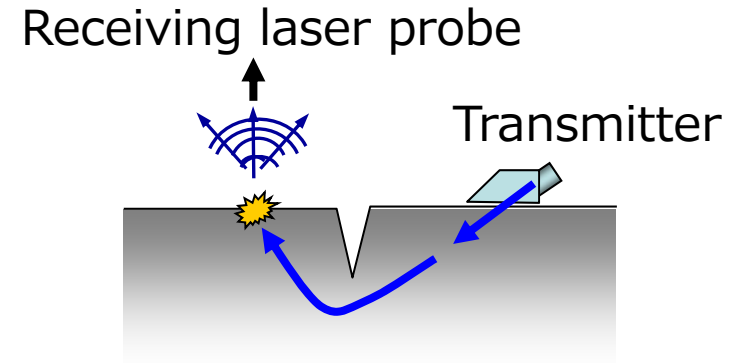
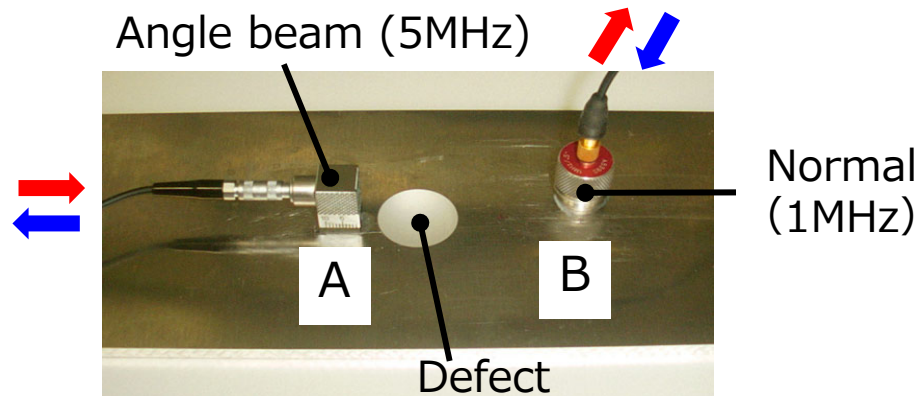
Our scanning excitation laser method

- Quick scanning; needs no focusing
- Wide-range inspection
- Complex shape object

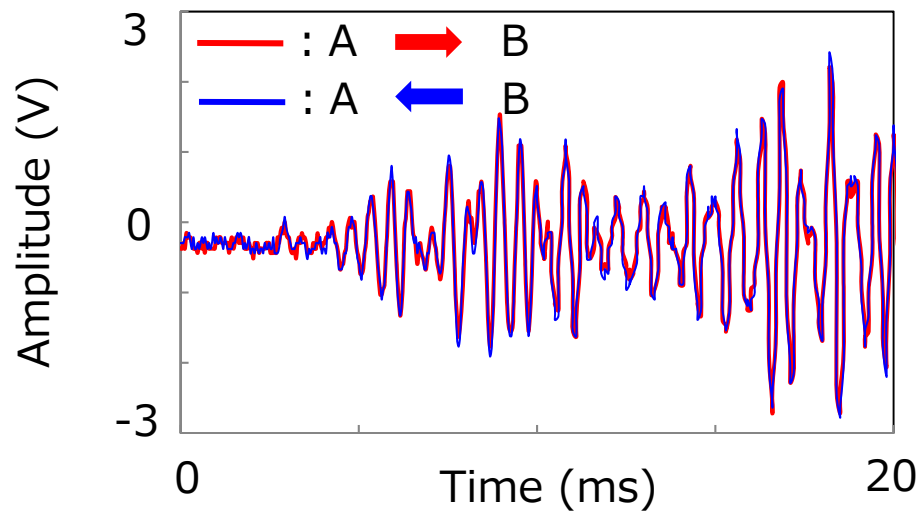
Applicable to real structure components

Key: Visualization of wave propagation from receiver using reversibility for wave propagation

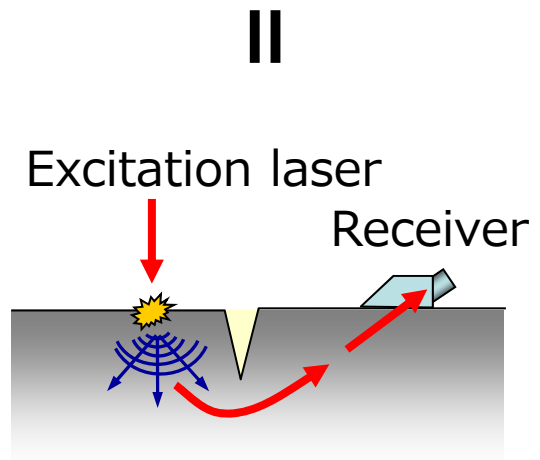
Reversibility for wave propagation



Needs focusing and control of incident angle



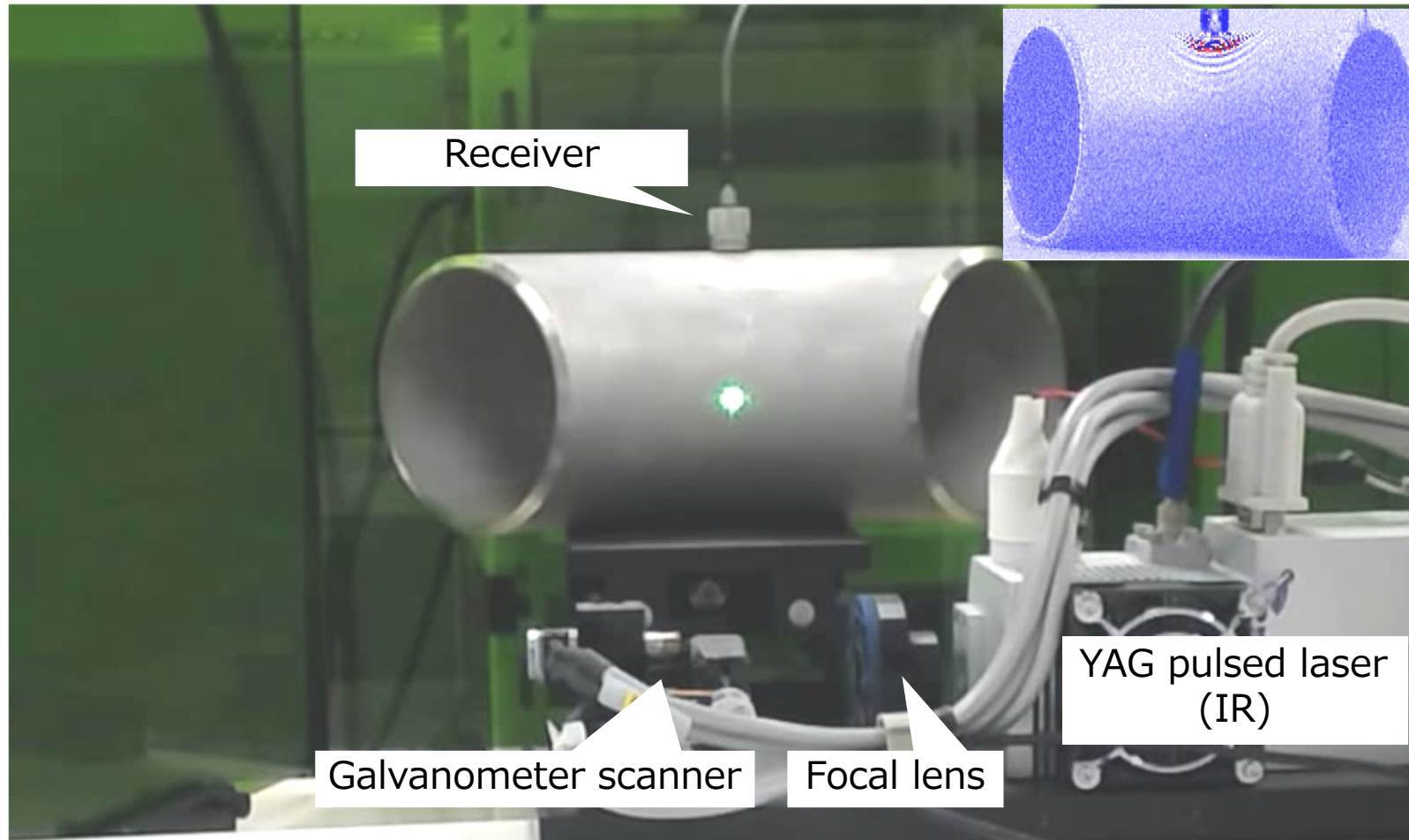
Comparison of detected signals



Much more suitable for NDT

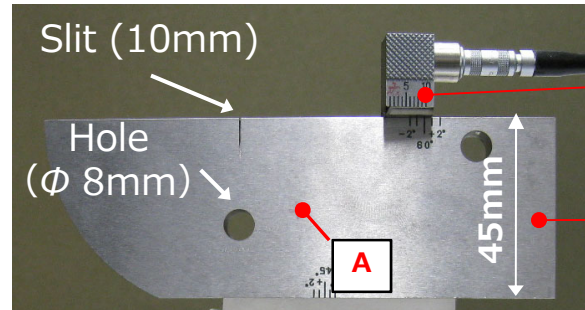
Yashiro et al., NDT&E International, 41, 2008

Movie: pulsed laser scanning for pipe elbow



Only 10 seconds for scanning $300 \times 150 \text{ mm}^2$ (22000 points)

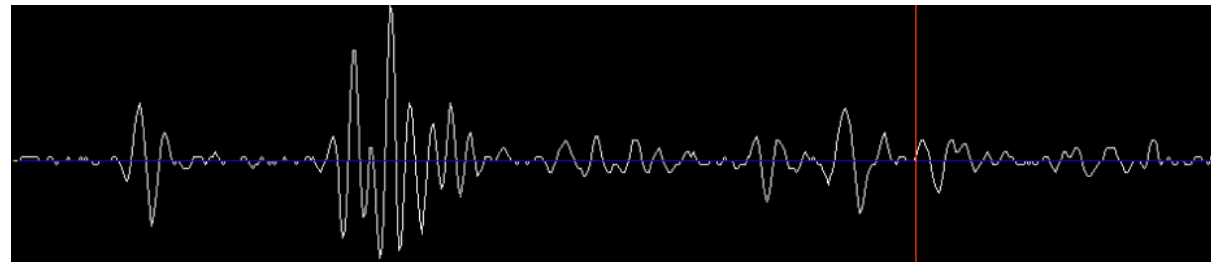
Easy UT method just to observe movie



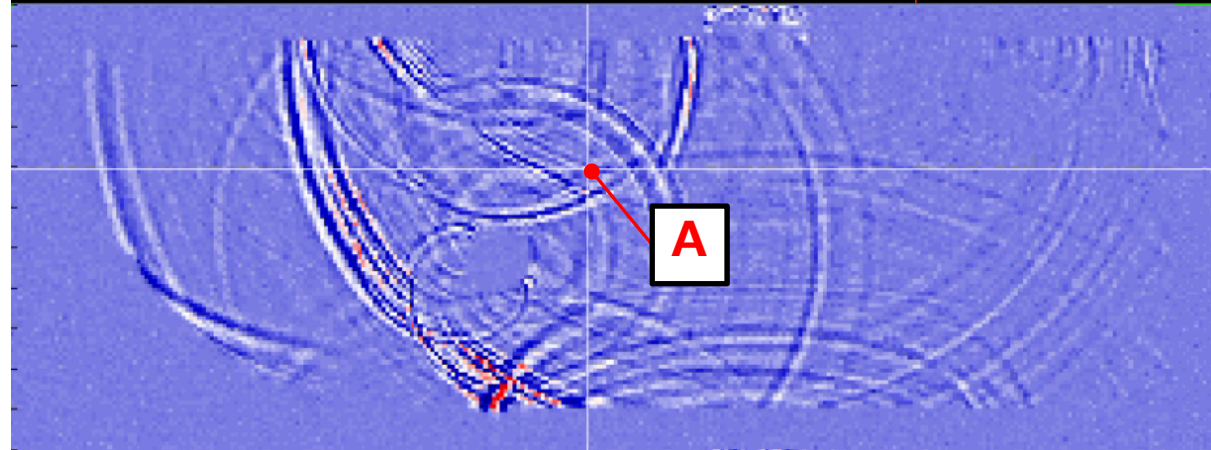
Angle beam transducer

Standard test specimen

Detected signal
at **A**

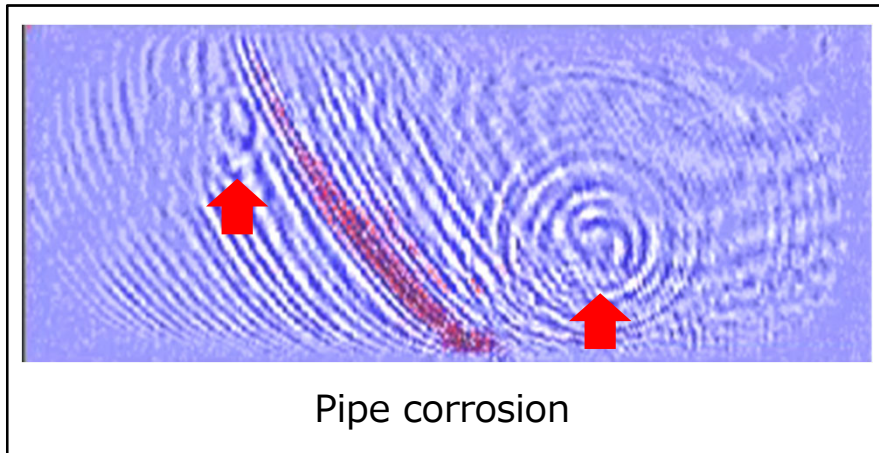


Visualized movie

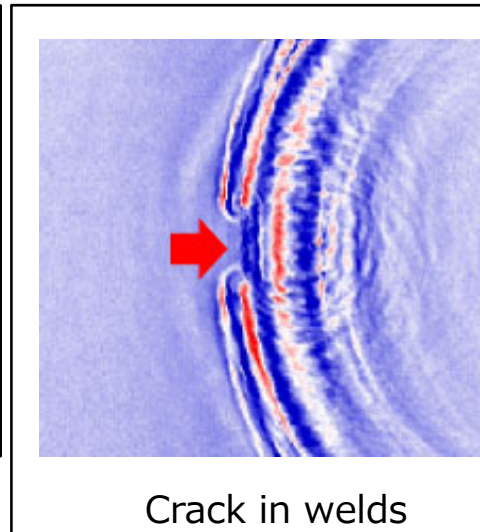


Examples for application to various structures

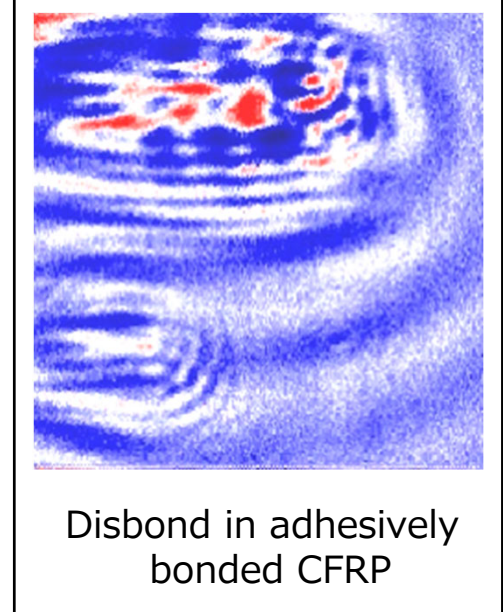
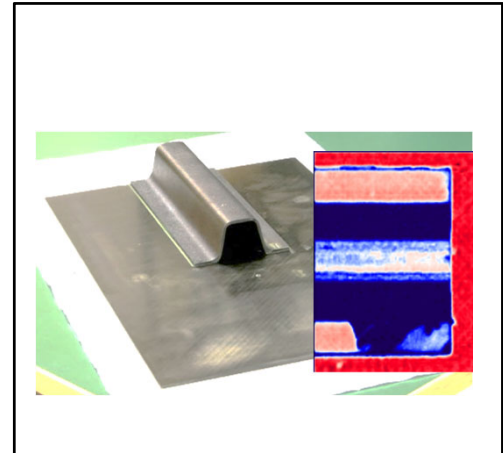
NDT for Transports, Infrastructures, Plants, Electric devices, etc.



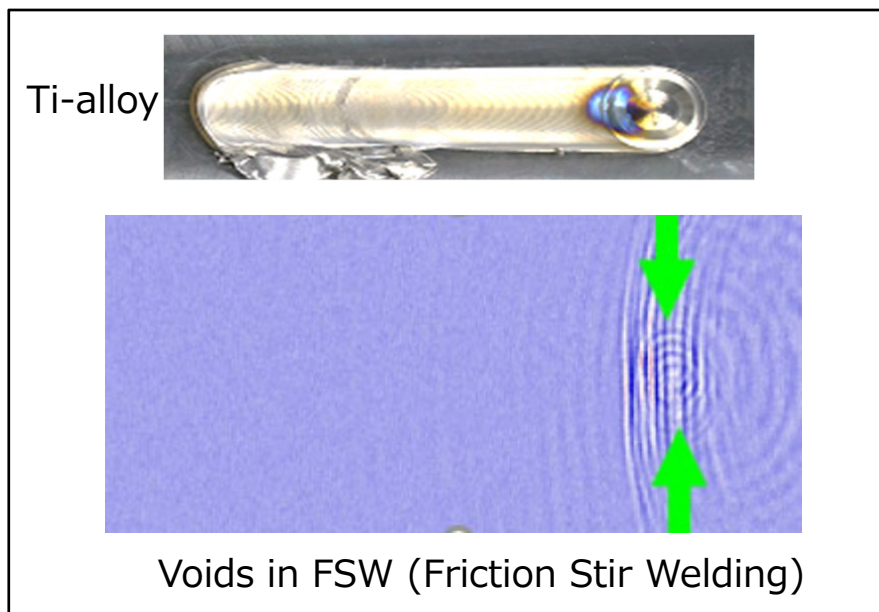
Pipe corrosion



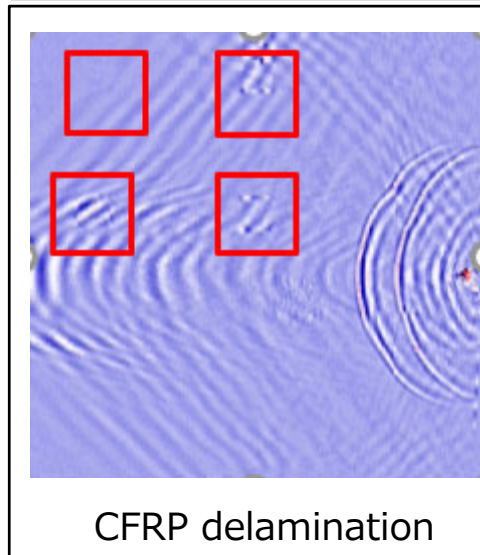
Crack in welds



Disbond in adhesively bonded CFRP



Voids in FSW (Friction Stir Welding)



CFRP delamination

Commercialization of inspection instrument



Portable : \$150,000



Standard : \$250,000

Tsukuba Technology, Co., Ltd
「Laser Ultrasonic Visualizing Inspector (LUVI)」

Standard Specification

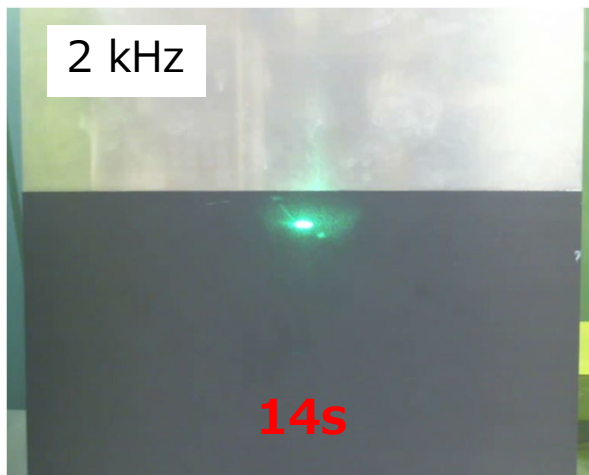
Laser	: YAG (1064nm)
Pulsed laser energy	: Max. 2 mJ
Scanning area	: 0.1×0.1m ² ~ 4×4m ²
Scanning speed	: Max. 2kHz
Distance to object	: 0.1m ~ 2m
Inspection object	: Metal, Ceramics, Polymer, Composite
Inspection thickness	: 0~100mm (Metal)
Detectable defect	: Min. 0.2mm (5mm thickness metal)

Faster pulsed laser scanning system

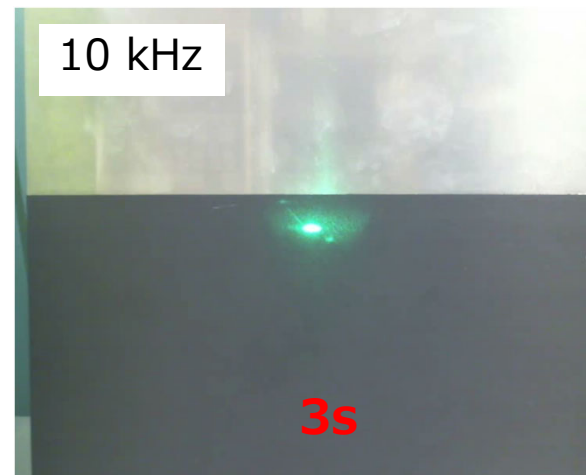


Scanning speed
2 kHz → 10 kHz

Faster pulsed laser (Special order)



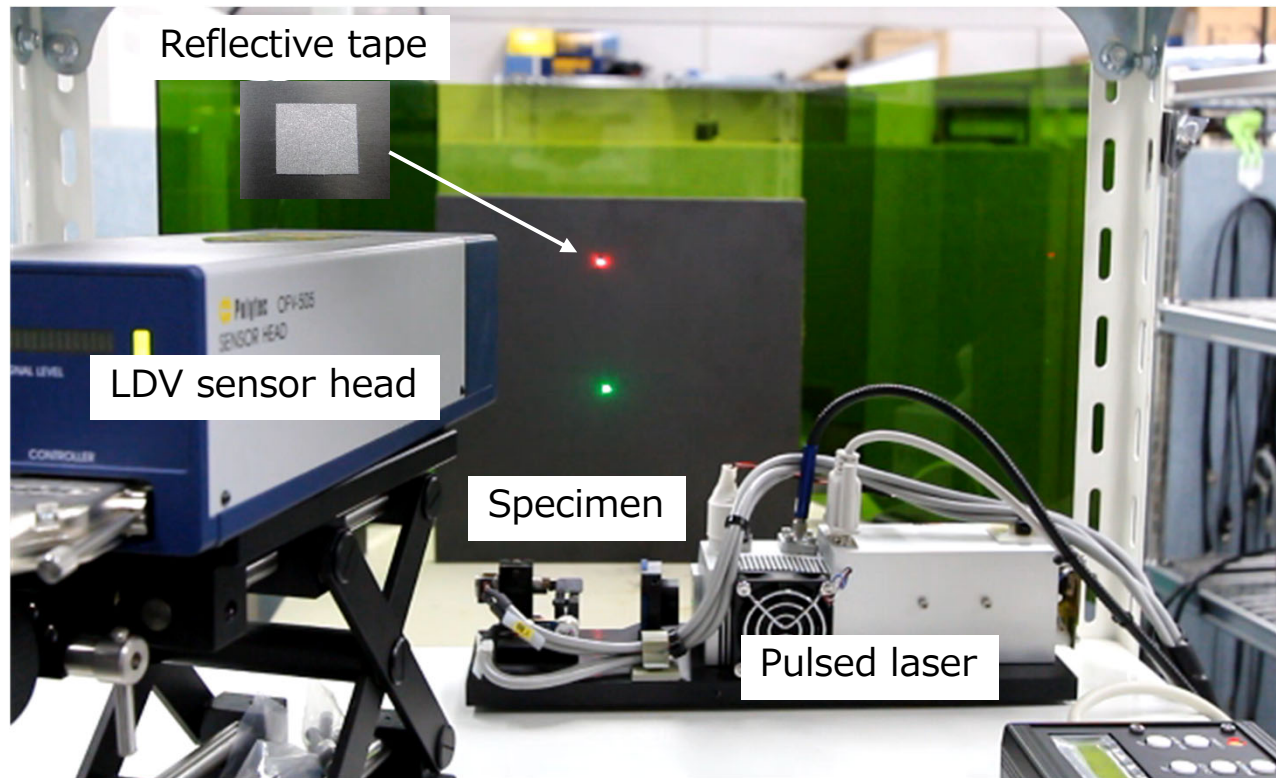
Commercial product



Our latest system

Toyama et al., *Advanced Composite Materials*, 28, 2019

Non-contact Laser ultrasonic visualizing system



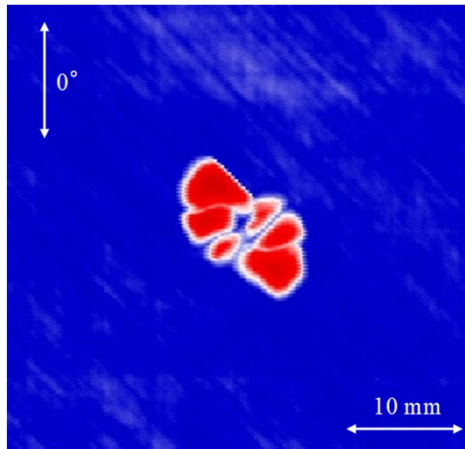
Non-contact Laser ultrasonic visualizing system using LDV

Non-contact Laser ultrasonic visualizing results

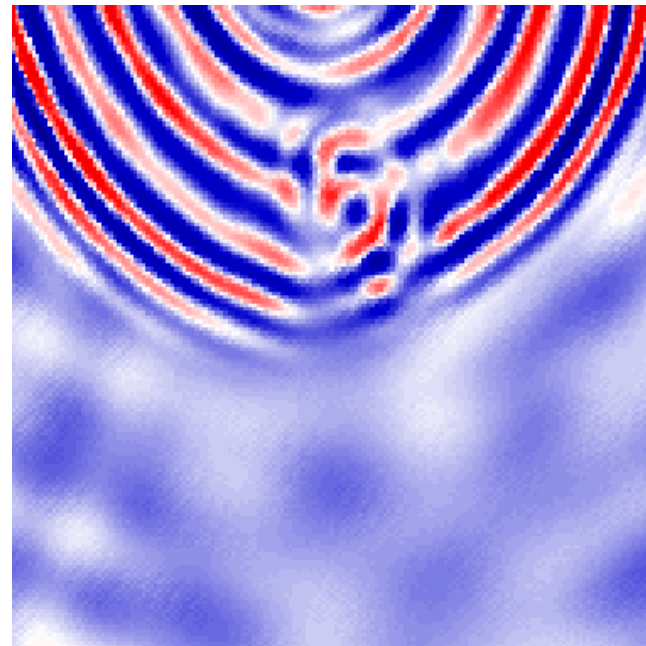
Bandpass filter : 100 kHz to 400 kHz



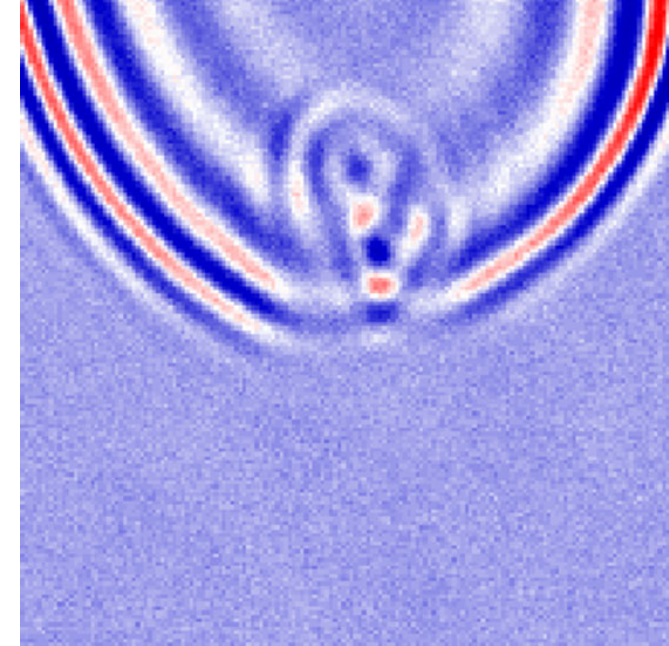
Impact-damaged CFRP



Water-immersion ultrasonic C-scan



Conventional contact receiver
(no signal averaging)

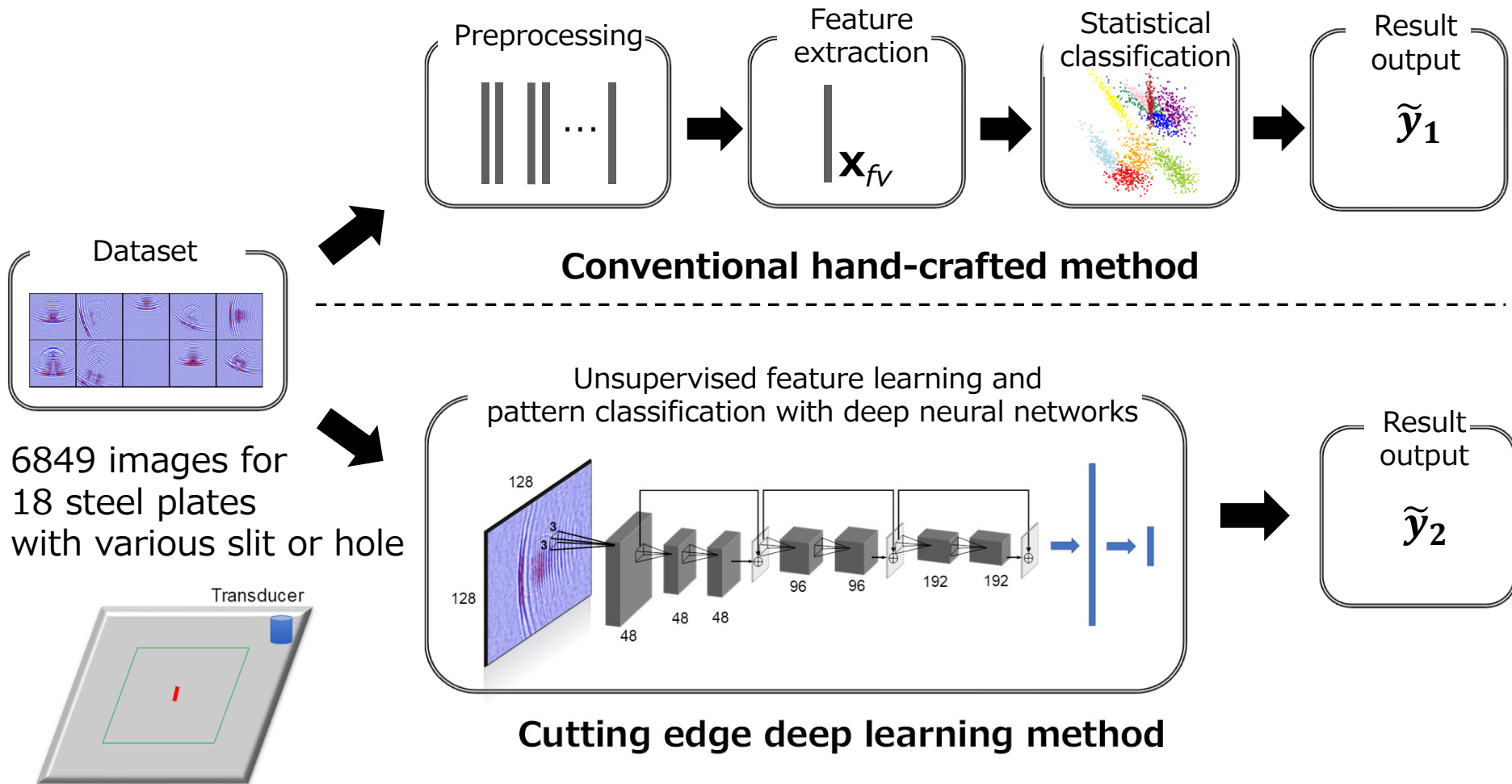


Non-contact using LDV
(10 times signal averaging)

- Reflective tape for LDV
- Time-consuming
- Expensive; LDV costs more than \$100,000

Toyama et al., Applied Sciences-Basel, 9, 2019

General design of computer vision system

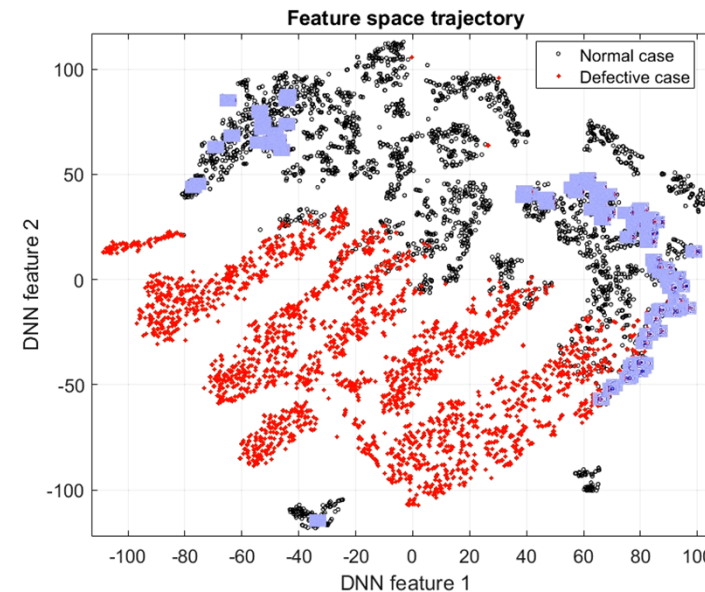
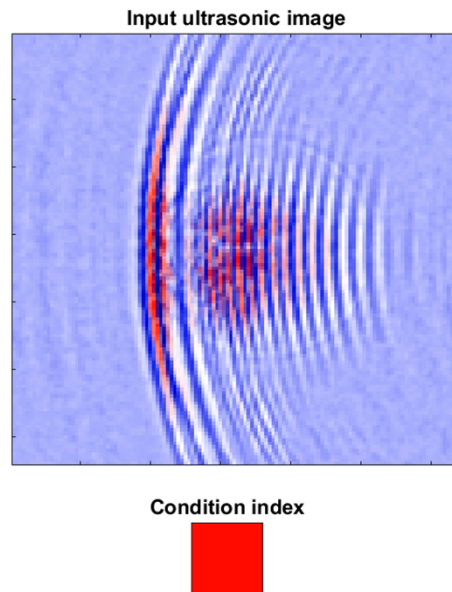


Automatic diagnosis using AI image analysis

Results of automatic image pattern using various methods

HoG	LBP	HLAC	GLAC	Fusion2D	USseqNet	USresNet
83.37	83.77	90.95	91.06	90.57	93.76	95.68

Conventional method
 Deep learning



Demonstration of automatic defect detection

Ye et al., Sensors, 18, 2018

New NDT technique of laser ultrasonic visualizing system is introduced

- Quick and easy NDT technique applicable to real structures
- Non-contact laser UT system using LDV is possible but still has problems to be overcome
- Automatic defect detection using deep learning is most promising

Thank you for your kind attention

Non-destructive Measurement Group, <https://unit.aist.go.jp/rima/ndm/en/>