Ultrasonic Concrete Testing: Principles and Instrumentation

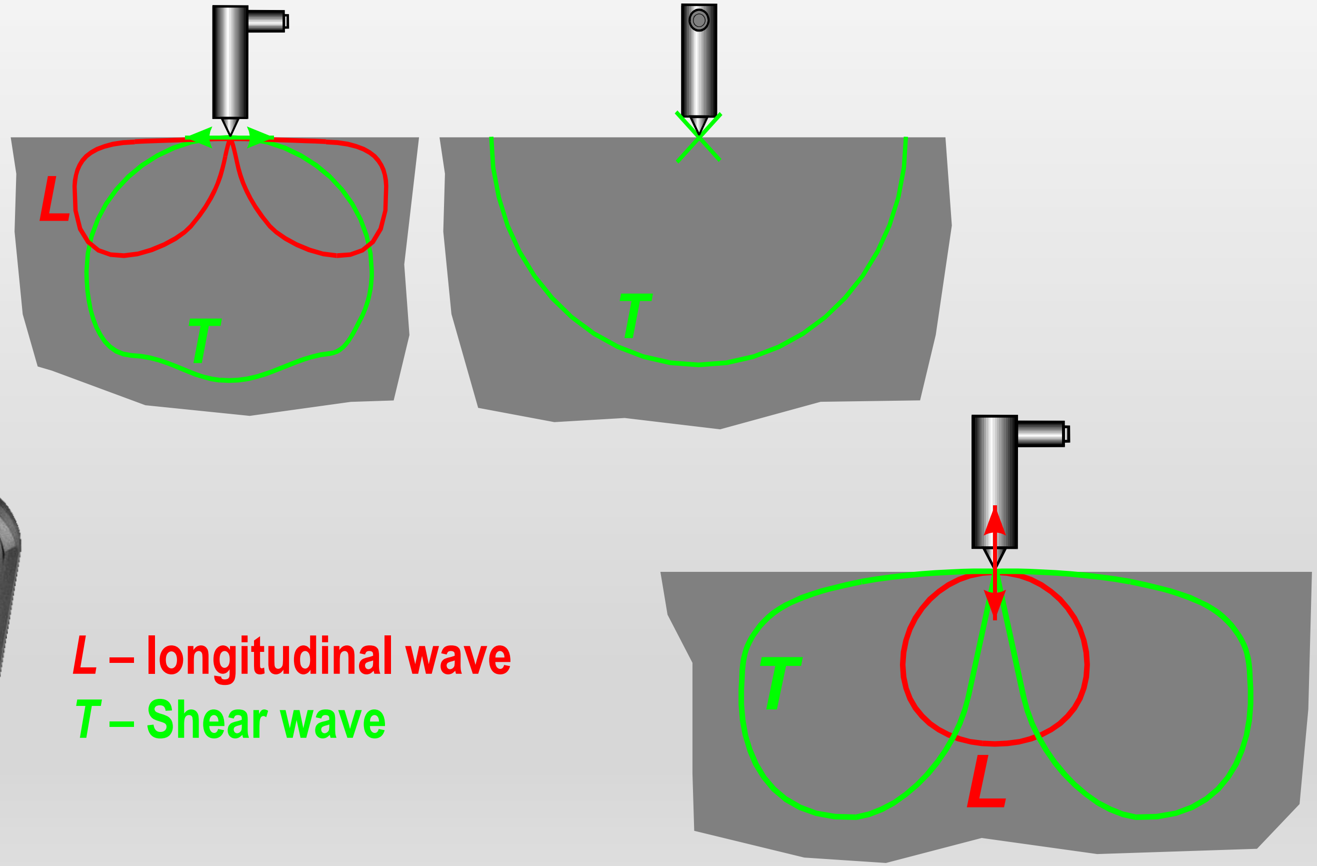
Ultrasonic Concrete Testing

Inspection tasks

- Data collection about the inner structure of the inspection object a part of it due to lack of information
- Estimation of the current state of the inner structure in comparison to the documentation
- Estimation of the state and level of damage of the object because of load during exploitation
- Detection and evaluation of material flaws appeared during construction and exploitation

Instrumentation for Ultrasonic Concrete Testing

Dry Point Contact – DPC transducers for concrete testing

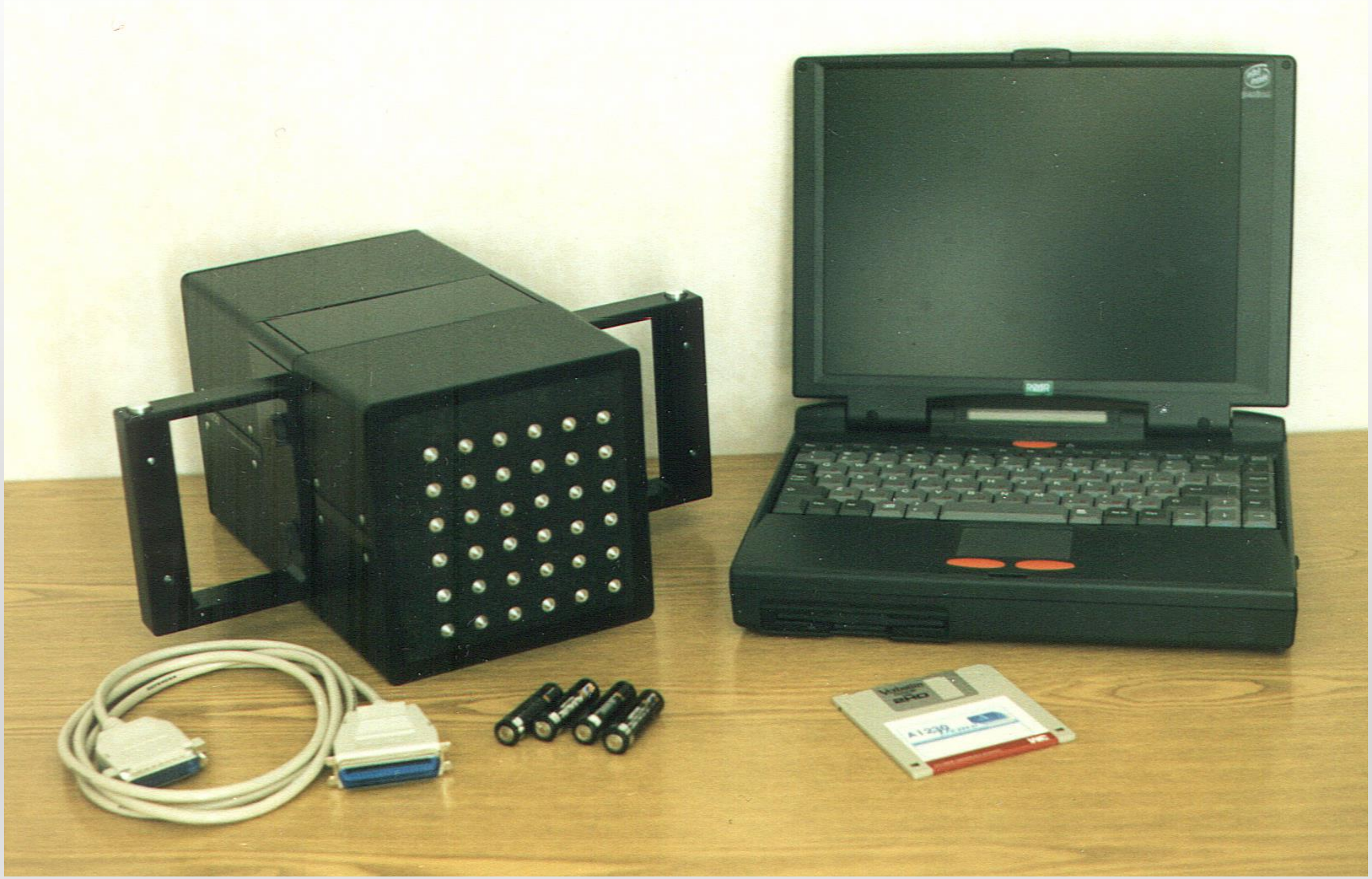


Instrumentation for Ultrasonic Concrete Testing

1989

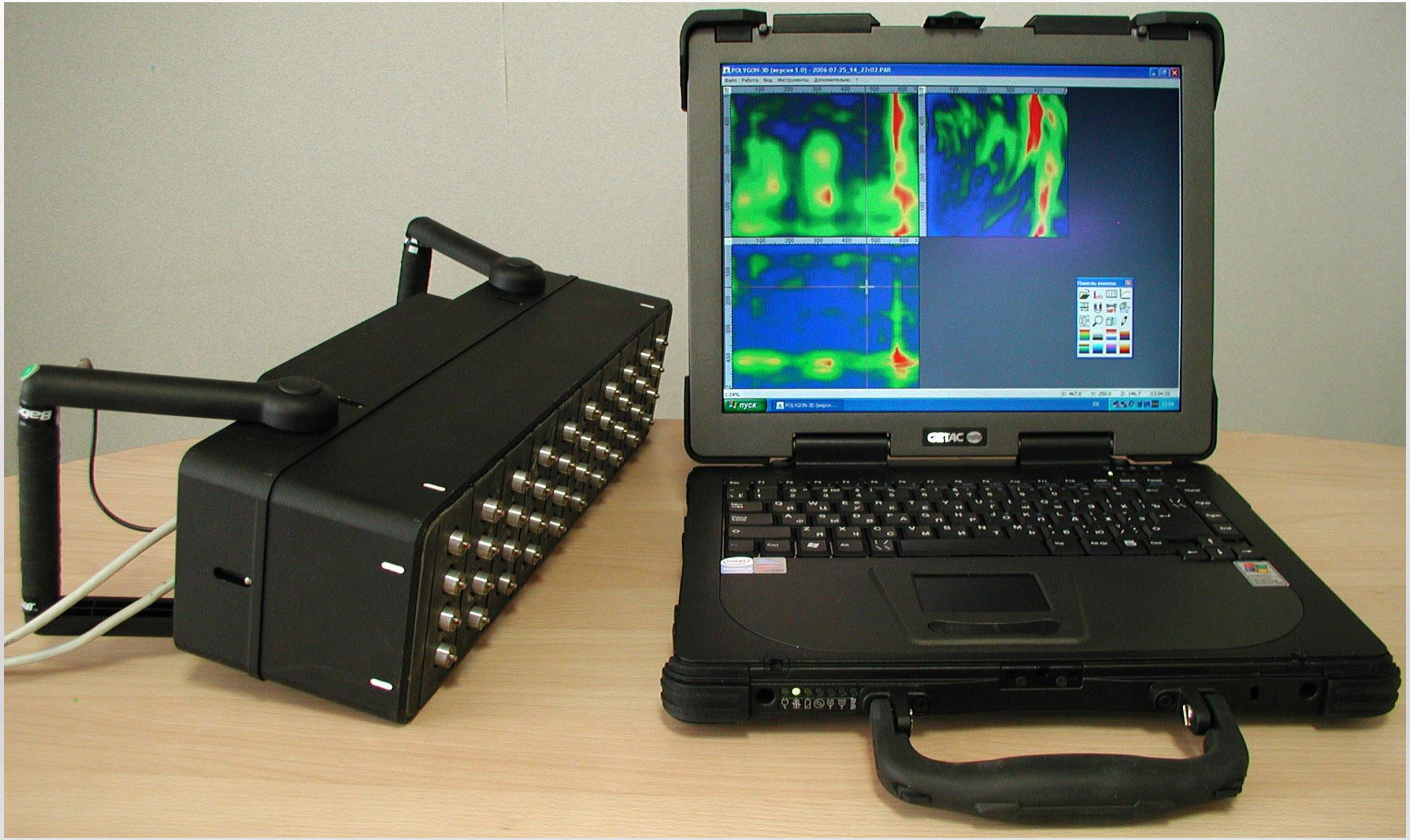
Instrumentation for Ultrasonic Concrete Testing

1995



Instrumentation for Ultrasonic Concrete Testing

2007



Instrumentation for Ultrasonic Concrete Testing

Ultrasonic Pulse Velocity Tester

Evaluation of the compressive strength

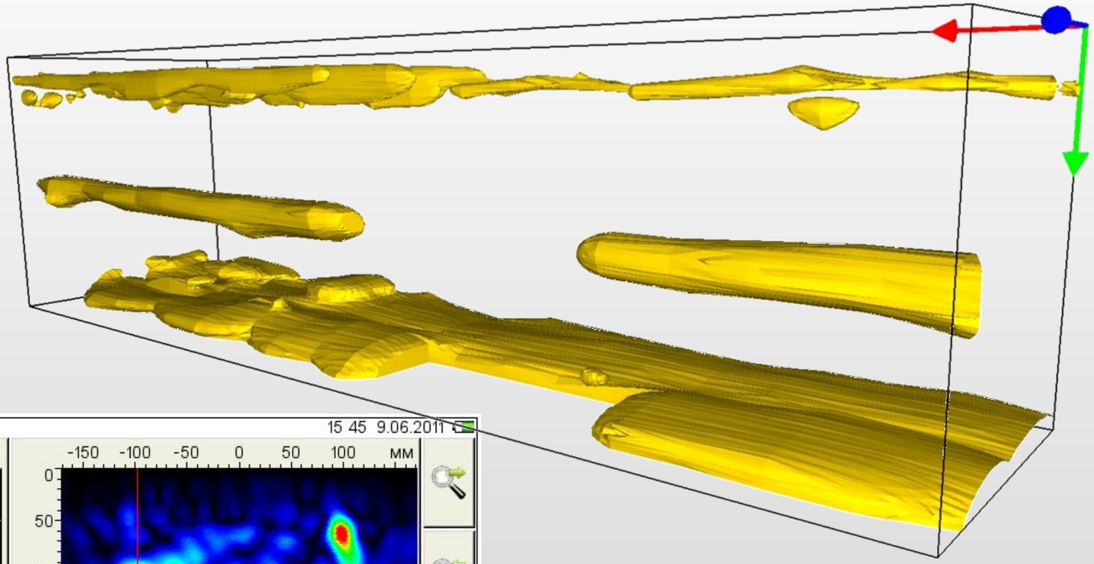
Ultrasonic thickness gauges / flaw detectors

Pulse-echo testing: from thickness measurement to 3D-imaging by SAFT

Instrumentation for Ultrasonic Concrete Testing

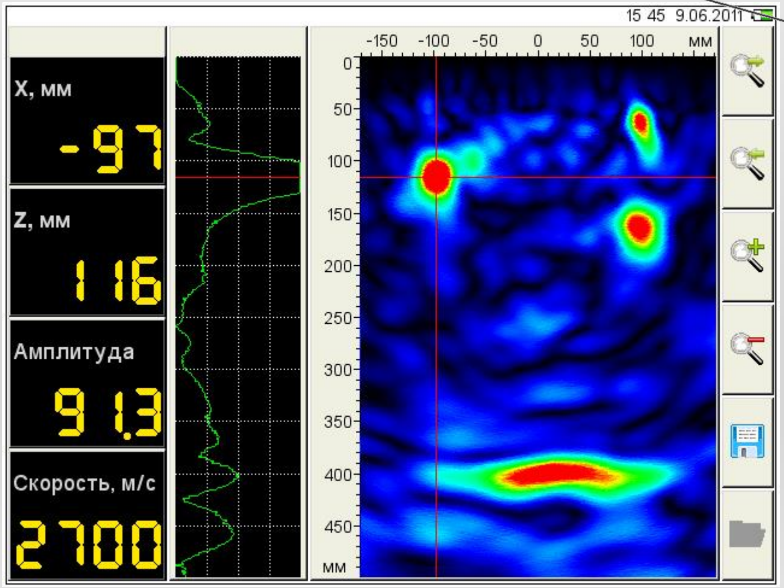
Ultrasonic tomography systems

3D representation of inspection results



In-Situ testing

B-Scan image



Ultrasonic Concrete Testing

Chalenges of UT on concrete

- **HETEROGENEOUS MATERIAL** with strong structural noise
- **STRUCTURAL COMPLEXITY** of the inspection objects (reinforcement, channels etc. Inside)
- **LARGE DIMENSIONS** of the objects
- Often the objects are in service – limited accessability

- Very less methodical / guiding documents available
- “Originality” and “specificity” of every object of inspection
- Strong influence of operator professional skills and experience

Ultrasonic Concrete Testing

Why Ultrasonics?

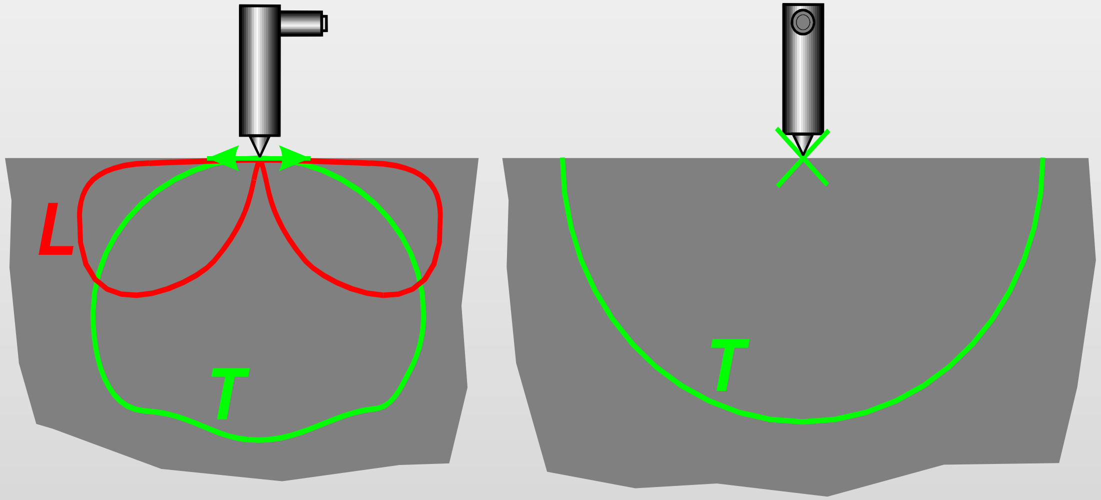
- High penetration depth
- Visualization of the inner structure and easiness of result interpretation
- Wide range of versatile measurement / analysis methods (surface pulse velocity, volume pulse velocity, pulse-echo, UT tomography by SAFT / DFA)
- Adjustability of inspection parameters to the object properties: working frequency range 20-150 kHz

Physical limitations:

- Strong frequency dependence of sound attenuation
- Less sensitivity to close laid reinforcement (in comparison with GPR)
- Inspection sensitivity and resolution are comparable to the wave length ($\lambda \sim 2 - 25$ cm)
- Inspectability can be affected by reinforcement elements

Ultrasonic tomography by DFA in concrete

Dry Point Contact – DPC transducers for concrete testing

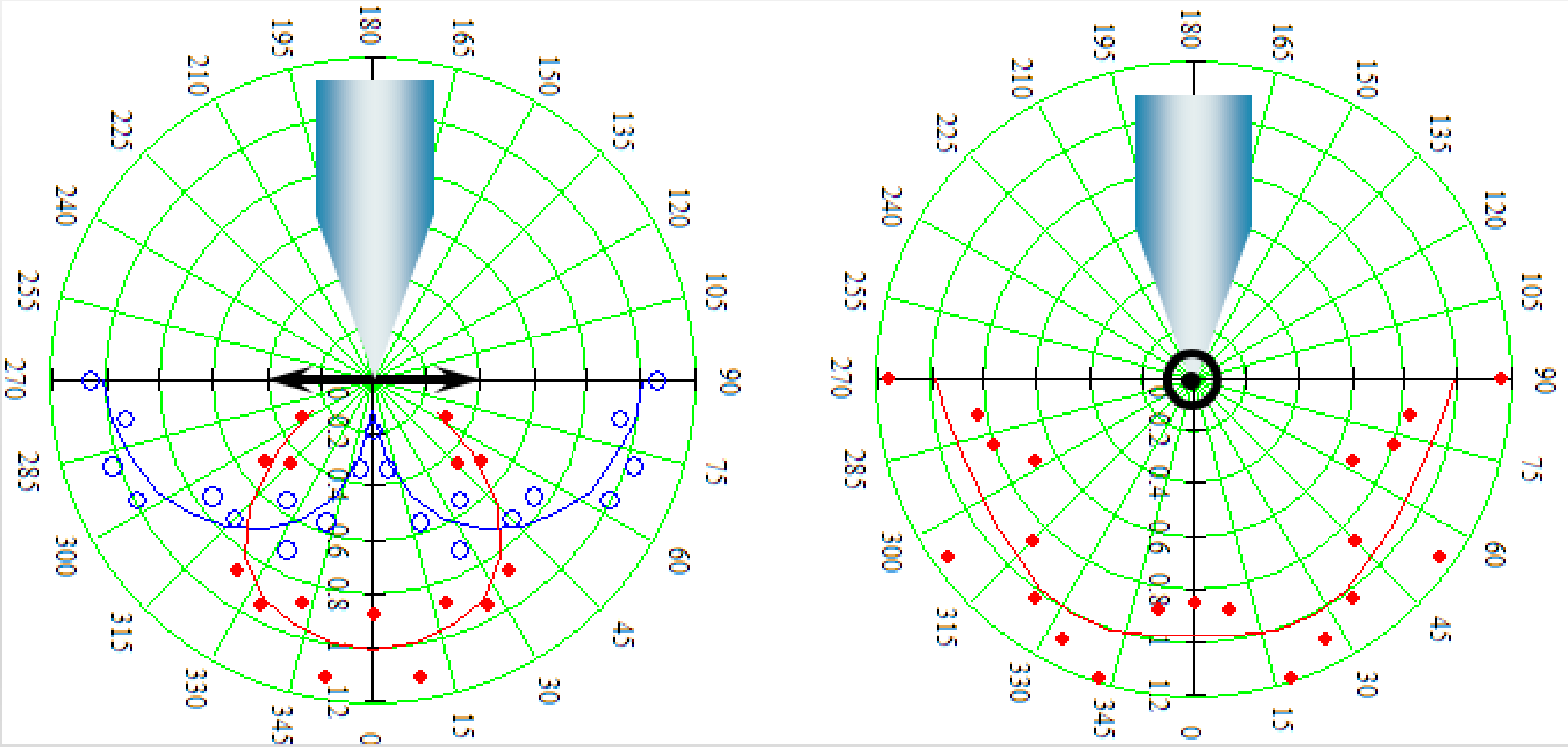


L **– longitudinal wave 纵波**

T **– Shear wave**

ACS

Dry Point Contact – DPC transducers for concrete testing



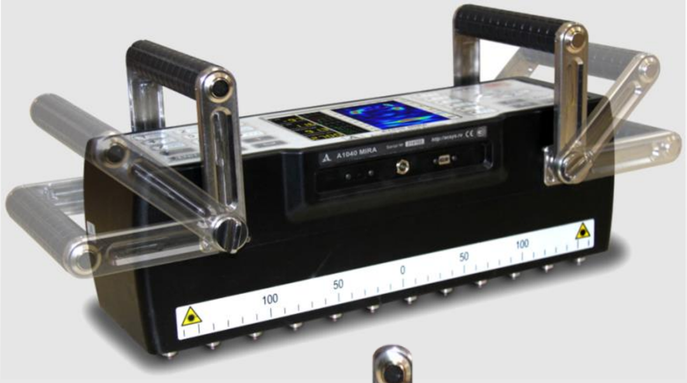
Ultrasonic tomography by DFA in concrete

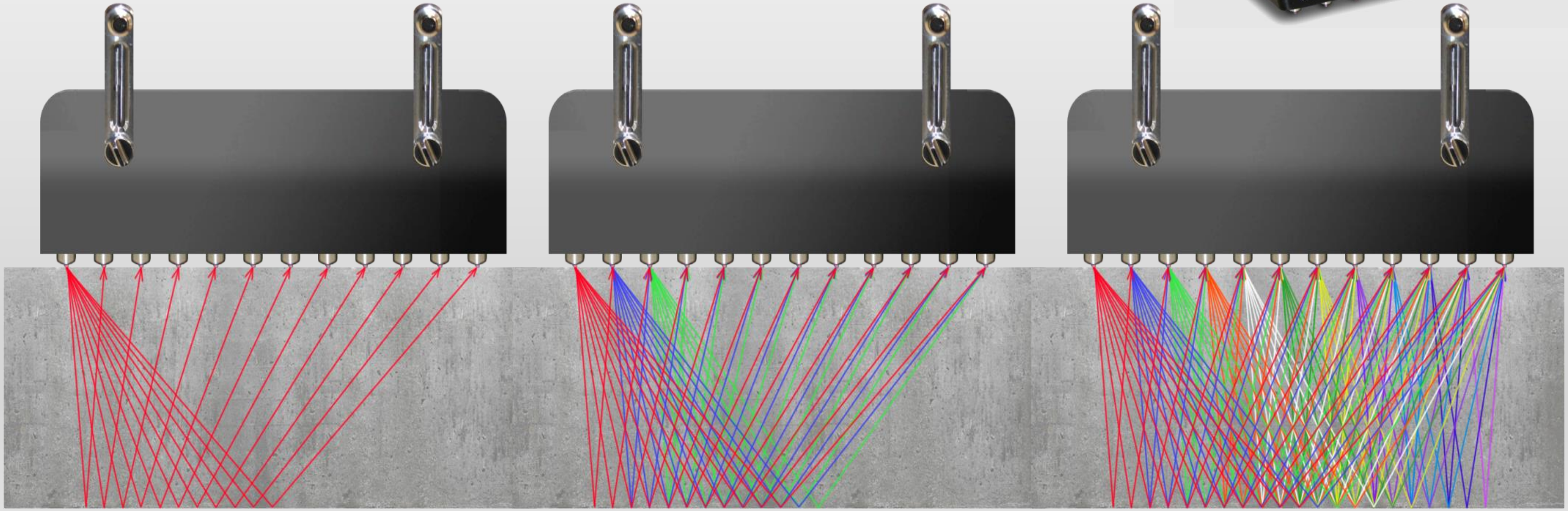
Dry Point Contact – DPC transducers for concrete testing

- Dry acoustic coupling, no special surface preparation is required
- Inspection with one-side access to the object
- Stable acoustic contact even on rough and uneven surfaces: spring-loaded antenna array elements allows to work on surfaces with roughness curvature radius up to 8 mm
- High signal / noise ratio while using antenna arrays

Ultrasonic tomography by DFA in concrete

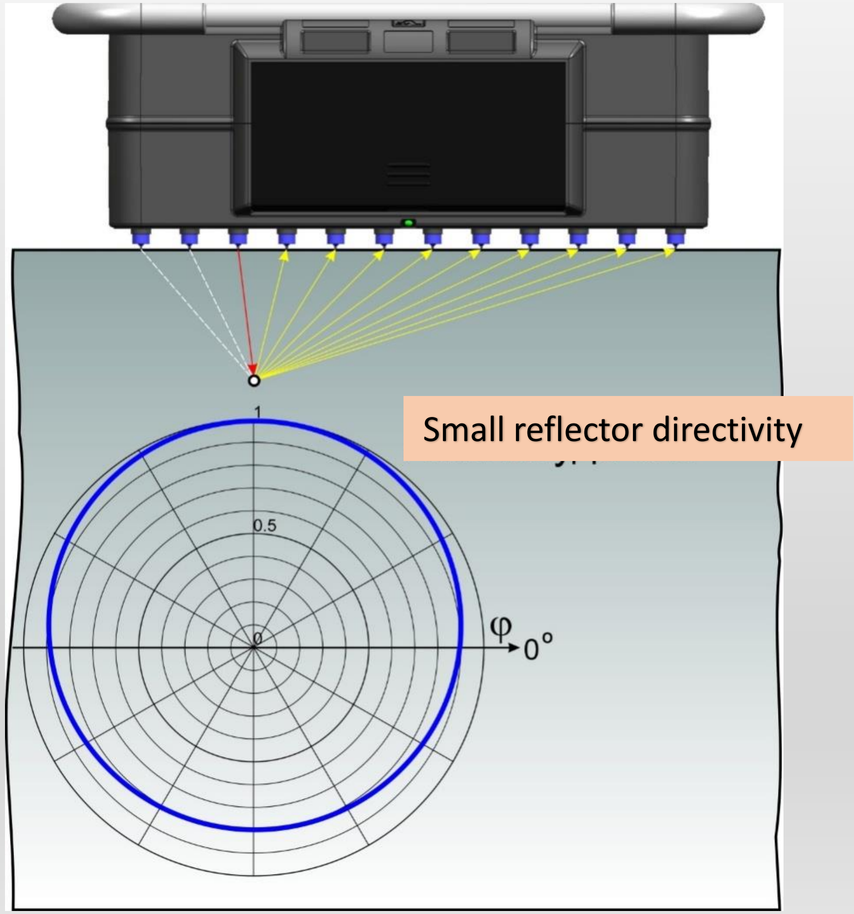
Data acquisition with the DFA system A1040 MIRA

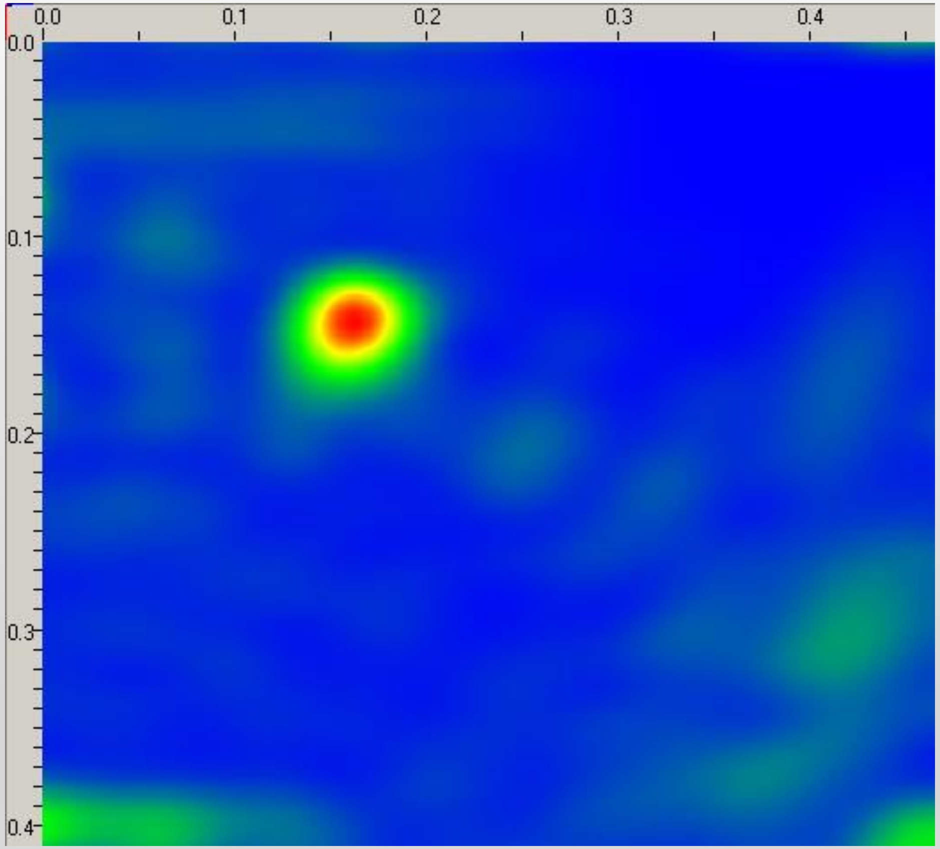




Ultrasonic tomography by DFA in concrete

Data acquisition with the DFA system A1040 MIRA

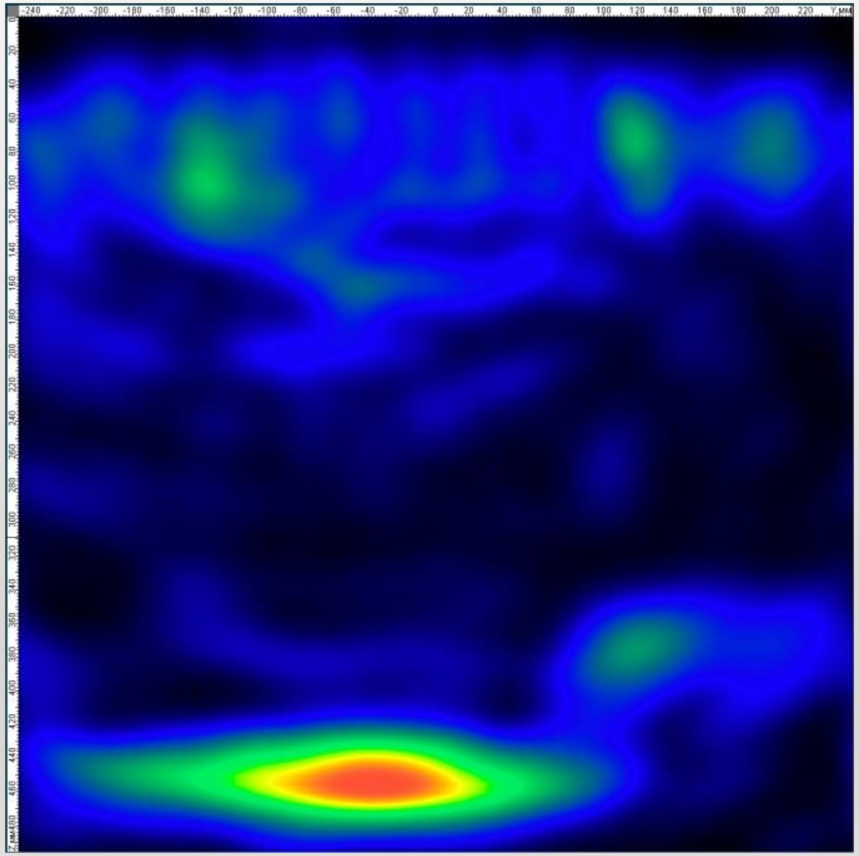


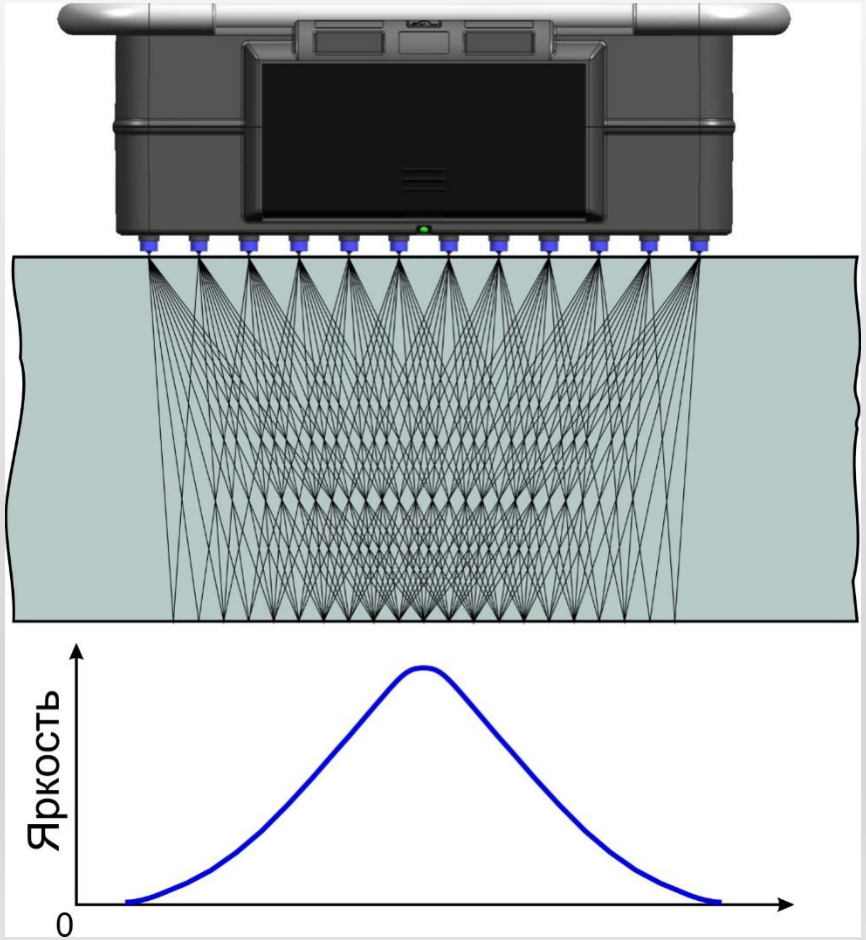


$\varnothing \approx \lambda$

Ultrasonic tomography by DFA in concrete

Data acquisition with the DFA system A1040 MIRA





Ultrasonic tomography by DFA in concrete

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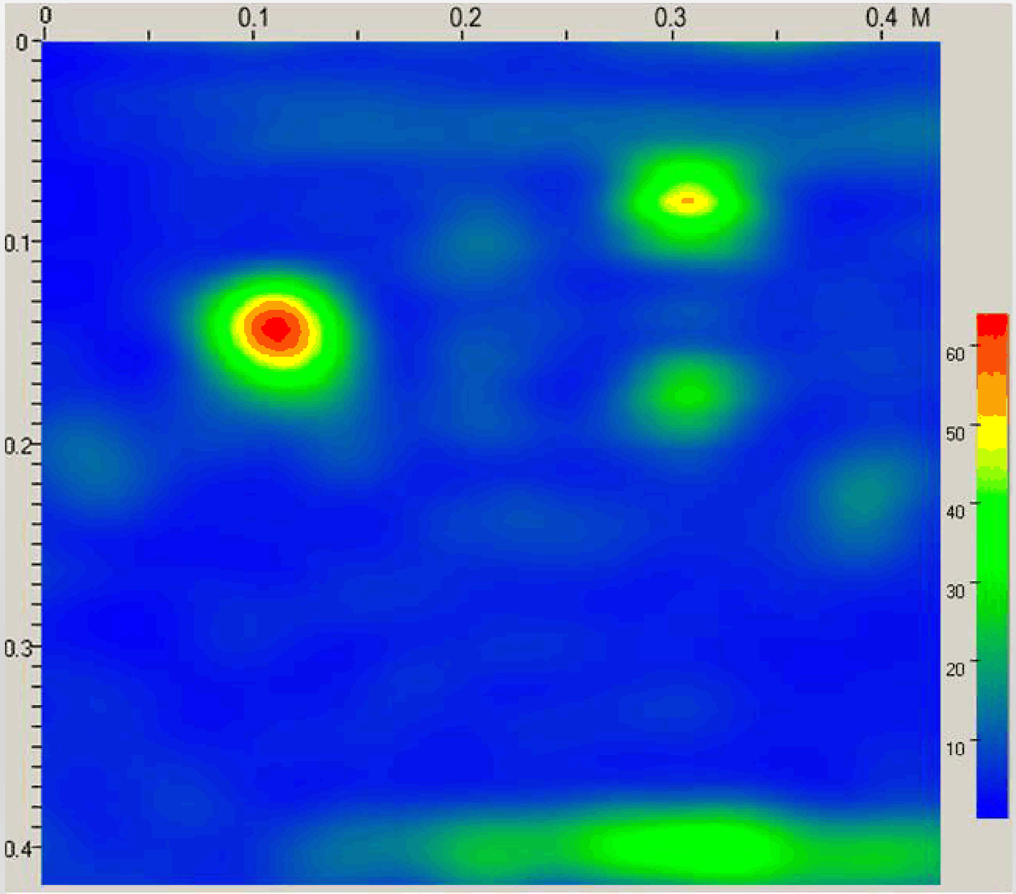
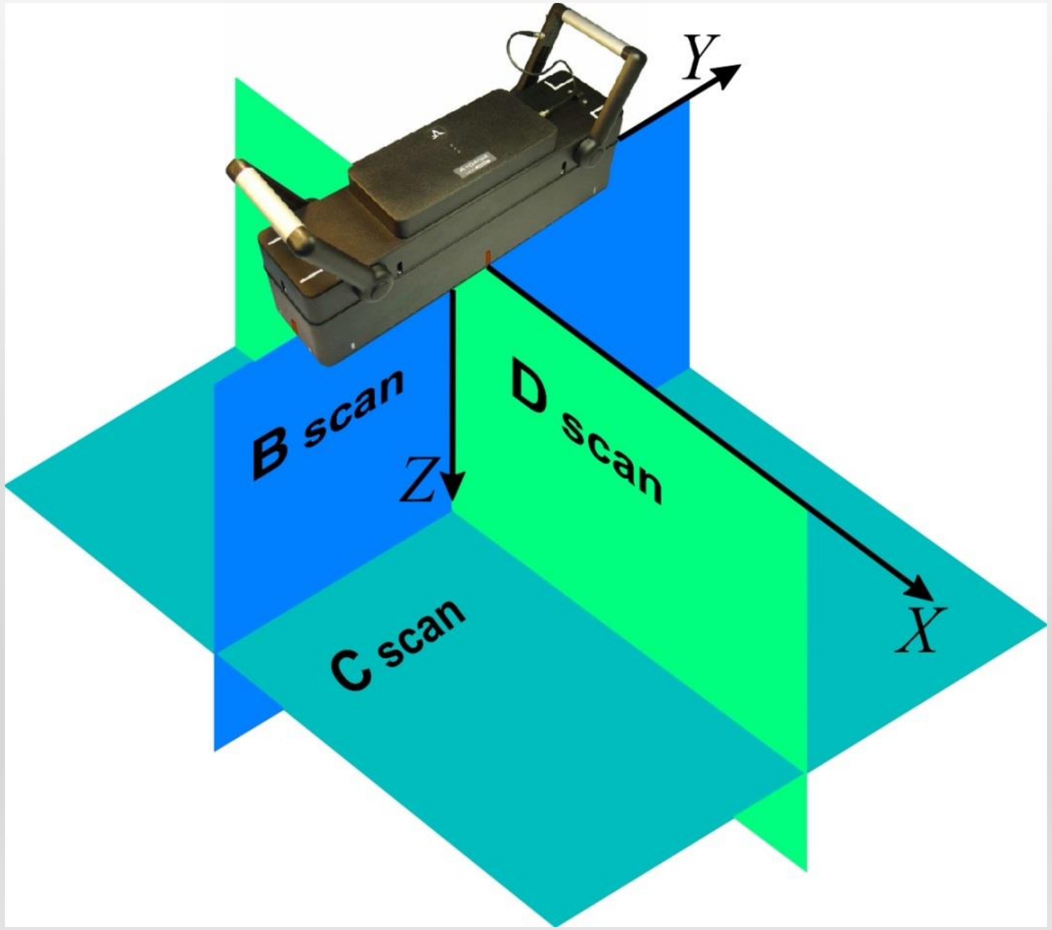
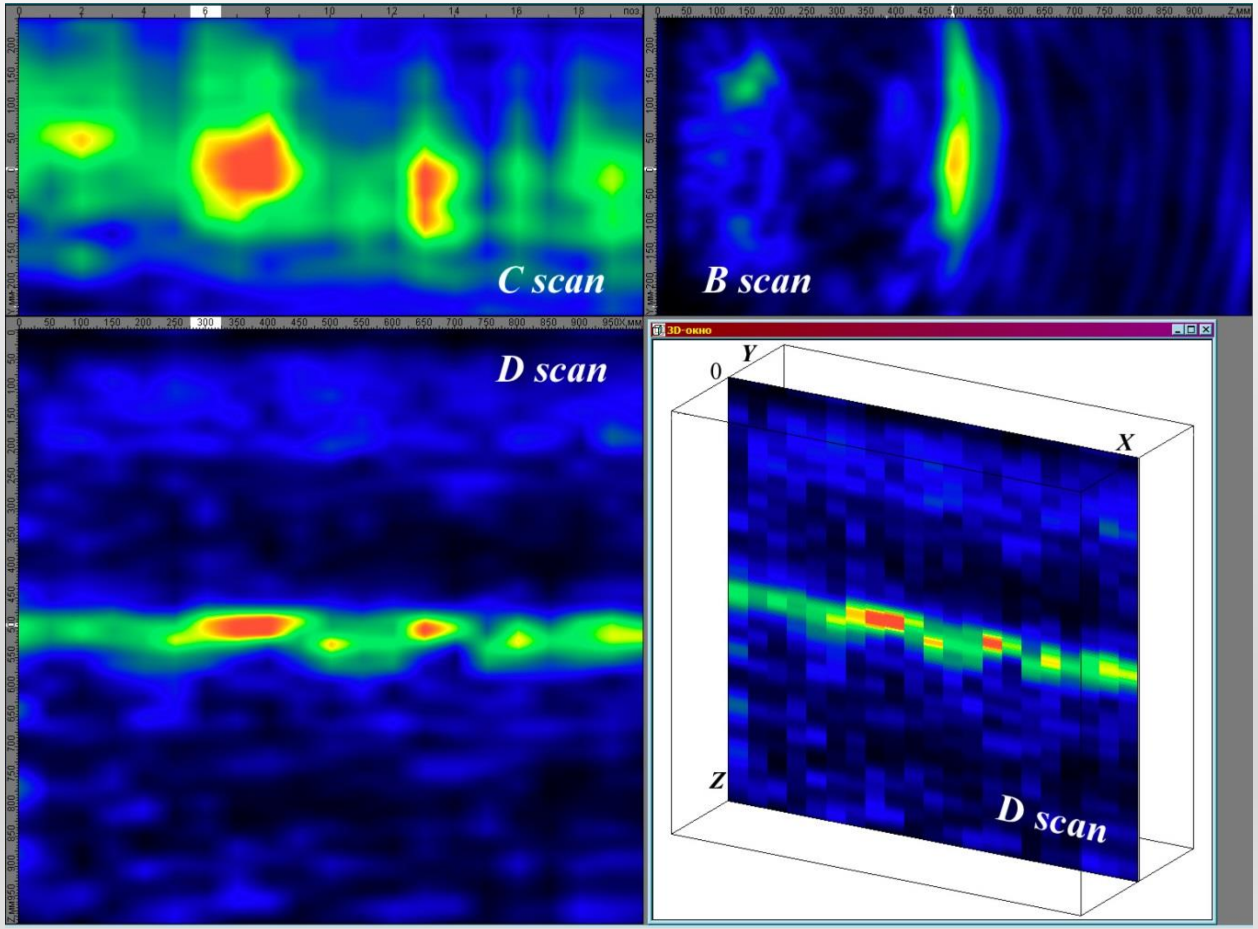


Ultrasonic tomography by DFA in concrete

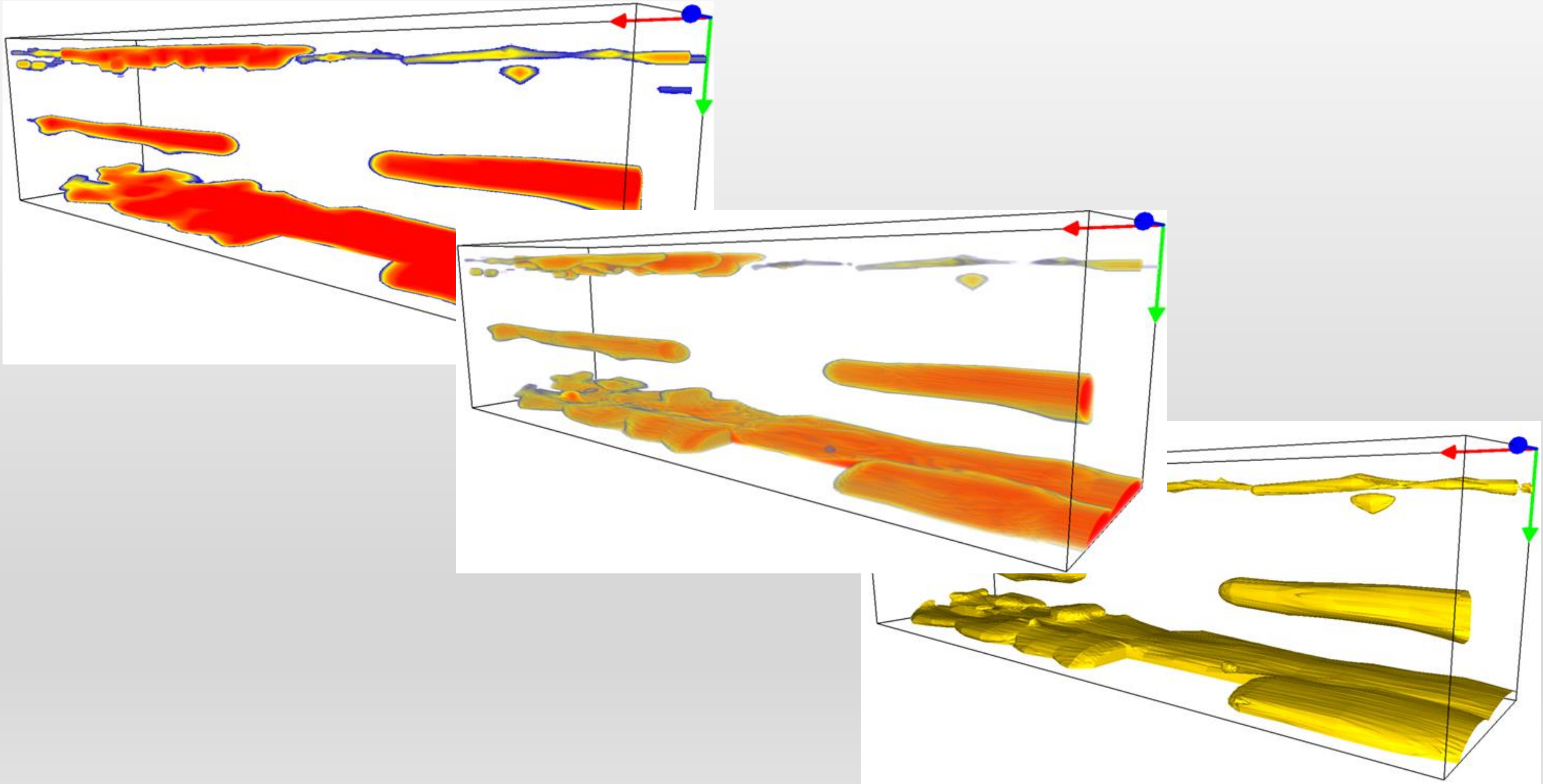
Data acquisition with the DFA system A1040 MIRA



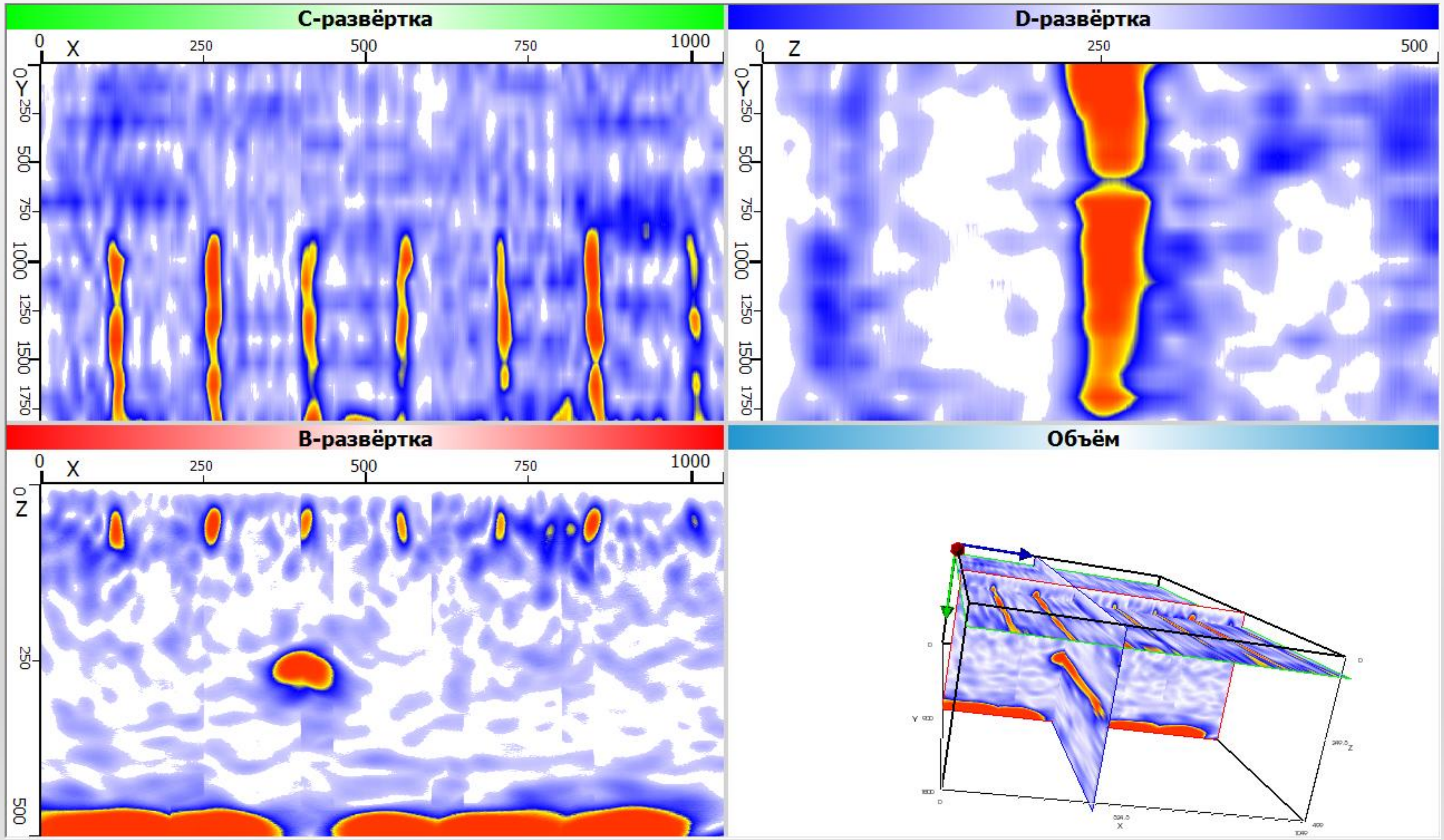


Ultrasonic tomography by DFA in concrete

3D Imaging of inspection objects by tomographic UT



3D analysis of the inspection data

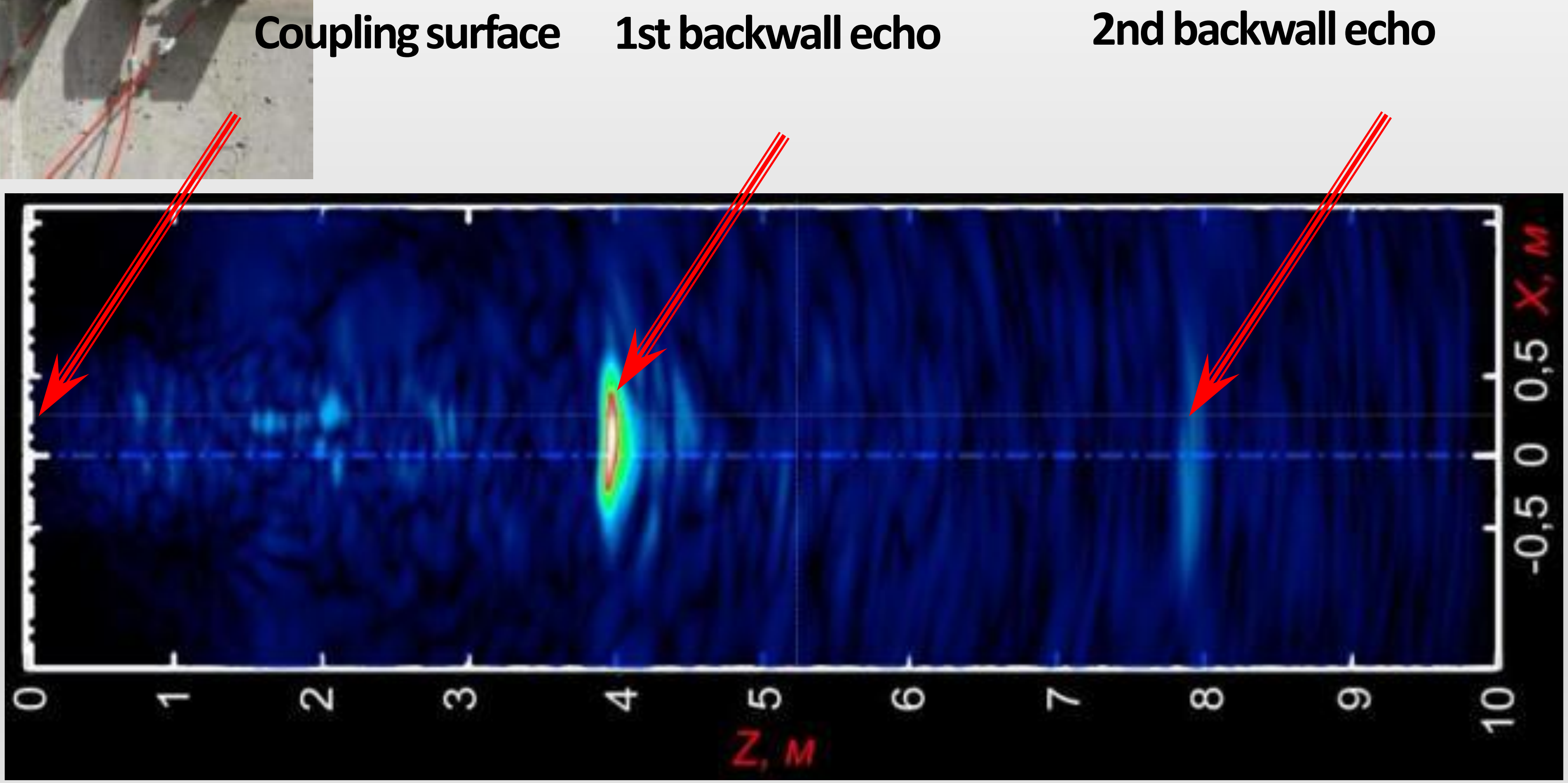


Deep-penetration concrete inspection system

Broad-aperture data acquisition system

Scalable wireless data acquisition module

Deep-penetration concrete inspection system



Instrumentation for concrete testing

Ultrasonic Concrete Testing

Available equipment for concrete testing

Surface
pulse velocity tester
UK1401 Surfer

Universal
pulse velocity tester
A1410 Surfer

Flaw detector
A1220 Monolith

Tomograph
A1020 MIRA-Lite

Tomograph
A1040 MIRA

Ultrasonic Concrete Testing

Surface pulse velocity tester UK1401 SURFER

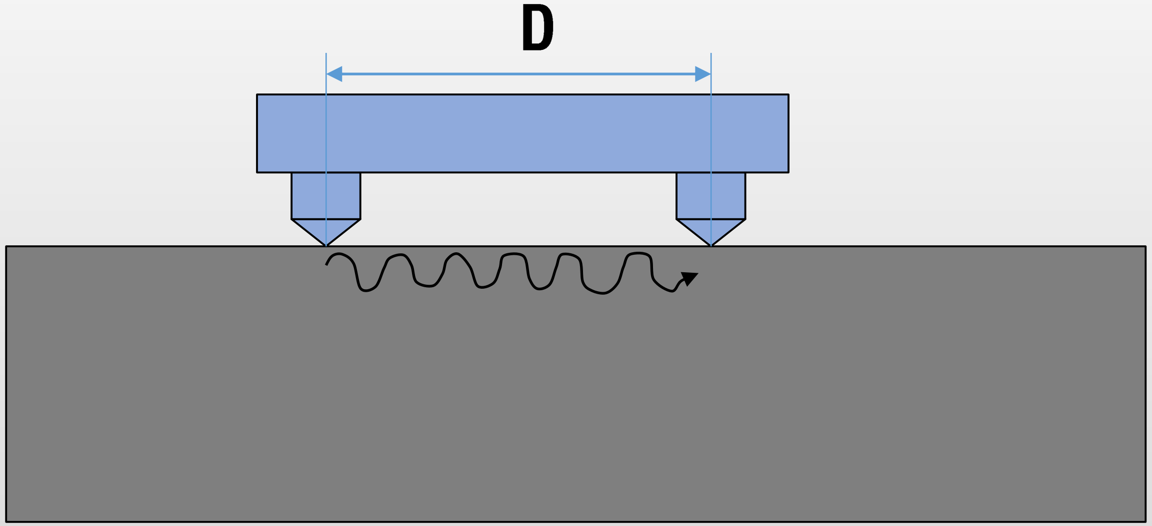
- Evaluation of propagation time / sound velocity in material
- Estimation of concrete strength
- Estimation of porosity and fissuring of concrete
- Estimation of the loading capacity of concrete piers and columns
- Estimation of the crack depth opened to the surface

Instrument features ：

- Dry acoustic contact with two built-in transducers
- Small sizes and weight
- Embedded memory for 4000 measured values

Ultrasonic Concrete Testing

Surface pulse velocity tester UK1401 SURFER



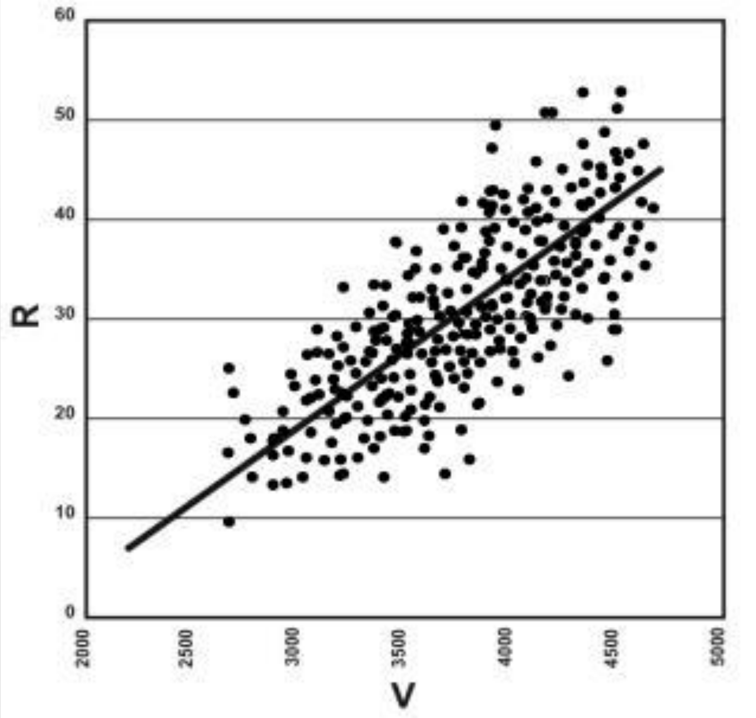
Sound velocity V = D / t

t – measured propagation time

Calibration curve

Surface pulse velocity tester UK1401 SURFER

Concrete strength evaluation

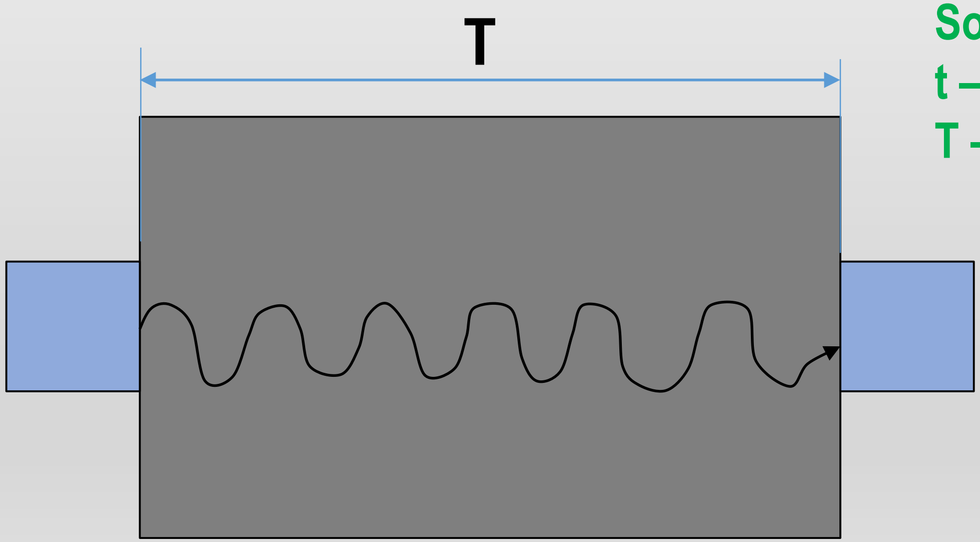


- Concrete strength estimation occurs based on preliminary calibration: sound velocity / propagation time directly correlates with concrete strength
- Fast concrete strength evaluation while testing of large objects is possible

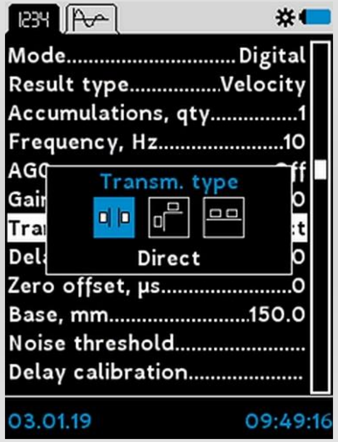
Instrumentation for Ultrasonic Concrete Testing

A1410 PULSAR - Volume pulse velocity tester

- Pulse velocity testing in through transmission mode by piezoelectric or Dry-Point-Contact transducers
- 7-element DPC transducer arrays with (longitudinal wave)
- Propagation time or sound velocity measurement (by known thickness value)



Sound velocity V = T / t
t – measured propagation time
T – wall thickness



Ultrasonic Concrete Testing

A1220 - Volume pulse velocity tester, flaw detector & tomograph

Patent No. RF 2080592

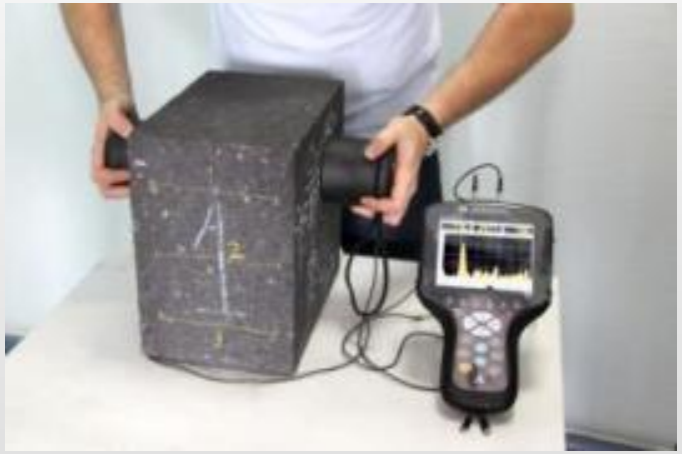
- Pulse velocity tester in through transmission mode (testing with both-side access)
- Thickness gauge in pulse-echo mode (testing with one-side access)
- Flaw detector in pulse-echo mode (testing with one-side access)
- 3D Tomography functionality available in configuration “Advanced”

<u>Instrument features</u>

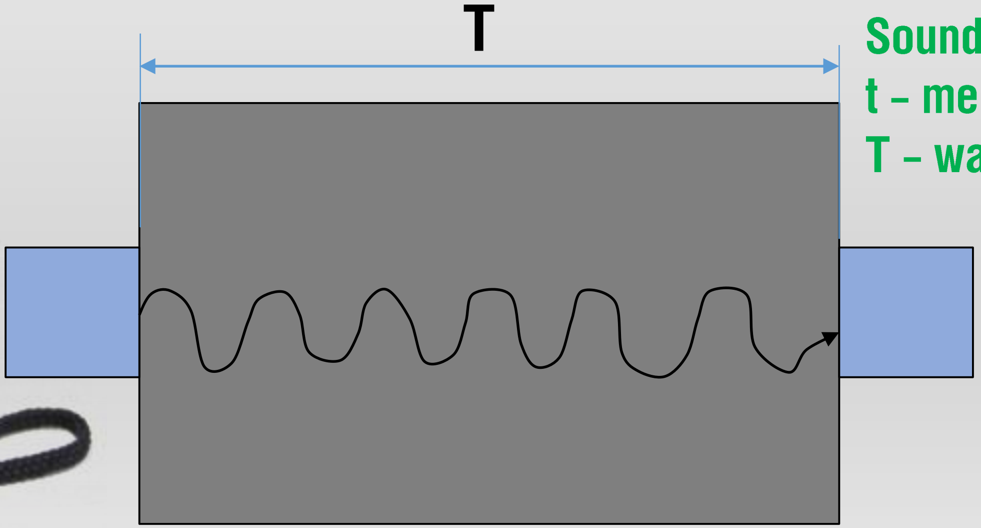
- Low weight of 750 grams only
- Operation temperature range from -20 to +45 °C
- Embedded memory for 200 A-Scans
- Imaging software with B-, C-, D-, 3D-Scan functionality, 3D SAFT reconstruction available in configuration “Advanced”

Ultrasonic Concrete Testing

A1220 MONOLITH - Volume pulse velocity tester



- Pulse velocity testing in through transmission mode by piezoelectric or Dry-Point-Contact transducers
- Two types of 12-element transducers with DPC applicable: M2103 (shear wave) and M2102 (longitudinal wave)
- Propagation time or sound velocity measurement (by known thickness value)

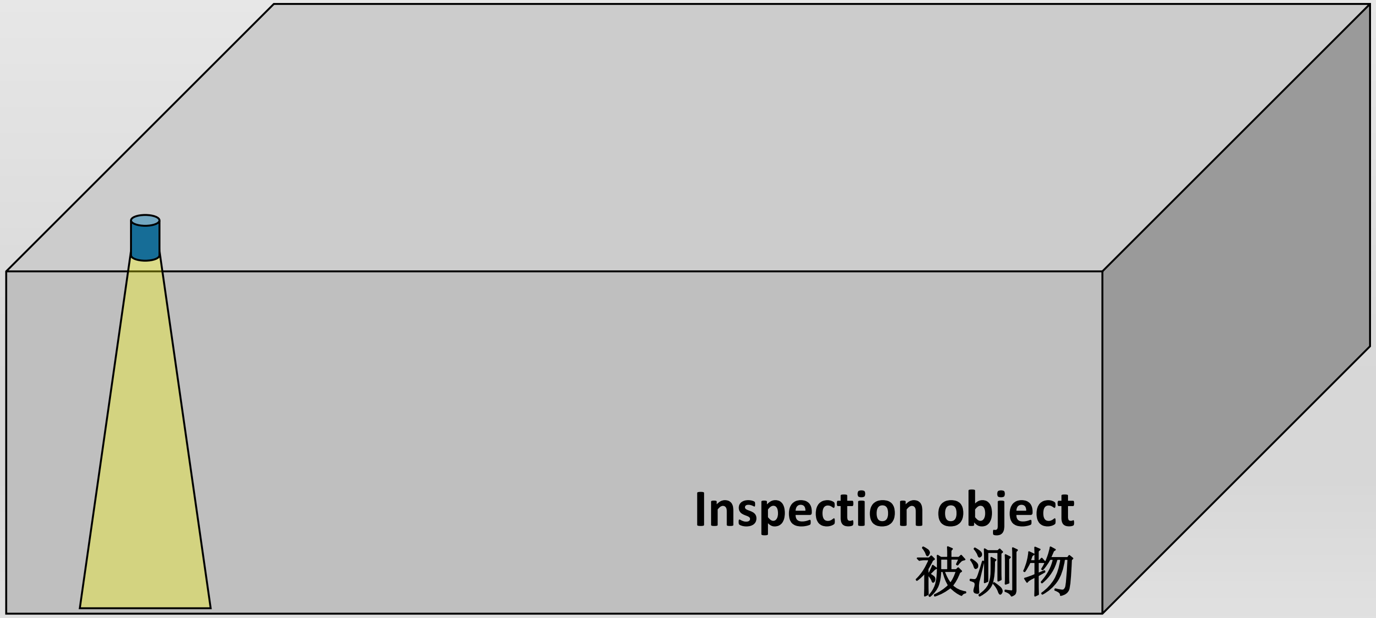


Sound velocity V = T / t
t – measured propagation time
T – wall thickness

Ultrasonic tomography by DFA in concrete

„Low-Cost“ tomography system on the base of A1220 MONOLITH

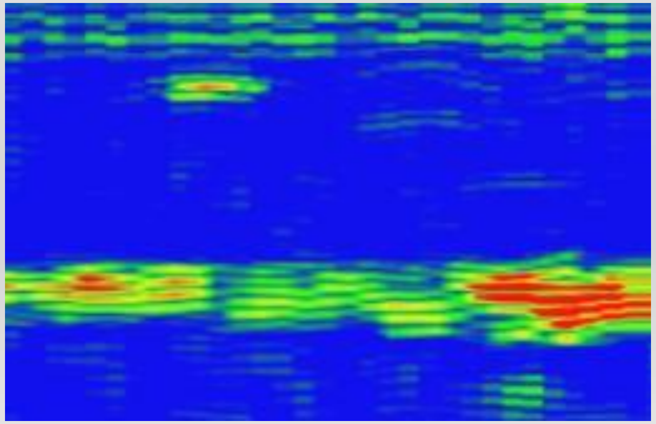
- Accurate small-step data acquisition by A1220 Monolith provides SAFT-suitable ultrasonic data for 3D volume reconstruction

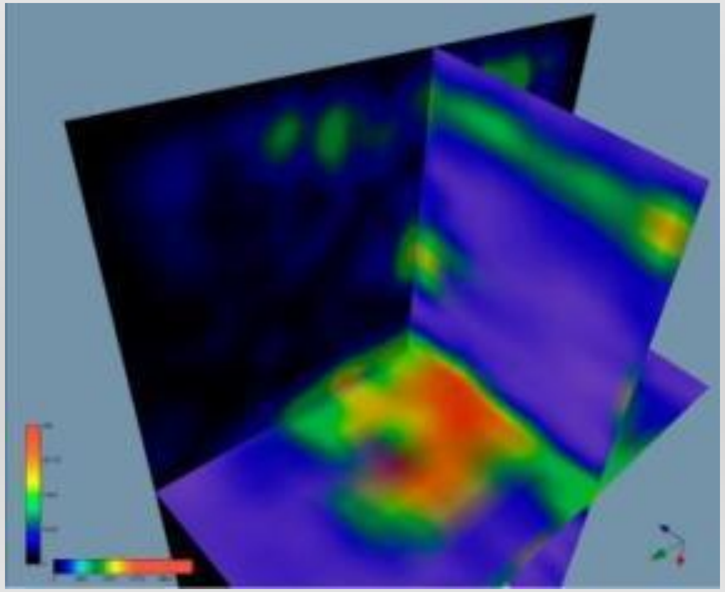


Ultrasonic Concrete Testing

A1220 MONOLITH – Thickness gauge, Flaw detector & Tomograph

- Thickness gauge & Flaw detector in pulse-echo mode (testing with one-side access)
- Testing by 24-element antenna array with Dry Point Contact (DPC)
- Working range up to 600 mm
- 2D / 3D imaging





A1040 MIRA – High-End tomography system

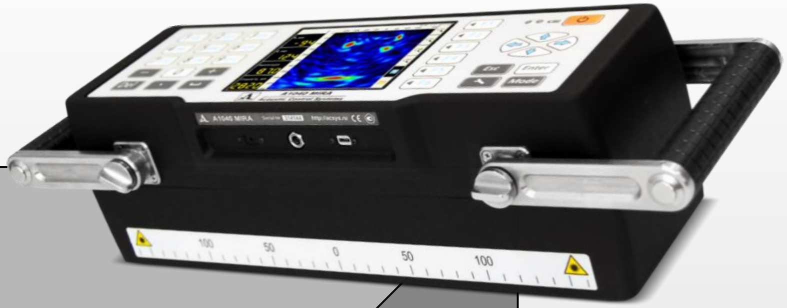
- Integrity assessment of concrete
- Flaw detection and thickness measuring on concrete, reinforced concrete and rock with on-side access
- Detection of material defects (voids, cracks)

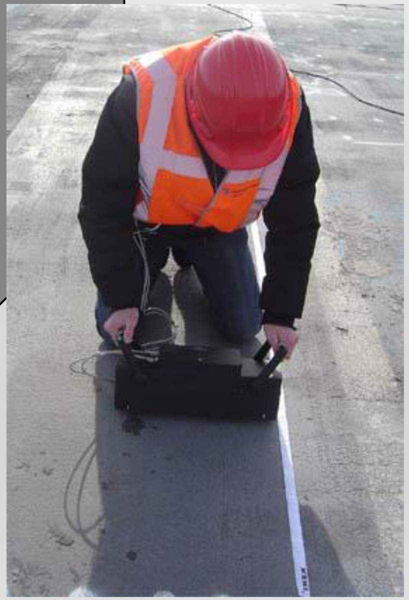
Instrument features

- Stand-alone instrument with 2D imaging
- Number of channels：12
- Maximum inspection range：2500 mm
- Operation Temperature Range：-10 - +50 °C
- Battery Operation Time：12 hours
- Weight (with battery)：4.5 kg

Ultrasonic tomography by DFA in concrete

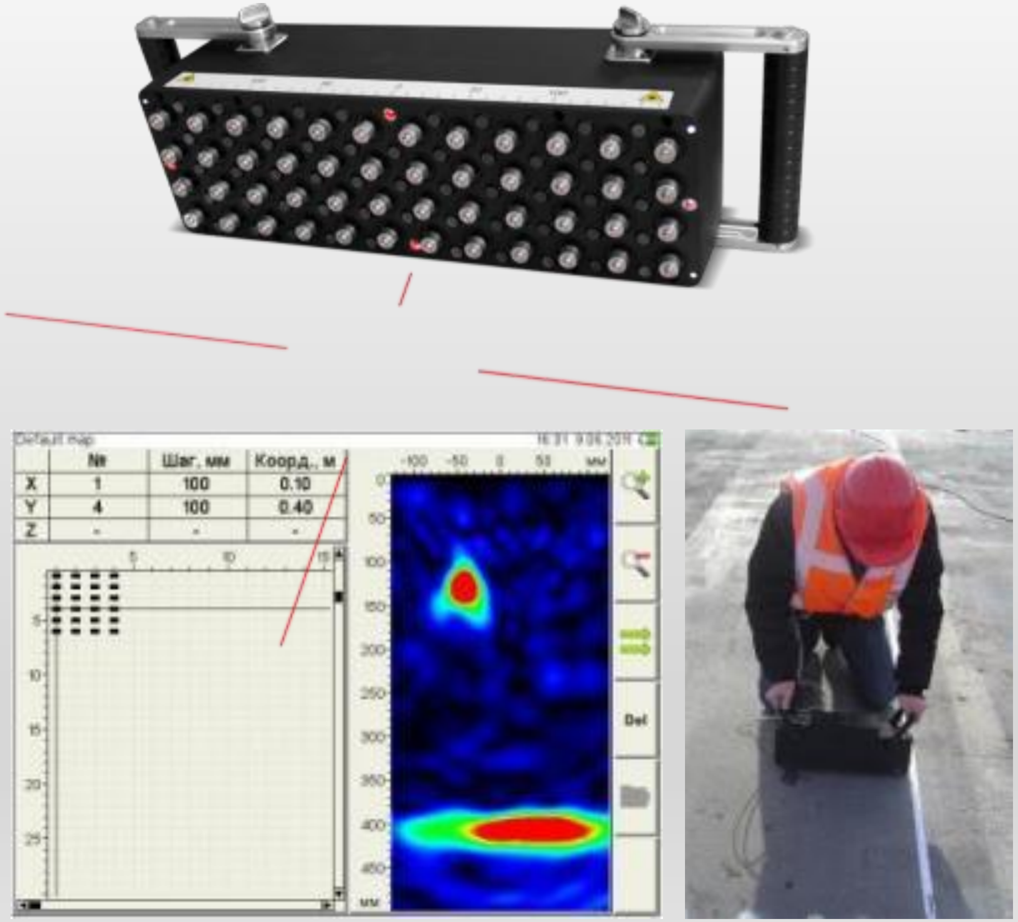
Data acquisition with the DFA system A1040 MIRA





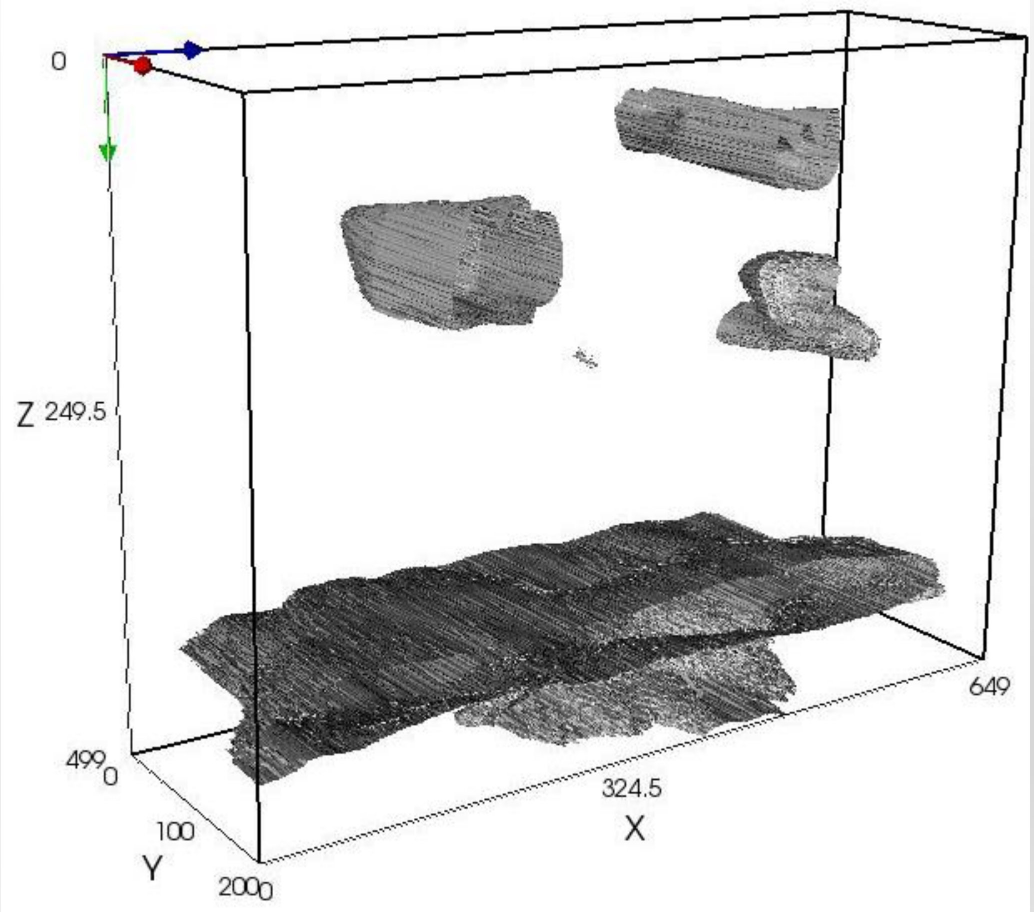
Ultrasonic Concrete Testing

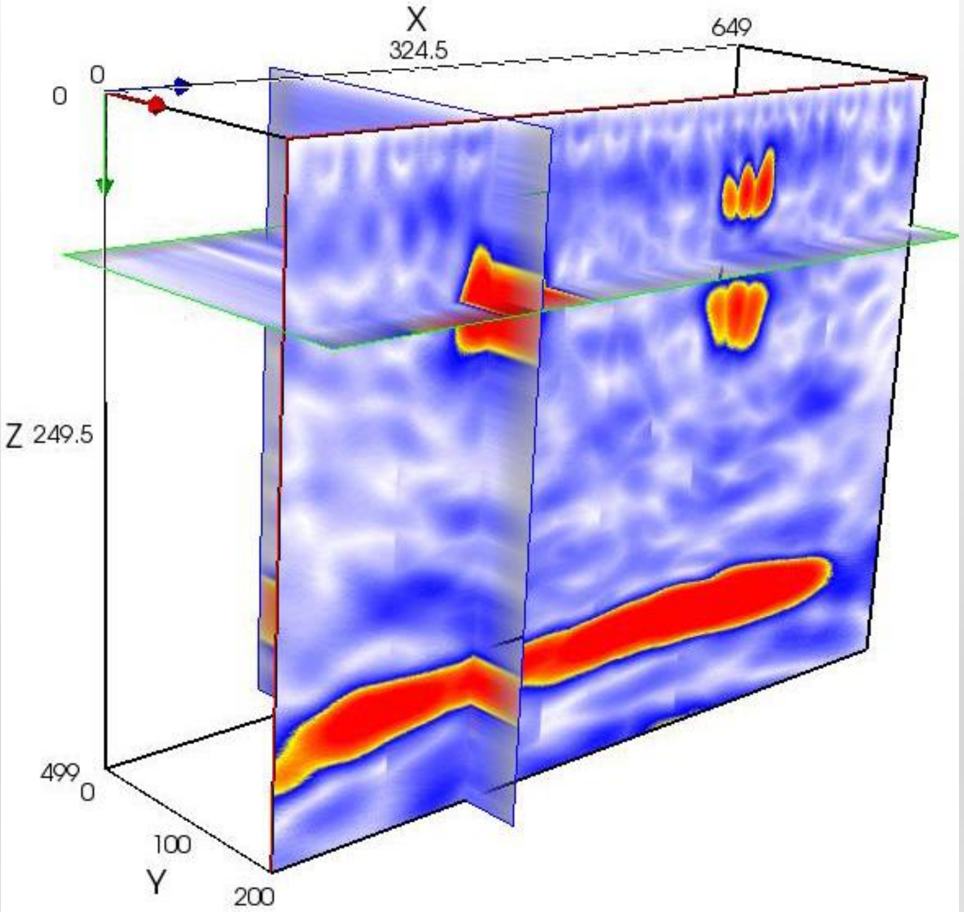
A1040 MIRA – High-End tomography system



- Testing is performed by step-by-step scanning along a drawn grid with equidistand measurement positions
- After data collection in “grid-mode” the 3D reconstruction of inspected area is conducted by external PC
- Depending on concrete grain size and applicable working frequency following discontinuities can be detected:
  - ✓ Cylindrical reflector up to ∅ 12 mm
  - ✓ Spherical reflector up to ∅ 20 mm

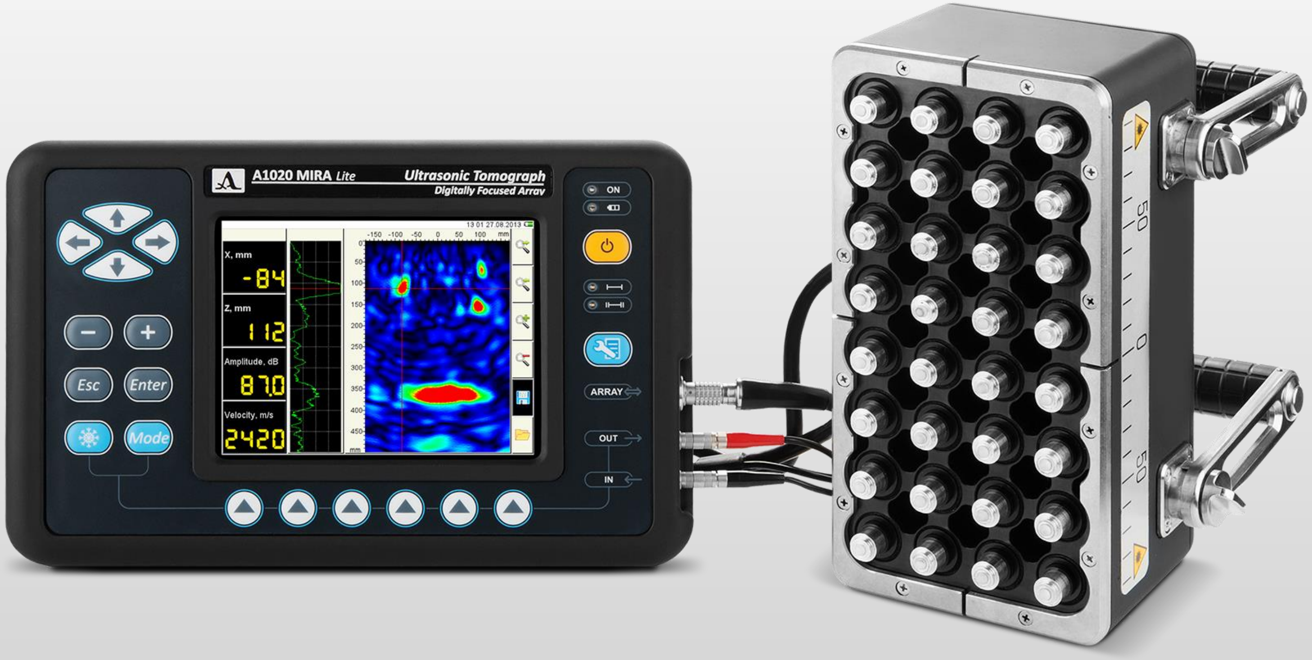
A1040 MIRA – High-End tomography system

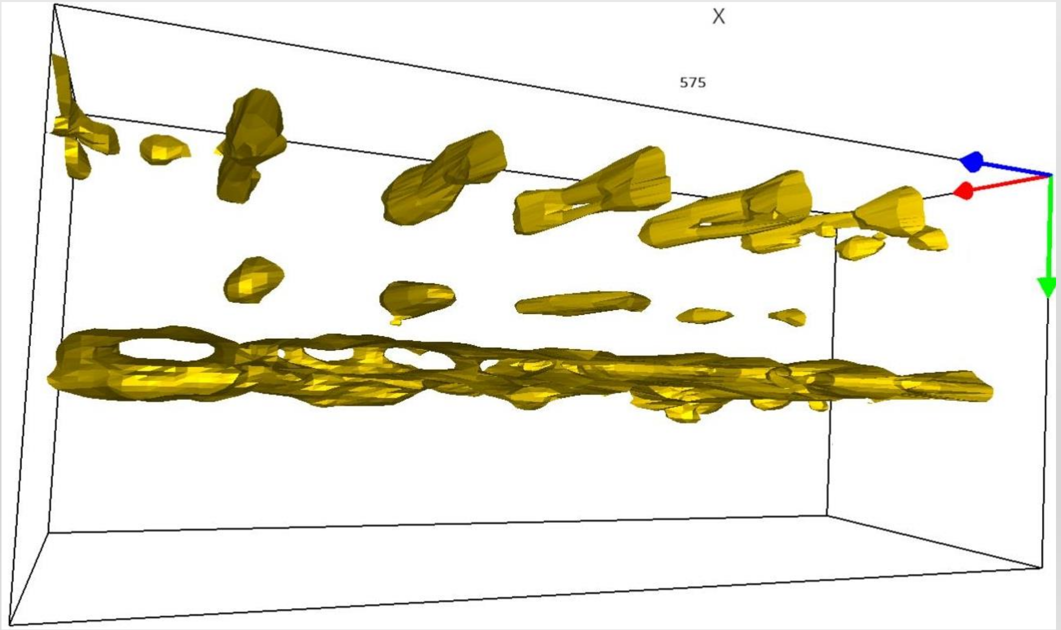




Ultrasonic Concrete Testing

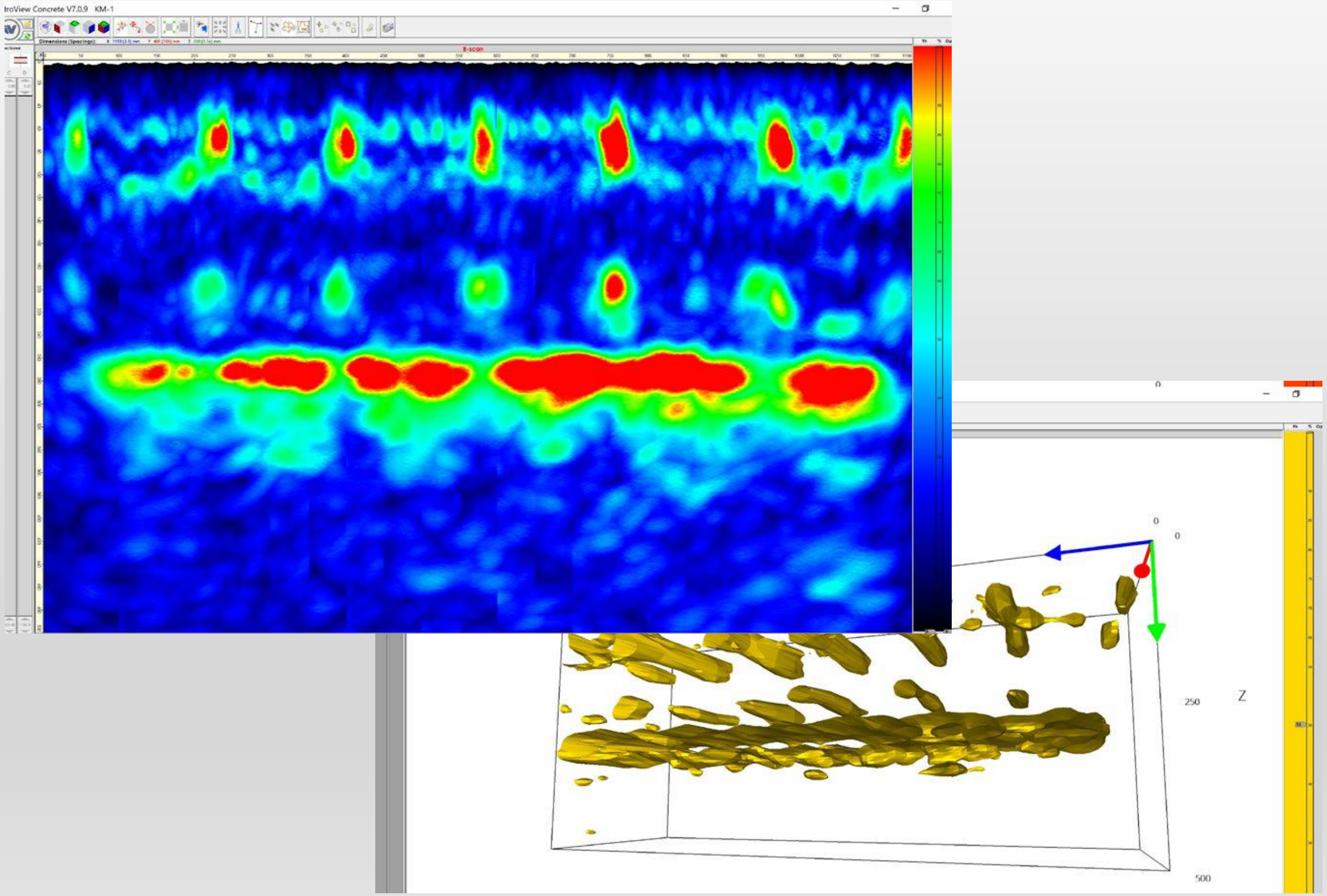
A1020 MIRA lite – affordable tomography system





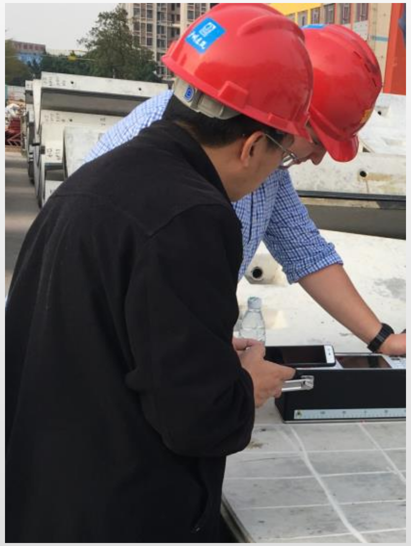
Ultrasonic Concrete Testing

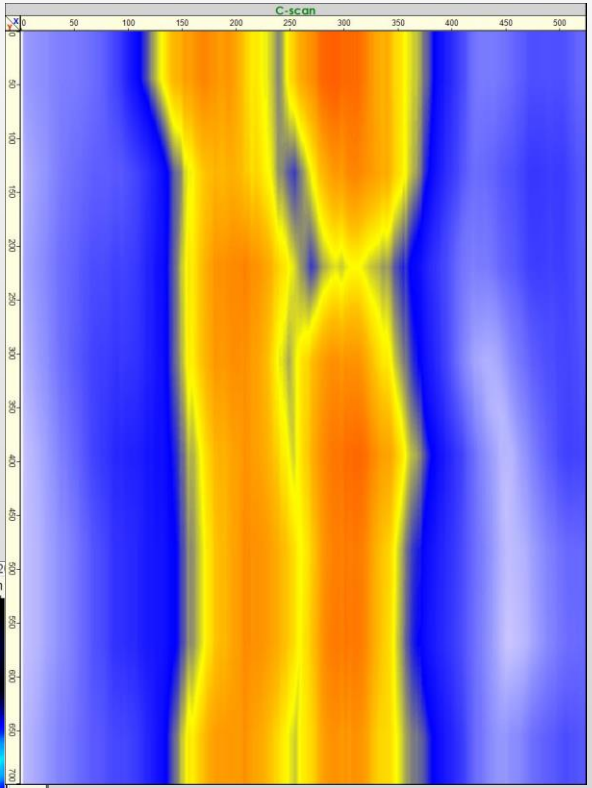
A1020 MIRA lite – affordable tomography system

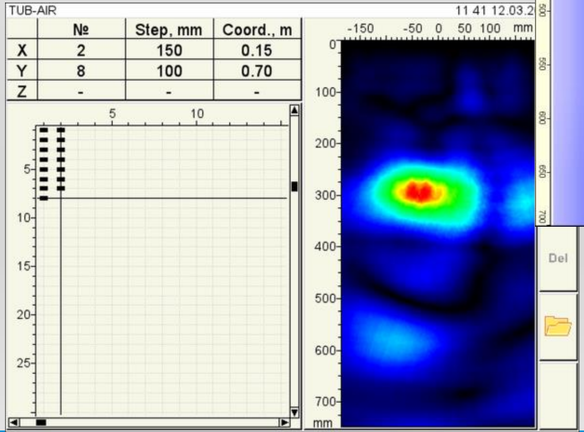


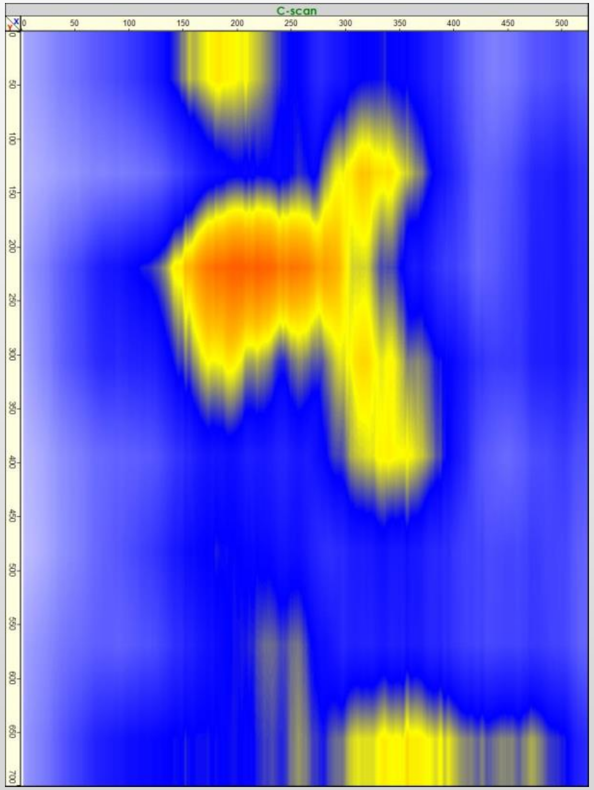
Applications

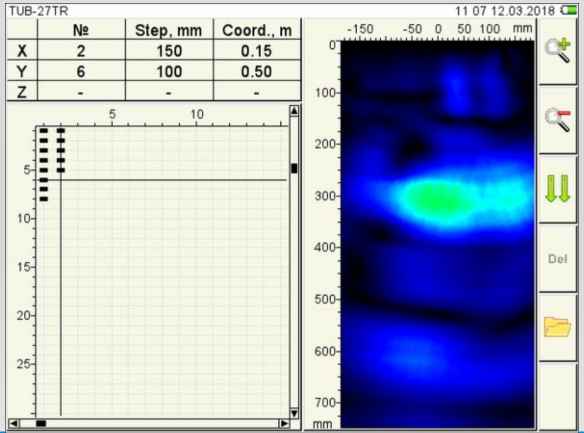
Inspection of tunnel tubings





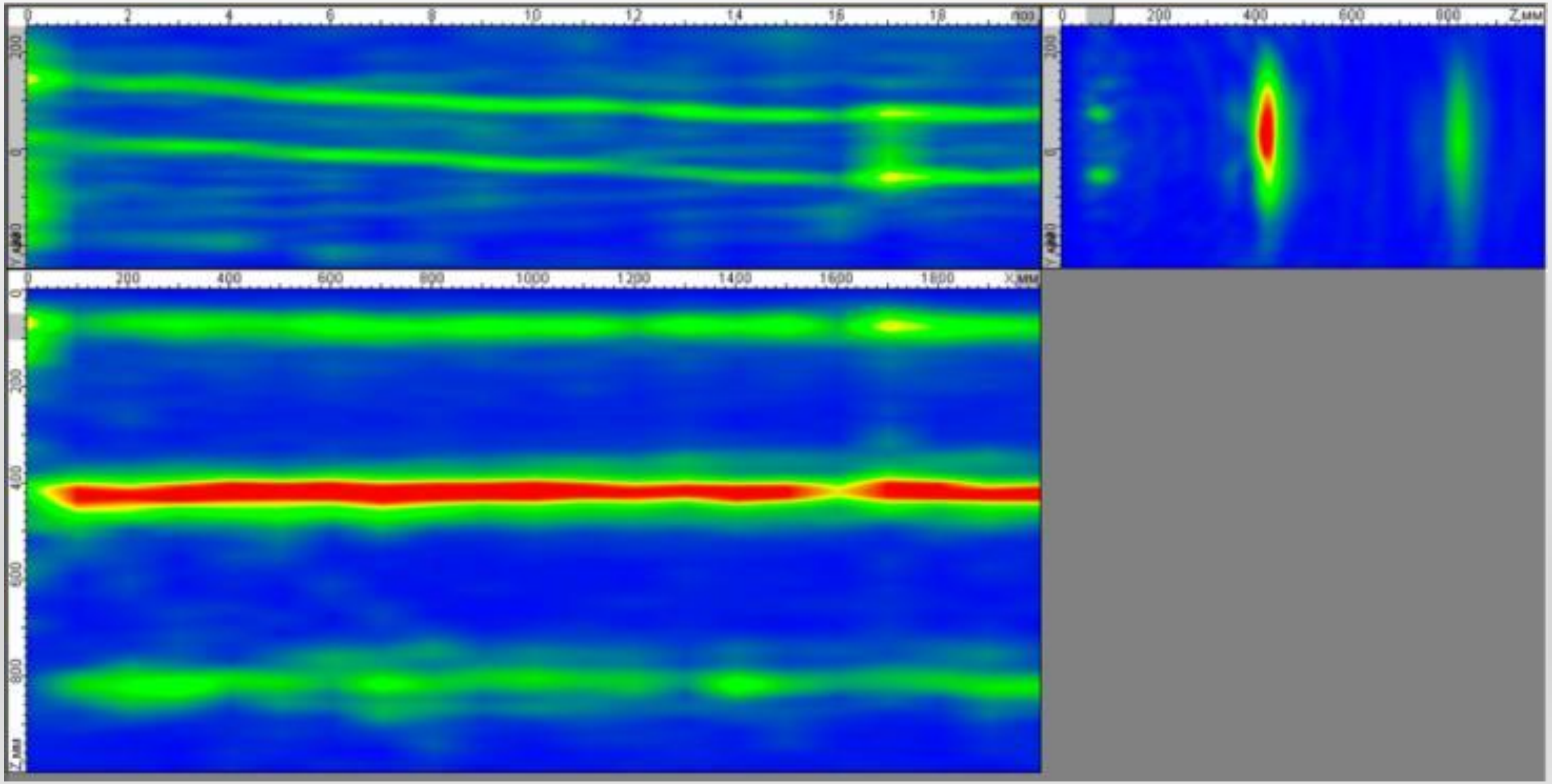






Ultrasonic Concrete Testing

Confirmation of reinforcement availability



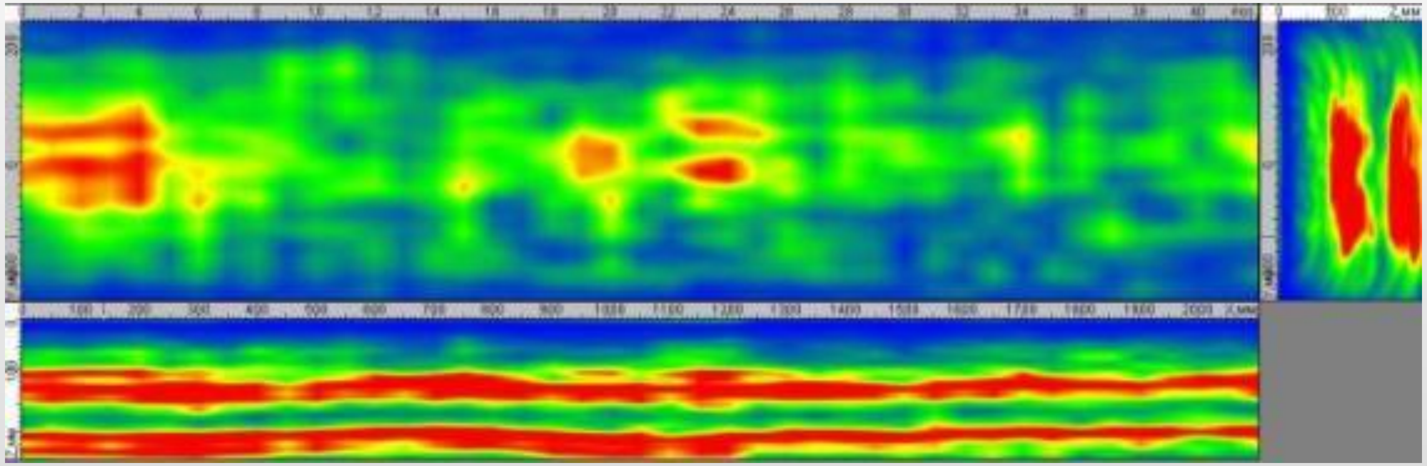
Ultrasonic Concrete Testing

Inspection of a bridge plates

- ➢ Material thickness 10 cm
- ➢ Reinforcement 5-7 layers

Ultrasonic Concrete Testing

Inspection of a bridge plates



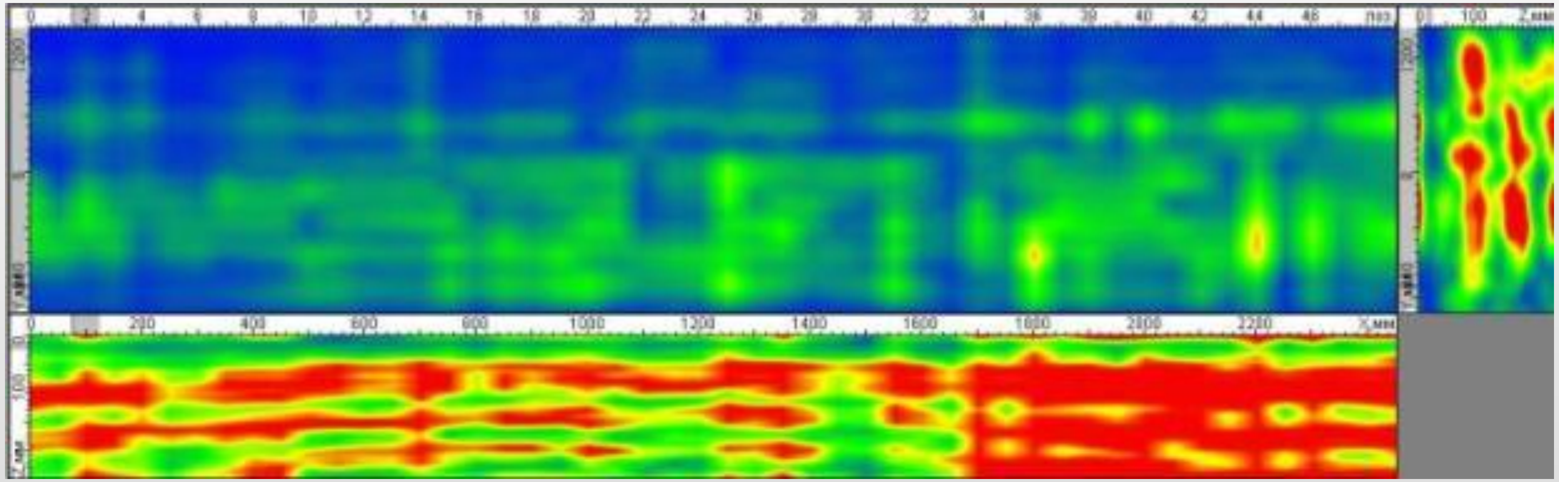
Core: bad zone

good zone

- Stable ground signal (double backwall signal)
- In the near ground area flaws a present:
  Lack of fusion between concrete and reinforcement, voids of concrete

Ultrasonic Concrete Testing

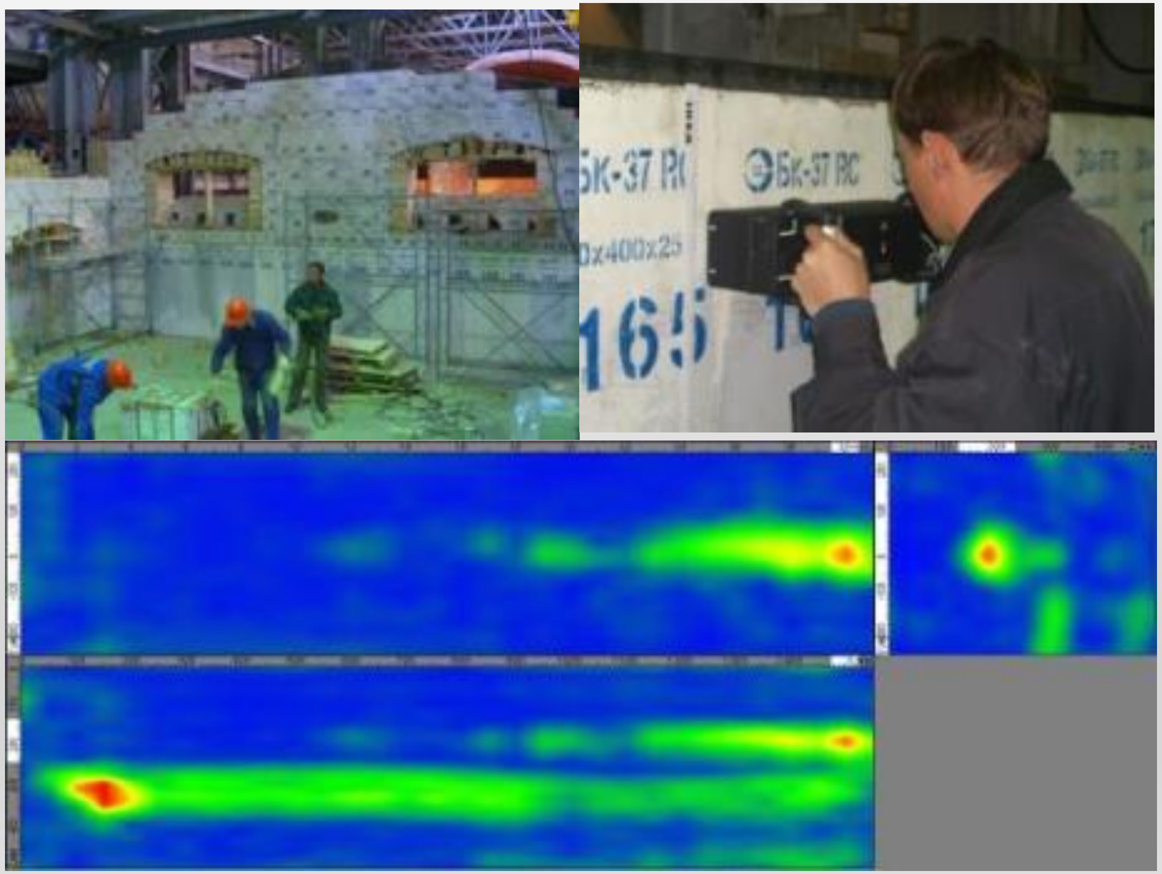
Inspection of a bridge plates



- Thinning of the plate: wall thickness decrease from 100 mm to 50 mm is observed

Ultrasonic Concrete Testing

Inspection of the fireproof blocks of a bulb-blowing oven



Inspection objects :

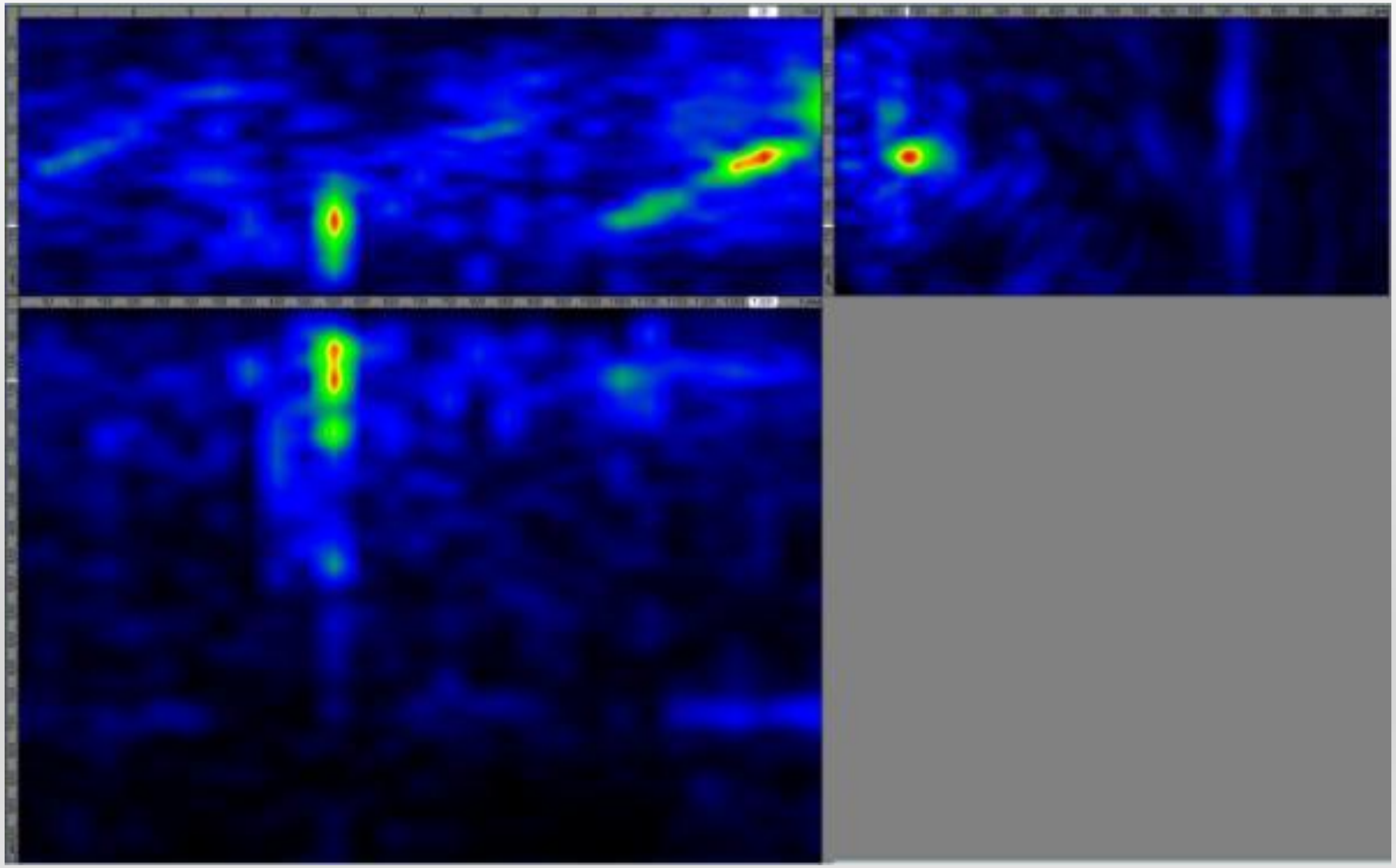
- Fireproof liner blocks of a bulb-blowing oven
- Dimensions 1700 x 400 x 250 mm

A cylindrical flaw was detected

Length	750 mm
Depth	130 mm
Diameter	80 mm

Ultrasonic Concrete Testing

Inspection of a rope-way pylon

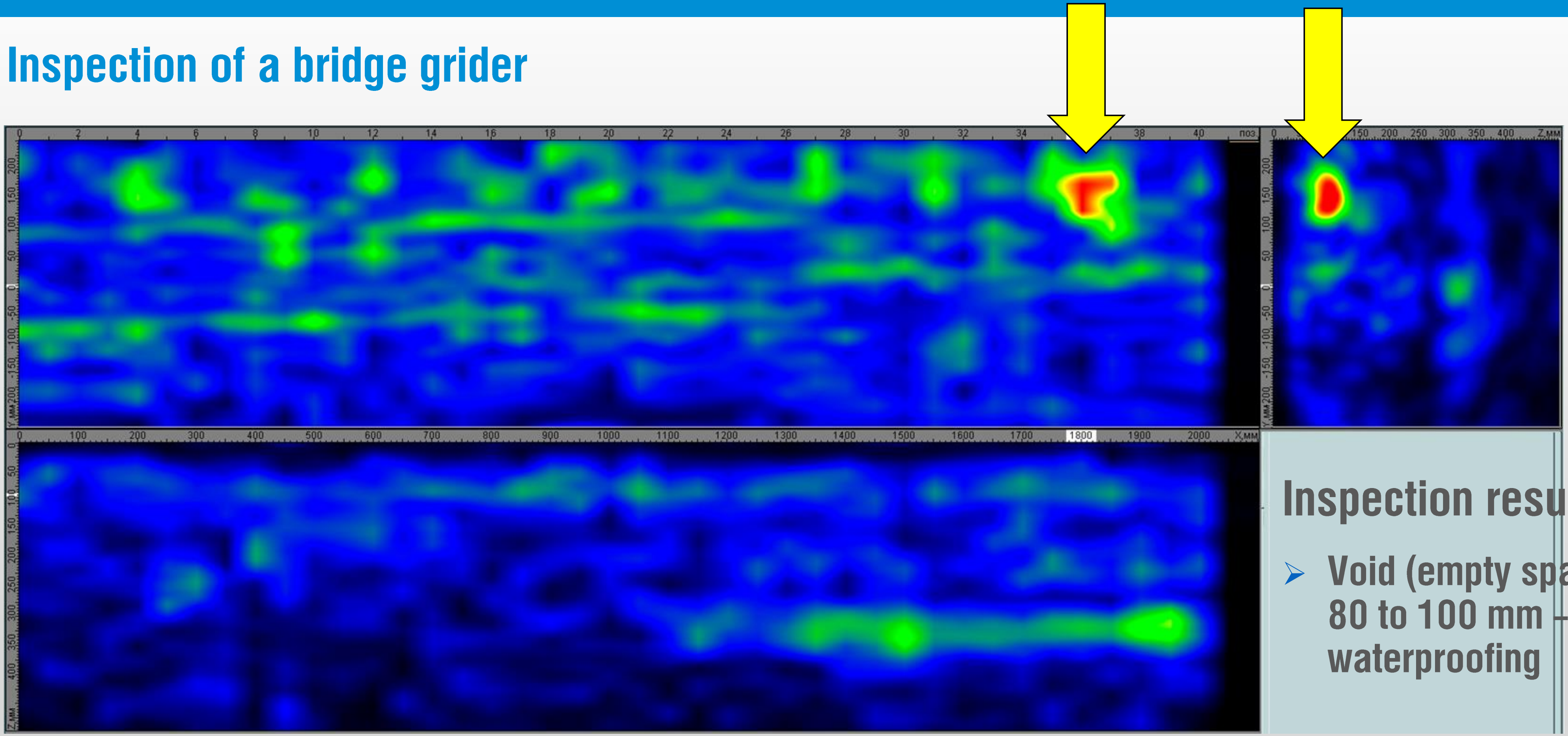


Inspection result

- Inner crack in the depth range from 50 to 250 mm

Ultrasonic Concrete Testing

Inspection of a bridge grider

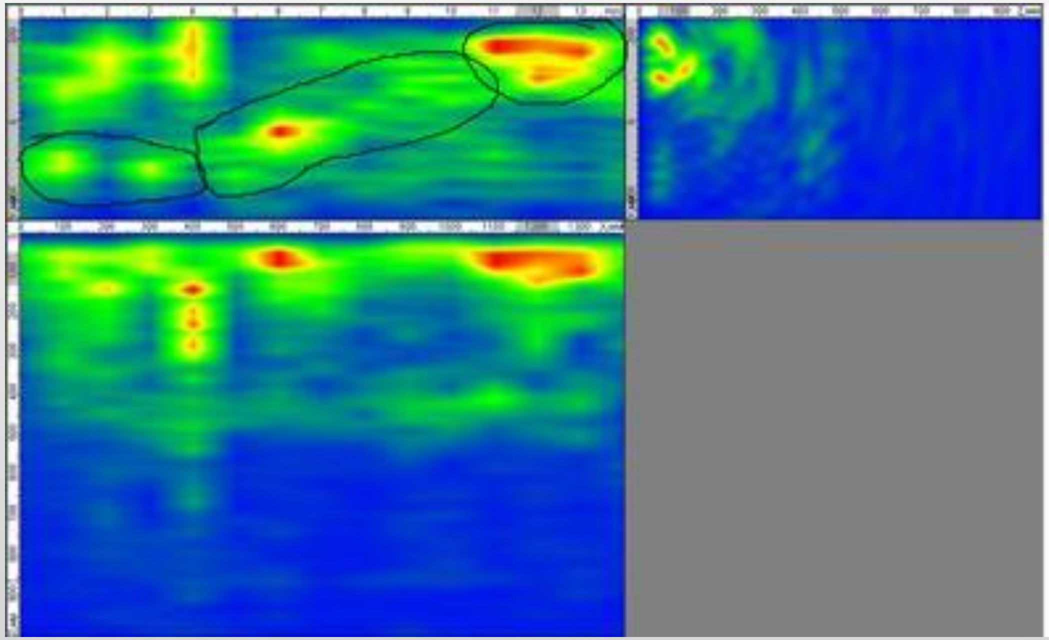


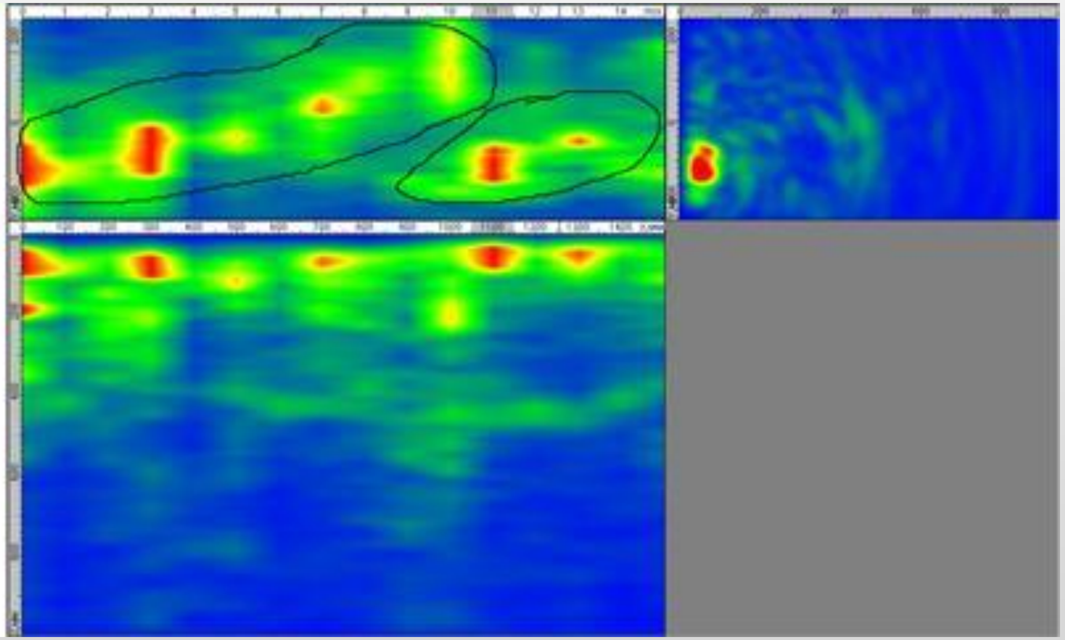
Inspection result

- Void (empty space) at the depth of 80 to 100 mm – damaged waterproofing

Ultrasonic Concrete Testing

Cracks in the railway tunnel





Thank you for your attention!

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