X THE PLACE OF USEFUL LEARNING

Surface Breaking Crack Detection on Thin-walled Austenitic Stainless Steel Cylindrical Rods with Periodic Ribbed Structures Using Laser Ultrasonics

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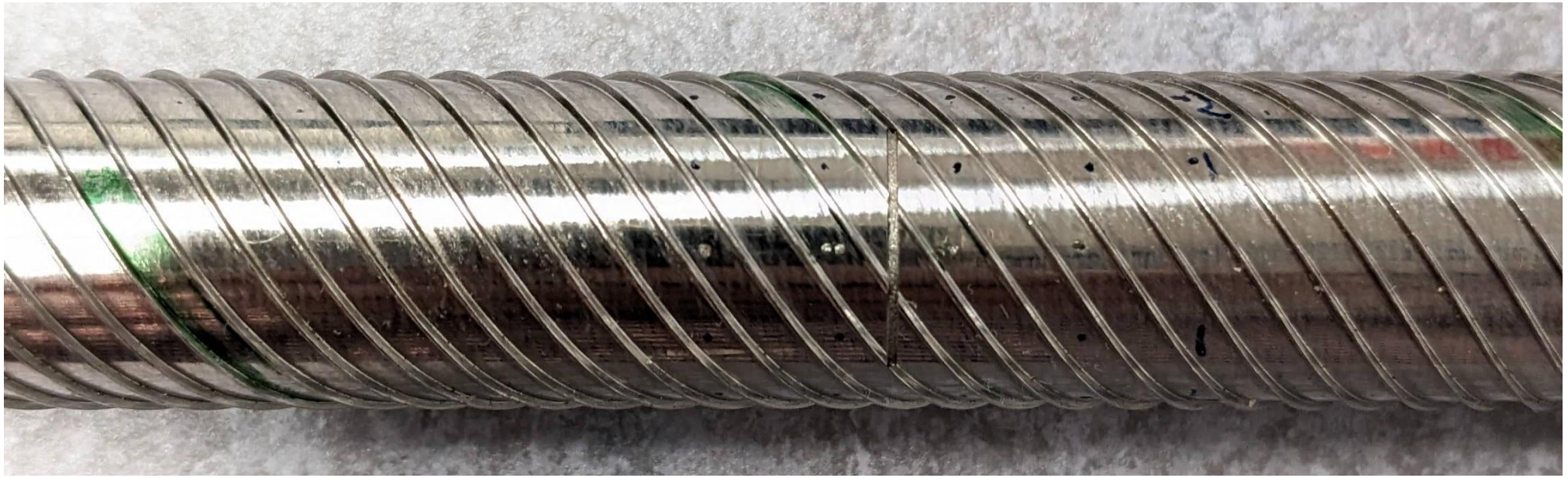
The Sample and The Research Problem

Material: Austenitic stainless Steel



Rod dimensions

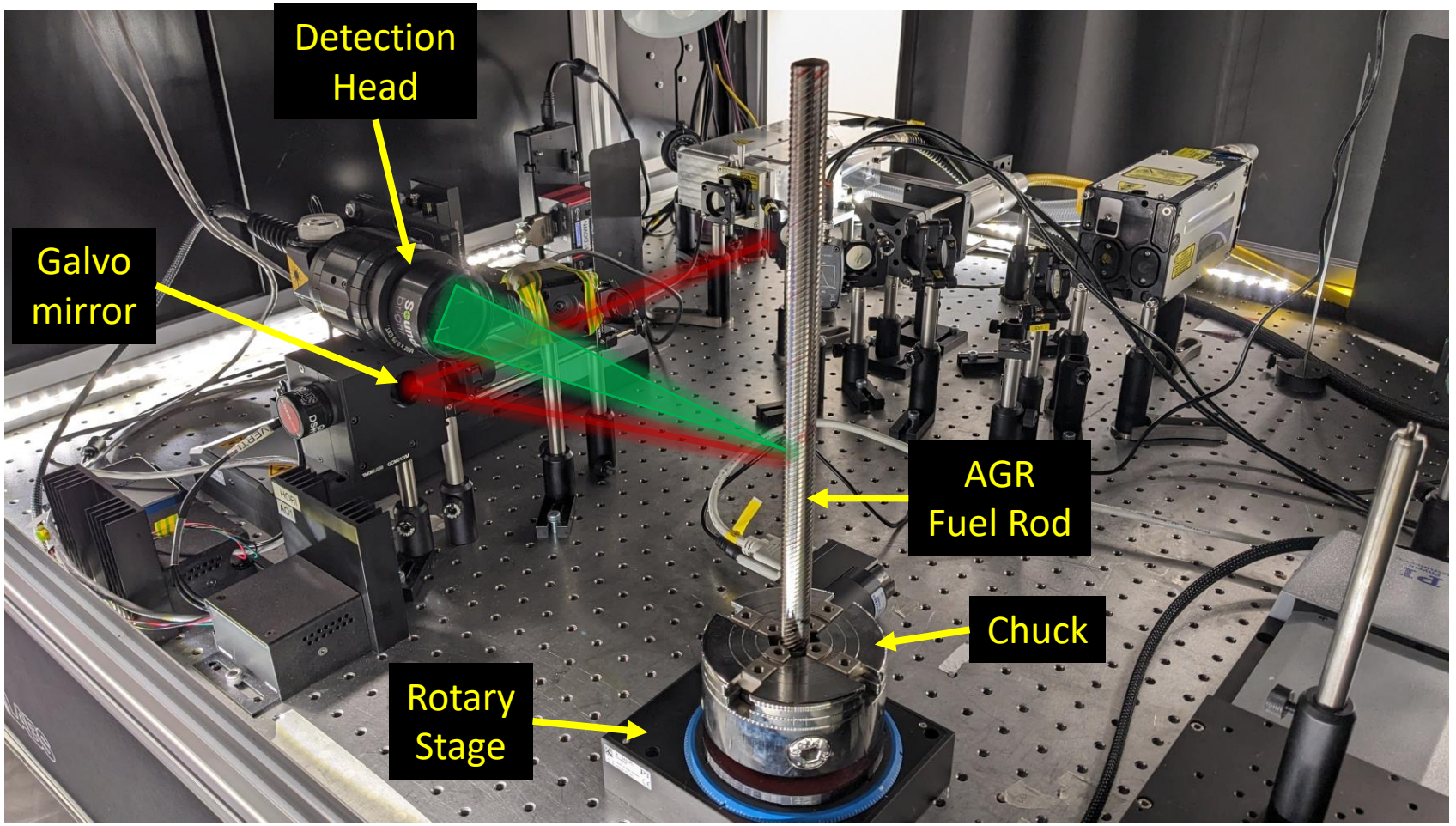
Diameter: 15 mm
Thickness: 400 µm
Rib height: 400 µm
Rib pitch: 2.75 mm

Notch dimensions

Measured depth range: 118 – 167 µm
Measured depth average: 149 µm
Measured width range: 471 – 488 µm

Experimental Setup

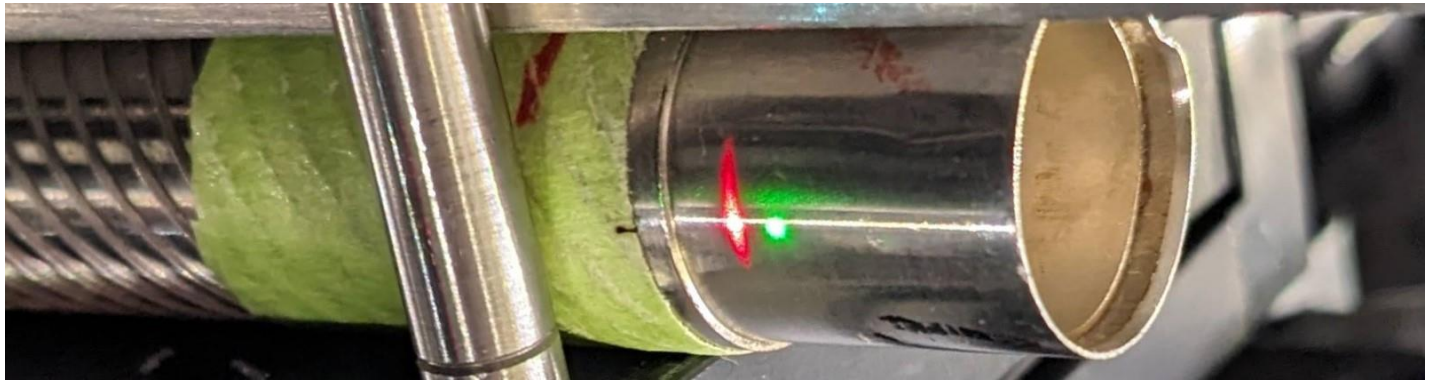
- 0.37mJ IR generation laser
  - ✓ 23ns Pulse duration
  - ✓ 5kHz Repetition rate
- 1W Green detection laser
- Receiver
  - ✓ Bandwidth: 1-66 MHz

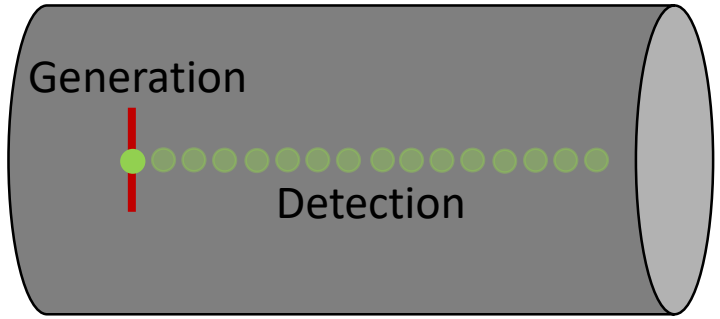


Test Parameters

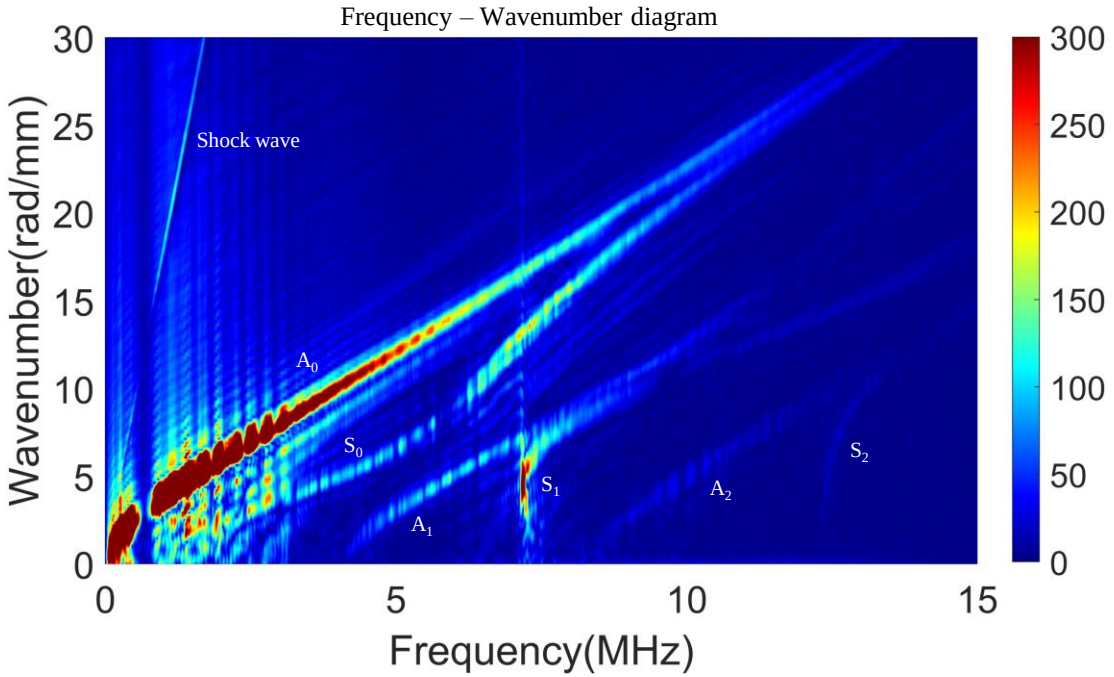
Instrument	Parameter	Value
Generation Laser	Energy per pulse (mJ)	0.31
	Pulse repetition frequency (kHz)	5
	FWHM pulse duration (ns)	23
Oscilloscope	Averaging	64
	Sampling rate (MHz)	20
	Signal Length (µs)	50
	Number of sampling points	1000

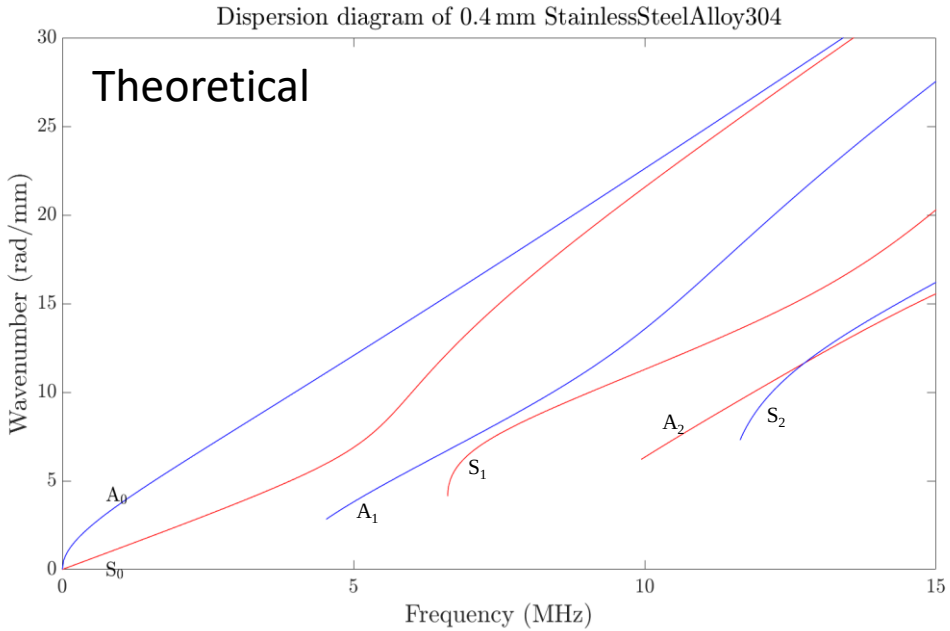
Experimental Methodology





1 generation, 1000 detection points, 0.01 mm pitch



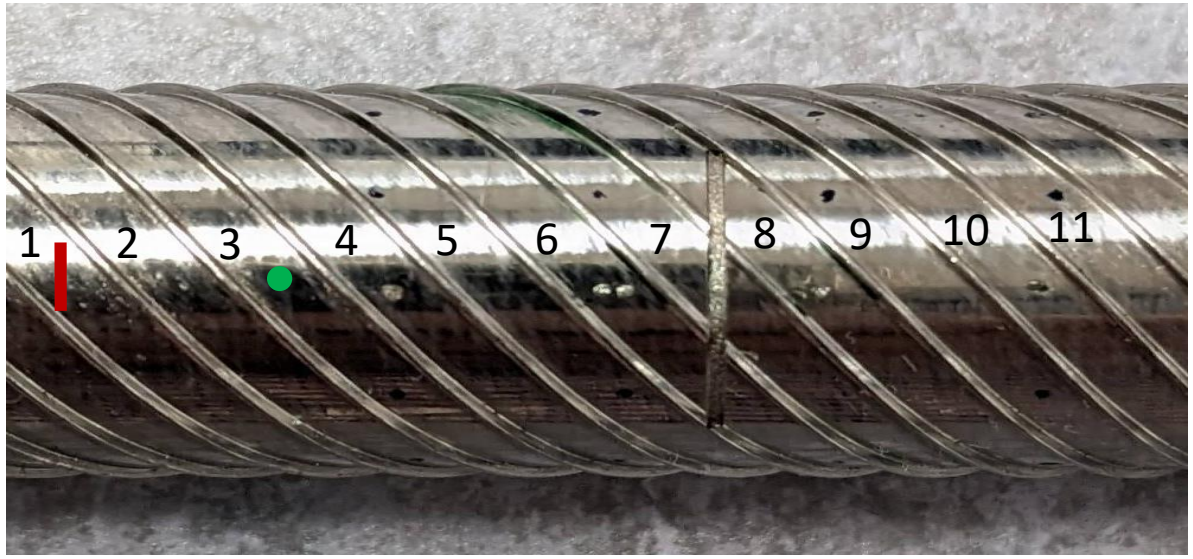


Dispersion Calculator: German Aerospace Center

Experimental Methodology

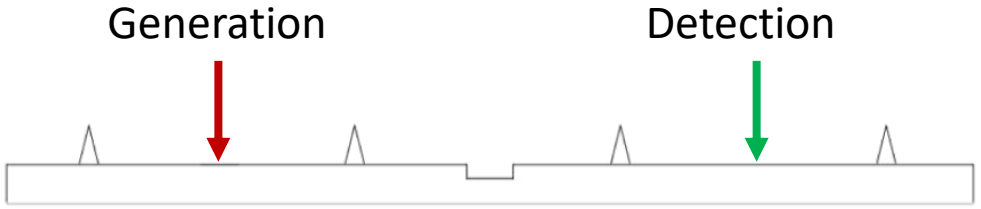
Generation

Detection



Not a continuous scan, but a step scan!

No Notch



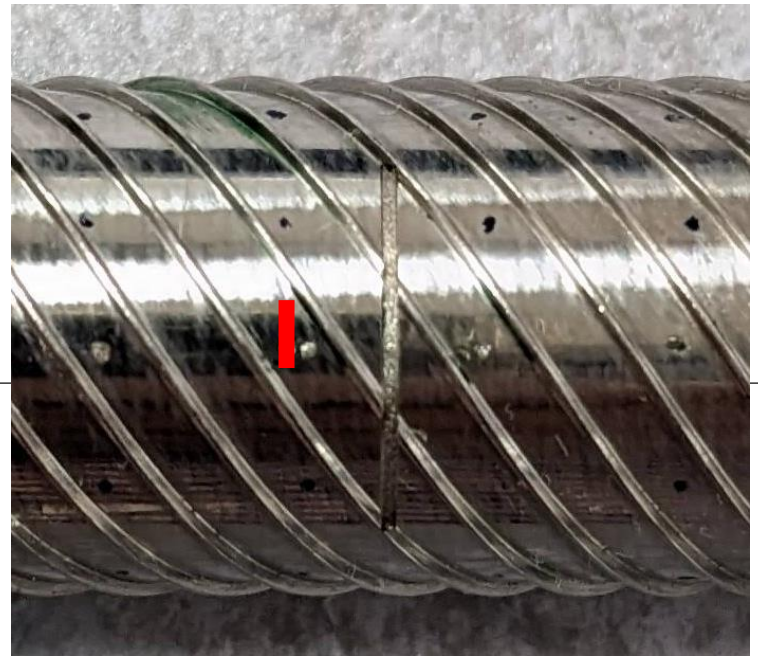
Notch

Finite Element Approach

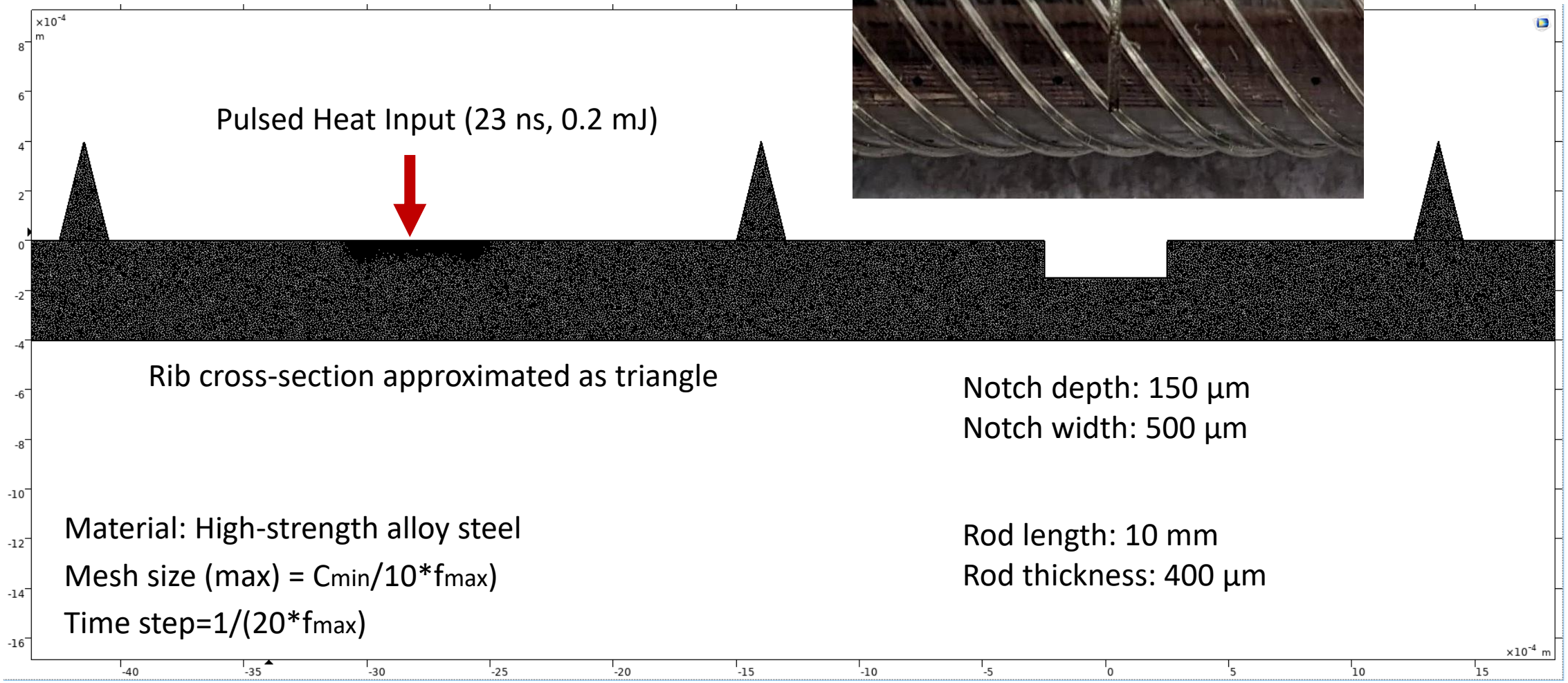
COMSOL Multiphysics 6.1

- Heat Transfer
- Solid Mechanics

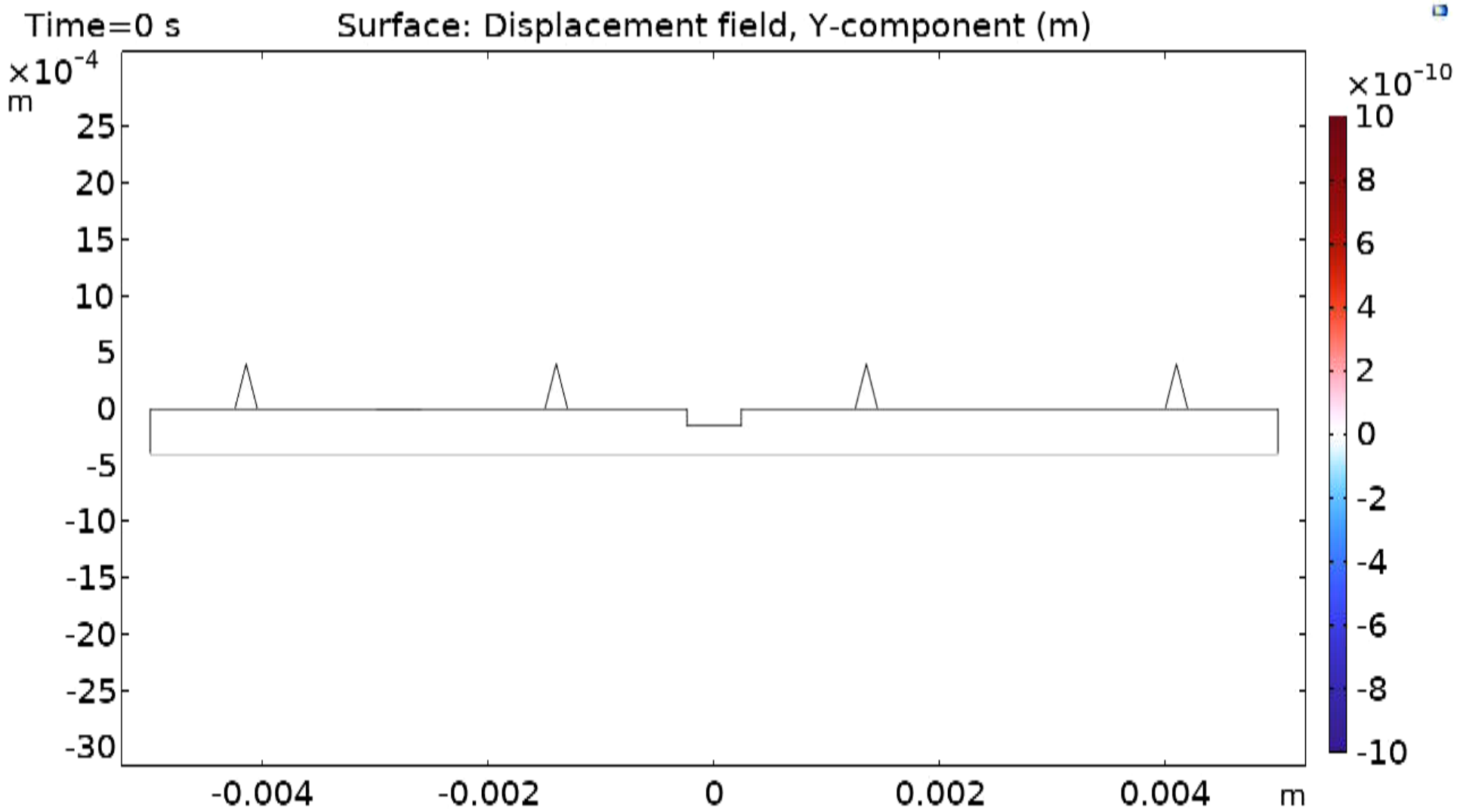
2D Plane Strain Problem



Generation

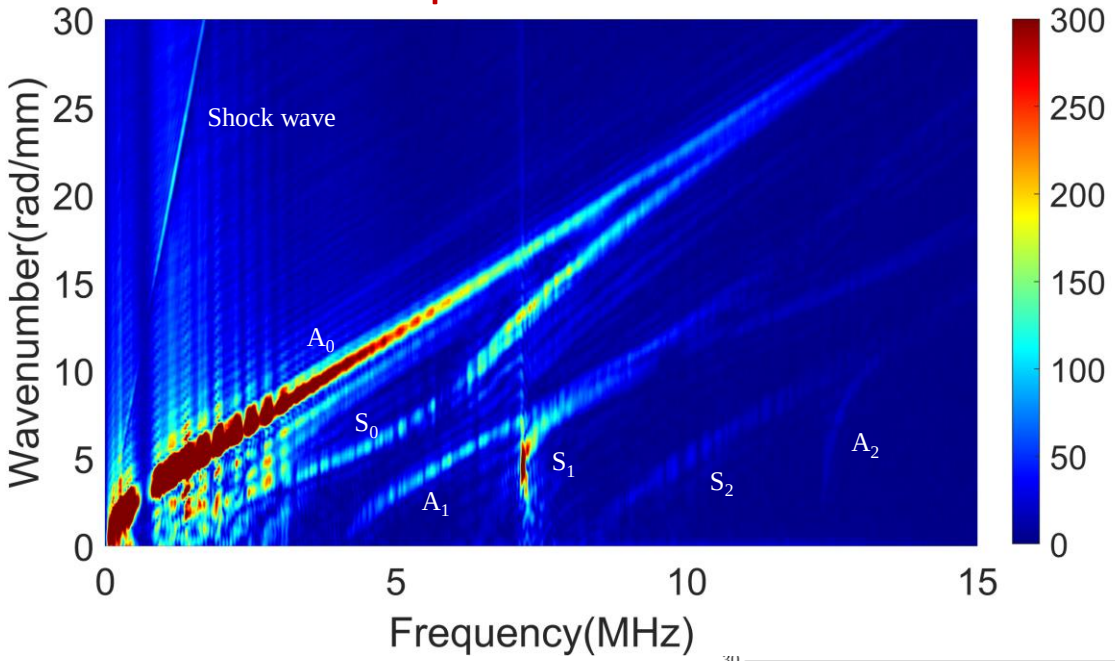


FE Results

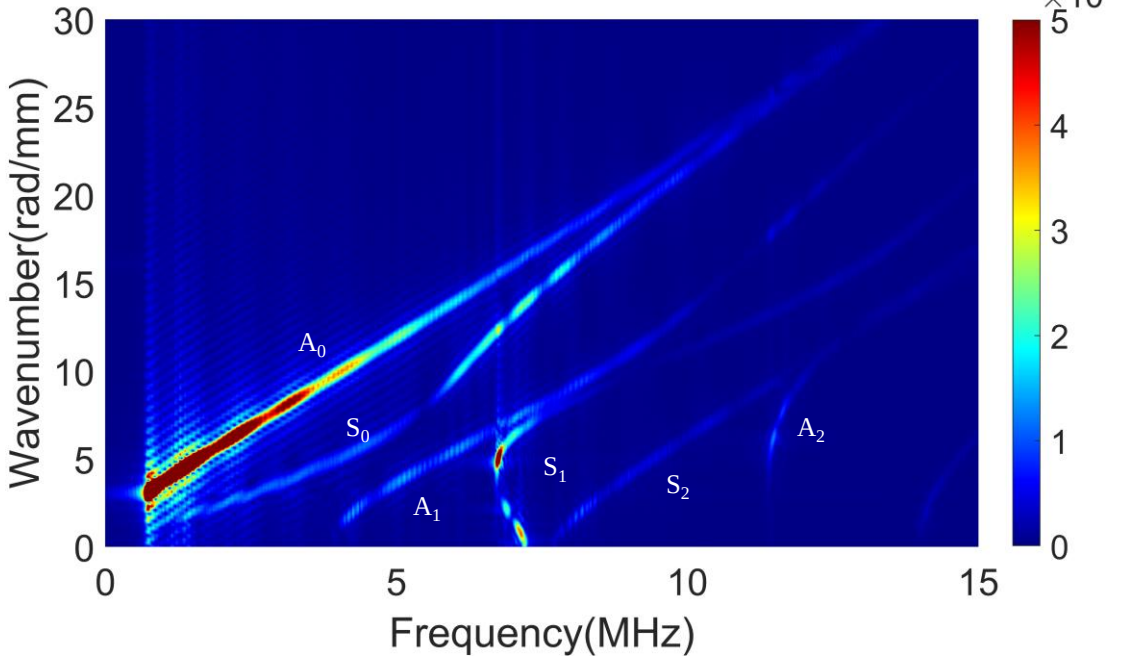

Time=0 s
Surface: Displacement field, Y-component (m)
×10^-4
m
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-0.004
-0.002
0
0.002
0.004
m
×10^-10
10
8
6
4
2
0
-2
-4
-6
-8
-10

Validation of FE model

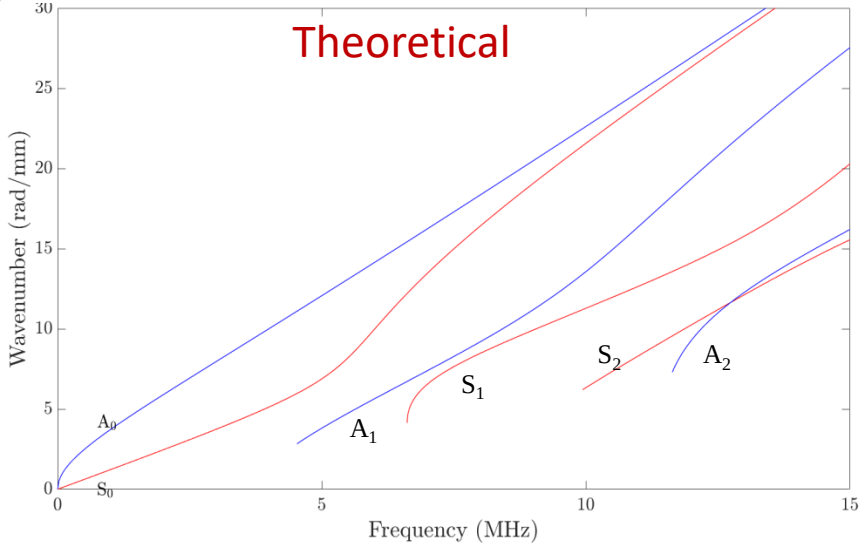
Experimental



Finite Element



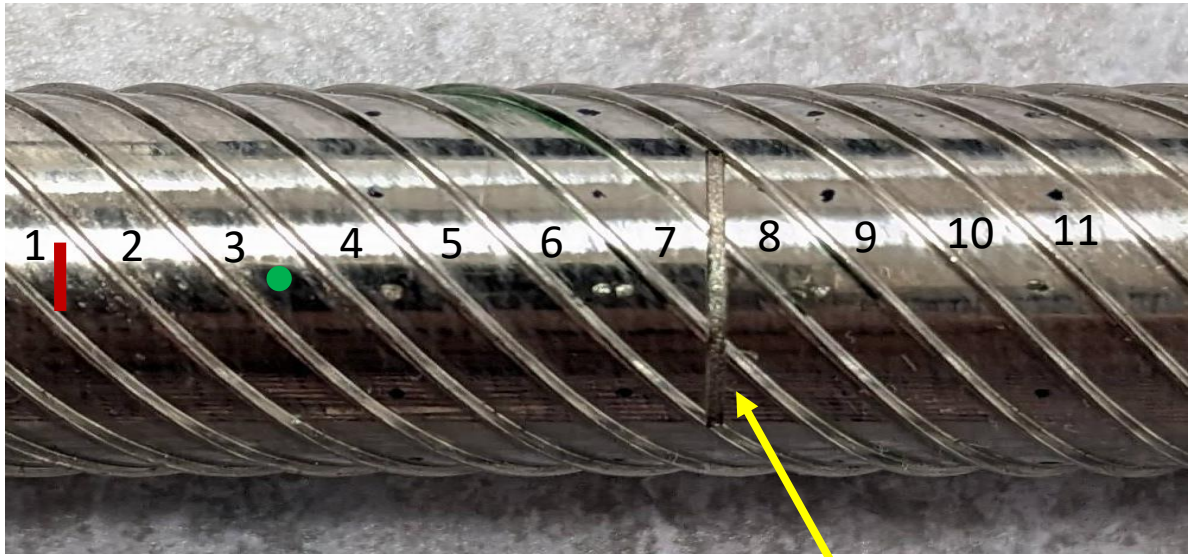
Theoretical

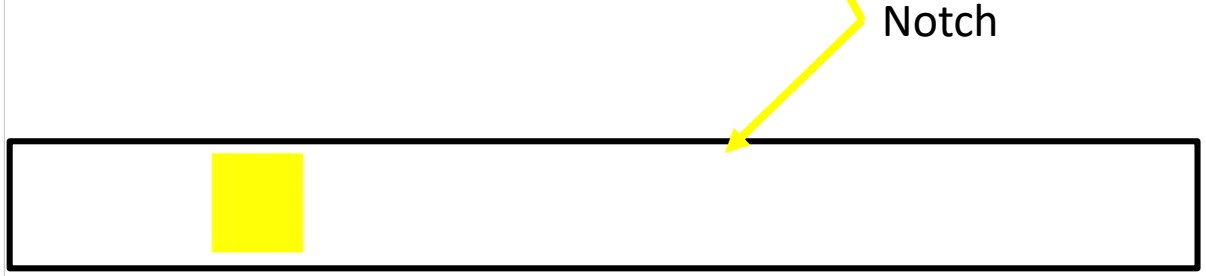


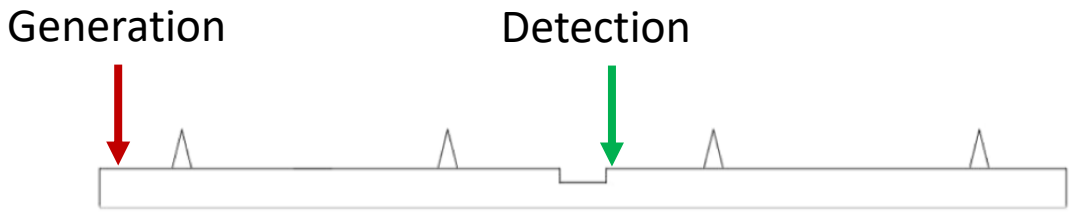
Experimental Results

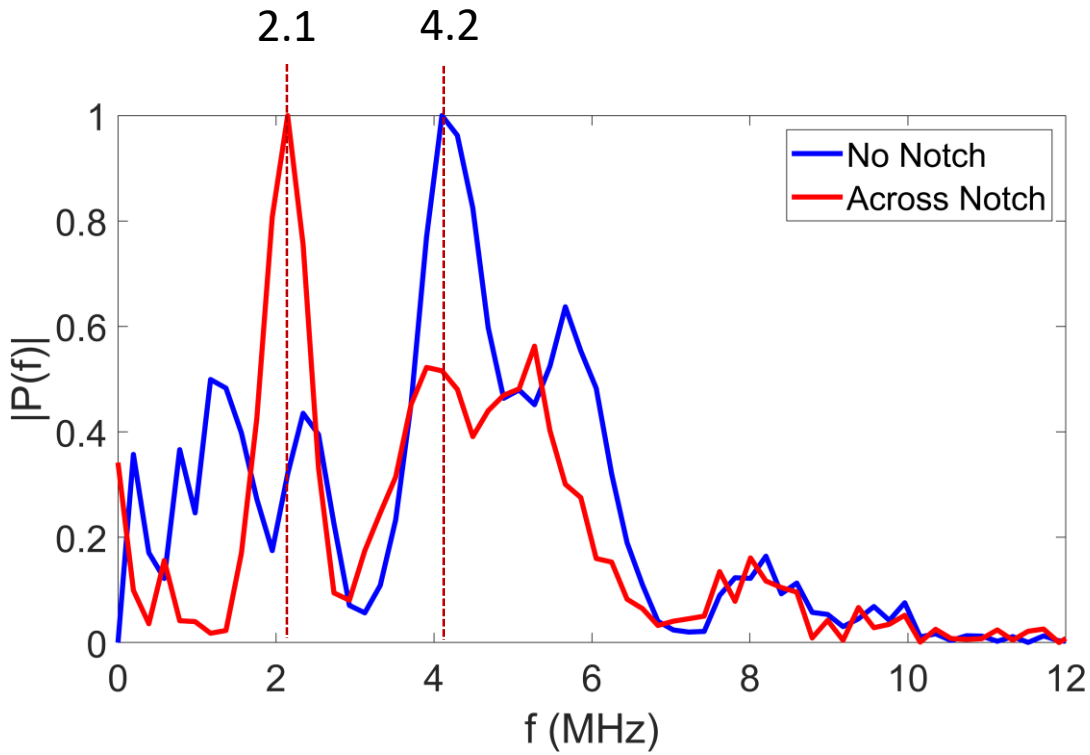
Generation/Transmit (T)

Detection/Receive (R)









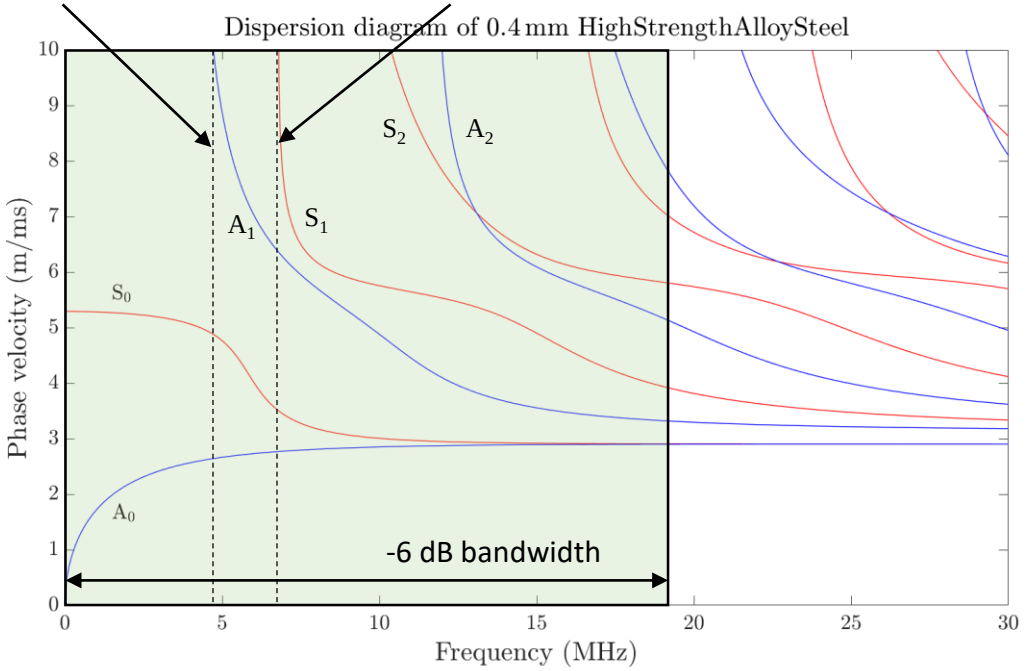
Discussion

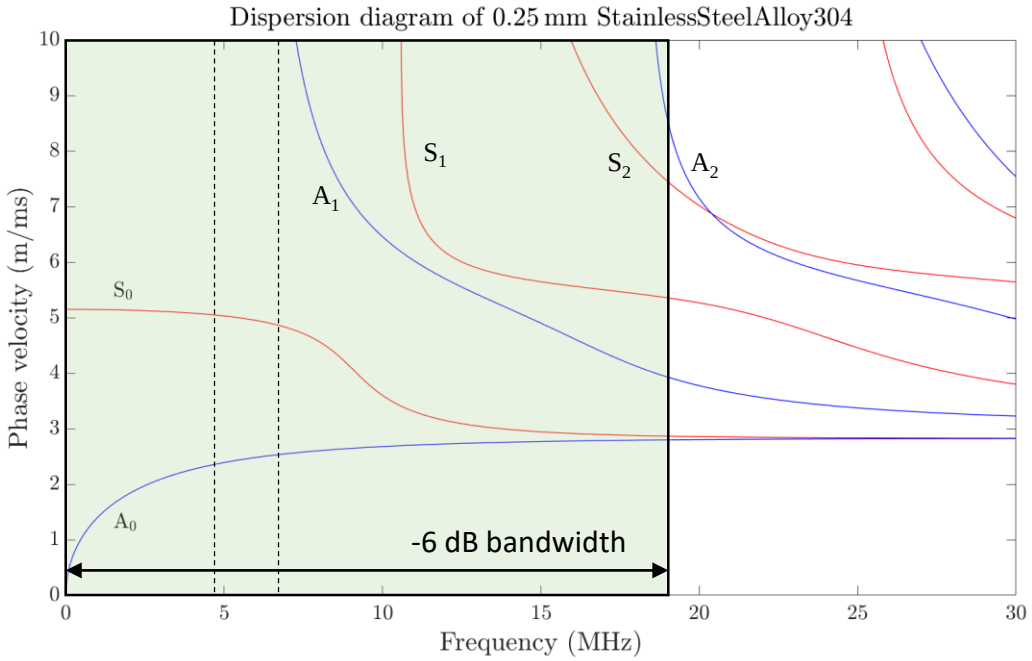
Notch dimensions

Measured depth range: 118 – 167 µm
Measured depth average: 149 µm
Measured width range: 471 – 488 µm

A1 cut-off frequency

S1 cut-off frequency





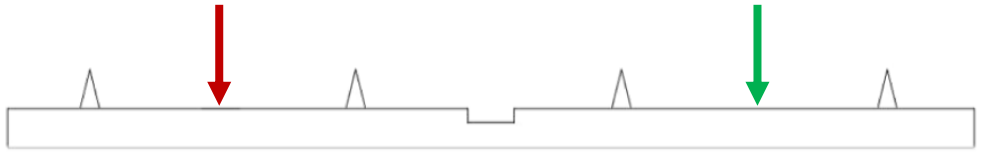
Generation

Detection

No Notch

Generation

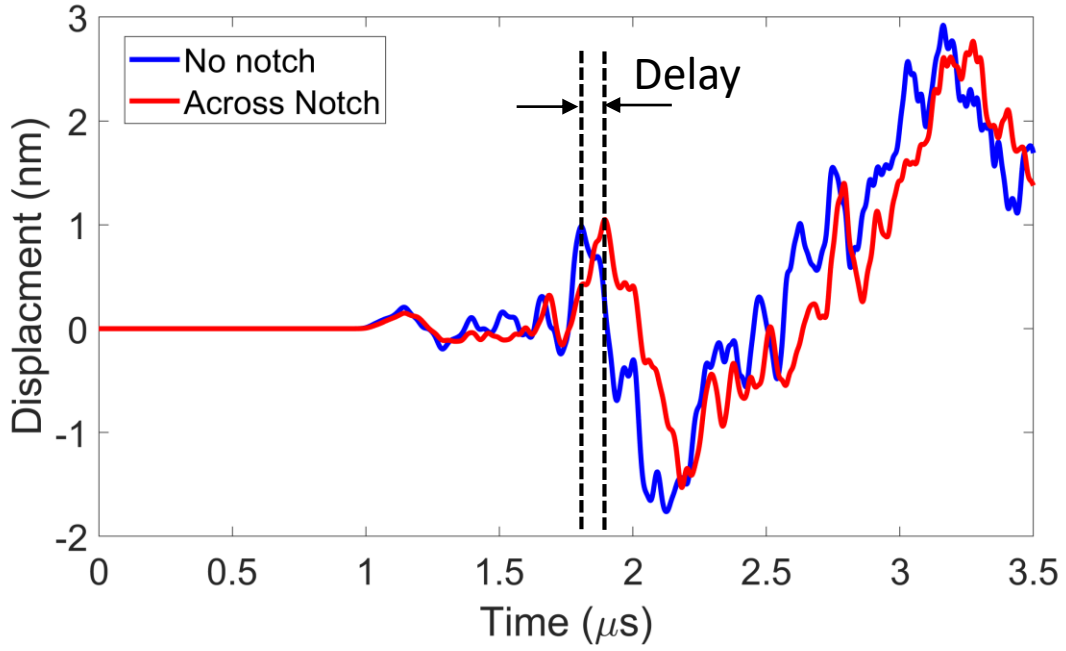
Detection



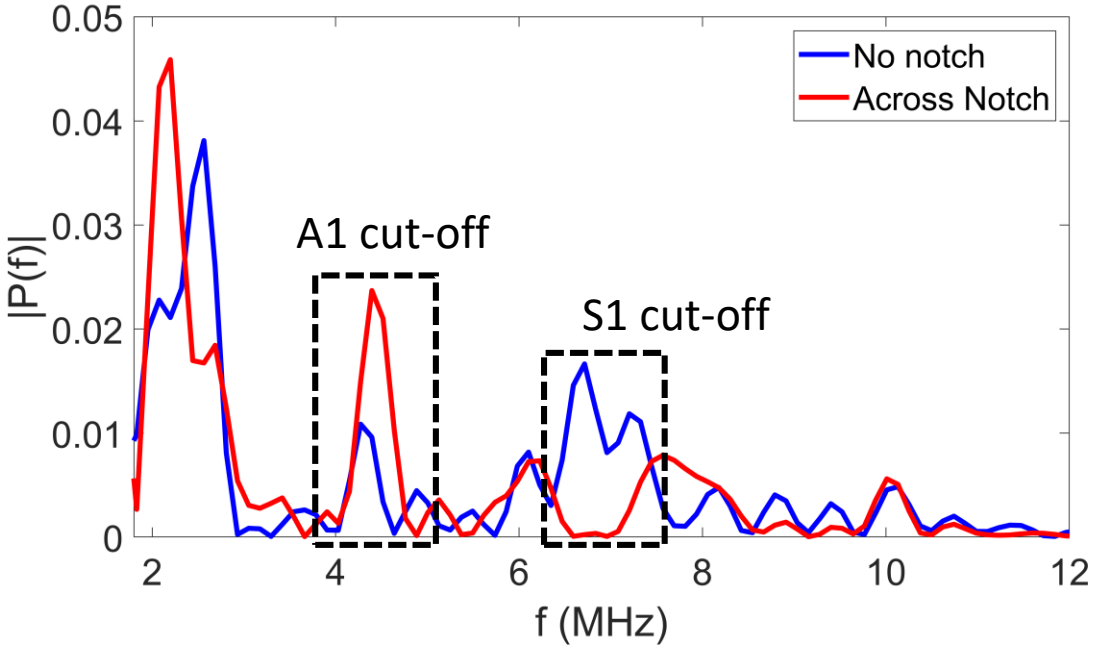
Notch

FE Results

Time domain

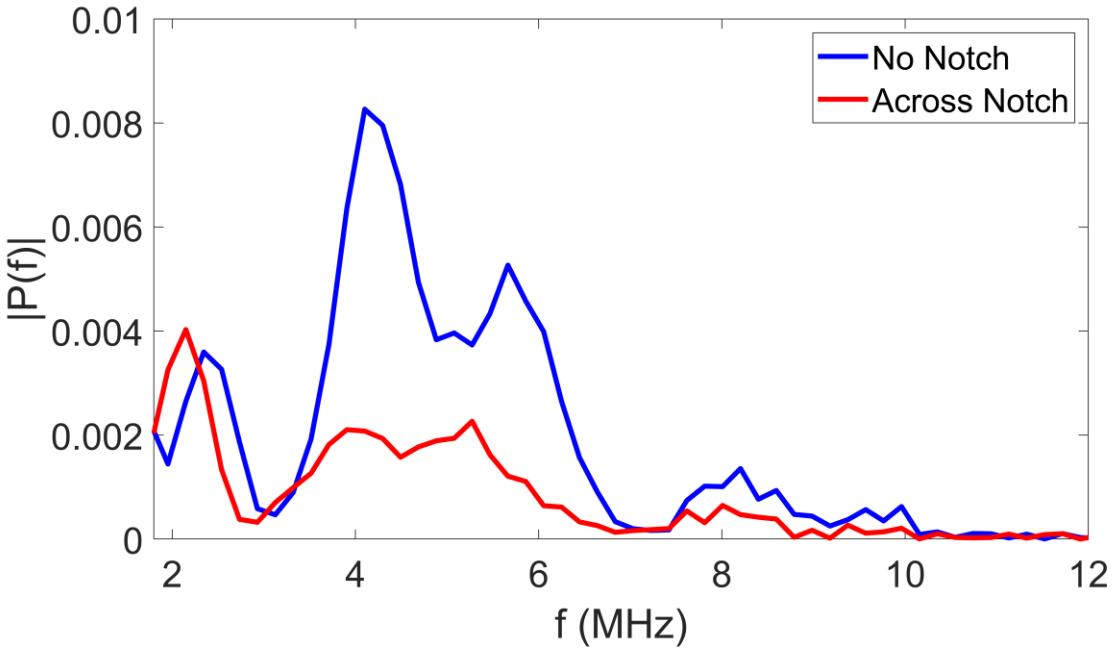


Frequency domain

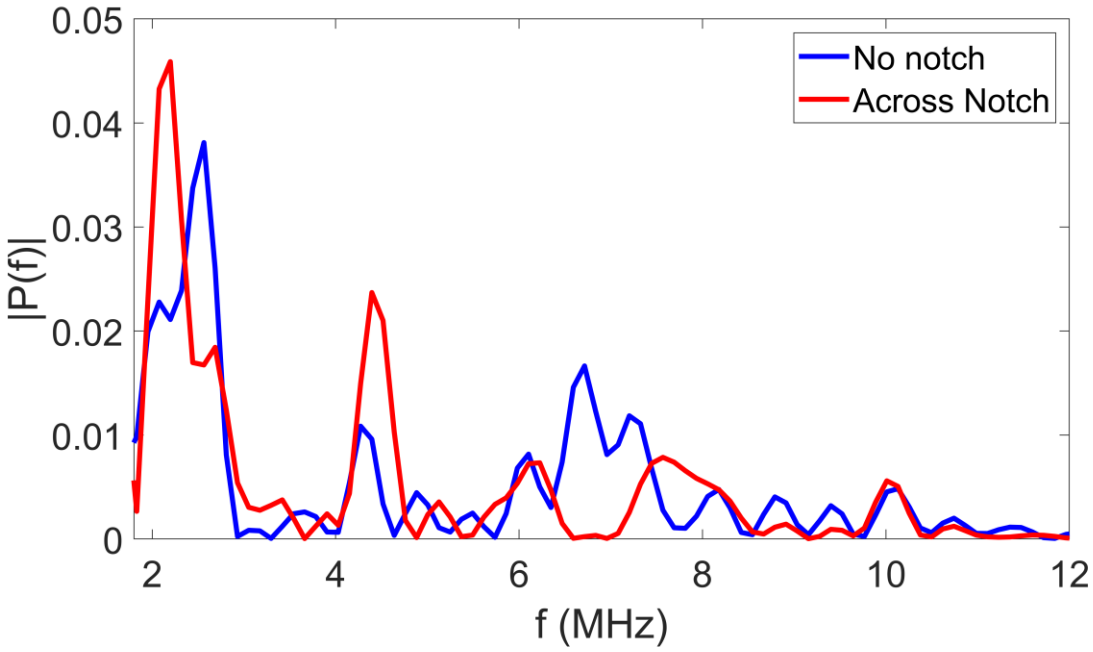


Comparison of experimental and FE ultrasonic signals

Experimental



Finite Element



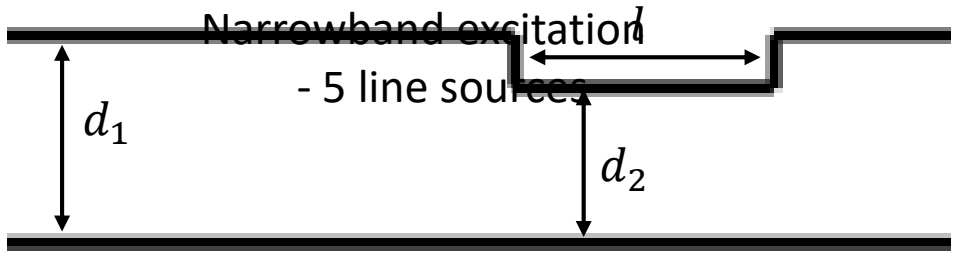
- Material
- Geometry

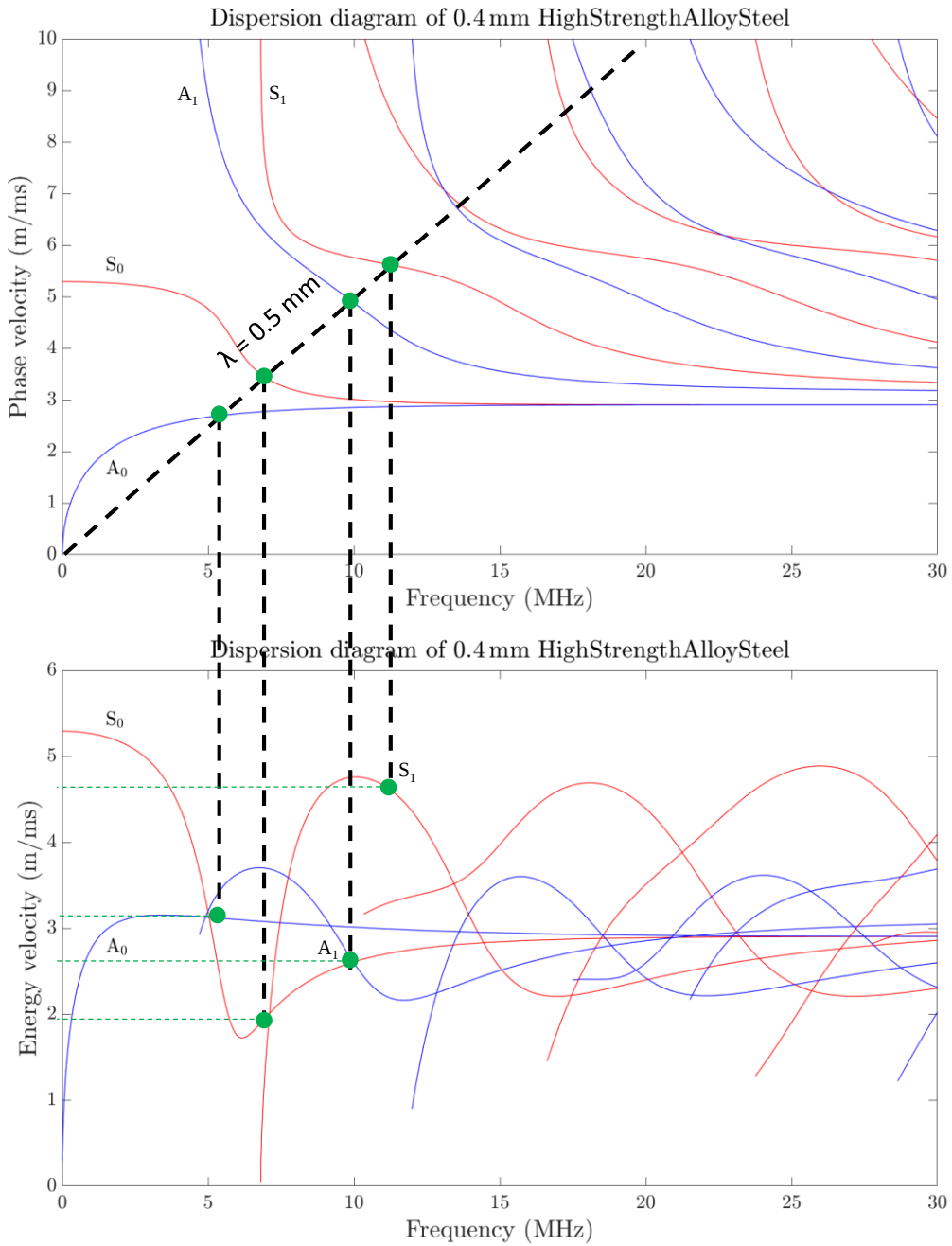
Summary & Conclusions

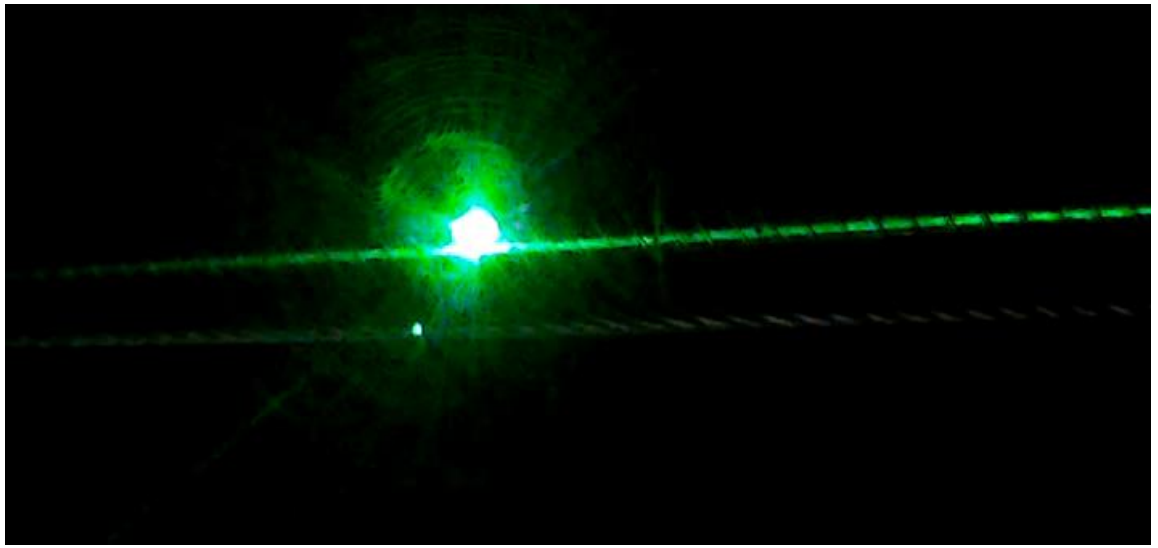
- A laser ultrasonic based inspection strategy is proposed and demonmstrated for detection of crack-like features on a cylindrical rod with ribbed structures.
- A finite element method using COMSOL Multiphysics was developed and validated against experiments.
- The mode cut-off/frequency shift of guided waves could be used as a metric to detect and identify the location of crack-like defects.

Future Scope

- 360° rotation of rod sample
- Characterisation of notch
- Narrowband excitation
- Real cracks







Thank you

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