Asymmetry around Local Defect Resonance Frequency in Sweep Vibro-thermography

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ABSTRACT

In this paper, local defect resonance-based vibrothermography has been studied for different sweep direction and ranges. Two different carbon fiber-reinforced polymer (CFRP) composite plate has been fabricated from vacuum assisted resin transfer molding. Two barely visible impact damages are created in plate using low velocity impact testing. The area of delamination has been determined from phased array ultrasound testing. Laser doppler vibrometry (LDV) has been performed first for different sweep ranges and directions. The CFRP plate is excited with a piezoelectric element at 150 Vpp and the vibration over defect area is captured using a single point laser doppler vibrometer, operating in scanning mode. It has been found that vibration amplitude at local defect resonance (LDR) frequency increases in narrow sweep range compared to a wideband excitation. Again, in both cases, it has been found that backward sweep produces more amplitude compared to forward one due to softening nonlinearity. An asymmetry in LDR frequency is also been observed when the sweep range is further narrowed. An uncooled microbolometer camera is used for reception in case of vibrothermography. Backward sweep is found to be more effective as compared to the forward one and the temperature increment increases in case of narrowband excitation range.

Keywords: Local Defect Resonance, Sweep Vibro-thermography, Laser Doppler Vibrometry, Barely Visible Impact Damage, Carbon Fiber Reinforced Polymer Composite.

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by

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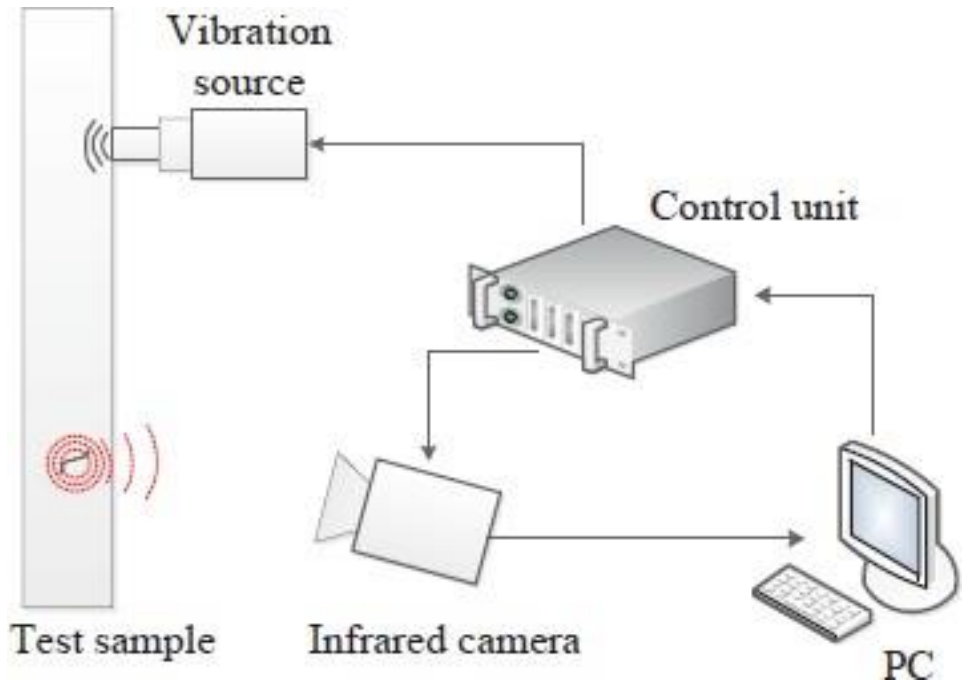
Vibro-thermography/ Ultrasound thermography

- In this method, the defect is converted to heat source due ultrasound excitation (15-35 kHz) which can be detected by high end thermal camera.
- It enjoys localized ultrasound excitation and wide/complex area reception using thermal camera.
- But extensive application of this method obstructed by non-repeatability and usage of high power ultrasound horn.



Principle of vibro-thermography (Pieczonka et al., 2014)

Principle of Local Defect Resonance

- It has been observed by Solodov et al. (2011) that temperature increment becomes maximum when the excitation frequency matches with local defect resonance (LDR) frequency

$$f_L = \frac{6.4t}{d^2}\sqrt{\frac{E}{12\rho(1-\mathrm{P}^2)}}$$

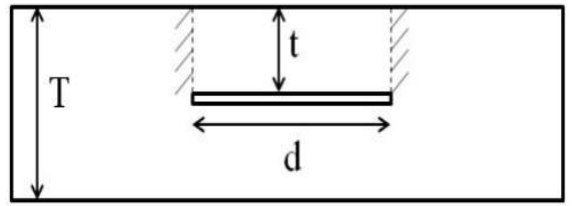
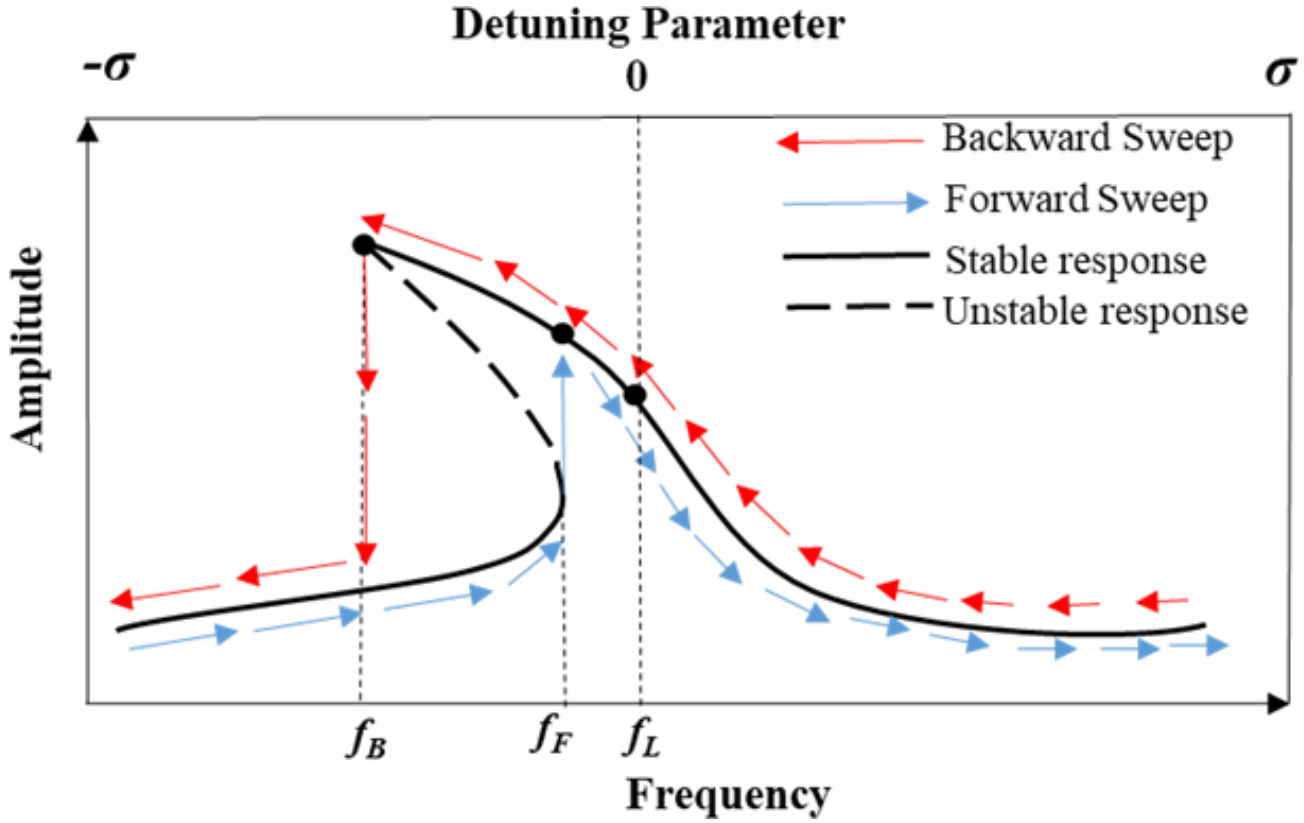


Plate with a flat bottom hole

- Later, it has been observed that sweep excitation around LDR frequency is more efficient than single frequency excitation at LDR frequency (Rahammer et al., 2017).
- Defects can be identified at mW power from temperature amplitude image. Repeatability of result is found with low power instrument (Dionysopoulos et al., 2018; Solodov et al., 2017).

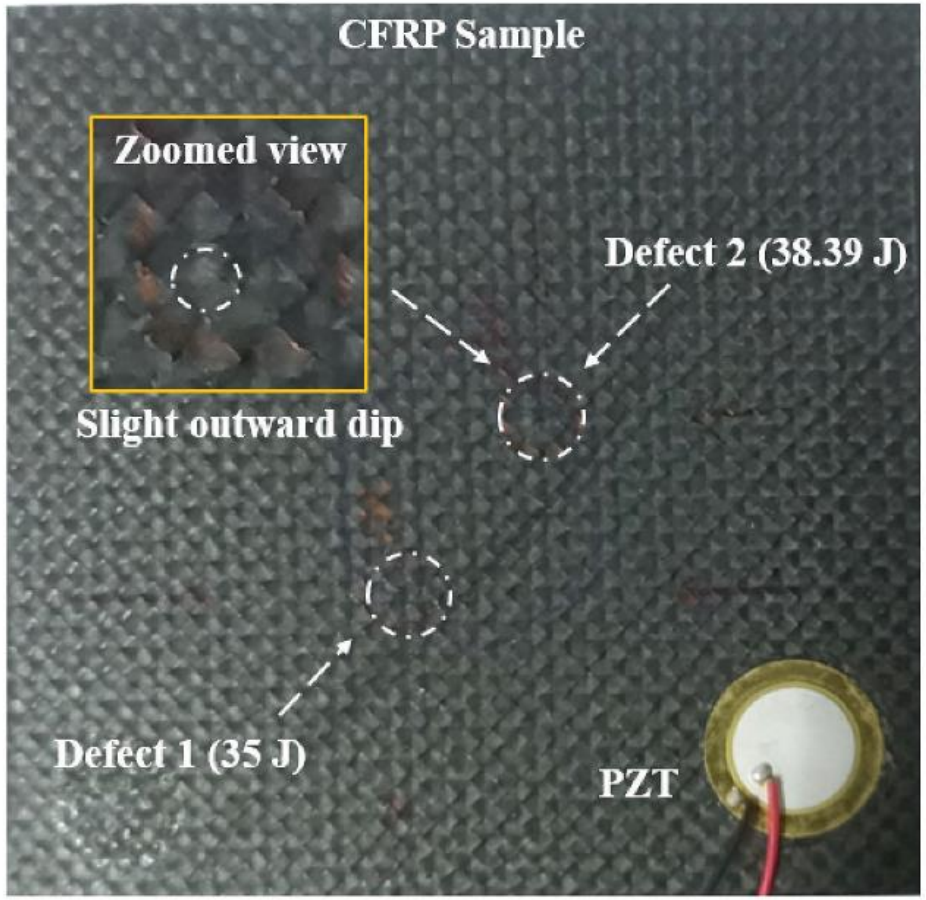
Nonlinear LDR

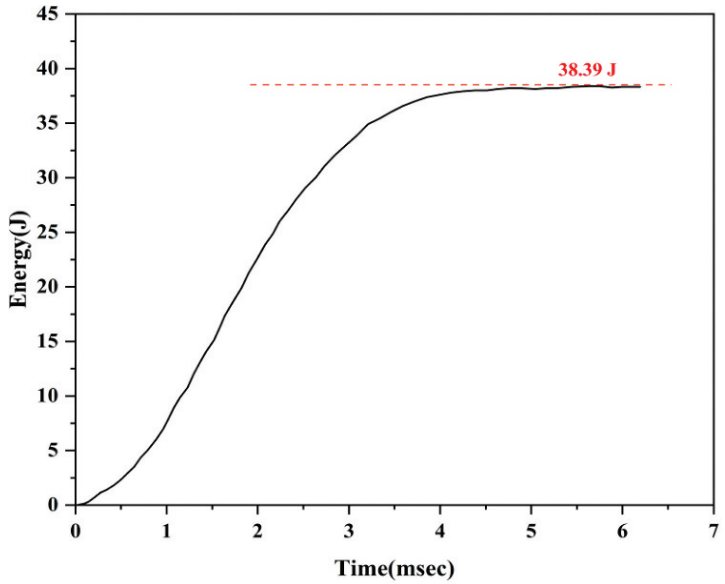
- Only forward sweep has been used in literatures.
- In this project, it has been observed that backward sweep increases the amplitude further.
- Due to jump phenomenon, nonlinear LDR frequencies (f_B, f_L) are observed along with linear LDR frequency (f_L).



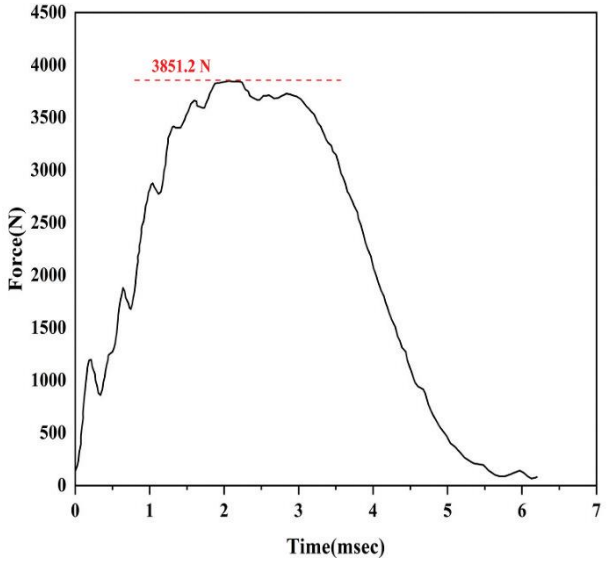
Jump Phenomenon near LDR frequency

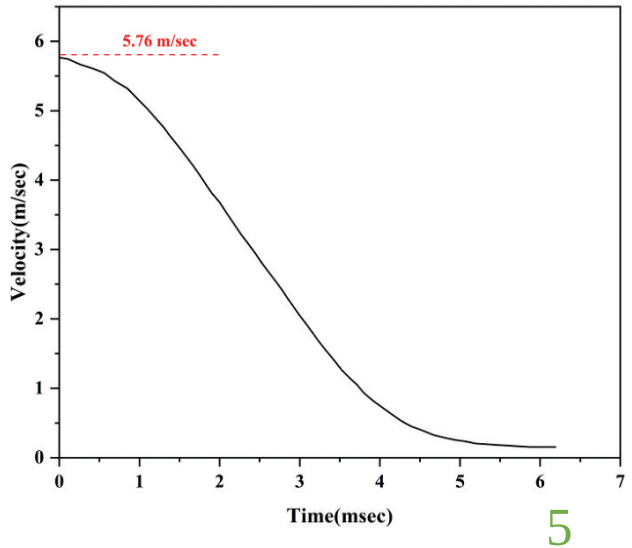
Barely Visible Impact Damage



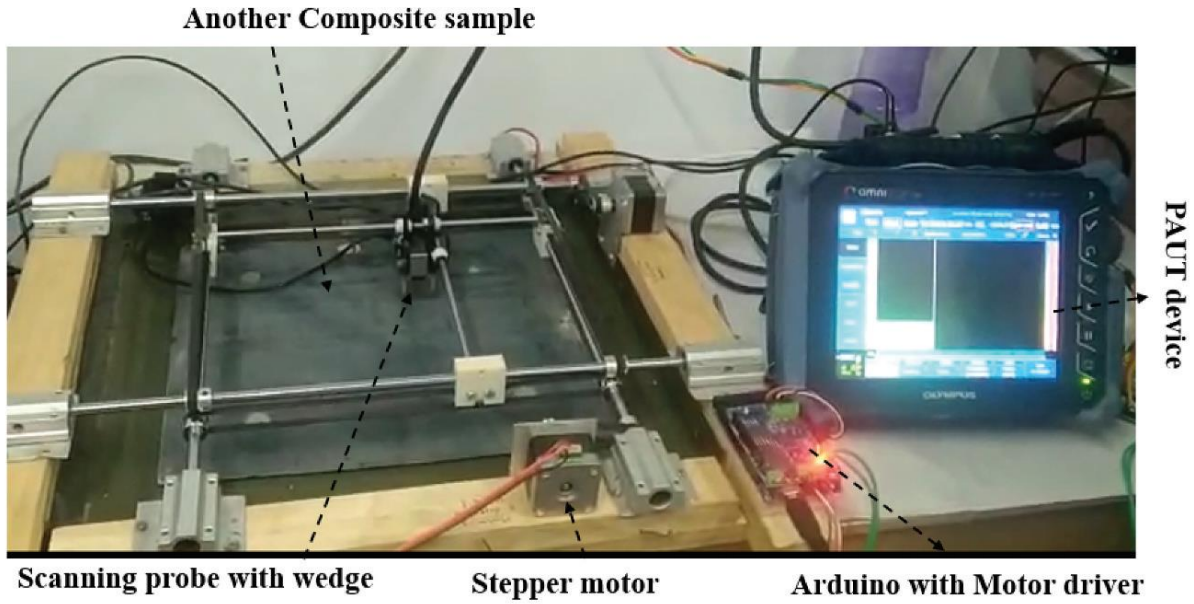


(c)

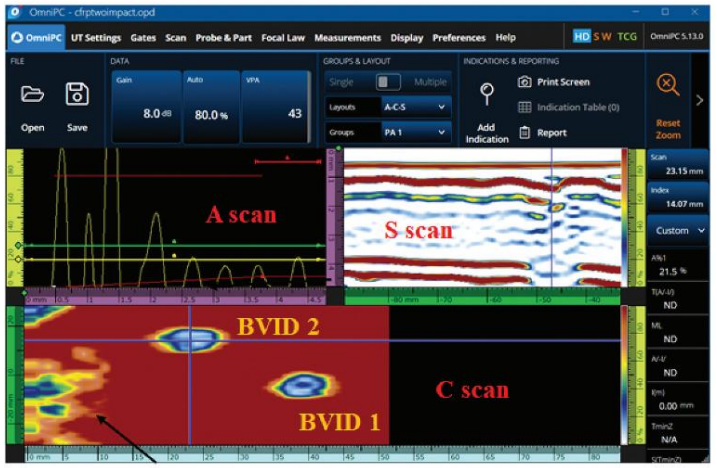




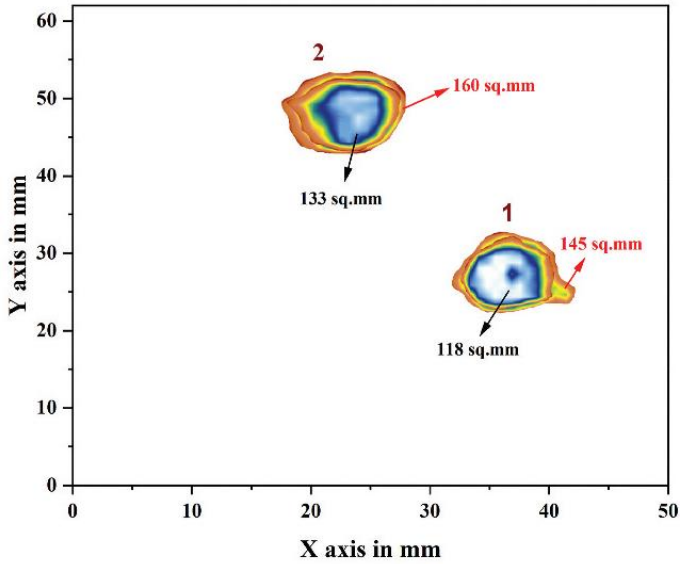
Ultrasound Scanning of Impact damage



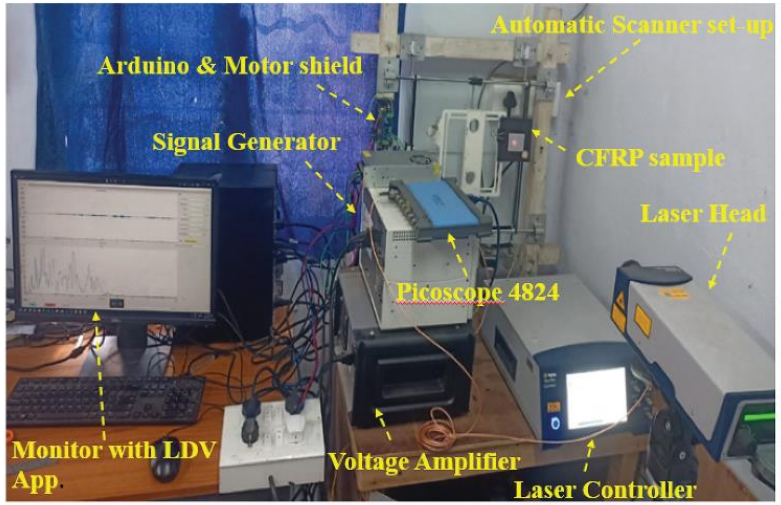
Automated scanning set-up



Disturbance while scanning

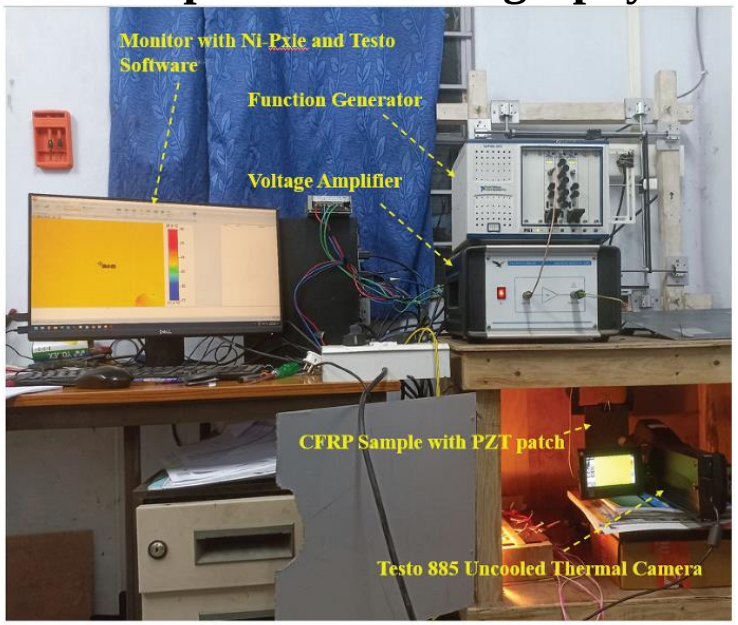


Experimental Set-up

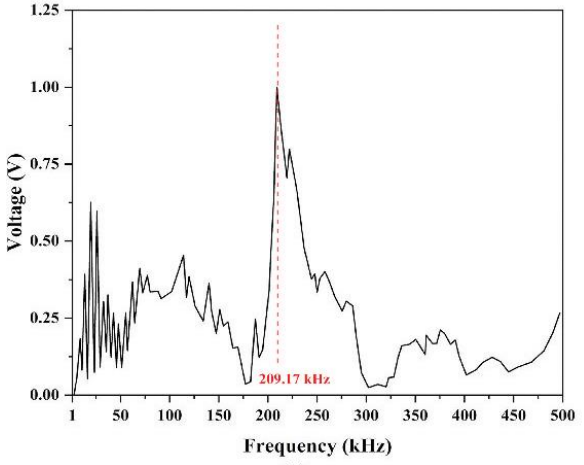


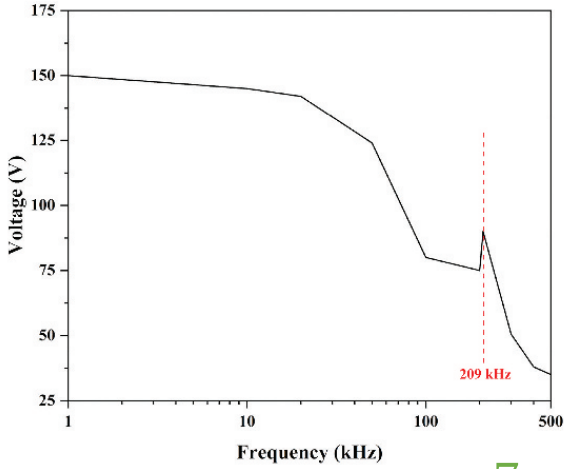
Laser Vibrometry

Sweep Vibro-thermography

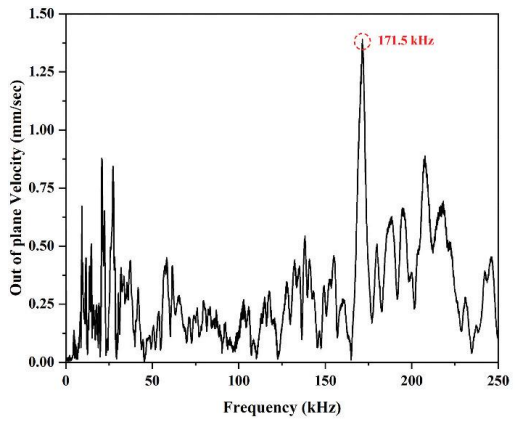


PZT characterisation

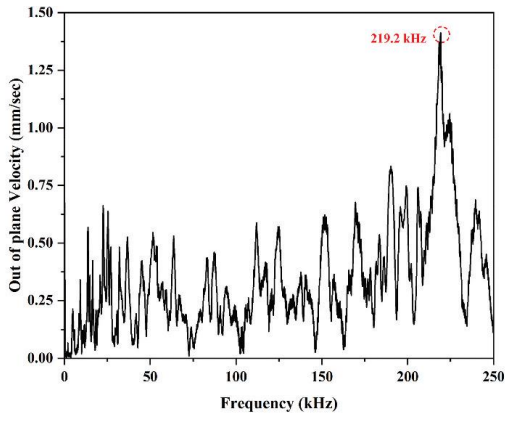




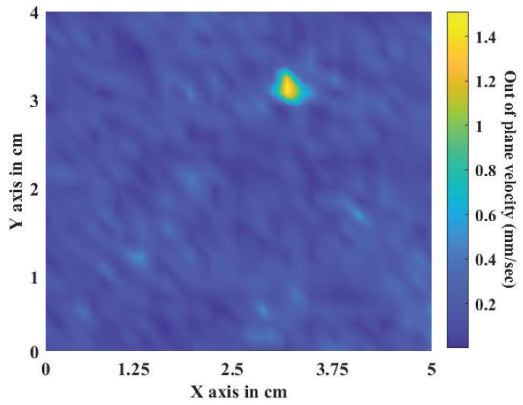
Laser Vibrometry



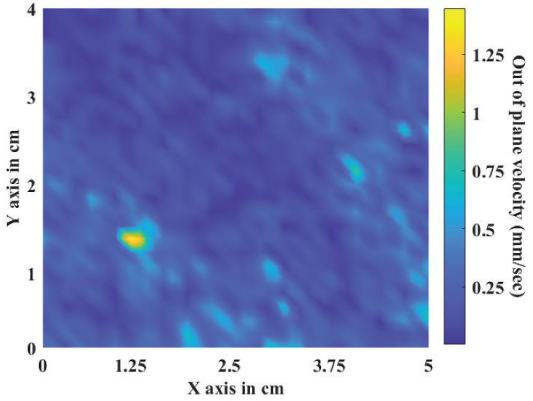
(a)



(b)



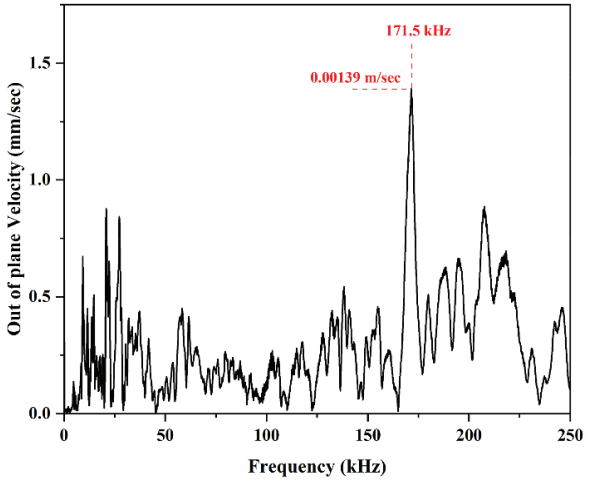
(c)



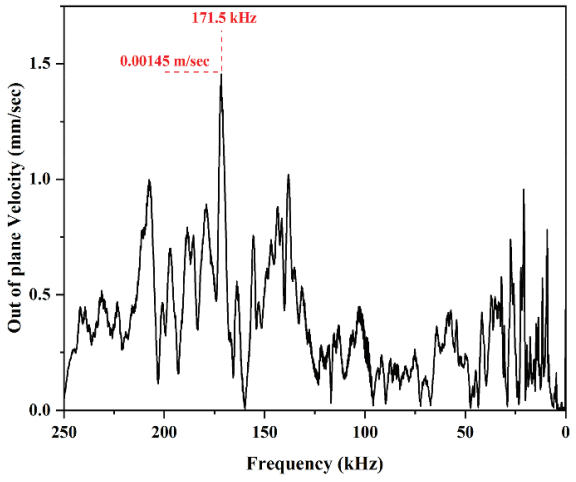
(d)

- The obtained LDR frequencies are shown in Fig. a, b for two BVIDs
- The defect shape is shown in Fig. c & d.

Sweep laser vibrometry



(a)



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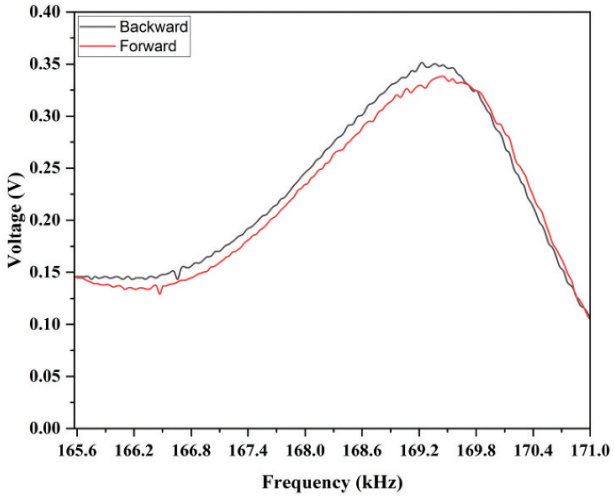
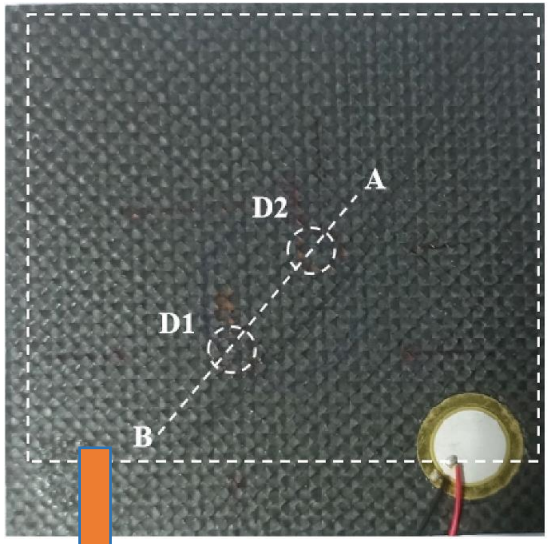
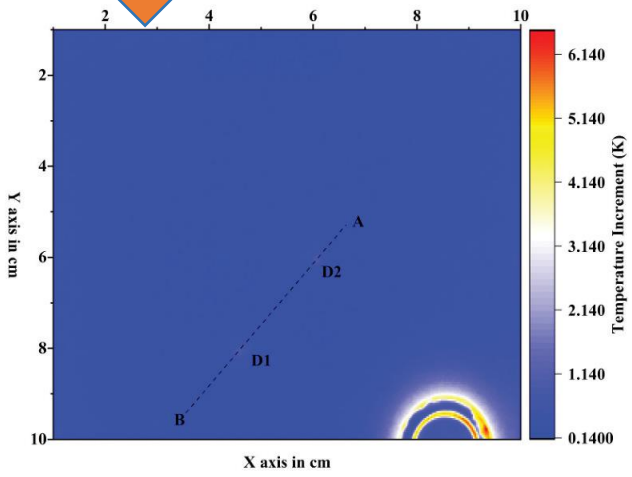


(b)

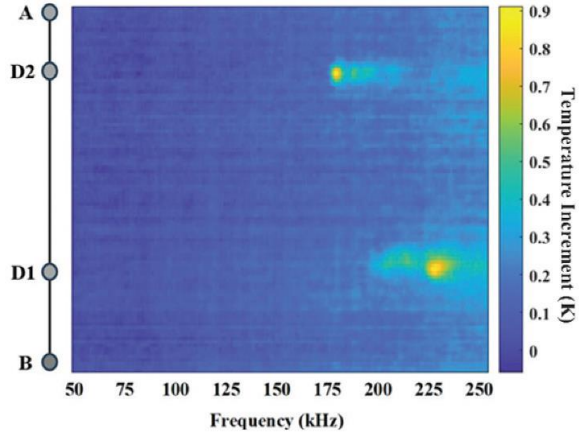
- In Fig. a &b the variation of peak amplitude for narrowband forward & backward sweep has been shown.
- In Fig. d, the amplitude variation over the defect close to LDR frequency has been shown.
- Backward sweep generates for amplitude and LDR asymmetry can be seen.

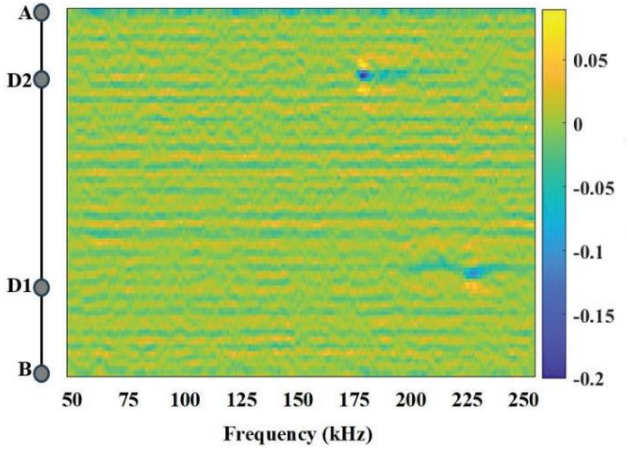
Sweep Vibro-thermography

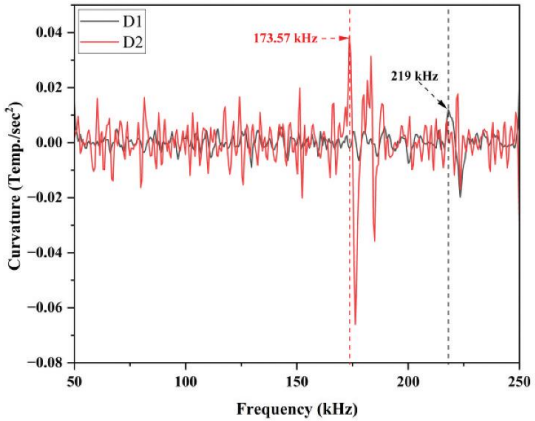




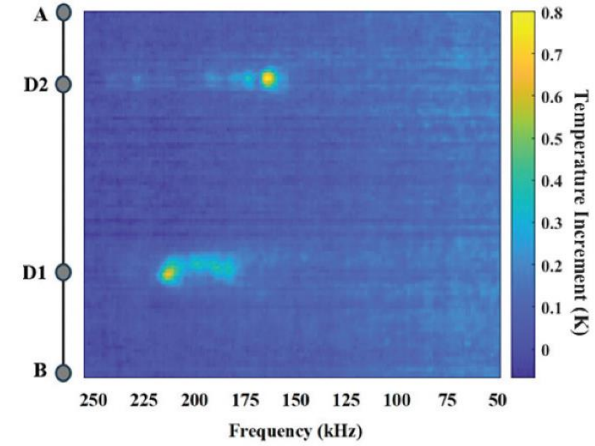
Forward

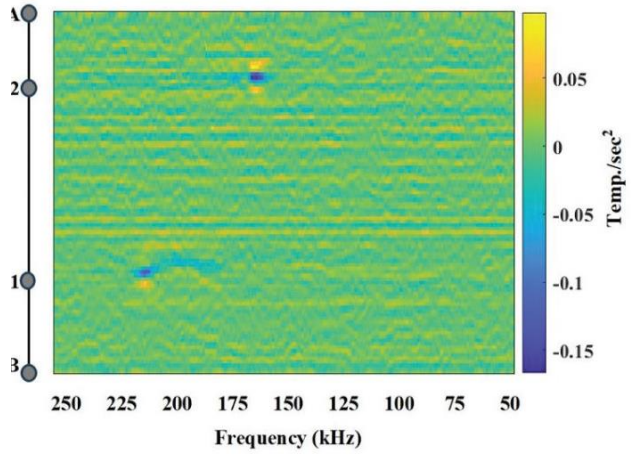


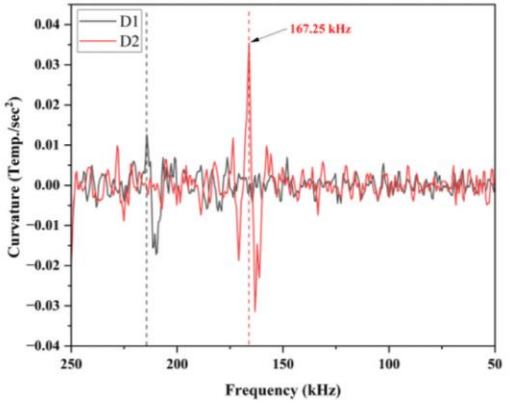




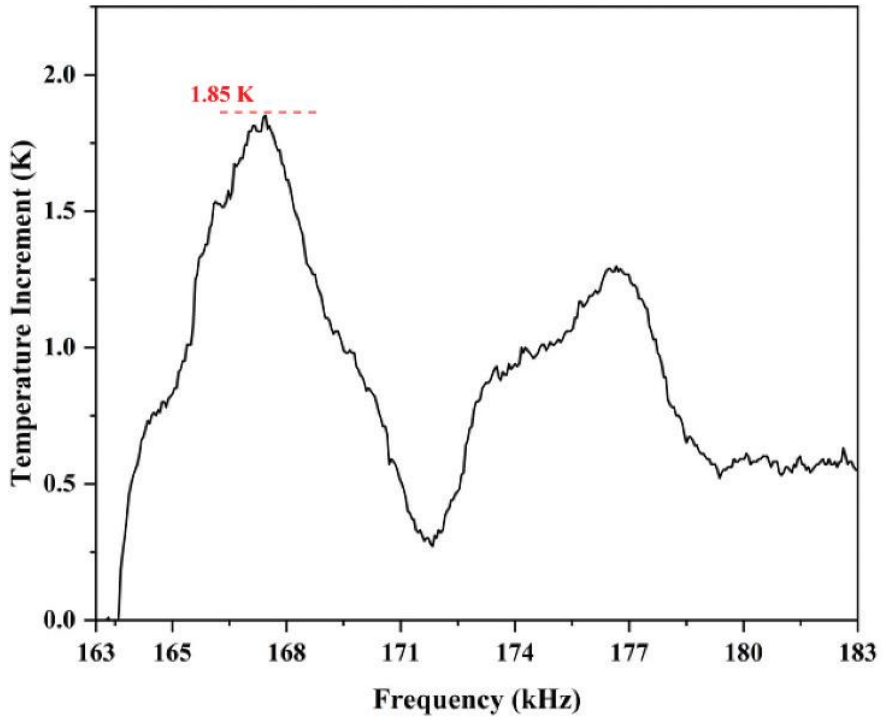
Backward

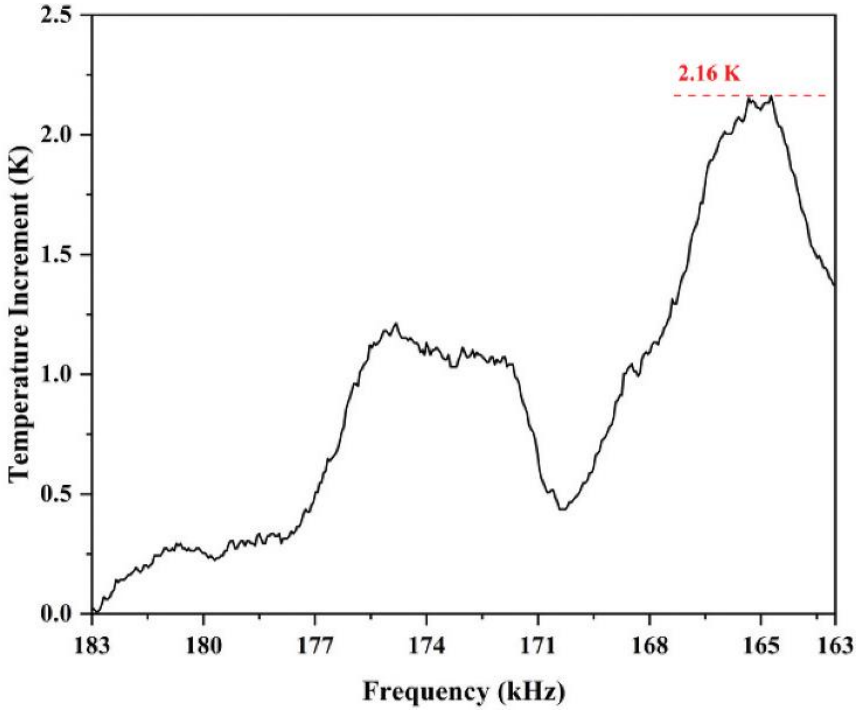






Temperature increment





- Backward sweep produces more temperature increment

Thank You