

(187)

## Optimization of Circular Symmetric Laser Source for Enhanced Generation of Zero Group Velocity Lamb Modes

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The laser based ultrasound technique is a convenient non-contact tool for generation and detection of guided modes in plate. This technique is well suited to observe the specific Lamb modes having a Zero Group Velocity (ZGV) and a finite wavelength. For these modes, the energy deposited by a laser pulse remains trapped under the source which results in a local and narrow resonance. The frequencies of these modes depend on the bulk velocities and the thickness, and for isotropic the local Poisson's ratio is provided by measurements of ZGV resonances[1]. The amplitude of the resonance depends on the laser pulse energy which is limited by the ablation threshold for non-destructive testing applications. To maximize the amplitude of resonance, the laser source needs to be matched with spatial distribution of the mode. The normal surface displacement of a ZGV mode of wavelength  $\lambda$  follows the Bessel function of the first kind of order zero  $u(r)=J_0(2\pi r/\lambda)$ . A first optimization was performed by adjusting the radius of a Gaussian beam in function of the wavelength of the ZGV mode. The theory predicts that the optimal source radius at constant maximum surface energy is  $\lambda/\pi$ . For the S1S2 mode in duralumin plate, the wavelength is about 4 times the plate thickness. This result is confirmed by semi-analytic simulations and by measurements on a 1-mm thick duralumin plate. The ZGV resonance amplitude is increased by a factor close to 5 when the radius increases from 0.5 mm to the optimized source radius (1.3 mm). A second optimization is performed on using annular sources. Experimentally, the annular beam is produced by a simple axicon-lens system. Both radius and width of the ring are controlled by varying the distances between the axicon, the lens and the sample and controlled on a ccd camera. We observe that for parameters well adapted to the ZGV mode's wavelength, the first annular source enhances ZGV mode's amplitude by a factor greater than 2 compared to the optimized Gaussian source at the same maximal surface energy. Moreover, simulations show that for a fixed width, ZGV amplitude increases pseudo periodically with the square-root of the ring radius. Besides, these annular sources are also interesting to enhance the generation of propagating modes.

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### References:

1. D. Clorennec, C. Prada and D. Royer, "Local and noncontact measurements of bulk acoustic wave velocities in thin isotropic plates and shells using zero group velocity Lamb modes", in *Journal of applied physics*, **101**(3), 034908 (2007)