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Development of photoelastic ultrasonic visualization system using pulse laser for the evaluation of high frequency phased array system
パルスレーザー光源を用いた超音波可視化装置の開発と高周波フェイズドアレイ音場の観察

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1. Introduction

The photoelastic ultrasonic visualization method is the most familiar experimental technique to observe the ultrasonic propagation in a transparent model sample. We have used this system to evaluate the detail of the ultrasonic propergation in industrial applications[2] and also to verify the accuracy of the several analytical ultrasonic simulation code. However, according to the requirement for highly quantitative analysis for an ultrasonic travelling behaviour, lack of a spatial resolution in photoelastic visualized image due to the duration time of the stroboscope became sometimes serious problem. Though new visualization systems using pulse laser as a light source have been proposed until now, no system have been widely used in industrial problem because Kanemitsu's system was too special in delay equipment[1] and auther's system was unstable in delay electric circuit[4]. In this study, in order to develop high accurate and stable ultrasonic visualization system photoelastic ultrasonic visualization system was improved for the optical setup and the delay circuit. As a demonstration of the developed system, sound feild of the 50MHz phased array system for inspection of semiconduct products was evaluated, and the visualized image by the new system was compared with the one by the ventional stroboscope light source system.

2. A principle and a limitation of photoelastic ultrasonic visualization method

Photoelastic method can estimate stress distribution and also ultrasonic propagation in a transparent materials as a stress wave using stroboscope as a light source. Author applied the system for several industrial inspection problems using a glass model sample that the acoustic properties are similar to steel. Also as an evaluation technique for an ultrasonic transducer also for phased array and its element and as a verification method of the ultrasonic simulations, photoelastic visualization will be useful.

Though a profile of an intensity distribution of a visualized image relate directly to the accurate ultrasonic waveform theoretically, the visualized image is distorted because ultrasound travels in a glass sample within a stroboscope luminescence time, e.g. ultrasound travels 0.5mm in 100ns luminescence in this study. For the improvement of this problem, pulse laser in photoelasticity system was useful because of the short luminescence time of ns order as a light source. Kanemitsu etal. developed the special laboratory system that delay time was controlled by changing the mechanical optical path. We also developed pulse laser visualization system with the flexible delay of electric delay circuit. However both systems could not applied general industrial problem because of the lack of flexibility and stability of the delay system of the luminescence of a pulse laser. Author also proposed the inverse analyzing procedures to obtain a right waveform with distorted waveform due to stroboscope[3] but the procedures were complicate and sometimes arisen an error.

3. Evaluation of the developed visualization system

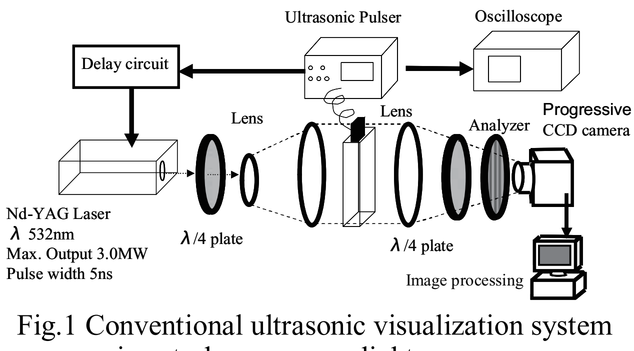

Fig.1 Conventional ultrasonic visualization system using stroboscope as a light source

As shown in Fig. 1, we developed the stable ultrasonic visualization system by adding highly stable digital delay equipments for luminescence of a pulse laser and wide-field optical lenses. In this system we prepared two digital delay equipments for lamp wave and Q switch for pulse laser which carry out an accurate synchronous delay in ns order.

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In addition to this, the delay time from the lamp wave to the Q switch kept 150 μs correctly by the third digital delay circuit.

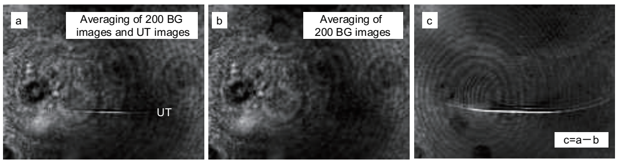

Fig.2 Image processing for visualized image

The visualization image by this developed system was shown in Fig.2(a). Speckle pattern as shown in Fig2(b) was overlapped on ultrasonic image. All the images were averaged with 200 images to reduce a jitter of the laser. Then, Fig.2(c) was obtained by subtraction processing of the (b) was carried out from (a) to remove the influence of the background. As the first sample, the commercial 5MHz longitudinal wave transducer was used. The visualized images of the incidence in the glass specimen by conventional stroboscope system and by developed pulse laser system compared as shown in Fig.3.

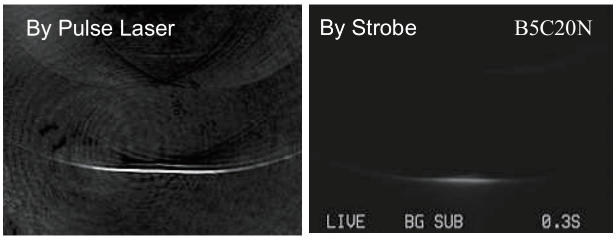

Fig.3 Comparison between the pulse laser system and the conventional stroboscope system

To investigate the spatial resolution for both systems, profile of the intensity distribution of Fig.3 at the center of the traveling waves were shown in Fig.4.

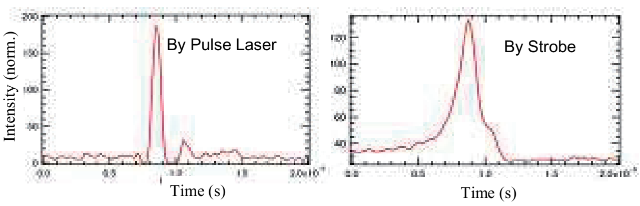

Fig.4 Comparison of the intensity profiles of Fig.3

The distribution profile by pulse laser system was sharp and symmetrical and the one by a stroboscope look faded and was not symmetrical.

As the second sample visualized images of 50MHz phased array system with 386 line focus elements for the inspection for electron devices were measured by stroboscope system and by developed pulse laser system. The results were shown in Fig.5.

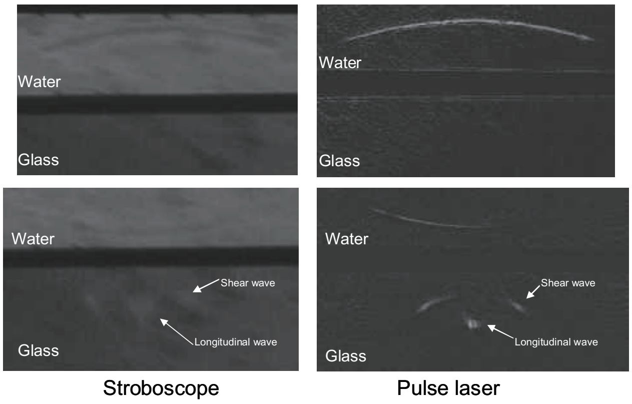

Fig.5 Visualized image of 50MHz Phased array system

Evident improvement of spatial resolution was observed in visualized image in pulse laser system comparing to the one by stroboscope system.

4. Conclusion

The stable ultrasonic visualization image can be obtained by developed photoelastic ultrasonic visualization system using pulsed laser as a light source. Obtained image of ultrasonic wave propagation show the extremely high spatial resolution and the accurate and quantitative measurement could be realized. This system especially expected to apply for high frequency ultrasound because conventional system was difficult to apply.

Acknowledgment

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