Experiment study on laser generating the surface acoustic waves

Gang Yan (严 刚), Zhonghua Shen (沈中华), Jian Lu (陆 建), and Xiaowu Ni (倪晓武)

Department of Applied Physics, Nanjing University of Science & Technology, Nanjing 210094

In the field of nondestructive evaluation, laser generation and detection of the surface acoustic waves (SAWs) are potentially useful for investigating material surfaces. SAW generated by laser line source is carried out on a kind of optical difference detection system based on optical beam deflection technique. The setup is simple and easy to adjust. Furthermore the system has advantages such as high efficiency of photo-electricity conversion, high frequency responding, the ability of ant-intervene and broadband detection etc.. It can be used not only to receive SAW, but also to detect surface-breaking defects in material. The experimental results verify that the SAWs generated by a line source have the advantages of powerful signal and good directivity. SAWs have been excited on sample aluminum with artificial surface-breaking defects. From the experiment, we attain the characters of reflected wave and transmitted wave by SAW interacted with the surface-breaking defects.

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Laser ultrasonic technique, which is based on the generation of ultrasound by a pulsed laser and the detection of stress wave with laser, is an ideal combination of laser and ultrasound for non-destructive testing. The considerable advantage of using lasers rather than conventional piezoelectric transducers is that this technique does not require any mechanical contact with the inspected surface. Moreover, it is considered that the amount of information contained in the received ultrasonic signals will be increasing, because the received ultrasonic signals are not influenced by the natural frequencies of piezoelectric transducers. Therefore, laser can be operated far from the material in hostile environments[1−3].

There have been considerable interest in laser ultrasound and many research achievements since 1960s[2,3]. In recent years, several new theories and applications of laser ultrasonic technique have been investigated[4−7]. Laser generation and detection of surface acoustic waves (SAWs) are potentially useful for investigation material surfaces. Most of the surface acoustic energy is contained in the SAW pulses, which propagates along the surface of the material, exhibiting elastic motion and containing components of displacement normal to the surface. The time-dependent behavior of the displacement can be predicted and compared with experimental waveforms. SAW can be used to detect defects and determination of elastic constants[5,6].

We introduce a non-contact all-optical method for surface photoacoustic detection. It is a kind of optical difference detection system based on optical beam deflection technique. The whole experimental setup is simple and compact. SAW pulses are detected on the surface of polished aluminum. Moreover, this technique is applied to detect the surface-breaking defects on sample aluminum.

A schematic diagram of the experimental setup is shown in Fig. 1. The SAW were generated by a Q-switched Nd:YAG laser providing pulses with the wavelength $\lambda = 532$ nm and duration $\Delta = 8$ ns. A beam expander and a cylindrical lens were used to create the thermoelastic strip on the surface of polished aluminum plate. SAW propagated on the surface of the sample. The propagation direction was vertical to the line source. The trigger signal was provided by a PIN photoelectric diode (with 100-ps rise time). The detection beam was emitted by an 11-mW He-Ne laser. It was focused on the sample surface by a spherical lens, the reflection beam was splitted into two symmetrical beams by a rectangular prism. Mirrors 3 and 4 were adjusted to conform the optical path difference of the two beams. Then these two beams were respectively focused onto the photodiode of the New Focus Model 1607-AC balanced photoreceivers. Signals detected by the optical probe were fed directly into a two channel digital oscilloscope (TEKDDS6800B).

The balanced photoreceiver consists of two matched photodiodes and an RF amplifier that generates an output voltage proportional to the difference between the photocurrents in the two photodiodes. In practice, the position of the rectangular prism is adjusted to equality in power of the two beams. In this case, there has no output signal from balanced photoreceivers. As SAW propagates on the surface of sample, it creates a surface deformation. So the reflection beam deflects slightly away from its original path, in which the information of SAW is contained. Therefore, the RF output of the balanced photoreceiver can contain the signals of SAW[7].

The experiment result on the sample of aluminum is shown in Fig. 2. The detection distance is 8.58 mm.

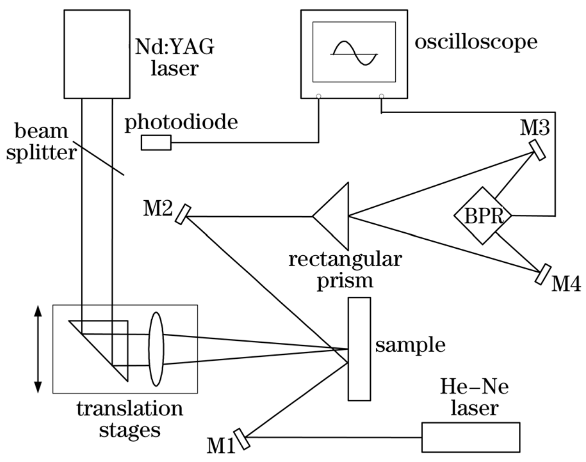

Fig. 1. Schematic diagram of experimental setup.

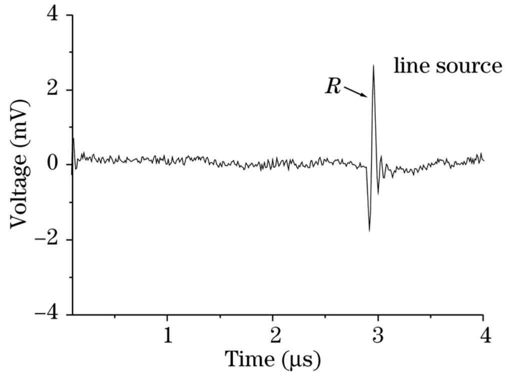

Fig. 2. The waveform of SAW detected at the distance $d = 8.58$ mm on the Al plate.

The waveform of SAW was well defined and had no oscillating tail. The excitation mechanism of laser ultrasonic in solid has been studied in detail[8,9]. Here, no absorption overlayer was used, and the power density of the excitation source was below to 10^8 W/cm^2, the excitation mechanism can be interpreted with thermoelastic model. Comparing with the work of others with traditional transducer[10], the result shows a higher signal to noise ratio (SNR).

We detected SAW on the surface of sample aluminum at different distance along the direction normal to the line source. The length of line source was 7 mm. As shown in Fig. 3, we described the relation between distance and amplitude. In experiment SAW waveforms were recorded at distances from $x = 4.85$ mm to 17.29 mm along the axis perpendicular to the thermoelastic line source. The vertical scale gave the amplitude of SAW. From Fig. 3, the amplitude did not have apparent attenuation with the increase of the distance of detection position in the near field. The result shows that the SAW generated by a line source has the advantages of powerful signal and good directivity. It can be applied to non-destructive testing.

In addition, we detected the ultrasonic waveform on the surface of sample aluminum with artificial surface-breaking defects. Figure 4 shows the SAW signal with both detection point and generation point at same side of defects, and Fig. 5 shows at another side of defect. A proportion of the SAW pulse is converted into shear and longitudinal modes, which may then be reflected

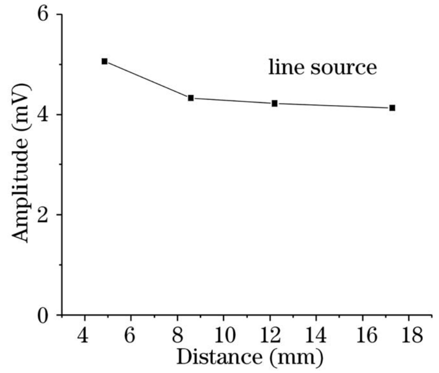

Fig. 3. The relation of SAW amplitude and detected position of line source.

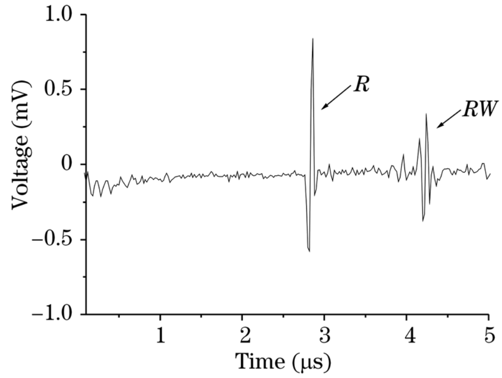

Fig. 4. The SAW signal with both detection point and generation point at same side.

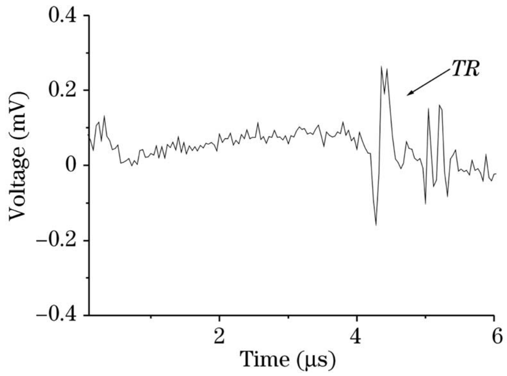

Fig. 5. The SAW signal with both detection point and generation point at another side.

along the surface, scattered into the bulk of the sample, or transmitted beyond the defect. From the experiment, we attained the characteristics of the reflected wave and transmitted wave by SAW interacted with the surface-breaking defects, which showed that the SAWs generated by laser line source are potential for the surface-breaking defects. The interaction is complex, with surface waveforms being generated that not only show the presence of the defect but also contain information about its depth. Such information can in principle be collected from method or a pulse-transmission method.

In conclusion, well-defined waveform of SAW can be acquired with the optical difference detection system based on optical beam deflection technique. Comparing with other techniques, this detection technique is very simple and effective. The whole setup is compact and easy to adjust. Furthermore, the light signal can be transforming into an electrical signal. The system has advantages such as high efficiency of photo-electricity conversion, high frequency responding, the ability of ant-intervene and broadband detection etc.. It can be used not only to receive SAW, but also to detect surface-breaking defects in sample.

The experimental results verify that the SAW pulse generated by a line source has the advantages of powerful signal and good directivity. Several correlative curves obtained show that the SAW generated by laser line source are potential for nondestructive detection. Furthermore, SAW have been excited on sample aluminum with artificial surface-breaking defects. From the experiment, we attain the characters of reflected wave and transmitted wave by SAW interacted with the surface-breaking defects, which show that the SAW generated by laser line source is potential for the surface-breaking defects.

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