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# Fast two-dimensional optical full-field imaging of GHz surface acoustic waves

GHz 帯表面弾性波の高速フルフィールド光学的イメージング

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## 1. Introduction

The propagation of surface acoustic waves (SAWs) is influenced by the structure and physical properties of the medium. There are methods to investigate these properties of the medium by observing the propagation of the SAWs.[1-6] One typical method of observing the SAW propagation is the optical imaging of the surface displacement caused by the SAWs. In this method, the optical phase change of the reflected light, which is caused by the surface displacement, at a single point is measured by using an interferometer, and the spatial scanning of the measuring point is used to obtain the 2-dimensional image of the displacement field.[4-6]

This approach, however, requires long total measurement time because of the scanning The measurement time can be reduced if one obtains the full 2-dimensional image at once using appropriate divices such as a camera.[7] The surface displacement on the sample modifies the way of light scattering and thus modifies the intensity and position of the speckle-like patterns observed by the imaging device. Relying on this modification, though it is not quantitative, it is possible to obtain a spatial pattern of the points where the surface is displaced. In this study, we construct and demonstrate an optical system that performs full field optical imaging of SAW using laser scattering due to surface displacement.

## 2. System design and measurements

The measurement is based on a time-resolved method called a pump-probe technique. As a light source, we use a mode-locked Ti-sapphire laser which generates a periodic train of ultrashort light pulses with the temporal width < 1 ps at repetition frequency 80 MHz. The laser beam is divided into two parts. One is used as the pump light and is focused to the sample to generate acoustic waves. The other is delayed and is used as the probe light to observe the acoustic wave field. By changing the delay time between the pump and probe light pulse arrival to the sample, one can track the temporal evolution of the acoustic field. In the previous works, both pump and probe light are focused on the sample and the position of the pump or probe focused point is spatially scanned [5,6]. On the other hand, in the method proposed here, the probe light irradiates a certain area of the sample to get the full-field image of the acoustic field without scanning.

Figure 1 shows the optical setup for the probing. The sample is a gold thin film with a thickness of 40 nm on a glass substrate. The pump light is focused to the sample to generate the SAWs. The probe light is incident as collimated light on a certain area of the sample. Two pairs of the lenses including an objective lens form two 4f optical systems to transfer the image on the sample surface to the imaging plane of a CMOS imaging sensor. The images with and without pump light are accumulated independently and then one of them is subtracted from the other to extract the modification caused by the SAW field.

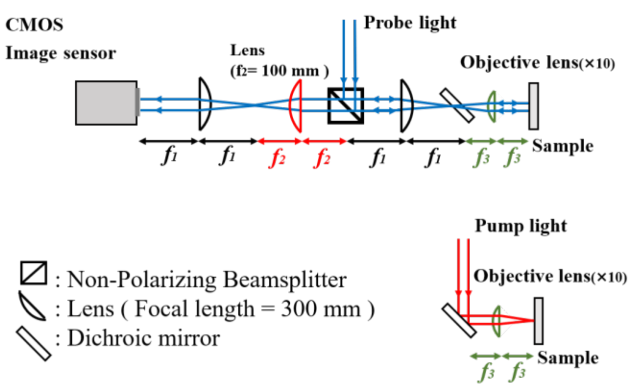


Fig. 1. Imaging system of sample with a CMOS imaging sensor

In this measurement method, the measurement area is determined by the magnification factor $f_1/f_2 \times f_1/f_3$ and the area of the CCD imaging plane (13.312 mm×13.312 mm). We use $f_1$=300 mm, $f_2$=100 mm and $f_3$=18 mm, thus are capable to observe 266 μm × 266 μm in a single frame.

## 3. Experimental results

**Figure 3** shows the typical image obtained at a fixed delay time. The measurement area was 130 μm × 170 μm. The pump light is focused around the center of the image. It is considered that the excited SAWs propagate isotropically in this sample. We can see the circular ripple around the excitation point, which is thought to be due to the surface displacement of the isotropic SAW. Total measurement time was 5 minutes which has not yet been very optimized. (A typical measurement time for a frame in our previous scanning method is about 10 minutes.) This measurement time, however, includes the data processing time of 100 sec which should be much more reduced by using better algorithm. In fact, this measurement time is much longer than the theoretical value (100 sec) derived from the performance of the CMOS sensor, and still has enough room to be improved. For this reason, we can expect a shorter time for the measurement under the same conditions by improving the measurement program.

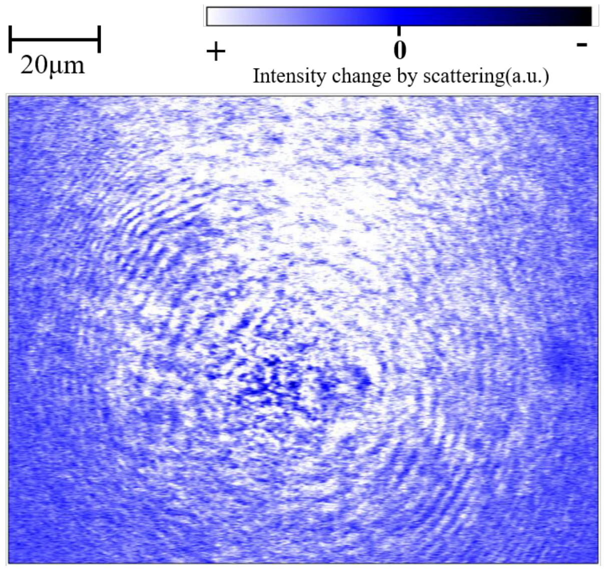


Fig. 3 Image by surface displacement on CMOS sensor (130 μm × 170 μm).

## 4. Conclusions

An optical setup for the time-resolved and full-field optical imaging of surface acoustic waves by a CMOS imaging sensor using laser scattering was proposed and some preliminary measurement was demonstrated. In future, we expect the method can be improved to track the propagation of surface acoustic waves over a wide range in a shorter time than that elapsed in the previous scanning methods.

## References

1. R. E. Vines *et al*., Z. Phys. B **98**, 255 (1995).
2. J. G. Gualtieriand *et al*., IEEE Trans. Instrum. Meas. **45**, 872 (1996).
3. T.Hesjedal *et al*., Appl. Phys. Lett. **70**, 1372 (1997).
4. J. Knuuttila *et al*., Opt. Lett. **25**, 613 (2000).
5. Y. Sugawara *et al*., Phys. Rev. Lett. **88**, 185504 (2002).
6. T. Tachizaki *et al*., Rev. Sci. Instr. **77**, 043713 (2006).
7. T. Pezeril *et al.*, Opt. Exp. **22**, 4590 (2014).