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A Detection Electronics Enabling Ultimate Suppression of Leakage Signals for RF SAW/BAW Laser Probes

究極的な漏れ信号抑圧が可能な RF SAW/BAW レーザプローブ用受信回路

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1. Introduction

Presently, the laser probe is well recognized as a versatile nondestructive diagnosis tool for surface and bulk acoustic wave (SAW/BAW) devices[1]. The authors developed a high-speed and phase-sensitive laser probe using the Sagnac interferometer (SI), and demonstrated its usefulness[2]. This year, they installed the Michelson interferometer (MI) coaxially in the probe, and demonstrated calibration of data captured by SI from those captured by MI[3].

They are attempting to apply the laser probe to detect acoustic fields generated by nonlinearity, which is one of the hottest topics in RF SAW/BAW devices[4]. In the measurement, nonlinear signals are quite weak, and thus extremely high dynamic range is necessary.

This paper proposes a detection electronics for the phase-sensitive laser probe enabling ultimate suppression of leakage signals, which limit the system dynamic range.

2. Detection System in Current Laser Probe

Fig. 1 shows present setup of the electronic system used in the current laser probe. An RF signal is

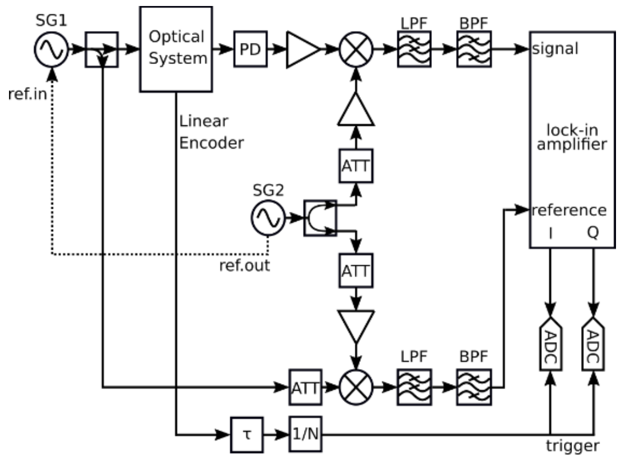

Fig.1 Typical setup for detection electronics

applied to the SAW/BAW device, and the output of photo diode (PD) is fed to the mixer after RF amplification by a low noise amplifier (LNA). Then the output signal is down-converted to the IF frequency ω_{IF} through the mixing with a local signal with a frequency of ω_{LO} and detected synchronously by a two-phase lock-in amplifier. The RF signal is also directly down converted to the IF frequency and fed to the RF lock-in amplifier as a reference signal. This configuration allows us to measure not only the vibration amplitude but also the phase, and obtained complex data can be used for processing in the wavenumber domain[5].

The system dynamic range is limited by the signal leakage from the reference path to the signal path through two mixers. For its suppression, two amplifiers and attenuators are added after a power splitter given to the IF oscillator output.[3] The signal leakage through the reference path is circa -125 dBm when the RF signal is +10 dBm is applied to the SAW/BAW device.

3. New Detection System

In many cases, absolute phase of the acoustic vibration is not necessary because de-embedding of connecting cables and mounted printed circuit board is not easy.

Fig. 2 shows the proposed detection electronics. The circuit is simpler than the one shown in Fig. 1, and the standard signal (10 MHz) of SG1 and SG2 are used as ω_{IF} and fed to the RF lock-in amplifier as the reference signal.

Since current RF oscillators are frequency synthesizers based on the PLL technology, we can stabilize relative phase of multiple oscillators by unifying their standard signal. Commercial RF oscillators can import and export the signal.

The configuration can the leakage ultimately owing to absence of the leakage path. In fact, the leakage signal could not be detected in the circuit shown in Fig. 2.

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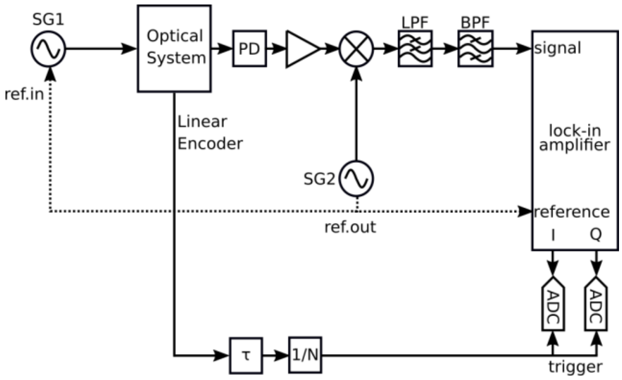


Fig.2 Modified setup of detection electronics

3. Impact of Phase Noise

In the configuration shown in Fig. 1, signals in two paths are generated from identical outputs of two oscillators, and thus short-term instability of the oscillators is cancelled to some extent in the lock-in output. In contrast, in the configuration shown in Fig. 2, signals in two paths are generated by different oscillators, and their instability is simply added, and deteriorates the measurement accuracy.

So, influence of the oscillator phase noise is examined. The optical systems including PD in Figs. 1 and 2 are replaced with an attenuator, and the lock-in output is carried out for one million times. Then the fluctuation is estimated from the measured data.

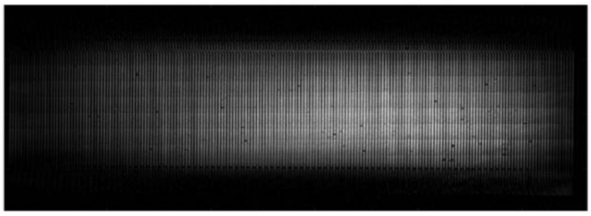
Table 1 shows estimated standard deviation of the measured phase. As expected, the configuration shown in Fig. 2 gives worse stability than that in Fig. 1, and the deviation is sensitive to selection of the oscillators. Note that Anritsu MG3740A possesses better phase noise performance than Keysight N5181A/B.

Table1 Estimated standard deviation

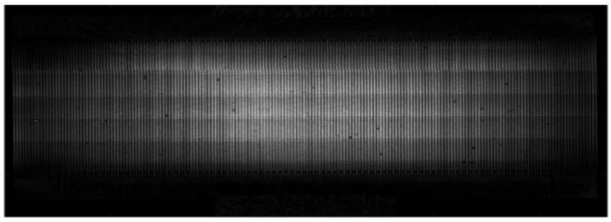
configuration	SG1 SG2	standard deviation[°]
Fig. 1	N5181A N5181B	0.013
Fig. 2	N5181A N5181B	0.051
Fig. 2	MG3740A	0.019

Next, the SAW field is measured using these two detection electronics, are the captured data are compared. As a sample, a one-port SAW resonator on a 42°YX-$LiTaO_3$ substrate is used.

Figs. 3(a) and (b) the two-dimensional image (amplitude) of captured data using the systems shown in Figs. 1 and 2, respectively. The difference is hardly seen between these two images.



(a) Image captured using the system shown in Fig.1



(b) Image captured using the system shown in Fig.2

Fig.3 Measured data

Although not shown in this paper, impacts of phase noise in the standard signal were also examined. The result indicated that its influence is small.

Acknowledgment
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