Vibration Sensor Based On Self-Mixing Interferometry To Identify Human Heart Rate

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Abstract. The monitoring heart rate by vibration sensor based on self-mixing interferometry (SMI) had been done. Experimental schemes and the performance of vibration sensor based on SMI as a function of frequency and amplitude of human heart rate signals had been examined. The vibration sensor consists of a laser diode as a light source ($\lambda = 785$ nm) with integrated detector, a mirror as a vibrating target, and a simulated heart signal from ECG generator. ECG generator signals and audio amplifier are adjusted in frequencies of 1-100 kHz. The result showed that the feedback parameter of SMI signal could be identified at frequency 50 Hz. The heart signal was shown clearly at frequency 100 kHz.

1. Introduction
Cardiovascular disease is the extreme disease in the world. The Institute for Health Metrics and Evaluation reported some diseases related to heart and blood vessels increased in the world since 1990, more than 17 million deaths in 2013. Between 1990 and 2013, overall global cardiovascular mortality increased nearly 41%. Moreover, mortality rates for all cardiovascular diseases increased [1]. Mortality rates in Indonesia were caused by cardiovascular disease reached 26% [2]. The early detection and routine control were required as the treatment of cardiovascular. However, the treatment was quite unreasonable [3]. Self-Mixing Interferometry (SMI) using vibration sensors was needed as a simple, non-contact and affordable method

SMI is a measurement method using optical technology. SMI was discovered by Lang and Kobayashi since 1980s. In early observation, the effect of optical external feedback on laser diodes was analyzed [4]. Furthermore, SMI can be used as alternative optical measurement techniques [5]. For SMI principle, laser light was release to the target. Then, it was reflected by the target’s vibration. Subsequently, the difference of amplitude and frequency were evaluated [6].

In this study, there were two evaluation. The first evaluation assessed vibration sensor based on self-mixing interferometry using waveform generator. The evaluation analyzed the feedback parameter (C) that used as indicator of feedback regime or the optical feedback power of the diode laser. The second evaluation applied to human heart signals using ECG generator simulations. It analyzed the frequency and amplitude human heart signals using vibration sensors based on self-mixing interferometry. Therefore, this work can be used as preliminary study of vibration sensors based on self-mixing interferometry to identify human heart signals.
2. Experimental Setup

![Diagram of experimental setup](image)

**Figure 1.** Human heart signal testing scheme using vibration sensors based on Self-Mixing Interferometry.

**Figure 2.** The setup of human heart signal testing using vibration sensors based on Self-Mixing Interferometry.

Artificial electrocardiogram signal is produced by an ECG generator as shown in Figure 1 and 2. The signal was employed to simulate the heart rate signal with frequency variations. The signal was strengthened by the audio amplifier and transmitted to the speaker to vibrate the mirror. While the laser diode was provided an input current 50 mA by the laser diode controller-LDC202C. The output photodiode was measured and analyzed with an oscilloscope for variations in heart rate frequency and amplitude. However, the heart rate amplitude was reformed by varying the voltage of the audio amplifier. Afterward, the frequency and the heart rate amplitude signal were identified.

3. Results

There was a vibration sensor testing based on SMI with 50 Hz vibration frequency given to the target.
The SMI signal were formed as shown in Figure 3. The time was decided around 0-1000 ms. The voltage was captured in 3.530-3.595 mV. The feedback parameter that became the characteristic of SMI signal was obtained in 50 Hz frequency. Previous study stated that it was vital since it distinguished from another feedback regimes [7]. The amount of feedback parameter indicated certain regime. The regime was an indicator of optical feedback power.

Furthermore, there was human heart signal testing using ECG generator. In addition, vibration sensor was tested using SMI. The simulation was programmed using Arduino Due. The evaluation was carried out in the frequency range of 10 Hz-100 kHz. The input voltage was provided 5 volts.

In the ECG generator signal, there was a signal pattern consisting of PQRSTU with segments and intervals as shown in Figure 4. It corresponded to the signal point, PQRSTU. It caused by the point of PQRST being more donated and visible than the U point which tends to be flat. There was a result of simulating the heart signal of various frequencies. As the result, the heart signal could be collected and analysed.

Figure 5 showed that the human heart signal with a frequency of 10 Hz was unidentified. It was probably caused by the tiny vibration frequency. Therefore, the heart rate simulation was undetected by the SMI.
Figure 6 showed a graph of the relationship between amplitude and time. It could be found that the human heart signal pattern was formed with a frequency of 100 kHz audio amplifier. The PQRSTU point on the graph of the human heart signal using this SMI ECG generator and vibration sensor could be observed clearly like a normal electrocardiogram chart. Although there was a slight change in shape at the QRS point. Where at point R is very short while at point Q and S is very long down. Therefore, it could be stated that the heart signal could be noticed clearly at a frequency of 100 kHz. Additionally, the suitable frequency for simulating heart signals using this SMI is with a high frequency. Compared to previous research [8], the frequency variation was range on 50-300 bpm. It showed that SMI worked in the low frequency range.

4. Conclusions
This study had concluded that the feedback parameter of SMI signal was unidentified. Nevertheless, it could be identified at frequency 50 Hz. Furthermore, the heart signal was shown clearly at frequency 100 kHz.

Acknowledgments
The authors would like to acknowledge to Director of Research and Community Service (DRPM) Ministry of Research, Technology and Higher Education of Indonesia (KEMENRISTEKDIKTI) for the support via grant “Penelitian Tesis Magister” (M.A.Y. and R.I.Y.).

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