A NEW OPTICAL METHOD FOR DETECTING SEISMIC VIBRATIONS

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In this paper we have described a new method to detecting characteristics of an oscillation system based on the Moiré technique. We can determine amplitude, resonance frequency and damping coefficient of an oscillation system both in vertical and horizontal direction which can use in vulnerable seismic sensors. There are several methods for detecting oscillation such as EM systems, optical interferometry, and etc. that have some advantages and disadvantages. Here, we have tried to reach an appropriate method that can be used as a good candidate. Figure 1 shows our instrument.

To do this approach, the displacements of oscillatory mass must be determined as possible as accurate. These displacements are recorded by Moiré detecting procedure. A spring-suspended mass (f0=10 Hz), whose position is monitored by Moiré technique, is used to testing this idea. Our detecting system consists of a pair of similar gratings which are installed near together without physical contact. The planes of the gratings are parallel and the lines of gratings have small angle respect together. Also, a laser diode (650 nm, input voltage 3 V, and power 1 mW), a silicon photo-diode (VTP1188) and a narrow slit (20 mm) have been used and fixed to the frame to illumination fringes movements due to the suspended mass movement. Due to moving the oscillatory mass and the fringes movements, the light intensity on the detector varies and is recorded as voltage. The output signal can be used to measure the oscillator characteristics. This method can detect displacements of the order of micron.

Mathematical simulation shows that the average intensity of a light beam through a slit of width *e* which oscillates with angular velocity w in front of the fringes is given by (Figure 1):

$$\overline{I}(t) = I_0 l[\frac{1}{4} + 2\sum_{n=1}^{+\infty} a_n^2 \sin c(\frac{n\pi e}{d_m})\cos(\frac{2\pi n(A\exp(-\gamma t)\sin(\omega t+\varphi))}{d_m})] \quad (1)$$

Where *g* is the natural damping constant of the oscillator, *t* is time, and *A* is the amplitude of oscillations. Figure 2 (a) shows numerical simulation of average intensity. We have considered the parameters, d_m = 2.22 *mm*, *e* = 20 *mm*, *w* = 20*p* (*f = 10 Hz*), and *g* = 0.012. These parameters have been chosen as identical to those of the real instrument. In this case oscillation phase changing identify with red circles in time series. We can derive the amplitude of oscillations from the time series by:

$$A=(N+d)d \quad (2)$$

Where *N* is the number of complete period in time series occurs at first quadrate period of oscillation, δ is the fraction of one complete period that occurred, and *d* is the period of gratings that is 0.05mm.We can derive δ by:

$$\delta = \frac{1}{2\pi}\sin^{-1}(\frac{V}{V_m}) \quad (3)$$

Where V_m is the value of maximum amplitude of output voltage due to passing the Moiré fringes in front of the light detector, and V is the output voltage of detector at the end of variations of light intensity at first quadrate period of oscillation and before the first phase change in time series.

Figure 1. Our instrument picture

To test our detecting system we subjected spring-suspended mass (without any additional damping mechanism) several times to a unit impulse produced by a controlled oscillator system. Figure 2 (b), shows an output of the Moiré system to a unit impulse (A= 0.25 mm). A very good agreement can be observe between theory and experiment by comparison Figure 2. The output shows that the amplitude of input pulls is equal to 5 moiré grating step that is 0.25 mm and by measuring two subsequence amplitudes damping constant of oscillation system can be determine. In this case that is 0.012. Also, Figure 3 shows the power spectrum of several output signals. As we can see, the 10 Hz component is clearly evident that shows the natural frequency of the oscillatory system.

By this method, we have some advantages. Its output is largely free of EM noise. Also, it is easier to install, and insensitive to environmental conditions such as temperature fluctuations. In our sensor, we can vary the sensitivity by varying the gratings period, and the angle between the rulings of the gratings. Also we can amplify the output signal of sensor by enhancing the power of light source and enhancing the proportion of signal to noise ratio.

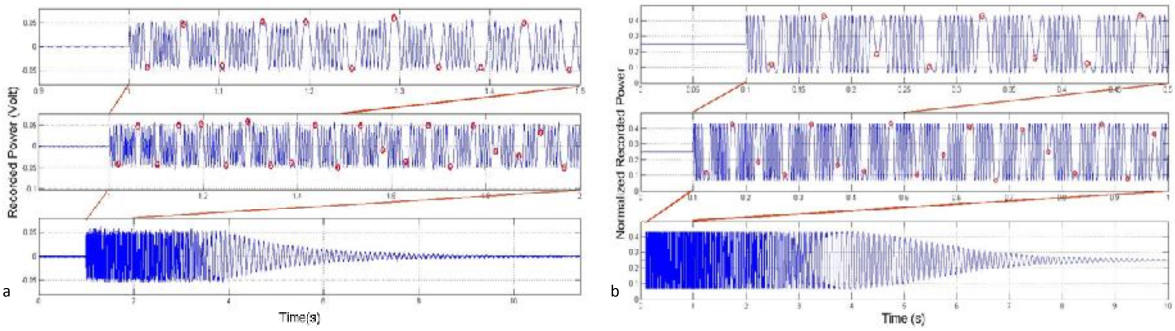

Figure 2. (a) The numerical simulation of the average intensity, Red circles show the location of changing in phases in time series, (b) The output times series of moiré detecting system

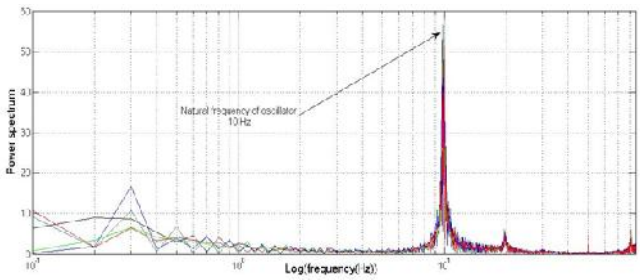

Figure 3. The power spectrum of several times series of moiré detecting system.
The 10 Hz pike is the natural frequency of oscillation system

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