Coherent detection of scattered laser beams

Adam Waz, Pawel Kaczmarek, Krzysztof M. Abramski

Institute of Telecommunications & Acoustic, Wroclaw University of Technology

mailto:adam.waz@pwr.wroc.pl

Laser beams which are scattered on the moving objects have different frequency because of the Doppler's effect, so there are possibilities to obtain information about vibrations parameters of this object. This paper describes several kinds of vibrometers and the demodulation devices.

1 The idea of vibrometer

The simplest vibrometer can be built as a Michelson interferometer. This construction has one significant disadvantage, there is no information about movement direction. If we would like to obtain information about movement direction we should use heterodyne detection of the laser radiation (Fig.1) [1].

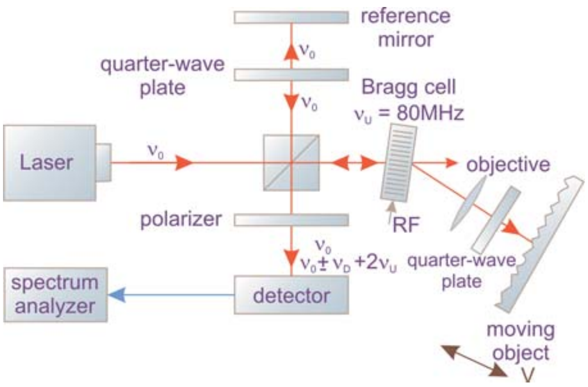

Fig. 1 *Our Doppler shifted vibrometer*

Doppler frequency shift is given by:

$$\nu_D = -2\frac{\overline{Vl}}{\lambda_0} \qquad (1)$$

where: V – object velocity, l – movement vector, λ_0 – wavelength of incident beam

This vibrometer includes frequency shifter – Bragg cell. In that case beams cross the frequency shifter twice, so we obtain frequency carrier as doubled Bragg cell frequency.

2 Fiber – coupled vibrometer

It is possible to build vibrometer which is based on telecommunication's components (Fig.2). Laser diode is used as a light source. The wavelength of this laser (1531nm) is eye safe. The important advantage is that the EDFA (Erbium Doped Fiber Amplifier) can be applied. In the case of very weak scattered signals, the EDFA plays crucial role. In this system frequency carrier is 40 MHz, and signal band can be solve by formula (1) [2].

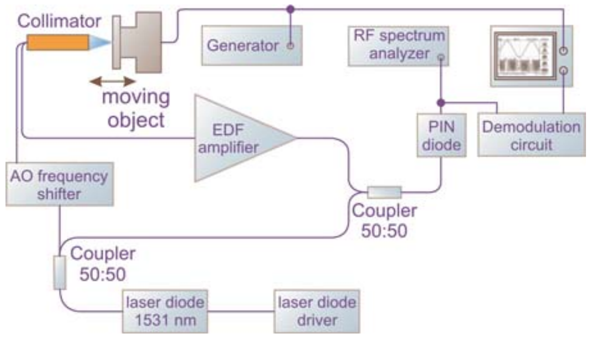

Fig.2 *Fiber coupled vibrometer 1550 nm*

3 Two mode laser vibrometer

Recently we started research with two mode laser vibrometer. The idea of this vibrometer is shown in Fig.3.

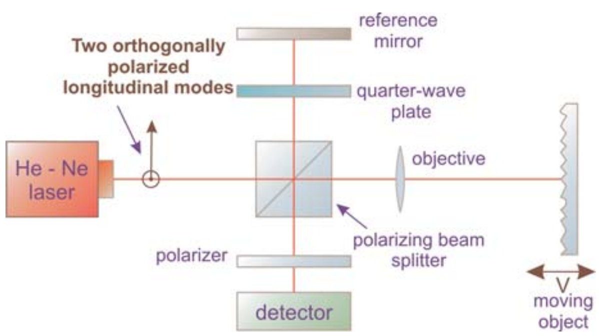

Fig. 3 *Two mode laser vibrometer*

Heterodyne signal frequency is equal to the laser free spectral range frequency – in our case it is 885 MHz.

4 Spectra of heterodyne signals

Electrical signal from detector is frequency modulated. Even small vibrations can cause large frequency deviation, for vibrometer with He – Ne laser it is 3,16 MHz/ m/s. Vibrometers were tested by measurement loudspeaker vibrations. Fig.4 shows the example of detected signal spectrum taken from system presented in Fig.1. In this case loudspeaker was supplied by sinus signal (frequency: 200 Hz)

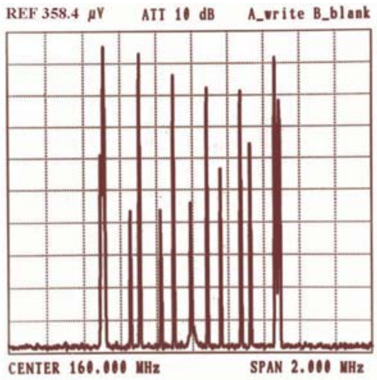

Fig. 4 *Spectrum of signal from He – Ne vibrometer*

Demodulators applied for vibrometers should have relatively wide band. We solved this problem by using a few kind of demodulators in different configurations.

5 Quadratular demodulator

For small signal deviation we use quadratural demodulator, which diagram is shown in Fig. 5.

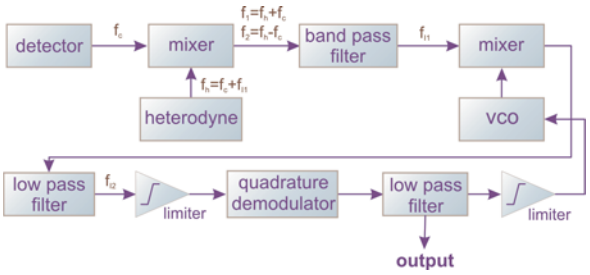

Fig. 5 *Quadratural demodulator*

Linear response of this demodulator is presented in Fig.6 where loudspeaker driving (top) and demodulated signal are illustrated.

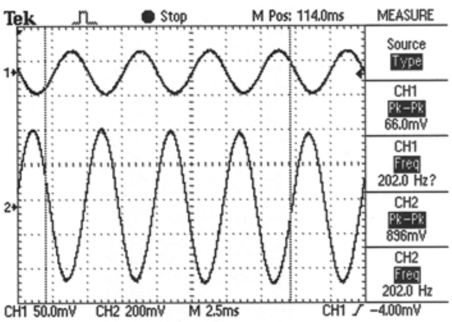

Fig. 6 *Linear response of quadratural demodulator*

Basic parameters of this quadratural demodulator:

- maximum frequency deviation: 75 kHz,
- high sensitivity,
- automatic frequency control ± 300 kHz

6 Demodulator based on PLL

Demodulator based on PLL (Fig.7) is better for larger signal deviation.

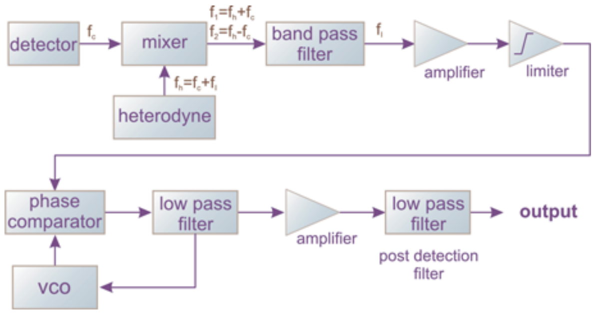

Fig. 7 *Demodulator based on PLL*

The example of PLL demodulator response to larger than previous loudspeaker driving signal is shown in Fig.8.

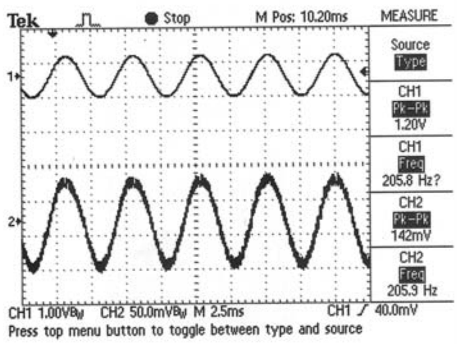

Fig. 8 *Example of signal demodulated by PLL*

Basic properties of our PLL demodulator:

- minimum frequency deviation: 50 kHz,
- small sensitivity for small signal deviation,
- minimum capture range: 0,2 x f_0,
- DC output voltage depends on input signal frequency.

There are possibilities to use PLL demodulator for automatic frequency control (AFC).

Conclusions

We presented current results of our research on electronics devices built to detect the weak heterodyne signals from different kind of laser, laser – fiber vibrometers. These research is under development and we elaborate different demodulation units for different vibrometry techniques.

References

[1] P.R. Kaczmarek, T. Rogowski, A.J. Antonczak, K.M. Abramski, *Laser Doppler Vibrometry with acoustooptic frequency shift*, Optica Applicata, Vol. XXXIV, No. 3, 2004, pp.373-384

[2] P.R. Kaczmarek, M. Kazimierski, A. Waz, K.M. Abramski, *Laser – Fibre Vibrometry/Velocimetry Using Telecommunication Devices*, Proc. SPIE, Vol. 5503, pp. 329-332