Laser Fiber Vibrometry at 1550nm Telecommunication Wavelength

Pawel Kaczmarek, Adam Waz, Krzysztof Abramski

Institute of Telecommunications and Acoustics, Wroclaw University of Technology

mailto:pawel.kaczmarek@pwr.wroc.pl

In this paper we present our investigations connected with a fiber laser vibrometry supported by erbium doped fiber amplifier. We built simple systems of fiber homodyne and heterodyne vibrometers based on single mode fiber interferometer with laser diode 1531nm.

1 Introduction

The laser fiber vibrometry or interferometry up till now have dealt rather with the red range of visible bandwidth. In the other hand fast development of the fiber optotelecommunications in the infrared band 1550nm has caused quite large price drop of such elements like: single mode fibers, fiber couplers, fiber isolators, laser sources, photodetectors, fiber Bragg gratings etc. As a result of above, there is practical opportunity to shift the optical coherent carrier into so called third telecommunication window of the infrared region. It allows to decrease the prices of fiber systems and experiments. However, there is another sufficient reason of shifting the wavelength of measurements into the telecommunication window.

There is also a problem of detection of very weak scattered signals in laser/fiber vibrometry experiments. The power of scattered beam from vibrating object is many order weaker than the power of extracted input beam and proper detection of reflected signal is often impossible because of too low signal to noise ratio. The use of the third telecommunication window gives in this case the great advantage. Weak optical scattered signals can be amplified by adding an erbium doped fiber amplifier (EDFA).

2 Principles of operation

The idea of EDFA application in a fiber interferometer is shown in the Fig.1.

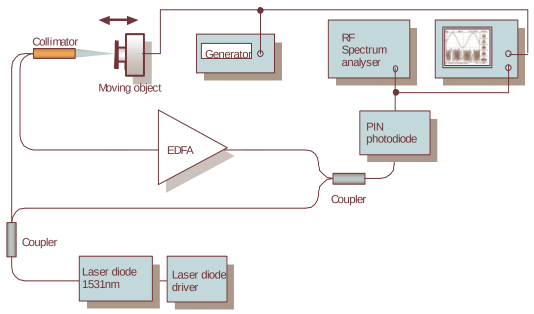

Fig. 1 *Basic homodyne fiber interferometer.*

It is based on Mach-Zehnder configuration. The coherent light from a laser diode is split on two beams in a first coupler. Reference one goes through second coupler to the photodetector while measurement beam falls onto moving object. The surface of an object is optically rough so only small amount of light goes back to the fiber system.

To avoid parasitic interference signals the double fiber collimator should be used for incoming and coming out beams separation. Standard double fiber collimators have very short working distance (about 10mm). To extend measuring distance additional optical elements are needed (Fig.2b) or two single fiber collimators assembled as in the Fig. 2b can be used.

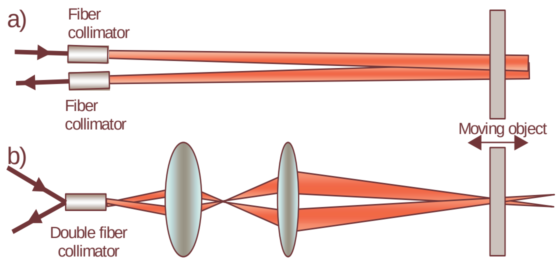

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Fig. 2 *The way to extend double fiber collimators measurement range.*

Weak scattered beam on an object goes to the fiber amplifier and next interferes with the reference beam in second coupler. Gain characteristics and a structure of an EDFA used in our experiments are shown in the Fig. 3.

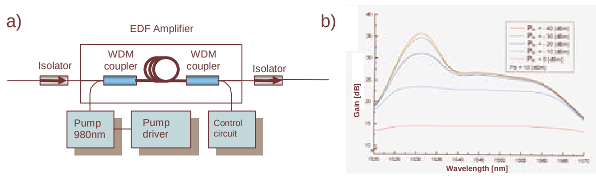

Fig. 3 *a) Erbium doped fiber amplifier, b) its gain characteristics.*

One can see that the best wavelength from amplification point of view is 1531nm where gain is bigger than 35dB.

As a light source a standard telecommunication DFB laser diode have been used. Its spectral linewidth is about 1.1MHz [2] which gives a coherence length enough for this kind of interferometry.

Vibrations measurements in homodyne systems can be performed by standard interference fringe counting method. It does not allow to determine direction of a movement and in the case of scattered light measurements amplitude noise introduced by a light source and EDF amplifier can also be a problem.

3 Heterodyne systems

The heterodyne scheme of interferometry has not this two disadvantages mentioned above. This regime of operation can be obtained by introducing a light frequency shifter in one arm of an interferometer. Figure 4 shows heterodyne system with acoustooptical Bragg modulator. The EDFA is used to amplify beam coming from an object.

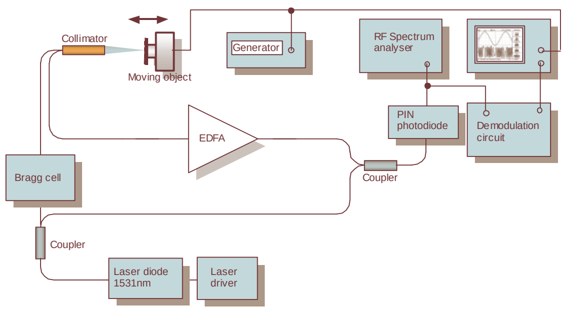

Fig. 4 *Amplifying before beating interferometer.*

From the signal to noise ratio point of view better solution can be first interfere both beams and next amplify a interference signal in the EDFA [3]. However, to get a maximum gain in the fiber amplifier a optical power in a reference beam should be decreased. Both goals (weak reference beam and amplification of an interference signal) can be achieved in setup shown in the Fig. 5.

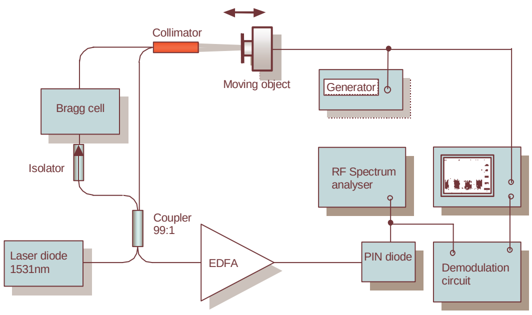

Fig. 5 *Amplifying after beating configuration.*

As a reference beam a backreflection from the coupler is used. Measurement beam goes through an optical isolator, Bragg cell and falls on the object. Then it goes back to the second fiber, interferes with reference beam after coupler and then weak interference signal is optically amplified in the EDFA. This setup produces interference signals with similar level and twice better S/N ratio than amplifying before beating configuration [4].

4 Measurements

Interference signals in the heterodyne vibrometers have form of frequency modulated (FM) carrier. Carrier frequency is equal to frequency shift introduced by a Bragg cell while the frequency deviation is proportional to the velocity of an object (due to Doppler effect) and in the case of 1,5μm wavelength is about 1.3MHz/$^{m}/_{s}$.

For vibrations measurements a simple PLL FM demodulator was applied. Figure 6 shows examples of vibrations measurements performed in amplifying after beating configuration and PLL demodulator.

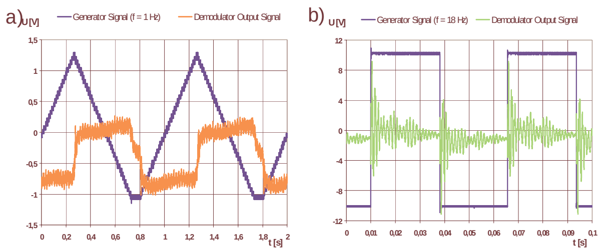

Fig. 6 *Vibrations measurements. b) loudspeaker, b) piezotransducer.*

5 Conclusions

Telecommunication fiber devices are suitable for fiber interferometers construction. In the case of scattered light measurements application of an EDFA enables longer working distances and signal to noise ratio can be easily increased by proper (amplifying after beating) setup development.

References

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