激光技术
Vol.14, No.1

A preferable set for stabilizing the intermediate frequencies (IF) of optical heterodyne

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Abstract: A preferable set for stabilizing the intermediate frequencies of optical heterodyne in optical coherent communications system is developed. A high stability for intermediate frequencies of optical heterodyne may be realized by this set, and stabilizing intermediate frequencies can be adjusted freely. In the coherent optical fiber communication system adopting 1.52μm He-Ne lasers, the tracking stabilization of optical heterodyne intermediate frequencies may be covered in the range of full TV channel when this set is used. Relative to the optical frequency, the frequency stability is better than 10^{-9}.

一种优越的光外差中频稳定装置

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摘要：一种优越的相干光通信系统中频稳定装置已经研制出来。该装置可以实现对光外差中频频率的高度稳定，且所稳定的光外差中频频率可以自由调节。本装置用于一个采用1.52μm He-Ne气体激光器的相干光纤通信系统中，光外差中频在整个TV频道范围内都能跟踪稳定。相对于光频的频率稳定度优于10^{-9}。通信系统传输的图象信号得到了满意的稳定接收。

Introduction

The stability of optical heterodyne IF is one of the key technique in coherent optical communication. There are many kinds and ways of stabilizing the IF. The AFC(automatic frequency control)technique is often used so far. Ordinary, the error signal of frequency is taken by the frequency discriminator and fed back to control the frequency of local oscillation laser, and stabilize the optical heterodyne IF. A "residual frequency difference" is needed to maintain the control in AFC technique. The "residual frequency difference" itself may cause an unstable frequency in certain extent, so the frequency stabilization will not be too high. As the frequency discrimination/phase discrimination technique is adopted, there is no "residual frequency difference" during stabilization, and the frequency stability is increased. In this frequency stabilizing set when an electrical heterodyne is once more proceeded for the optical heterodyne IF, the performance of frequency stabilization set is further increased. It presents an easier realization of frequency discrimination/phase discrimination technique. Particularly the electrical heterodyne (or the secondary heterodyne) gives an optical heterodyne IF stabilization for different frequencies by the convenient adjustment of local electrical oscillating frequency.

Frequency stabilization principle of secondary heterodyne frequency discrimination/phase discrimination

This kind of frequency stabilization method may be called as "secondary heterodyne frequency discrimination/phase discrimination frequency stabilization". The systematic block diagram is shown as Fig. 1.

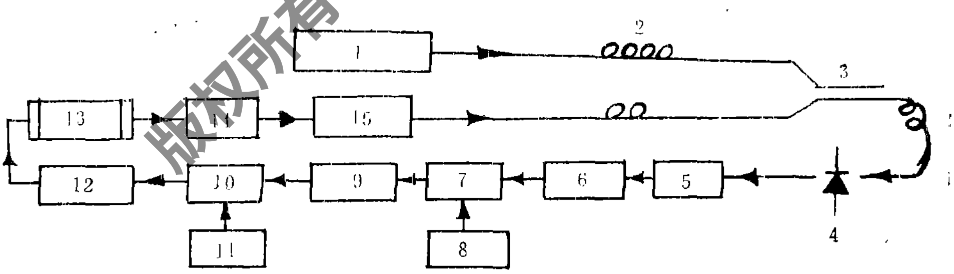

Fig.1 Schematic diagram of 2nd heterodyne frequency stabilizer
1—Optical transmitter 2—SM fiber 3—3dB direction coupler 4—PIN 5—Preamplifier 6—IF recovery 7—Electrical mixer 8—Electrical OSC 9—IF amplifier 10—Frequency discriminator/phase discriminator 11—Reference OSC 12—Filter driver 13—Local oscillation laser 14—Polarizer 15—Polarization control

The signal light sending from optical transmitter through transmission optical fiber and the local oscillation light exciting by local oscillation laser will be received by O/E detector after coupling through 3dB SM optical fiber direction coupler and the optical frequency conversion, i.e. the first heterodyne, will be realized. The optical heterodyne IF, ω_{IF}, is the difference between the local oscillation optical frequency ω_L and transmitted optical frequency ω_C:

$$\omega_{IF}=\omega_L-\omega_C \tag{1}$$

The optical heterodyne signal obtained from the first heterodyne is divided into two path after amplified by the broadband preamplifier. One path is used for communication procession, another path is sent to the electrical mixer after IF carrier recovering, and mixed with electrical local oscillation signal giving the secondary heterodyne. The Ω_{IF} (the frequency of 2nd IF) depends on Ω_L and ω_{IF}, i. e. the local electrical oscillation frequency and the first IF frequency respectively, that is

$$\Omega_{IF}=\Omega_L-\omega_{IF} \tag{2}$$

By passing through a filter driving circuit the second IF will be frequency discriminated/phase discriminated with a highly stabilized frequency reference signal. The output error signal will control the frequency and phase of local oscillation laser and stabilize the optical heterodyne IF frequency.

Frequency discrimination/phase discrimination circuit possesses the frequency discrimination at different frequencies and the phase discrimination at same frequencies. The acquisition lock-in performance of loop circuit is obviously improved owing to the error control signal present also at different frequencies.

After the loop circuit getting into the phase discrimination from frequency discrimination, and causing a phase lock-in state, the second IF frequency will be strictly equal to the frequency of referency frequency:

$$\Omega_{IF}=\Omega_r \tag{3}$$

The electrical local oscillation frequency Ω_L in equation (2) is a determined value on which the optical heterodyng IF frequency ω_{IF} is just stabilized when the second IF frequency is locked in the reference frequency. The stabilized value is in relation to the electrical local frequency Ω_L. Different electrical local frequency gives different stabilized optical heterodyne IF. So, by adjusting the electrical local oscillation frequency, the stabilizing track will be presented for different optical heterodyne IF.

Only one phase difference is needed for maintaining this type of stable frequency control. This technique possesses a favorable frequency stability of no residual frequency.

Frequency stabilization tracking experiment

In the experimental system, 1.52 μm He-Ne laser light sources are adopted as both transmitting laser and local oscillation laser. The transmitting laser frequency is stabilized by a Zeeman laser frequency stabilizer. The amplitude modulation of transmitted optical signal is obtained by an acousto-optic modulator. The optical heterodyne IF frequency is realized by controlling the PZT of local oscillation laser.

Under the condition of laboratory now available, the frequency stabilization may be proceeded for any optical heterodyne IF of 12 TV-bands (TV system in China) frequency range. The experimental result shows the system stability relating to optical frequency stability is better than 10^{-9}. Fig. 2 shows a photograph taken from oscillograph at the frequency stabilization experiment.

a

b

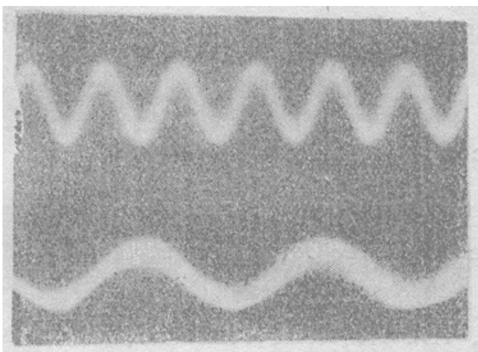

Fig2. Photograph of 2nd heterodyne stabilizing waveform (10ns/div)
a—Optical heterodyne IF, 80 MHz b—2nd IF, 34 MHz

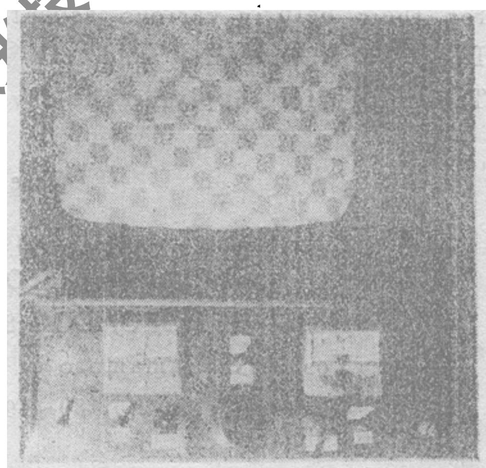

Fig.3 The received TV signal at stabilized optical heterodyne IF

In transmission experiment, the analogue TV test signal was transmitted and received by TV set. The stable receiving gives a satisfactory result.

Fig. 3 shows a screen photograph of TV receiver when the monochromatic check signal was received.

Conclusion

Theoreticaly, frequency stabilizing set may carry on tracking stablization for optical heterodyne IF, far exceeding the TV-band. It is in relation to the amplifier bandwidth, the response speed of O/E detector. Moreover, it does not need special requirement for optical wavelength and the laser applied. In order to realize the IF stabilization for semiconductor laser coherent system, this system may also be adopted. In addition, the optical heterodyne IF to be stabilized can be adjusted freely. This feature will offer a possible technique for heterodyne detection of optical wave multiple channel communications.

The author Xiao Shilin would like to express his thanks to Associate Prof. Tang Mingguang and to Prof. Liu Shuqi of the University of Electronic Science for giving him the foundation of developing this kind of frequency stabilization at his study for M.S.degree. The authors wish to thank their colleagues, He Zhenchuan, Jiang Lijuan and Fan Xiaohong at the Guilin Institute of Optical Communication for their help in various aspects of the work. Also, thanks to the Dong Nan University and the Shanghai University of Science and Technology for supplying the devices concerned.

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收稿日期：1989年7月13日。