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HETERODYNE DETECTION OF SAW-MODULATED LIGHT WAVES[1)]

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For applications of integrated optic in communication systems the interaction of Surface Acoustic Waves (SAW) and light waves is an important method for signal processing. The paper deals with the heterodyne detection of modulated light by use of SAW on $LiNbO_3$-integrated optical devices; experimental results are given.

I. INTRODUCTION

The development of Broad—Band—Fibre—Optical communication-systems requires new methods of light-modulation, in order to utilize better the great brandwidth of light (10^{14} Hz). Besides the earlier existing intensity — modulation we also have to employ phase- and frequency-modulation of light. A method to receive frequency-modulated optical signals is the heterodyne detection, which has been known since 1930 for receiving broadcasting signals.

In the optical communication technique it is possible to modulate light with an integrated optical Bragg-modulator, which works with Surface Acoustic Waves (SAW) and afterwards receives the light through heterodyne detection.

This paper deals with the Bragg-modulation of light and the heterodyne detection of a frequency-modulation-signal.

II. BRAGG-MODULATOR

For modulation of guided optical waves we applied an integrated optical Bragg-modulator on the basis of $LiNbO_3$. (Fig. 1)

On the left the light is guided by a Titanium-doped $LiNbO_3$-waveguide (monomode light from He—Ne-LASER, wavelength 0.6328 μm). There we have the interdigital transducer (IDT), which has produced the SAW. The SAW forms a phase-lattice in the interaction-zone and the guided light is diffracted.

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When the angle between the guided optical wave and the SAW is the Bragg-angle

$$\Theta_B = \arc \sin \frac{m \cdot \lambda_L}{2n_f \Lambda_{SAW}}, \tag{1}$$

λ_L = wavelength of light; Λ_{SAW} = wavelength of SAW; n_f = Break-index (=2.28); m = order of diffraction, then all the energy would be deflected in the first order $m = 1$. Besides the frequency of light ω_B changes according to formula

$$\omega_B = \omega_L \pm \omega_{SAW}, \tag{2}$$

ω_L = frequency of the input light.

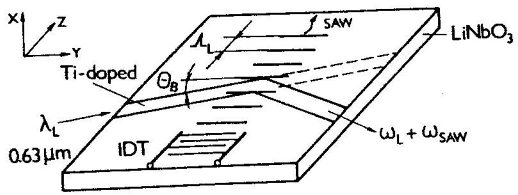

Fig. 1

Because the SAW is propagated in one direction, we have the doppler-effect and only "plus" in the formula (2). The Bragg-modulator is a single-sideband-frequency-modulator.

III. HETERODYNE DETECTION

A direct detection of frequency-modulated light is not possible, because a simple Avalanche-Photodiode integrates over the power of light. For frequency-detection therefore the light is mixing in a heterodyne detector by heterodyning the received light with the light of the local oscillator and the mixing at a nonlinear optical device (fotodiode).

Compared with direct detection we get by the heterodyne detection a greater signal power. By direction the signal current i_{SD} is proportional to the optical signal power P

$$i_{SD} = k_1 * P \tag{3}$$

but by heterodyne detection the signal current i_{SH} is also dependent on the power of the local oscillator P_{LO}

$$i_{SH} = k_2 * \sqrt{P_{LO} * P}. \tag{4}$$

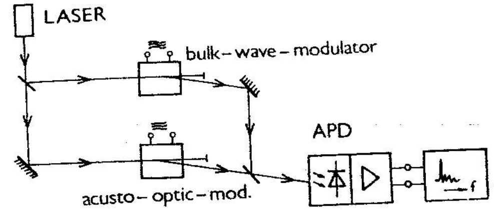

Fig. 2

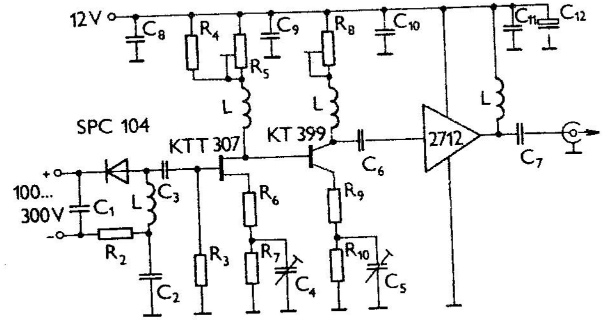

Fig. 3

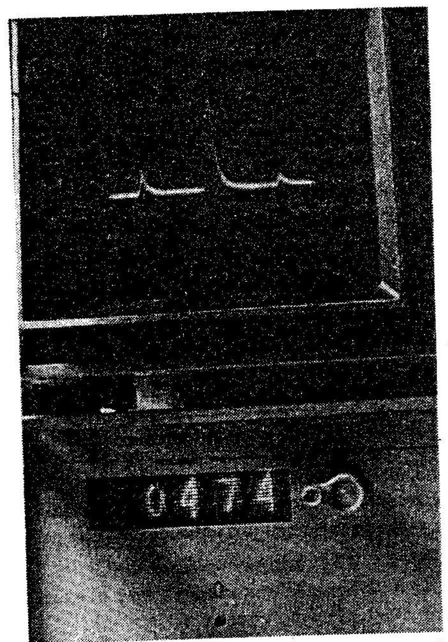

Fig. 4. The spectrum of the direct detected signal

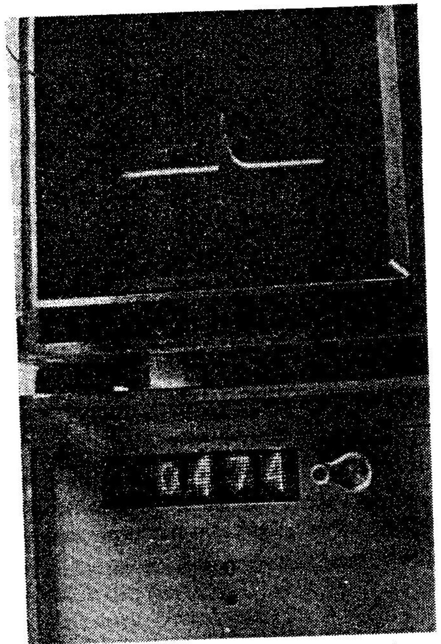

Fig. 5. The spectrum of the heterodyne detected signal

It is possible to use high power of a local oscillator, and therefore the signal current at the output of the heterodyne detector will be higher.

Fig. 2 shows the optical circuit of the heterodyne detector. At the top the light from the He—Ne-LASER enters the Bragg-modulator and at the bottom the bulk-wave-modulator. This reference-bulk-wave-modulator produces the reference—frequency—signal (like the local oscillator). Over a transparent mirror both beams fall in the Avalanche diode and we get at the output of the amplifier the mixing of the signals $\omega_{Bragg} + \omega_{reference}$. Fig. 3 shows the electric circuit of the optical detector with the electronic amplifier.

Fig. 4 and Fig. 5 show the results of detection by a spectrum analyser.

IV. CONCLUSION

This arrangement has little efficiency of diffraction, but currently we are preparing a better Bragg-modulator with a Chirp-Interdigital-Transducer and Horn-structure of the lightwaveguide. The Bragg-modulator and the heterodyne detector find applications in communication systems (especially frequency-multiplexing) and in measuring methods (Gyroscopy, Spectroscopy).

At the Technical University of Dresden we work on the improvement of the Bragg-modulator and the heterodyne detector.

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ГЕТЕРОДИННОЕ ИЗМЕРЕНИЕ ПАВ — МОДУЛИРОВАННЫХ СВЕТОВЫХ ВОЛН

В применениях интегральной оптики и системах связи взаимодействие поверхностных акустических волн (ПАВ) со световыми волнами является важным методом для обработки сигналов. Работа посвящена гетеродинному измерению модулированного света при помощи ПАВ на $LiNbO_3$ интегральных оптических устройствах. Приведены экспериментальные результаты.