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OPTICAL DIFFERENTIAL METHOD FOR PROBING OF SURFACE ACOUSTIC WAVES[1]

K. ČÁPOVÁ[2], Žilina

A coherent light beam reflected by a sample surface is diffracted if a surface acoustic wave propagates along the reflecting surface. The diffracted light contains information on the surface acoustic wave properties. The differential heterodyne method of processing the diffracted light using two diffraction ±1 order beams is described in this paper.

ОПТИЧЕСКИЙ ДИФФЕРЕНЦИАЛЬНЫЙ МЕТОД ДЛЯ ЗОНДИРОВАНИЯ ПОВЕРХНОСТНЫХ АКУСТИЧЕСКИХ ВОЛН

Если фронт акустической волны распространяется вдоль отражающей поверхности, то пучок когерентного света, отраженный от поверхности образца, испытывает дифракцию. Дифрагированный свет содержит информацию о характере фронта акустической волны. В работе описан дифференциальный гетеродинный метод обработки дифрагированного света, использующий два пучка ± 1 порядка дифракции.

I. INTRODUCTION

With the present-day rapid development of integrated techniques the demand for the measurement of the characteristics of planar structures increase. In accordance with the development of integrated optics there are some possibilities to investigate characteristics of these structures by means of surface acoustic waves. The propagation of surface acoustic waves is influenced by the characteristics of a surface layer of the same depth as a wave length of the SAW (surface acoustic wave). The local properties of SAW are an image of local properties of the surface structure. Thus the need of a local scanning and measurement of the acoustic field arises. This need is connected with the investigation of the SAW field in application elements working on the principle of SAW.

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[2] Dept. of Physics of the Technical University of Advanced Transport and Communication Engineering, CS—010 88 ŽILINA.

II. FUNDAMENTAL METHODS

The interaction of a light beam with a solid surface offers some possibilities in this case. If SAW propagate along the solid material surface, this surface becomes a periodical structure which can cause a light beam diffraction. The diffraction pattern gives us information on the character of the structure in a point of light incidence. Fig. 1, [1], represents an arrangement of a light-acoustic interaction for an optical probing of SAW suitable also for opaque materials, even if the light-acoustic interaction efficiency is relatively small in this case.

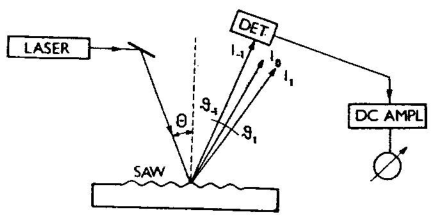

Fig. 1. The principle of the simple optical probing of SAW.

The main problem of the optical probing of SAW is the way to obtain information on SAW from the diffraction pattern. From this point of view optical probing methods can be divided into two groups. The former involves simple SAW probing methods, the latter heterodyne optical methods [2]. In case of simple probing the resulting signal created by direct detection of one of the diffraction beams gives us information on the SAW amplitude and propagation velocity, but it

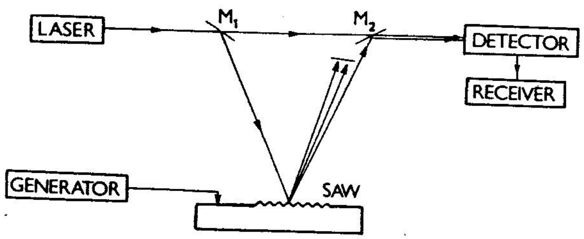

Fig. 2. The principle of the optical heterodyne probing of SAW.

does not allow to measure phase relations of the acoustic field. To be able to measure phase relations the heterodyne detection of the diffraction light beam must be used. The principle of this detection consists in a superposition of the signal beam and a reference light beam usually separated directly from the incident light beam, Fig. 2 [3]. In such a case the reference beam does not carry any information on the SAW.

III. OPTICAL DIFFERENTIAL METHOD

The optical differential method of the SAW measurement represents the special optical heterodyne probing method. Two laser beams created by means of semitransparent mirrors are reflected from the same point of the surface along which SAW propagates. If angles of incidence of both laser beams Θ are equal to the 1st order diffraction angle

$$\vartheta_{\pm 1} = \arc\sin \lambda/\Lambda\ , \qquad (1)$$

where λ and Λ are light and SAW wavelengths, the photodetector evaluates the superposition of two diffraction ± 1 order beams, Fig. 3. Both superimposed

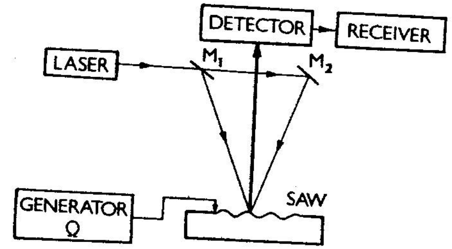

Fig. 3. The principle of the optical differential method.

diffraction light beams carry the required information on SAW, because both beams are created by means of the acoustic field. We have obtained the expression for the resulting light intensity of the scanned signal under the condition of the total overlap of both diffraction beams

$$I = I_0(2k\cos\Theta)^2\{[a_1^2 + a_2^2 + 2a_1a_2\cos 2Kx_0] - [(a_1^2 + a_2^2)\cos 2Kx_0 - 2a_1a_2]\cos 2\Omega t - (a_1^2 - a_2^2)\sin 2Kx_0 \sin 2\Omega t\}\ , \qquad (2)$$

where I_0 is the incident light intensity, k the incident light wave number, Θ the angle of incidence of both light beams, a_1 and a_2 amplitudes of the direct and the reflected SAW, K the SAW wave number, Ω the SAW angle frequency, x_0 the coordinate of the centre of the laser beams reflection region in the SAW propagation direction. The resulting light contains both the dc and the ac components. The latter component is modulated by the frequency 2Ω. This fact allows both simple and heterodyne signal processing. The detector signal contains also information on the standing wave ratio of SAW, which is important for the investigation of inhomogeneities of solid surfaces as well as of properties of planar structures.

In comparison with the other heterodyne methods the optical differential method is not so sensitive to mechanical perturbations (vibrations) of the basic solid material. In classical heterodyne methods vibrations of the sample cause additional variations of the optical path of the signal beam and so phase variations, while the reference light phase is unchanged. In the optical differential method the phase variations are the same for both beams, so that there is no additional phase shift in the resulting light signal. Another advantage of the optical differential method is the possibility of using a simple optical arrangement.

V. CONCLUSION

The optical differential method analysis gives us information enough on SAW, it is relatively simple and therefore suitable to measure both the SAW characteristics and the planar structure properties.

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