HIGH FREQUENCY ACOUSTOOPTICS

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Paper is devoted to the development of acoustooptical (AO) components such as Bragg modulators, deflectors, others on very high frequencies (up to 10 GHz) working in wide frequency range (up to 3 GHz). There also considered some traditional and modern applications of these devices.

The main principles and peculiarities of Bragg cells design are discussed. The results of experimental investigation are correspond to theoretical predictions. The specific problems, which are stipulated by very high frequency range, are considered. There are: large sound attenuation influence; peculiarities of interaction geometry and light aperture forming; multilayer transducer's features; electrical matching with electromagnetic power wave guide. The ways of High Frequency Bragg cells parameters optimisation are discussed.

1. Introduction

In spite of a wide range of today's AO use, there remains a big temptation to find new applications of acoustooptics due to its unique abilities for various domains of informational signal's processing. This especially concerns to high frequency acoustooptics, which attracts the attention by possibilities to increase the speed, the bandwidth, the spatial and time resolution of processed signals.

The main problem, which restricts the shifting to more high frequencies, is the big sound attenuation in known materials, which fit for the acoustooptical use. There are also some problems like electrical and acoustical matching of piezoelectric transducer with electromagnetic power wave guide and sound conductor, reduction of relative AO frequency band due to lessening of sound beam divergence, peculiarities of AO interaction geometry and others. In present work we decided to attract the attention to some specific questions when creating high frequency AO components and besides to discuss possible new applications of high frequency acoustooptics.

2. Some applications of high frequency acoustooptics

2.1. High frequency AO deflectors

To obtain big absolute frequency band, the enlarging of central frequency is reasonable. But due to some natural problems the upper frequency of produced for market deflectors not exceed about 3 GHz. At the same time there are many tasks in which the use of real time AO processing is desired at very high frequencies. In our recent works we showed the possibilities to build the AO deflectors with very high central frequency (up to 10 GHz) and very wide bandwidth (up to 3 GHz) [1]. Now we pay attention to some peculiarities when creating very high frequency AO cells.

To extend the bandwidth of AO interaction on high frequencies usually multielement transducer is used as the application of unique element leads to decreasing the diffraction efficiency. The application of anisotropic regime restricted by crystal's features at certain frequency regions. The choice of multielement transducer's type depends mainly on necessary central frequency. Say, at frequencies about 1 GHz the filter-type multielement transducers are more preferable, as they allow providing good electrical matching accordingly to equivalent scheme and planar architecture of filter's cell. At frequencies about 10 GHz the electrical separation to unique elements drastically enlarges electrical losses. The best solution in this case is to use the acoustical separation of unique elements providing the necessary phase shift between neighbouring elements. The electrical matching in this case can be provided by application of smooth or step-type transformers of electrical impedance. The acoustical matching of the transducer's layers with elasto-optical medium provides by fulfilment of theoretically predicted relationships between acoustical impedances as well as between the thickness of layers.

The next task concerns to decreasing of sound attenuation influence. This problem can be partly solved by optimisation of interaction geometry in AO cell in such a way that optical beam diffracted on the inclined sound beam outputs from the cell in parallel to transducer's plane at the central frequency of interaction region. In this case the optical beam can be displaced very closed to the transducer and the influence of sound attenuation can be minimised.

2.2. AO high frequency standing wave modulators

Acoustooptical modulator of the light diffracted on standing sound waves has found some specific domains of applications like, for example, laser mode synchronisation, fluorometry light modulation and others [2]. Main advantage of AO standing wave modulator consists in the possibility to obtain 100% light modulation. Of course one can talk about 100% light modulation just in the case when attenuation of sound can be neglected [3]. Such a device can be designed at low frequencies, not higher than about one hundred megahertz where sound attenuation in some materials still not very big. The optical beam then must be directed closed to the free end of acoustical resonator, so that to decrease the influence of sound wave attenuation. But on more high frequencies the sound attenuation became big enough and sound amplitude degradation leads to difference between the amplitudes of opposite direction sound waves, which form the acoustical standing wave. And as a sequence the modulation index is drastically decreased.

Nevertheless in some tasks (for example for light modulation in manufacturing robots image recognition) it is very attractive to have high frequency light modulator with 100% modulation coefficient.

In our laboratory was offered and designed the AO standing wave modulator on central frequency 5 GHz with modulation index closed to 100% [4]. To overcome before mentioned problem the acoustical standing wave was formed by two sound waves generated by two, separated electroacoustical transducers which were placed on opposite butt-ends of acoustical resonator. 5 GHz electrical signal from generator output after amplification was separated onto two signals, the amplitudes of which could be tuned with separated attenuators. Such an approach allowed building the device in with the acoustical standing wave is situated in the middle of crystal and can be easily reached by optical beam destined for modulation. AO standing wave modulator designed for 5 GHz showed good accordance to theoretical predictions.

2.3. AO holographic display for 3D moving image reconstruction

The basic idea of such kind of display consists in substitution of classical static optical hologram by dynamic optical hologram created by refraction index variation stipulated by acting of complicated high frequency sound field [5-7]. It is assumed that the transmission function, both static optical hologram and dynamic acoustically created optical hologram are equal at certain moment of time. This sound field is created by the set of unique thread-type transducers each of that excites wide angle, wedge divergent sound beam. Electrical signals, which directed to the transducers are came from computer controlling driver. These signals are formed in accordance to special algorithm, which takes into account the sound attenuation, each beam divergence, pixel's distortion and other peculiarities. Such electronically created dynamic optical hologram is illuminated at certain moment of time when the whole frame is formed. The sequence of electronically controlled continuously changed frames allows recreating bulk holographic moving image. Each unique transducer has a thread-kind shape that together with high frequency regime stipulates forming of thick optical hologram similar to so-called Denisyuk Hologram [8]. Such hologram can be called Bragg acoustically created hologram as it allows realising the Bragg diffraction of light on such a hologram. The Bragg regime allows to concentrate the energy in one first order of diffraction; to enhance the diffraction efficiency; to enlarge the space resolution; using the anisotropic regime of diffraction - to cut the useless zero order transmitted and scattered light. In spite of number of problems, which meet at the way of building of such systems, this approach seems prospective for large application areas.

2.4. Other applications

It is possible to continue the list of applications of Acoustooptics at very high frequencies; but due to restricted space of this paper we just briefly touch some more of them.

- When creating of acoustical microscopes for frequencies more than 1 GHz one can meet the problem to digitise the short time signal, which outputs from acoustical objective. The acoustooptical architecture of sound microscope offers the original decision of this task solving.
- The set of effective high frequency AO devices can be build on the effect of resonant acoustooptical conditions [9], when the optical wave length rushes to the band gap in semiconductor materials like GaAs or InP. Thus, the AO switch for about 32x32 and more channels for optical fiber use can be easily designed for the wave length 1.3 micrometers which is very claimed for telecommunication needs.

3. Conclusion

The great attractiveness of high frequency acoustooptics stipulated by it's advantages like: big absolute frequency bandwidth; Bragg regime of diffraction, that allow to save the optical energy in one diffraction order; small sound wave length, which can be compared with optical one; and others. The restriction for shifting for more high frequency mainly concerns to high sound attenuation in today's known materials fit for acoustooptics. But in spite that problem, taking into consideration the peculiarities of AO cells design, there are some ways to build the effectively working real time systems based on high frequency acoustooptics.

4. References

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