Two-axes Acousto-optics Deflector on KGW crystal

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Abstract. The problem of creating an acousto-optic two-axes deflector for a high-power laser radiation is considered. The two-axes deflector is a suitable device for laser technology, capable to replace the scanning module based on agile mirrors. The scanning module convenient to control a laser beam, for example, in laser engraving. It can also be used for 3D printing additive technologies.

1. Introduction

Acousto-optic (AO) filters, deflectors and modulators are effective devices to control laser radiation using Bragg's methods of light diffraction on sound wave. A two-axis deflector is a device which is suitable for laser technology, capable of replacing the scanning module on adjusting mirrors. The scanning modules are necessary to control deflection of the laser beam, for example, for laser engraving. It can also be used for additive 3D printing technologies. AO deflector allows you to tune in one position to another without scanning the space between them. Which is fundamentally impossible to realize with traditional devices based on mirrors. Design of a two-coordinate deflector requires the development of a conceptual diagram of the AO interaction, the creation of a functional layout and its approbation. It will also be necessary to carry out tests of resistance to high-power optical radiation to confirm the available literature data on ability of KGW to withstand high power laser radiation, up to 180 GW / cm^2 [1], which is more than an order of magnitude higher than that for any other materials used in the acousto-optics.

Any AO device usually consists of a single crystal with specific physical properties, where the transmitted optical radiation diffracting on acoustic wave, generated by piezoelectric transducer. With extension of laser technologies, for example, prevailing uses of diode pumping, the variety of high-power sources is growing, which increases the demand for devices to control high-power laser radiation. The acoustical, optical, and photo elastic properties of biaxial crystals of the potassium-rare-earth tungstate family, especially of the potassium-gadolinium tungstate $KGd(WO_4)_2$ (short: KGW) were studied for the first time [2]. It has been demonstrated for the first time that their AO figure of merit M_2 is comparable with that of $LiNbO_3$ and better than M_2 of SiO_2. Moreover KGW crystal has monoclinic structure, transparent in visible and infra-red ranges (0.4-5.5 μm), has significant anisotropy and optically biaxial.

A laser shutter to "switch" on and off the optical radiation are widely used in laser systems for engraving or photolithography, based on two axes deflecting mirror. A two-axes AO deflector could replace the scanning module on movable mirrors, proposed. It allows to perform arbitrary local addressing – to adjust from one position to another without scanning all the space between. The

absence of moving parts is also an advantage to the basic scanning modules. In addition, the proposed device can simultaneously perform the functions of a gate, and the higher AO efficiency of KGW does not require a high control power (not more than 4 W), which makes it possible to refuse forced cooling of the AO cell. This significantly simplifies the design of the device and allows you to expand the scope of the deflector.

2. Two-axes AO deflector

To use the material in acousto-optics, it is necessary to know its characteristics, including optical, acoustic, and photoelastic properties. Crystals of the $KRE(WO_4)_2$ family, especially potassium gadolinium tungstate $KGd(WO_4)_2$, are well known materials. The mediums are transparent in the wavelength range 0.4-5.5 μm of light, from UV to near IR. Nowadays, the power of available laser sources is increasing, and traditional AO materials don't fully satisfy the requirements for controlling such irradiation. With high radiant power, it is not possible to use TeO_2 paratellurite crystals, which is state of art medium in acousto-optics. With high transmitting optical power the TeO2 changes irrecoverably, for example, colorization of the crystal happens. To solve this problem, crystalline quartz α-SiO2 is still used, which requires a higher power of the control signal, which makes it necessary to cool the piezoelectric transducer and the AO cell [3, 4].

Creation of a two-coordinate AO deflector requires the development of a conceptual scheme of interaction, the development the functional layout and its approbation. Such a device is necessary to control deflection of the laser beam and is capable to replace the scanning module on movable mirrors. The analysis shows that it is impossible to realize the deflection geometry on the single acousto-optics cell made of KGW, due to low efficiency for one of directions. That;s why devise consists of two AO cells, as shown at figure 1.

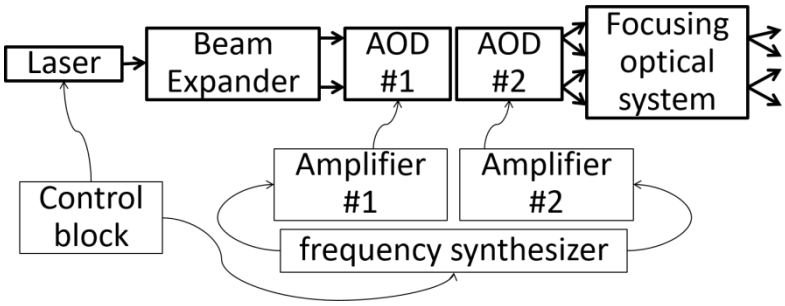

Figure 1. Scheme of two-axes AO deflector.

3. Conclusion

The problem of creating an acousto-optic two-axes deflector for a high-power laser radiation is considered. The two-axes deflector is a suitable device for laser technology, capable to replace the scanning module based on agile mirrors. AO deflector allows performing arbitrary spatial addressing - changing from one position to another without scanning the space between the positions, which cannot be realized with traditional devices with tilting mirrors in principle. Theoretically, it is possible to perform the deflectors operation in the shutter mode and combine both function on the same device. The absence of mobile optical elements is also a feature and an advantage with respect to traditional scanning modules. The scanning module convenient to control a laser beam, for example, in laser engraving. It can also be used for 3D printing additive technologies.

A very promising AO element suggested which can control high-power laser beams. It is capable to operate with more intensive laser beams than the existing TeO₂ deflectors, requiring somewhat higher driving power.

4. References

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