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Auto-Generator on Magnetic-Optical Crystal

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Abstract—The paper considers principles of designing an auto-generator with optical channel in the feedback circuit based on magnetic-optical crystal, in which magnetic-mechanical oscillations take place. A reference design of auto-generator based on yttrium iron garnet is provided along with its experimental research results.

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INTRODUCTION

Auto-generators with frequency stabilization provided by means of quartz resonators are widely used in different electronic devices. Frequency tuning in such generators is practically impossible, since the frequency of automatic oscillations is defined by high-quality mechanical oscillations in resonator. On the other hand, it is well-known that ferromagnetic (FM) materials placed in constant polarizing magnetic field change the absolute value of their Young parameter by up to 10–15% [1]. Thus, FM provide a possibility of controlling the propagation velocity of ultra-sound waves by changing the value and/or orientation of magnetic field.

This property of FM is suggested to be exploited to design a controlled auto-generator based on magnetic-optical crystal (MOC). Papers [2, 3] deal with research on resonance change of inductance of a coil with original structure and toroidal core that can make radial mechanical oscillations. However due to peculiarities of magnetic field in toroidal core it is extremely difficult to control core's stiffness and the corresponding frequency of automatic oscillations.

This paper aims to consider physical principles of designing and finding amplitude and phase balance conditions for magnetic-controlled auto-generator based on MOC in the magnetic-mechanical resonance mode. We also experimentally confirm the possibility of controlling auto-generator's frequency by changing constant magnetic field.

1. INFLUENCE OF MAGNETIC-MECHANICAL OSCILLATIONS IN MOC ON POLARIZATION OF A LIGHT WAVE

Consider an MOC with a shape of a long rod with length $2l$ and transverse dimensions much less than its length. In order to facilitate magnetic-mechanical oscillations MOC is placed inside a solenoid, whose magnetic field is aligned with the rod ($0x_2$ axis) and consists of a constant H_0 and a variable $h(t)$ components.

Field H_0 is polarizing and its value is chosen considering the necessity of providing maximum sensitivity of FM's magnetization to deformation. According to [1], the value of H_0 should provide magnetic inductance at the level of $\approx 0.6B_s$ inside the FM, where B_s is saturation inductance. The variable component is given by $h(t) = h^* \exp(i\omega t)$, i.e. it oscillated with frequency ω. In order to provide high-quality mechanical oscillations the crystal is left in a free state, i.e. it is not constrained by any structure elements.

Magnetic field H_0 generates a matrix of piezomagnetic constants m_{kij} whose linear-approximation values are given by

$$m_{kij} = m_{pkij} H_p^0 \equiv m_{2kij} H_0, \tag{1}$$

where m_{pkij} denotes components of tensor magnetostriction constants. Therefore