Faraday isolators for high (>1kW) average power lasers

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Abstract— Faraday isolators for high average power lasers are surveyed. Four devices with the most known optical schemes are considered: traditional scheme, schemes with compensation of thermally induced depolarization inside magnetic field and outside magnetic field and cryogenic Faraday isolators.

Keywords— Faraday isolators, thermally induced depolarization, cryogenic cooling

Intense development of laser technique and average power enhancement of CW and pulse-periodic radiation demand reduction of thermal effects arising in different optical elements due to laser radiation absorption.

The Faraday isolator (FI) is one of laser optical elements heavily exposed to thermal self-action due to relatively high radiation absorption in the medium of a magneto-optic element (MOE). The first experimental observation of thermal effects in FI was described in [1]. Later theoretical and experimental studies of thermally induced effects and their compensation was initiated [2]. Heat generation leads to an increase in average MOE temperature and a temperature gradient in its bulk which, in turn, results in inhomogeneous changes of all temperature dependent characteristics and nonuniform expansion of the optical element. Thermal expansion of the MOE and temperature dependence of the refractive index give rise to wave front distortions referred to as “thermal lens”, but do not cause pronounced polarization distortions of the laser radiation.

Temperature dependence of Verdet constant lead to the change in the path difference between two circular eigen-polarizations inhomogeneous over the cross-section but do not change the eigen-polarizations. This results in an inhomogeneous distribution of the Faraday rotation angle; hence, there arises a depolarized field component. The depolarized radiation is the radiation whose polarization is constant in time but is distributed nonuniformly over cross-section. As was shown in [2], in the rod MOE the contribution of this effect is negligible compared to the contribution of the photoelastic effect and, according to [3], it becomes significant at small MOE lengths and cryogenic temperatures. The arising inhomogeneous distribution of the rotation of the polarization plane depends on the power of laser radiation and, at fixed power and shape of heat generation source, may be compensated by profiling the magnetic field when fabricating the magnetic system [4].

The temperature gradient causes mechanical stresses in the MOE bulk that give rise to linear thermally induced birefringence due to the photoelastic effect. The eigen-polarizations become elliptical at each point of the MOE cross-section and have their own path difference and inclination relative to the crystallographic axes. As the laser radiation power is changing, both the path difference and the eigen-polarization inclination generally change too. This leads to additional distortion of the wave front that depends on mutual orientation of the laser radiation polarization relative to the crystallographic axes and to appearance of a depolarized field component. So, for the FI operating at room temperature the photoelastic effect completely determines the depolarized radiation, the isolation ratio depends on the power of laser radiation and decreases appreciably with its increase. Therefore, search for methods that would reduce or suppress thermally induced birefringence in FI caused by mechanical stress due to temperature gradient is one of the most urgent problems in high-power laser engineering.

In this work FI-s for high average power lasers are surveyed. Four devices with the most known optical schemes are considered: traditional scheme, schemes with compensation of thermally induced depolarization inside magnetic field and outside magnetic field and cryogenic FI-s. The possibilities of constructing high-power FI-s on new magneto-optical media (ceramics: TGG, TAG [5], Ce:TAG, crystal TSAG) are analyzed.

REFERENCES