Effect of magnetic field orientation on the behavior of linear dichroism in YIG:Co epitaxial film

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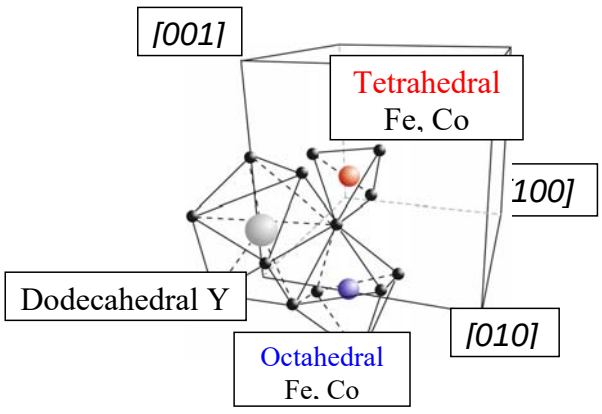


The $Y_3Fe_5O_{12}$ structure:
8 formula units in the cubic unit cell;
a lattice constant of equal 12.376 ± 0.004 Å;
24 Y^{3+} ions in dodecahedral *c* sites;
16 Fe^{3+} ions in octahedral *(a)* sites;
24 Fe^{3+} ions in tetrahedral *(d)* sites

The magnetization in pure YIG originates from the superexchange interactions between the Fe^{3+} (*a*) and Fe^{3+} (*d*) ions.

Inserting the highly anisotropic Co ions in the sites of tetrahedral and octahedral Fe^{3+} has a dramatic effect on the properties of the garnet. Of special interest are magnetic anisotropy behavior and promising for practical applications photomagnetic properties [1] which are not characteristic for pure YIG.

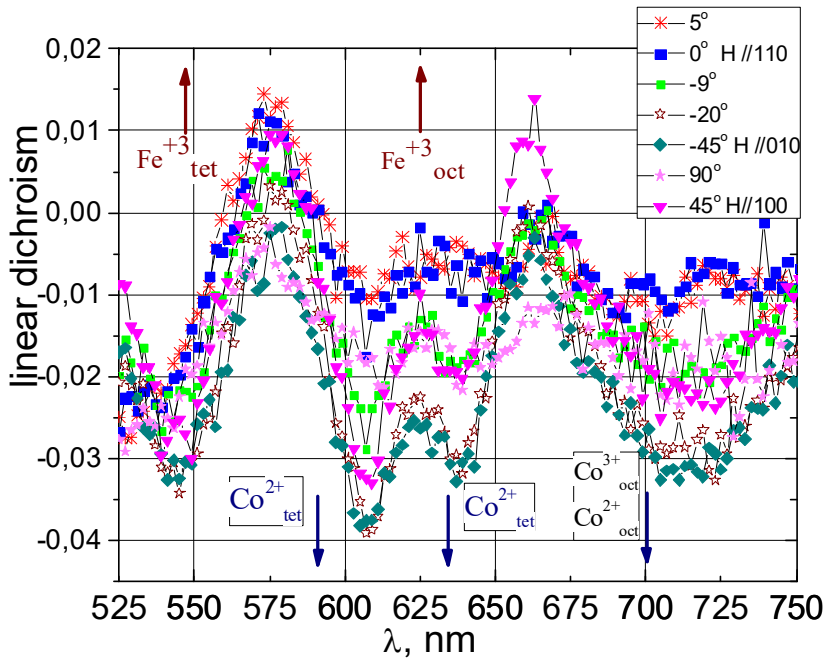
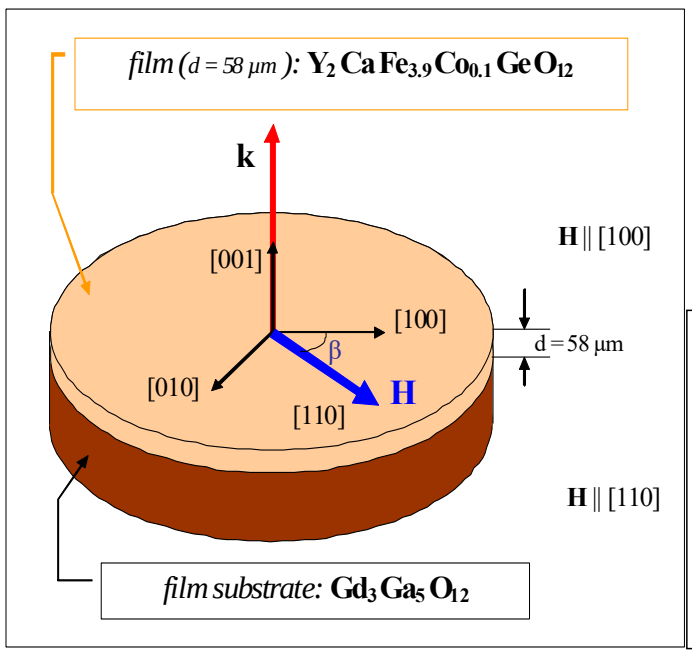
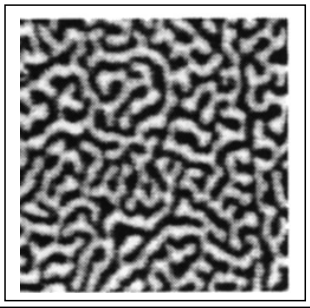


Fig.1. Linear dichroism spectra measured in a magnetic field **H** = 8.8 kOe, that changes the orientation relative to the crystallographic axis [110]. The angle β=0º corresponds to the orientation **H**|| [110]. T≃ 50K The value $(I_1 - I_2)/(I_1 + I_2)$ (linear dichroism) was measured using the modulation method, I_1 and I_2 being the intensities of light with the orthogonal polarizations. **k**||[001]. The arrows indicate the wavelengths of transitions in Co and Fe ions at tetra- and octahedral positions [6].





The domain structure of $Y_2CaFe_{3.9}Co_{0.1}GeO_{12}$ film observed in polarization microscope. The easy axis direction is along [001] axis [2].

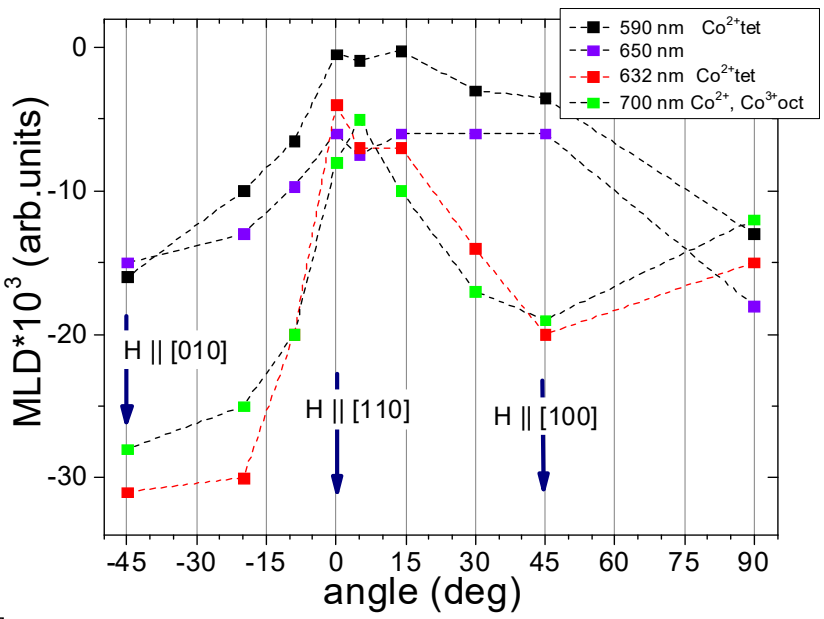


Fig.2. Dependences of the magnitude of linear dichroism induced by a magnetic field (MLD) in $Y_2CaFe_{3.9}Co_{0.1}GeO_{12}$, film on the angle between the magnetic field and crystallographic axis [110]. The values of MLD were measured at the wavelengths of transitions in Co ions [6] and at arbitrary wavelength. Direction of the light beam **k**||[001], **H** = 8.8 kOe, T≃ 50K.

The Co^{2+} magnetic ions in the tetrahedral sites of the YIG lattice create a strong uniaxial magnetic anisotropy in the [111] direction and play a leading role in creating a single-ion magnetic anisotropy in the doped crystal YIG:Co [3].

The exact composition of the YIG:Co film is **$Y_2CaFe_{3.9}Co_{0.1}GeO_{12}$.** The Ca^{2+} replace Y^{3+}, the Ge^{4+} and Co^{2+} and Co^{3+} ions replace Fe^{3+} ions in both *a* and *d* sites. The chemical equilibrium is attained by Ca^{2+} and Ge^{4+} ions.
A 5.8 μm thick **$Y_2CaFe_{3.9}Co_{0.1}GeO_{12}$** film was grown by the method of liquid-phase epitaxy on a substrate cut from a transparent isotropic $Gd_3Ga_5O_{12}$ single crystal with a plane parallel to crystallographic (001) one. At the temperature of the present experiment, **T≃ 50K**, the easy magnetisation axis direction along [001] is assumed to be dominant [*2*]
The magnetic field **H= 8.8 kOe** was applied in the plane of the sample, changing its direction relatively to [110] axis. At **H**||[110], **β=0**

3. In the clearly defined dependence of linear dichroism on the direction of the magnetic field in the $(Y_2Ca)(Fe_{3.9}Co_{0.1}Ge)O_{12}$ film, the strongest changes are observed at the wavelengths of transitions in Co ions. The result demonstrates the important role of the cobalt ion subsystem in the formation of magnetic anisotropy and may be useful for the further development of optical information recording technology.

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2. The modern practical interest to the doped YIG:Co is caused by the latest development of all-optical time-resolved recording and reading information using the ultrafast laser illumination. In this technology studies the central role belongs to the known photomagnetic properties of this material [1, 4]

For effective application of all-optical time-resolved information recording the authors [4] formulate the so-called Selection rules which consist in choosing the wavelengh and orientation of polarization plane of light illumination.

Earlier in [5] it was shown that photoinduced linear dichroism spectra are actually similar to those induced by a magnetic field. The result of exposure to magnetic field of certain directions correlates with the results obtained when exposed to light with similar directions of the plane of polarization.

Presenting here the linear dichroism spectra measured in wavelength range where according to [6] the features associated with transitions in Fe and Co ions in octahedral and tetrahedral positions are observed and at magnetic field acting at different orientations we expect to find out the wavelengths at which the angle-dependent MLD changes are most clearly manifested.