Position of optical axes in close in energy crystalline states of magnetized tetragonal antiferromagnetic garnet $Ca_3Mn_2Ge_3O_{12}$

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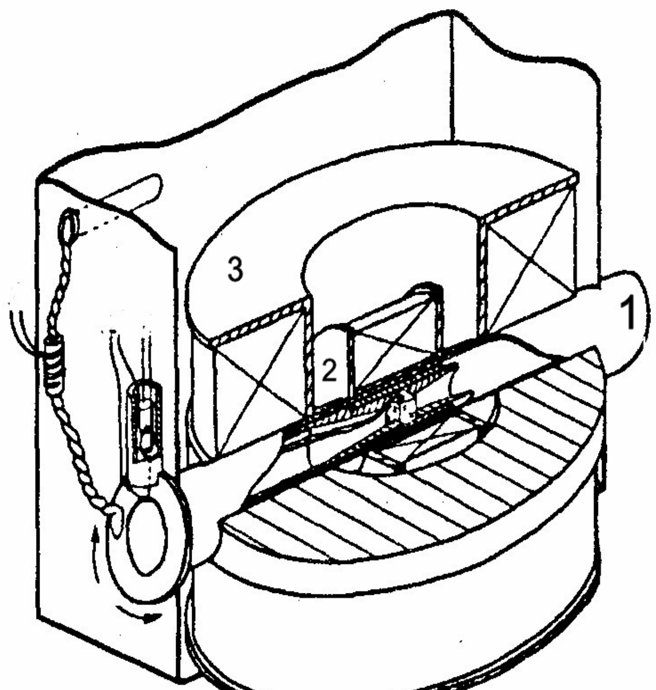
The study of the structural and symmetry properties of calcium continues to be relevant. The characteristic properties of this compound are related to the presence of the Jahn-Teller ion Mn^{3+} with degenerate ground energy state. During cooling, the Jahn-Teller distortions of $Mn^{3+}O^{2-}_6$ octahedra are ordered at T = 516K and the symmetry of the crystal lattice decreases from cubic m3m to tetragonal as a result of the second order phase transition. The ferroelastic properties which appear in the crystal are accompanied by formation of deformation twins that can be switched by applying mechanical stresses. Under action of IR and visible light the manganese ion Mn^{3+} loses an electron by the charge transfer process and becomes the ion Mn^{4+}. It causes the new distortions of the MnO_6 octahedra and emergence of photoinduced birefringence of linearly polarized light.

At temperatures lower 13.5K, the CMG crystal loses its antisymmetry center as a result of antiferromagnetic ordering of magnetic moments of manganese ions. Due to this fact the magneto-optical effects which are forbidden in paramagnets are now allowed by symmetry and in CMG crystal one can observe the linear magneto-optical effect (a magnetic analogue of the electro-optical Pockels effect) and rotation of polarization plane of light quadratic with respect to magnetic field (quadratic Faraday effect [1]).

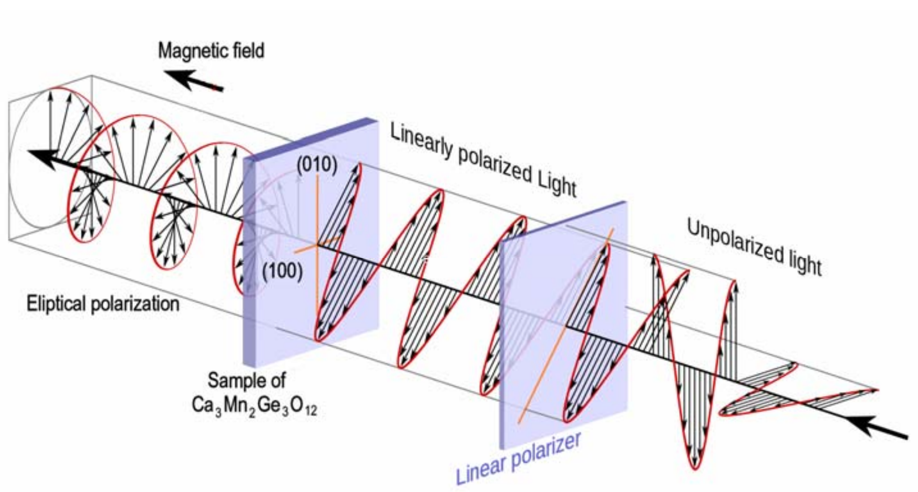
. Polarization magneto-optical experiments allow visual control of the twin structure and can be also useful for more accurate establishing the point group of magnetic symmetry and clarifying the possibility of existence of certain symmetry elements.

The number of unique properties makes CMG garnet a promising model crystal for the creation of multifunctional materials [2]. But although $Ca_3Mn_2Ge_3O_{12}$ is a long-investigated compound, there are still many questions even about its crystal structure [3] and symmetry properties.

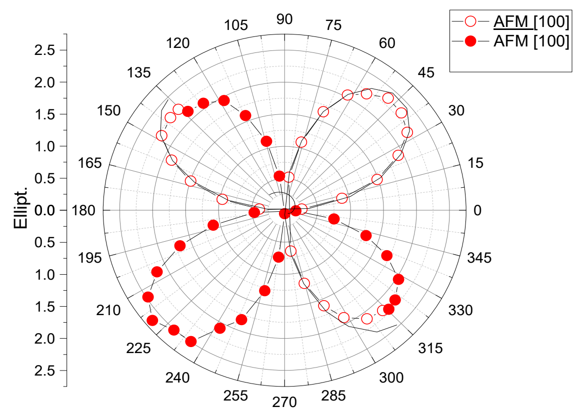


Schematic representation of a part of the optical cryostat that was used in the experiment. 1 - capsule with sample; 2- solenoid, source of longitudinal magnetic field; 3 - source of transverse magnetic field [1].

Magneto-optical studies require special preparation of $Ca_3Mn_2Ge_3O_{12}$ samples. The samples must be in the homogeneous AFM state and free from twins resulting from the Jahn-Teller phase transition. Single-domain AFM states were obtained during cooling the sample from a temperature higher than T_N =13.5 K, in the tilted magnetic field H= [H_X,H_Y,H_Z].



Schematic representation of the geometry of the experiment of measurements of the magneto-optical ellipticity of a tetragonal crystal $Ca_3Mn_2Ge_3O_{12}$. Magnetic field is oriented along the tetragonal axis C_4 (crystal axis {001}) and direction of light propagation. Polarization plane changes its orientation relatively to {100} crystal axis in the (001) sample plane.



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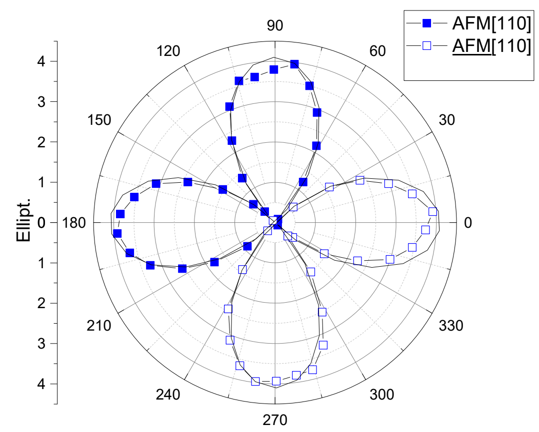

b

Fig. Azimuthal dependences of the ellipticity of the light propagating in the sample on polarisation plane orientation relatively to [100] crystallographic axis in the (001) plane. The ellipticity was measured for the sample in single-domain states: AFM[100] and AFM'[100] (a) and AFM[110] and AFM'[110] (b). **k**||**H** ||C_4, light wavelength λ=633 nm, T=6 K, $H_{||}$=15 kOe

For two pairs of antiferromagnetic states of a tetragonal garnet crystal the position of splitting plane of the optical axes in magnetic field was determined. The data obtained allow us to make a qualitative estimation of the optical anisotropy and can be considered as important for determining the magnetic point symmetry of antiferromagnetic garnet $Ca_3Mn_2Ge_3O_{12}$.

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[3] Stefan Heinemann and Ronald Miletich, Structure and twinning of tetragonal $Ca_3Mn_2Ge_3O_{12}$ garnet, American Mineralogist, 85, 993 (2000).