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Magnetooptics in Gold and Silver NanoSizes Low-Dimensional Objects

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The spectra of optical absorption and of magnetic circular dichroism (MCD) have been measured in the 350–1150 nm wavelength range for a set of colloidal solutions containing Au and Ag nanoparticles. The average size of Au nanoparticles was 6 nm and having thiolate coatings with different degrees of chirality. (The average size of Ag nanoparticles was 14 nm and having citrate coatings) The form of absorption and MCD spectra suggests the dipole character of interband transitions involving the 5*d*–6(*sp*) for Au orbitals and 4*d*–5(*sp*) for Ag orbitals. The absence (within the experimental error) of the MCD spectra dependence on the coating type rules out the hypothesis on the orbital nature of the observed magnetism. We argue that the spin polarization plays the dominant role in the magnetism both for Au and Ag nanoparticles.

Keywords: Nanostructures, Gold, Silver, Magnetism, Magnetic Circular Dichroism (MCD), THz, Surface Plasmon

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Noble metal nanoparticles attract significant interest of physicists, chemists, and engineers since they are promising for high-density data storage, catalysis, sensors, targeted drug delivery, and a new generation of electronic devices (such as single-electron transistors). They are also important for fundamental physics. The unique properties of metal nanoparticles are directly related to their size. They are in drastic contrast to the corresponding characteristics of bulk materials. In addition to the accurate control of size and shape of nanoparticles, there appears such an important problem as their stability. For obtaining the specified nanoparticle sizes, stabilizers of different kinds are used, for example, surfactants, polymers, and thiol-functionalized molecules.

To check the hypothesis on the orbital nature of the magnetism in gold nanoparticles, we produced and studied a set of nanoparticle samples differing in the chirality of the thiolate coating. It is well known that the MCD is proportional to the total magnetic moment, including the spin and orbital components. Similar to the situation with a spherically symmetric atom, which can be in the state with nonzero orbital angular momentum, a spherically symmetric nanoparticle can also have a nonzero orbital angular momentum. The molecules of the stabilizer, in turn, can also have their own orbital angular momenta, which obviously depend on the degree of their chirality. Owing to the coupling between a nanoparticle and molecules of the stabilizer, the total orbital angular momentum should also depend on the degree of chirality. Therefore, observation of the dependence of the MCD signal on the degree of chirality could verify the hypothesis on a significant contribution related to the orbital magnetism. On the contrary, the MCD signal independent of the degree of chirality of the stabilizer molecules would suggest a small contribution coming from the orbital angular momentum and the dominant role of the spin magnetism [1].

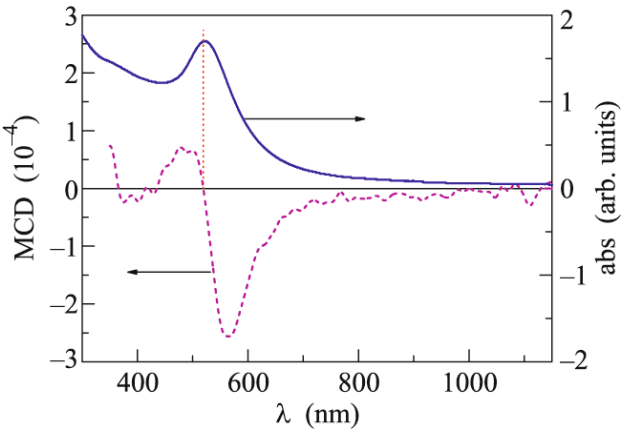

Fig. 1 – Absorption and MCD spectra for the colloidal aqueous solution of gold nanoparticles with the chiral coating.

The magnetic circular dichroism was measured in the 350–1150 nm wavelength range using the original spectropolarimeter setup designed at the Kirensky Institute of Physics based on the MDR-2 monochromator. Figure 1 shows the absorption and MCD spectra for colloidal gold nanoparticles dispersed in an aqueous solution (Au-L-Ala sample) recorded at room temperature. The peak in the absorption band is observed at a wavelength of 523 nm (for Au). At the same wavelength, the MCD changes its sign. We can see that the S-shaped MCD curve is not symmetric: the amplitude of the negative peak by about a factor of 3 exceeds the amplitude of the positive peak. The picture is similar for all other samples. The values of absorption and MCD normalized with respect to the nanoparticle density are nearly independent of the degree of chiral-

ity of the coating. The peak in the absorption is in agreement with the results reported in [2, 3], where it is attributed to the surface plasmons.

MCD in silver on the one hand similar to gold (spin polarization plays the dominant role in the magnetism of silver nanoparticles). On the other hand it has some differences from gold. For example relation MCD to absorption depends on the coating type and is changed over time.

Diffraction of a surface THz wave on gold rectangular wedge with impedance faces is studied using the Sommerfeld-Malyuzhinets technique. The scattered waves propagate predominantly at a grazing angle along the direction of propagation of the incident surface wave and mainly in the upper hemisphere regarding the wedge face. The profile of radiated intensity is nonmonotonic and does not resemble the surface wave profile which exponentially evanesces with the distance from the wedge face [4]. Application of a magnetic field perpendicular to the gold surface leads to a change in the character of diffraction (Fig. 2).Comparison with experiments carried out in the terahertz spectral range at Novosibirsk free electron laser has shown a good agreement of the theory and the experiments.

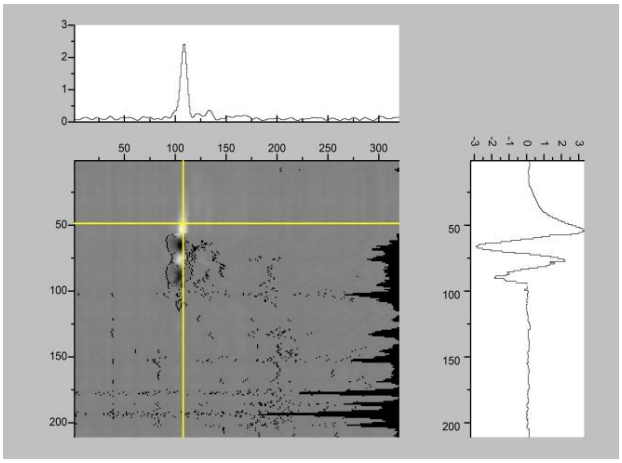

Fig. 2 – Difference for diffraction of a surface THz wave on gold rectangular wedge at H + and H- Top and Right - cross-section diffraction pattern of a surface wave on axes.

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