4.3.14. NANOPHOTONIC MATERIALS AND METHODS FOR MEASURING THEIR CHARACTERISTICS

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The development of optics is inseparably linked with occurrence of new materials which allow creating new optical elements and systems. Nanophotinics is the science which studies characteristics of optical materials composed of nanosize elementary particles. Today nanophotonic is a developing area of optics. It was caused by creating of metamaterials and low-size structures, photon crystals and planar chiral plasmon metamaterials. The most interesting contemporary nanophotonic materials, their possible applications and the basic methods of measurement of their characteristics are described in the paper. 40 years ago a soviet scientist Viktor Veselago hypothesized existence of materials with a negative refractive index. These hypotheses were actualized in creating new materials with unique features – metamaterials. Metamaterials (from Greece "Meta" – over limits, beyond) are composed not of atoms and molecules as usual materials. Metamaterials are composed of microstructures: tiny (less than a micron), artificial metal resonators. If size of resonators less than the illumination wavelength, it is become possible to change the basic optical characteristics – dielectric and magnetic conductivity of materials.

In year 2002 the group of scientists from the University of California, created a metamaterial with a negative refractive index in the microwave range. V. Shalaev with American colleagues were the first scientists who created a material with a negative refractive index $n = -0.3$ (in optical range, wavelength 1,5 mcm This material included a massive of microscopic (in nanometeric spectral range) couples of parallel gold wires. The group of scientists from the University of California applied another method. They showed than a thin silver film could have a negative refractive index. Having placed the object and the photoplate near to the film and applied an ultra-violet laser they got the object's image with the resolution in 6 times better then the wavelength. The diffraction limit was exceeded.

The discovery of metamaterials gave birth to a new field in nanophotonics based on resonance interaction. Resonance arises in special conditions between light waves pointed to an interface "Metal- dielectric" and free electrons on a metal surface. In other words, electrons begin to oscillate in resonance with electro-magnetic field's oscillations over the metal surface. As a result superficial plasmons arise. They are waves of the electron density propagating upon an interface "metal-dielectric".

Recently, the great interest is paid to so-called planar chiral (from English "chirality", from Greece χειρ – a hand) metamaterials (PCM) due to the fundamental nature of their properties in nanophotonics. In general PCM consists of a massive of thin submicron metal objects having a twirled form and lying on a transparent dielectric substrate. These structures don't possess a mirror symmetry in the plane but they show a huge specific optical activity reaching $10^{4\circ}$/ mm. Excitation of superficial plasmon-polaritrons in these structures leads to occurrence of not only a negative refractive index but a so-called circular dichroism effect. We used the scanning near-field optical microscope for investigation of a distribution of near-field electro-magnetic components. This microscope is a part of metrological complex of FGUP "VNIIOFI" for measurements of nanostructured media and metamaterials' optical constants in nanophotonics.

The other medium created in the end of the last century and having the big future in nanophotonics is a photon crystal. Photon crystals are dielectric materials in which due to changing of the crystals' formation density their refractive indexes are being changed. They could be modulated in one, two or three directions. The photon grating is created on the basis of silicon and porous silicon and allows transferring coherent light with minimum losses. The grating of cross dielectric strips is "ideally" reflecting media for light waves of a certain range of frequencies which is called "the forbidden zone". Light waves inside this range cannot extend in the grating. Applications of photon crystals are: light guide channels, spectral separation of channels and intersection of light beams.

Certainly, the described examples do not cover all nanophotonics materials which have been created today and have already been widely applied. We can regard all heterostructures, alloyed Bragg's fibers, materials with quantum points, segneto- and magnetostriction materials created with using of nanotechnologies – it is not a full list of successes in this area. It's especially important for us that these new structures entail a development of new measuring instruments. What are their features in? It is easy to notice that all of them are three-dimensional structures with a physical parameter changing in space – a complex refractive index. The rule of changing of this physical parameter defines properties of a nanostructured media and elements made of it.

The solution of the technical problem of getting three-dimensional images could have a huge value for development of nanophotonics and nanoelectronics where multilayered and three-dimensional structures are being applied much wider. Nowadays researchers try to reveal advantages and disadvantages of various techniques, but the necessity of a progress in this direction is obvious. Measurement of refractive indexes of substances is a basis of contactless determination of composition and density of optical transparent media.

The solution of this task is being tackled in creation of interferometric tomographic microrefractometer for measurement changes of refractive index which is already used for research of internal structure of living cells and measurement of such biophysical characteristics as a density, an amount of protein, a concentration of enzymes, medicines, etc.