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17.15 QTu17

FAR- AND NEAR-FIELD OPTICAL SECOND-HARMONIC MICROSCOPY OF DOMAIN STRUCTURES

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Local probing of second-order susceptibilities with a scanning near-field optical microscope and a conventional far-field microscope arrangement is demonstrated for domain structures in a periodically poled LiNbO₃ crystal and a multilayer Langmuir-Blodgett film of 2-docosylamino-5-nitropyridine (DCANP). In the first configuration, an uncoated fiber tip is used as a light source, and the transmitted radiation at the fundamental and second harmonic (FH and SH) wavelengths is detected while simultaneously recording surface topography. The experimental setup used consists of a stand-alone illumination scanning near-field optical microscope combined with a shear force based feedback system. The linearly polarized light beam from a mode-locked Ti:Sapphire laser ($\lambda_0 \sim 800$ nm, $P_0^{av} = 200$ mW, repetition rate $f = 80$ MHz, pulse duration $\tau \sim 200$ fs) is coupled into a single-mode fiber terminated with a sharp etched tip. FH radiated from an uncoated fiber tip (and transmitted through a sample) and SH generated in a sample are collected by a microobjective and detected with a photodiode and a photomultiplier (connected with a photon counter), respectively. The tip can be scanned along the sample surface at a constant distance (~ 5 nm) by virtue of shear force feedback, thus resulting in a topographical image of the sample surface. In the far-field microscope arrangement, the SH radiation, that is generated in a small region illuminated by a focused laser beam (directed from the same laser), is collected with the help of a microobjective (N.A. = 0.4) to form a SH image registered with a CCD camera. The CCD camera is connected with a TV monitor to view and a computer to storage the images.

Domain walls in a periodically poled (z-cut) LiNbO₃ crystal have been observed on near-field SH-images in the form of bright lines of ~ 500 nm in width for the SH polarization being perpendicular to the domain walls. Similar images have been also obtained with the far-field configuration and for different periods (from 8 to 20 microns) of the domain structure. Origin of the contrast in SH-images of domain walls is yet to be established, but it is believed that the scattering of the pump FH-wave by defects concentrated along the domain walls might be responsible for the SH enhancement observed. Near-field SH-images of a DCANP film exhibited very bright submicrometer-sized spots with signal enhancement of up to 10 times. Their brightness is found dependent on the polarization of the pump indicating that the domains observed oriented differently but predominantly in the dipping direction. The spatial resolution of ~ 100 nm is achieved in near-field SH-images that are not correlated with both topographical and FH-images. These features have been confirmed by the low resolution images obtained with the far-field microscope arrangement. The effect of domain rotation by the strong optical field (away from the field polarization) has been also observed. Overall, the developed near-field second-harmonic microscope in combination with the conventional far-field configuration has been found useful to quickly identify and survey surface structures showing nonlinear optical contrast, e.g., domain structures, with subwavelength resolution. SH generation is known to be very sensitive to the symmetry and interface properties, and therefore this technique can provide a wealth of additional information (not available from linear imaging) on the nanometer scale.

17.30 QTu18

NONLINEAR PROPAGATION OF ELECTROMAGNETIC RADIATION IN VACUUM

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There are two mechanisms of a pure vacuum optical nonlinearity with respect to high-power radiation. First, it is a quantum-electrodynamical phenomenon of electron-positron vacuum polarization. Second, it is a classical (Einsteinian) phenomenon of gravitation induced by electromagnetic radiation [1]. Although these phenomena are locally weak, their effect can be accumulated for a long distance of radiation propagation.

In the present paper, a theory of propagation of high-power electromagnetic radiation beams and pulses with small (diffractive) angular divergence in such a vacuum is developed. Important point of the theory is use of developed in nonlinear optics method of parabolic (quasioptical) equation. For the quantum-electrodynamical mechanism, the Heisenberg-Euler theory is modified to take into account vacuum dispersion which is important for ultrashort radiation pulses. Under approximation of slowly varying envelope a parabolic equation is deduced that describes radiation diffraction, spatio-temporal dispersion, and vacuum nonlinearity. I show existence of dark optical solitons in the vacuum [2]. These phenomena can be demonstrated in high-power laser facilities of existent level.

For the classical gravitational mechanism, additionally to the Maxwell's equations, the linearized Einstein's equations of gravitation are involved (the first approximation of perturbation theory which is valid for weak gravitational fields), and the parabolic equation is deduced. Contrary to the previous case, nonlinear effective electrical permittivity is highly nonlocal here. For approximation of quadratically inhomogeneous effective electrical permittivity, solution of the parabolic equation is received which describes nonlinear focusing and defocusing of a weak probe electromagnetic radiation on the background of a strong radiation beam/pulse. Estimations show that gravitational mechanism of a pure vacuum nonlinearity can be important for extreme cosmological events.

References

1. R.C.Tolman. *Relativity, Thermodynamics and Cosmology*. Oxford, Clarendon Press. 1969.
2. N.N.Rosanov. On self-action of high-power electromagnetic radiation in electron-positron vacuum. *JETP*, **113**(2) (1998).