waveguides) is actively studied. This is due to the possible manifestation in the electrodynamics of the Hartman effect known from quantum mechanics: the tunneling time for a quantum particle is independent of the thickness of the opaque barrier. In the radio wave range, the natural medium that allows modeling this effect is gas discharge plasma, since its permittivity can take negative values. In this work, we performed theoretical estimations of the tunneling time of nanosecond microwave pulse through plasma layer taking into account the electron collision frequency. We used the two approaches to extract the propagation time from our calculations – (i) the time estimated via the pulse center of gravity and (ii) the phase (Wigner) time. We showed that these approaches mostly agree with each other and demonstrate some characteristic features below the plasma frequency. Finally, for experimental verification of the obtained dependencies, we propose the scheme based on nanosecond microwave pulse tunneling through the plasma electromagnetic band gap structure formed by gas discharge plasmas placed in microwave waveguide, in which changing the electronic concentration allows us to switch between the regimes above and below the effective plasma frequency.

Vector magnetometry implemented using 14NV-13C hybrid spin systems in nanodiamonds

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In the modern world, quantum technologies are being actively developed. One of them is quantum magnetometry, in which single nitrogen-vacancy centers (NV centers) in diamond are used as sensors for measuring magnetic fields with nanometer spatial resolution [1]. However, due to the symmetry of the NV center, information about the azimuthal angle of the magnetic field vector is lost. Recently, a method of complete vector magnetometry was proposed [2,3], based on the analysis of experimental spectra of optically detected magnetic resonance (ODMR) of the system NV-13C, in which the electron spin of the NV center is coupled by hyperfine interaction (HFI) with the nuclear spin of 13C.

Here, we simulate ODMR spectra of 14NV-13C systems using HFI matrices calculated by quantum chemistry methods. It is shown that the simulation method ensures the implementation of vector magnetometry. A quantitative description of the ODMR spectra obtained with high spectral resolution in [2] for the 14NV-13C system, in which the 13C atom was the nearest neighbor of the vacancy, is performed. Similar predictive simulation of the ODMR spectra is performed for a number of other NV-13C systems.

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Superferromagnetoresistors

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The strong ferromagnetic nanoparticles are analysed within the band structure based shell model [1] accounting for discrete quantum levels of conducting electrons. As is demonstrated such an approach allows to describe the observed superparamagnetic features of these nanocrystals. Assemblies of such superparamagnets incorporated into nonmagnetic insulator, semiconductor or metallic substrates are shown to display ferromagnetic coupling resulting in a superferromagnetic ordering at sufficiently dense packing. Properties of such metamaterials are investigated by making use of the randomly jumping interacting moments model accounting for quantum fluctuations induced by the discrete electronic levels and disorder. Employing the mean-field treatment for such superparamagnetic assemblies we obtain the magnetic state equation indicating conditions for an unstable behaviour. Respectively, magnetic spinodal regions and critical points occur on the magnetic phase diagram of such ensembles. The respective magnetodynamics exhibit jerky deportment expressed as erratic stochastic jumps in magnetic induction curves. At the critical points magnetodynamics display the features of self-organized criticality. Analyses of magnetic noise correlations are proposed as model-independent analytical tools employed in order to specify, quantify and analyse magnetic structure and origin of superferromagnetism. We discuss some results for a sensor mode application of superferromagnetic reactivity associated with spatially local external fields, e.g., a detection of magnetic particles. Transport of electric charge carriers between superparamagnetic particles is considered as tunneling and the Landau level state dynamics. The tunneling magnetoresistance is predicted to grow up noticeably with decreasing nanomagnet size. The giant magnetoresistance is determined by ratio of respective time of flight and relaxation and can be significant at room temperatures. Favorable designs of superferromagnetic systems for sensor implications are revealed.

[1] V.N. Kondratyev, and V.A. Osipov, Nanomanufacturing. 3, 263 (2023).

On scattering resonances in monolayer and bilayer graphene circular quantum dots

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We analyse in detail eigenstates and possible resonance structure for monolayer and bilayer graphene circular quantum dots within the known massless Dirac pseudo-fermion graphene model. Concept and reasonability of the recently introduced quasi-bound states is also discussed.

Collapse of Klein tunneling resonances in pseudo-Majorana-type pn-graphene junctions

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Strongly correlated many-electron systems whose quasi-particle excitations are subject to non-Abelian statistics are promising for application in quantum devices. Graphene belongs to such systems. A highly efficient Andreev conversion of incident electrons into electron-hole pairs at the interface between graphene-like materials in quantum Hall-effect and superconducting regimes occurs due to hybridization of the quantum Hall edge modes with the states in superconductor [1]. To remain the topologically nontrivial hybridized modes along the edges of the superconducting sample the local and crossed Andreev states should exist on both sides of the superconducting phase. The topological nontriviality of the hybridized modes disappears due to defects and impurities and intensity of the crossed Andreev states is negligibly small also due to the defects. This impedes to design robust quantum processing based on graphene platform However, the local and crossed nontopological Andreev states reside in a superconductor coupled to the two conventional quantum dots [2-4], resulting in SQUID-like oscillations. In our paper we will study a collapse of Klein-tunneling resonances in pseudo-Majorana graphene p-n junctions which are electrically confined graphene quantum dots (GQDs) without physical termination. The p-n graphene junctions are able to support the supercurrent at the superconducting interface along the edges of the sample under conditions of detuning Klein tunneling. To approach it we will elaborate a mechanism for finely tuning collapse of Klein transmission states.

We suppose that graphene quasi-particle excitations are pseudo-Majorana particles. A graphene band structure determined by the pseudo-Majorana Hamiltonian holds electron and hole flat bands where a pseudo-Majorana force (interaction) confines electron-hole pairs in Majorana configurations. We have used the pseudo-Majorana Hamiltonian to describe collapsing Klein-resonances in the graphene p-n junctions. Figure 1 depicts simulation results. As can see, the wave functions for the Klein-tunneling resonances in the toroidal-and spherical-type Majorana GQDs can narrow and the collapse of these transmission states occurs.

States of this kind are lacking in an electrostatically-confined graphene toroidal p−n junction hosting Dirac-Weyl fermions. Dirac-Weyl fermions in the spheroidal GQD can reside on quasi-zero energy levels at any energies because the centrifugal force due to the curvature of the sphere prevents the electrons (holes) from keeping on resonant trajectories. It means that charge carriers of the spheroidal pn junction can escape into bulk graphene, that leads to the pseudo-Dirac-Weyl GQD collapse

Our simulation results in Fig. 1 testify that the pseudo-Majorana force acts similarly to a centripetal (centrifugal) force in the spherical graphene quantum dot. Since the space of the toroidal