described by J. S. Russell in 1884. The mathematical theory of solitary waves was created by Korteweg and De Vries almost half a century later. The new theory caused a significant stir in the scientific community. Indeed, as follows from the famous equation of Korteweg-De Vries (KdV), the soliton profile has an asymptotic $f(x) \sim \mathrm{sech}^2 x$ for small amplitudes. This means that the soliton remains nonlinear for arbitrarily small amplitudes and does not turn into a linear wave. Further studies have shown that solitons are general phenomenon of nature that describes the properties of nonlinear ion-acoustic waves, magneto-acoustic waves, electric currents in nonlinear transmission lines, and much more. A large number of scientific papers have been devoted to the study of soliton properties, but the physics of nonlinear waves and solitons is far from complete.

The goal of this work is to study the ability of solitary waves to transport matter [1]. On the one side, a soliton is a wave. As expected, material waves do not carry matter (they transfer momentum and energy). It is known that this statement is true only for linear waves of infinitely small amplitude. However, for finite amplitudes waves (even harmonic ones), nonlinear effects lead to the emergence of non-zero drift of matter. This phenomenon was predicted in 1847 by Stokes and was named after him (Stokes drift). As is known, the drift speed for a harmonic wave of small but finite amplitude is proportional to its square. Subsequently, the phenomenon of Stokes drift was repeatedly observed in practice for waves on the water surface, acoustic waves, etc. In the Stokes drift situations, the particle motion represented by a superposition of drift and oscillatory motions. Decrease in the wave amplitude leads to a linearization of the wave process and subsequent rapid (quadratic) decrease in the drift component. In this way, for small amplitude harmonic waves, this nonlinear phenomenon is usually neglected.

In the case of solitons, the nonlinearity cannot be neglected. It is shown theoretically that the unidirectional transport of matter (over a finite distance in the direction of soliton motion) is a fundamental property of KdV solitons. It is also shown that the matter transport cannot be neglected as the wave amplitude decreases (in contrast to the Stokes drift), because the magnitude of the transport decreases in proportion to the square root of the soliton amplitude. Due to the universality of the KdV equation, we expect generalization of our results to a wide range of nonlinear problems.

[1] Phys. Plasmas. 2023. V.30, P.112302.

Half-cycle dissipative solitons in resonant media

Anton Pakhomov

(St. Petersburg State University, St-Petersburg, Russia)

When dealing with a subcycle pulse propagation in a resonant medium, common approximations, such as the two-level model, become invalid due to ultrabroad pulse spectrum. Therefore multiple energy levels in the medium have to be properly considered. We develop the higher-order sudden-perturbation approach to derive the general nonlinear equations for the propagation of subcycle pulses in a multi-level medium. Using these equations, we demonstrate the existense of stable half-cycle dissipative solitons in non-equilibrium media with multiple resonant transitions.

Kosambi-Cartan-Chern geometric invariants, and the structure of the radial differential equations for a Dirac particle in the Newman-Unti-Tamburino space-time

N.G. Krylova, V.M. Red'kov[1]

B.I. Stepanov Institute of Physics, Minsk, Belarus

Applying the methods of differential geometry and technics of Kosambi-Cartan-Chern invariants, we study the radial equations for a spin ½ particle in the Newman-Unti-Tamburino space-time. Starting with the system of two differential equations for massless Dirac particle, we calculate the deviation curvature tensor P^i_j associated with Jacobi stability of the dynamical system. We proof that the real parts of its eigenvalues are positive near the horizon and at infinity, which corresponds to divergence of a pencil of geodesics near these singular points. We construct an effective Lagrangian function associated with this dynamical system. For massive Dirac particle, we study the relevant system of four radial equations and analyze behavior of eigenvalues of corresponding deviation curvature tensor. We found that the real parts of the eigenvalues are positive near the horizon, but at infinity the eigenvalues tend to $1 - (M / \varepsilon)^2$ / so they are positive for all physically interpreted energy values bigger than the particle mass. The Newman-Unti-Tamburino parameter does not influence on the character of geodesics behavior.

Resonant tunneling in QCD

Roman Shulyakovsky
Institute of Applied Physics NAS of Belarus, Minsk, Belarus

Tunneling processes in QCD described by classical solutions of field equations in Euclidean space (instantons) are considered. It has been shown that the exponential suppression of such transitions is removed due to resonance effects. Thus, energy bands are formed by analogy with the effects in crystals. The results are consistent with phenomenological considerations obtained by E. Shuryak, D. Dyakonov and others and also from the analysis of the Shifman–Weinstein–Zakharov (SWZ) sum rule. There are very strong arguments in favor of the fact that instantons in QCD provide the existence of quark and gluon condensates. Moreover, such non-perturbative fluctuations of gluon fields appear enough often. There are very strong arguments in favor of the fact that instantons in QCD provide the existence of quark and gluon condensates. Moreover, such non-perturbative fluctuations of gluon fields appear often enough (the density of instantons is estimated at 1 per Fm^4 in 4-dimensional Euclidean space). So, instanton tunneling transitions will not be suppressed even for medium energies 1 – 10 GeV, i.e. energies that will be achieved at the SPD facility (NICA, JINR). At the LHC accelerator, the range of kinematic regions is much wider, which significantly expands the variability of the task of searching for instantons.

Testing single micro-particles as individual luminescent upconversion probes

Victor G. Nikiforov, Andrey V. Leontyev, Larisa A. Nurtdinova, Evgeny O. Mityushkin, Artemi G. Shmelev, Dmitry K. Zharkov, Anton P. Chuklanov, Niaz I. Nurgazizov
Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, Kazan, Russia

Upconversion nano(micro) crystallites doped with rare earth ions are promising luminescent probes in a wide range of applied and fundamental problems. Particular attention should be paid to the biomedical area: visualization of biological objects, biosensing, therapy and diagnosis of cancer, drug delivery, etc. As a rule, the methods presented in the literature use a large ensemble of upconversion particles. Note that modern confocal optical microscopy makes it possible to detect the luminescent response of single phosphors. Thus, a attractive prospect arises for the development of single particle technology allows one to use an individual probe for monitoring the parameters of the local state of the environment (temperature, viscosity, pH, electric and magnetic fields, etc.). In problems of this kind, the decisive role is played by the features of the photophysical parameters of a single particle chosen as a probe. It should be noted that the parameters of a particle can differ greatly from the values averaged over a large ensemble of similar particles. The report presents studies of the luminescent upconversion response of various single oxide and fluoride submicroparticles, analyzes the multiphoton activation mechanisms of rare earth ions emission and the sourses of luminescence significant polarization. Examples of using single phosphors as temperature and orientation sensors are demonstrated. The prospects for their use in biological objects are discussed.

Vizualization and Probing the Surface of Isolated Nervous System of Grape Snail Using Luminescent Nanoparticles

L.A. Nurtdinova, A.V. Leontiev, A.G. Shmelev, D.K. Zharkov, R.M. Gataullina, E.O. Mityushkin, A.N. Solodov, R.R. Zairov, A.R. Mustafina, V.V. Andrianov, L.N. Muranova, Kh.L. Gainutdinov, A.P. Chuklanov, N.I. Nurgazizov and V.G. Nikiforov
Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, Kazan, Russia

Of particular interest is the problem of visualization in biomedicine, when the position of probes introduced into living tissue is registered remotely and noninvasively by optical methods in real