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EXPERIMENTAL STUDY OF THE RESIDUAL STRONG NUCLEAR INTERACTION VIA RENORMALIZATION OF THE ELEMENTARY EXCITATIONS ENERGY OF SOLIDS

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Keywords: strong interaction, quarks, gluons, excitons, phonons, quantum chromodynamics and electrodynamics.

Abstract. Artificial activation of the strong interaction by adding of one neutron to the nucleus causes the global reconstruction of the macroscopic characteristics of solids. The experimental evidence of macroscopic manifestation of the strong interaction in optical spectra of solids which are differ by term of one neutron from each other (using LiD crystals instead LiH) has been presented. This evidence is directly seen from luminescence and scattering spectra. As far as the gravitation, electromagnetic and weak interactions are the same in both of kind crystals, it only changes the strong interaction. Therefore a sole conclusion is made that the renormalization of the energy of electromagnetic excitations (electrons, excitons, phonons) is carried out by the strong nuclear interaction. The necessity to take into account the more close relation between quantum chromodynamics and quantum electrodynamics is underlined. In the first step the quantum electrodynamics should be taken into account the strong interaction at the description of elementary excitations (electrons, excitons, phonons) dynamics in solids.

Most of physical properties of solid depend on its isotopic composition in some way or another. Soddy realized that there are mixtures of isotopic effect are source of elements which cannot be separated by chemical means [1, 2]. He then postulated that such elements, usually obtained at the beginning XX century by radiactive transmutations (see, e.g [3]) have the same intraatomic charge but different atomic masses. Soddy calles them isotopes because they occupy the same place in the periodic table of D.I. Mendeleev. Isotopes are classified into stable and the unstable species. The unstable isotopes are radioactive and widely used as tracers in medical diagnostics (see, e.g. [4]). Modern physics distinguishes three fundamental properties of atomic nuclei: mass, spin (and related magnetic moment) and volume (surrounding field strength) which are source of isotopic effect (see also [5]).

In the last four decades the study of isotopic effect in solid state physics was devoted the investigation of the energy spectrum of elementary excitations via detailed measurements of the optical characteristics of the isotope - mixed substances. There were detailes studies as well as dynamical properties (scattering phonons processes, heat characteristics, the change of the lattice constants) as the processes of the excitation and energy relaxation of the electron excitations. It was very brightly demonstrated via precisely experiments the dependence of the indicated properties on the isotope composition of studied objects. Obtained in the last thirty years experimental results and theoretical models and calculations are completely repel in the reviews [6, 7] and monographs [3, 5, 8].

Perhaps the Plekhanov's paper [9] was the first one where was noted, that in the isotope effect of solids the main role is played by the force of the strong nuclear interaction (see, also [10]). After the discovery of the neutron in 1932 by Chadwick, there was no longer doubt that the building blocks of nuclei are protons and neutrons [11, 12] (collectively called nucleons). The electron, neutron and proton were latter joined by fourth particle, the neutrino, which was postulated in 1930 by Pauli in order to reconcile the description of β^- decay with the fundamental laws of conservation of energy , momentum and angular momentum (see, also [13, 14]). Thus, by the mid - thirties of the 20th century, these four particles could describe all the then known phenomena of atomic and nuclear physics. Today, these particles are still considered to be the main constituents of matter. In the fifties and sixties was showed that protons and neutrons are merely representative of a large family of particles called hadrons [15, 16]. More tham 100 hadrons have thus far been detected. These hadrons, like atoms, can be classified in groups with similar properties. It was therefore assumed that they cannot be understood as fundamental constituents of matter. In the late sixties, the quark model (see Fig. 4 of chap.5 in [10]) established order in the hadronic zoo [17, 18].

Together with our changing conception of elementary particles, our understanding of the basic forces of nature and so of the fundamental interaction between elementary particles has evolved. As is well - known subatomic physics combines nuclear and particle physics. The two fields have many concepts and features in common. Subatomic physics, the physics of nuclei and particles has been one of the frontiers of science since its birth in 1896. [13, 15, 16].

Our present knowledge of physical phenomena suggests that there four types of forces between physical bodies (see, e.g. [16, 3]):

1) gravitational; 2) electromagnetic; 3) strong; 4) weak.

Both the gravitational and the electromagnetic forces vary in strength as the inverse square of the distance and so able to influence the state of an object even at very large distances. Gravitational is important for the existence of stars, galaxes, and planetary systems as well as for our daily life, it is of no significance in subatomic physics, being far too weak to noticeably influence the interaction between elementary particles [19]. Electromagnetism is the force that acts between electrically charged particles (atoms, molecules, condensed matter). When nuclear physics developed, two new short - ranged forces joined the ranks. These are the nuclear force, which acts between nucleons (proton, neutron, etc.) and the weak force, which manifests itself in nuclear β - decay (see, e.g. [15). The nuclear force is a result of the strong force binding quarks to form protons and neutrons. Due to experimental results of this report connected to the manifestation of the strong interaction, we should briefly analyze the structure of subatomic particles and the strong interaction. The discovery of the neutron by Chadwick in 1932 [13] may be viewed as the birth of the strong interaction: it indicated that the nuclei consists of protons and neutrons and hence the presence of a force that holds them together, strong enough to counteract the electromagnetic repulsion. In 1935, Yukawa [20] pointed out that the nuclear force could be generated by the exchange of a hypothetical spinless particle, provided its mass intermediate between the masses of proton and electron - a meson. Yukawa predicted the pion [15, 16]. The strong forces does not act on leptons (electrons, positrons, muons and neutrinos), but only on protons and neutrons (more generally, on baryons and mesons - this is the reason for the collective name hadrons). It holds protons and neutrons together to form nuclei, and is insignificant at distances greater than 10^{-15} m [16]. Its macroscopic manifestations are restricted up to now to radioactivity and the release of nuclear energy.

The modern quantummechanical view of the three fundamental forces (all except gravity) is that particles of matter (fermions neutrons, protons, electrons) do not directly interact with each other, but rather carry a charge, and exchange virtual particles (gauge bosons photons, gluons, gravitons) which are the interaction carriers or force mediators. As can be see from Table 1, photons are the mediators of the interaction of electric charges (protons, electrons, positrons); and gluons are the mediators of the interaction of color charges (quarks). In our days, the accepted view is that all matter is made of quarks and leptons (see Fig. 6 in [10]). As can be see, of the three pairs of quarks and leptons, one pair of each - the quark u and d and the leptons e^- and ν_{e} (electrons neutrino) - are necessary to make up the every day world, and a world which contained only these would seem to be quite possible.

The facts, summarized in the modern nuclear and subatomic physics (see, e.g. [15, 16]) allow to draw several conclusions in regard to nuclear forces, most notably that the binding energy of a nucleus is proportional to the number of nucleons and that the density of nuclear matter is approximately constant. This lead to conclude that nuclear forces have a "saturation property". It seems from the last conclusion it is enough to change the number of neutrons in nucleus to change strength of nuclear force. But the last one constitutes the main ideas of the isotope effect [3].

We should remind very briefly about the electronic excitations in solids. According to modern concept, the excitons can be considered [19] as the excited of the N - particles system: An electron from the valence band (see Fig. 1) is excited into the conduction band.

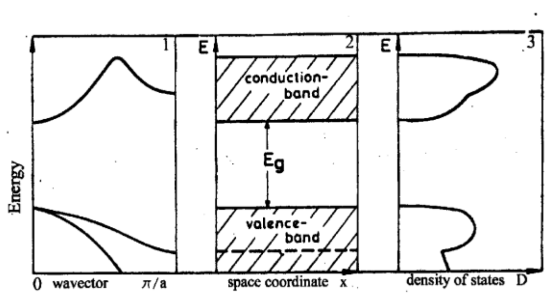

Figure 1. Various possibilities to present the band - structure of homogeneous, undoped insulator (semiconductor). 1 - the dispersion relation, i.e. the energy E as a function of the wave vector k, 2 - the energy regions of allowed and forbidden states as function of a space coordinate x and, 3 - the density of states (all curves are schematic ones)

The attractive Coulomb potential between the missing electron in the valence band, which can be regarded as a positively charged hole, and the electron in the conduction band gives a hydrogen - like spectrum with an infinitive number of bound state and ionization continuum (see Fig. 3 of chapt. 4 in [10]).

In this report we call the bound states of electron - hole (e - h) pairs exciton states (exc), while we refer to ionized e - h pairs as free carriers. However, the expression free carriers does not imply that the effect of the strong Coulomb forces between electronic excitation could be neglected. Thus, an exc - state can be built by appropriate superposition of e - h pairs, which in a simple two - band model for cubic crystal symmetry is given (the more details see [21]).

As demonstrated early (see, e.g. review [22]) most low - energy electron excitation in LiH crystals are the large - radius excitons [21]. Exciton luminescence is observed when LiH (LiD) crystals are excited in the midst of the fundamental absorption. The spectrum of exciton photoluminescence of LiH crystals cleaved in liquid (superfluid) helium consists of a narrow (in the best crystals, its half - width is $\Delta E \leq 10$ meV) phononless emission line and its broader phonon repetitions, which arise due to radiative annihilation of excitons with the production of one to five longitudinal optical (LO) phonons (see Fig. 2).

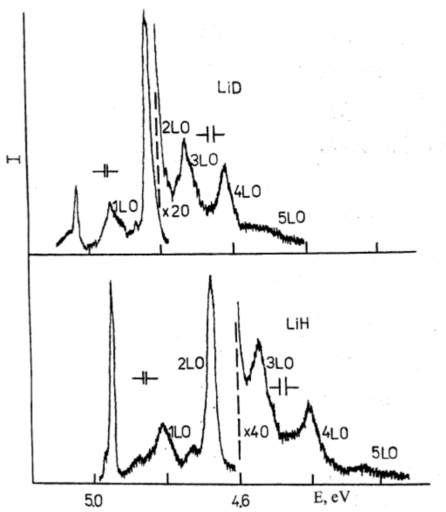

Figure 2. Photoluminescence spectra of free excitons at 2 K in LiH and LiD crystals cleaved in superfluid helium

The phononless emission line coincides in an almost resonant way with the reflection line of the exciton ground state which is indication of the direct electron transition X_1 - X_4 of the first Brillouin zone [21].The lines of phonon replicas form an equidistant series biased toward lower energies from the resonance emission line of excitons. The energy difference between these lines in LiH crystals is about 140 meV, which is very close to the calculated energy of the LO phonon in the middle of the Brillouin zone [22] and which was measured in (see, e.g. [23] and references quoted therein). The isotopic shift of the zero - phonon emission line of LiH crystals equals 103 meV. As we can see from Fig. 2 the photoluminescence spectrum of LiD crystals is largely similar to the spectrum of intrinsic luminescence of LiH crystals. There are, however, some distinctions one is related.

Firstly the zero - phonon emission line of free excitons in LiD crystals shifts to the short - wavelength side on 103 meV. The second difference concludes in less value of the LO phonon energy, which is equal to 104 meV. When light is excited by photons in a region of fundamental absorption in mixed $LiH_{x}D_{1-x}$ crystals at low temperature, line luminescence is observed (see Fig. 21 in [22]), like in the pure LiH and LiD crystals. As before [22], the luminescence spectrum of crystals cleaved in superfluid liquid helium consists of the relatively zero - phonon line and its wide LO replicas. For the sake of convenience, and without scarfing generality, Fig. 21 shows the lines of two replicas. Usually up to five LO repetitions are observed in the luminescence spectrum as described in detail in [7]. In Fig. 21 we can see immediately that the structure of all three spectra is the same. The difference is in the distance between the observed lines, as well as in the energy at which the luminescence spectrum begins, and in the half - width of the lines. Very interesting and nonlinear results are depicted on Fig. 3.

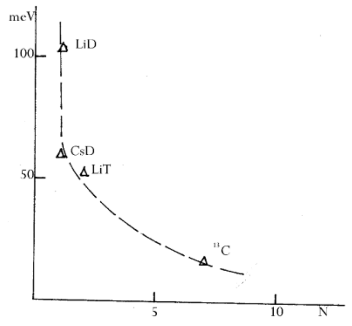

Figure 3. The dependence of the strong force on the number of neutrons in different substances

Typical energy differences of hyperfine multiplets are only about 10^{-7} eV (in case of the deuteron it is $3.16 \cdot 10^{-7}$ eV (see also [10])). This value is by more than seven order less than we observe in experiments: the isotopic shift of the n = 1s excitons is equal to 0.103 eV.

The short range character of the strong interaction doesn't possess direct mechanism of the elementary excitation energy renormalization, which was observed in the experiments.

However, we can distinguish three mechanisms of this renormalization:

1. Electric field of the neutron's quarks - this mechanism is limited by the boundary of the neutron.
2. The possible new structure of the quarks and leptons - so - called preons [23 - 28].
3. The most possible mechanism is connected to the magnetic - like field of the neutron quarks.

For the solution of this new task we need more experimental as well as theoretical investigations.

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ОПРЕДЕЛЕНИЕ СКОРОСТИ ЗВУКА ЗА ФРОНТОМ УДАРНЫХ ВОЛН ВО ФТОРОПЛАСТЕ И ЭПОКСИДНОЙ СМОЛЕ

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Использование полимерных материалов в качестве конструкционных в некоторых отраслях промышленности требует достоверного знания свойств материалов. Особый интерес представляет область динамических свойств.

Определение скорости звука, в частности, позволяет получать информацию об упруго-пластических свойствах материалов при ударном сжатии. Данные по скорости звука используются