On quantum uncertainty relation features at subatomic distances and the possibility of nonrelativistic and relativistic solutions in the problem of the electron motion in the Coulomb field of a proton

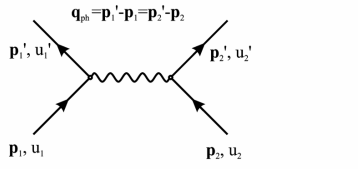
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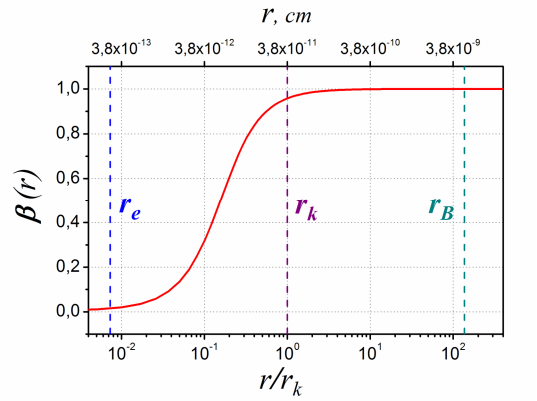
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Introduction. Although the quantum uncertainty relations (UR) date back to about a century, extensive discussions are still being continued concerning the interpretation and understanding of their physical meaning. First and foremost this refers to UR $\Delta\varepsilon\Delta t \geq \hbar$. Most of the discussions show not only different but even contradicting understanding of the physical meaning of uncertainties described by this inequality in non-relativistic quantum theory [1].

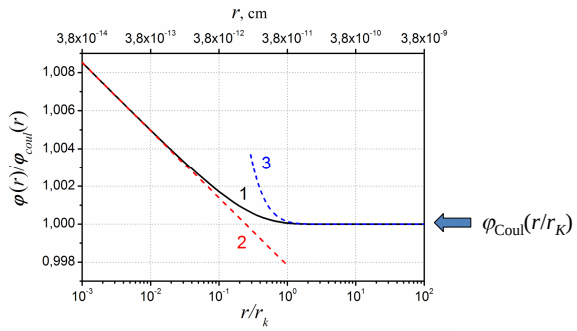
The present paper is based on the results of our recent work [2] in which the fundamental regularity - invariance of the UR with respect to the parameters of virtual photons (VPH) is established. Here we focus mainly on the features of the interaction processes and on the wave properties of particles and UR under conditions of strong electromagnetic interaction of particles (electrons, protons, etc.) at short inter-particle distances comparable with the particles dimensions. With the view of better understand of the physical nature of the quantum UR and the phenomena underlying the quantum UR, the features of the UR are considered on the basis of the relationship between the wave-like properties of particles and the peculiarities of the VPH which were considered not only as playing an essential role in inter-particle interaction processes, but also as directly related to the wave-like properties of interacting particles.



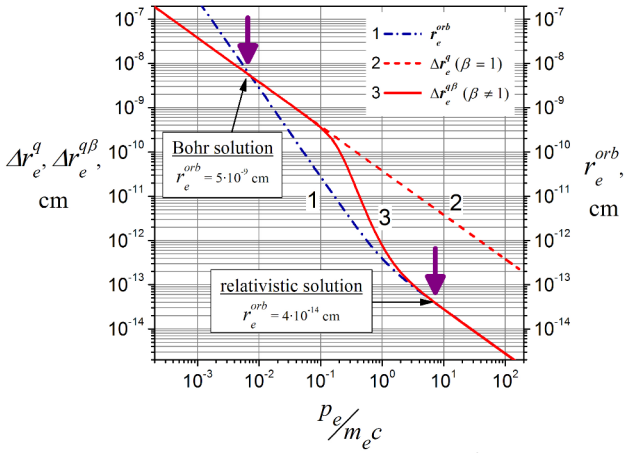
Feynman diagram for the interaction of two charged particles (1 and 2) including emission and absorption of virtual photons. Transitions of particle 1 from the initial state $\{p_1, u_1\}$ to the final state $\{p'_1, u'_1\}$ and of particle 2 from the initial state $\{p_2, u_2\}$ to the final one $\{p'_2, u'_2\}$ (in the simple spin approximation $q_{ph} = p'_1 - p_1 = p'_2 - p_2$) are shown [3,4].



The results of approximate calculation of coefficient $\beta(r) \leq 1$ (which describes the changes in Heisenberg's uncertainty relations $\Delta p\Delta r \approx \beta(r)\hbar$ at subatomic distances) in depend on distance between proton and electron with considering the recoil effect ($r_K = \hbar/m_e c$ is Compton wavelegth, where m_e is a mass of electron).



The electrical potential $\varphi(r/r_K)$ formed by proton on a distance r as a function of r/r_K calculated in the framework of QED in the first order of the perturbation theory. As can be seen it is very close to the Coulomb potential $\varphi_{Coul}(r/r_K) = e/r$ (curve 1) within the distances $r/r_K = 10^{-1} \div 10^{-3}$ ($10^{-11} \div 10^{-13}$ cm).



The calculated values for radius of electron orbit $r_e^{orb}(p_e)$, uncertainty of electron coordinate $\Delta r_e^q(p_e)$ at $\beta = 1$ (without considering recoil effect) and uncertainty of electron coordinate $\Delta r_e^{q\beta}(p_e)$ at $\beta \neq 1$ (with considering recoil effect), in depend on momentum of electron p_e.

Conclusion. The virtual photon approach made it possible not only to highlight the physical nature of the phenomena that underlie the UR relationships, but also to give a self interpretation of the UR relationships from the point of view of VPH properties, and to reveal a number of regularities and singularities relating to both the behavior the UR and the features of electronic states and interaction processes at small subatomic distances, compared with dimensions of the interacting particles. We have found that at the subatomic distances, the Heisenberg's UR change, become less constraining and allow smaller values for the uncertainty of the momentum. In the problem of the electron motion in the Coulomb field of a proton, it leads to the possibility of appearance of two fundamentional solutions. The first is nonrelativistic Bohr solution with the electron orbit radius ≈ $5\cdot10^{-9}$ cm (the binding energy ≈ 13 eV), and the second one is the relativistic solution with the electron orbit radius ≈ $0.4\cdot10^{-13}$ cm (the binding energy ≈ 0.46 MeV). The relativistic solution is characterized by nuclear scales of energies and distances and fitmatch to the parameters of a neutron as a relativistic quasi-atom. Some of the parameters are given in the abstract. The presented results may be of interest and can be considered in more correct way in quantum electrodynamics.

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[2] Murzin, V.N. On the invariant properties of quantum uncertainty relations with respect to parameters of virtual photons responsible for interaction processes in quantum particle systems. Physics Letters 2017, A381, p. 233-238
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