GRAPHENE: CERN ON THE DESK

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Graphene, a recently (2004) discovered two-dimensional allotrope of carbon (this discovery was awarded by Nobel Prize in physics 2010), has initiated a huge activity in physics, chemistry and materials science, mainly, for three reasons. First, a peculiar character of charge carriers in this material makes it a "CERN on the desk" allowing us to simulate subtle and hardly achievable effects of high energy physics. Second, it is the simplest possible membrane, an ideal testbed for statistical physics in two dimensions. Last not least, being the first truly two-dimensional material (just one atom thick) it promises brilliant perspectives for the next generation of electronics which uses mainly only surface of materials. I will tell about the first aspect of the graphene physics, some unexpected relations between materials science and quantum field theory and high-energy physics.
Electrons and holes in this material have properties similar to ultrarelativistic particles (two-dimensional analog of massless Dirac fermions). This leads to some unusual and even counterintuitive phenomena, such as finite conductivity in the limit of zero charge carrier concentration (quantum transport by evanescent waves) or transmission of electrons through high and broad poential barriers with a high probability (Klein tunneling). This allows to study subtle effects of relativistic quantum mechanics and quantum field theory in condensed-matter experiments, without accelerators and colliders. Some of these effects were considered as practically unreachable. Apart from the Klein tunneling, this is, for example, a vacuum reconstruction near supercritical charges predicted many years ago for collisions of ultra-heavy ions. Another interesting class of quantum-relativistic phenomena is related with corrugations of graphene, which are unavoidable for any two-dimensional systems at finite temperature. As a result, one has not just massless Dirac fermions but massless Dirac fermions in curved space. Gauge fields, of the central concepts of modern physics, are quite real in graphene and one can manipulate them just applying mechanical stress.