Fracton mediated superconductivity in the “net fractal” systems

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The concept of fractal geometry has proven useful in describing structures and processes in the nanoscale, many-body systems. The conjecture that superconductivity comes about because of the fractal structure of underlying medium was raised firstly by Buettner and Blumen [1] in discussion of the high-temperature superconductivity (HTC).

In this contribution we present theoretical study of fracton excitations in a special class of elastic self-similar fractals, which we call the “net fractals”. We show, that these systems, when presented in the logarithmic scale are isomorphic with some conventional crystals. This opens possibility to describe the symmetries of self-similar fractals, in the way, that is reminiscent of conventional formalism, developed for crystalline systems [2]. Motivated by this fact, we present study of vibrational excitations (fractons) in a “net fractal” system, which is similar in spirit to the phonon approach in the solid state theory. We prove, that in the elastic “net fractal “ systems the vibrational excitations (fractons), can be mapped onto conventional lattice phonons. This means that the fractons can be assumed as the logarithmic-scale phonons. Next with the use of Cauchy type boundary condition the “quantization” rules for the fracton eigenfrequences are found. Further, within elaborated by us formalism, we will show that in the log-coordinates the Hamiltonian of the fracton based superconductivity receives the conventional BCS form derived for a system of fractional spectral dimension [3]. The fact that fractons can be expressed as the log-phonons suggests that they are (or at least some of them) bosons. This supports the idea of fracton pairing in superconductors. In the HTC copper oxides the onset of superconductivity is closely related to the oxygen deficiency. It was postulated that the oxygen vacancies located mainly within the CuO_2 planes of the YBCO system form a fractal structures. Since the fracton vibrational frequency cutoff ω_{fd} is much greater than the Debye frequency of crystalline systems there arose conjecture that conduction electron scattering off fractons can be responsible for the high critical temperature [4]. We believe, that our approach gives better understanding of complex many systems and our results give practical indications for engineering of functionalized nanostructures for nanotechnological applications.

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