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Low Energy Electrodynamics of Quantum Matter

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Abstract

The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are ... completely known...'...or so was claimed in 1929 by P.A.M. Dirac shortly after the Schrodinger equation had been verified for few electron systems like H2 and He. Dirac continued that the difficulty in extending this success to larger systems is 'only that the exact application of these laws leads to equations much too complicated to be soluble'. One could not have anticipated in 1929 that it is precisely this complexity and the resultant effects of 10^{24} particles acting in quantum mechanical unison that gives rise to a host of beautiful and striking phenomena in materials like superconductivity and magnetism. Like waves on the sea, these are collective phenomena with elementary excitations not easily reducible to the properties of the underlying electrons. Almost a century after Dirac, we know better; to paraphrase P. W. Anderson, more really IS different.

The occurrence of exotic quantum phenomena that emerges on long length scales heightens the need for new experimental tools that probe finite, yet long time scales (compared to bare electronic ones). This talk will review recent advances in the area of THz spectroscopy and its application to exotic quantum states of matter. I will give examples of its use on material systems as diverse as high-temperature cuprate superconductors, 1D quantum spin chains, 'heavy-fermion' magnets, and topological insulators. From the observations of quarks and meson-like bound states in spin-chains to Dirac strings and to nematic electronic liquid crystals, these systems are host to phenomena which are found repeated across the diverse length and time scales of physics. A desire to characterize materials in a novel fashion and answer specific scientific questions is driving the THz technology forward, while new technology is changing the kinds of questions we think to ask.