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Features of a Coming Revolution in Low-Dimensional Electronics: A Result of Advances in Quantum Geometry

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Abstract

There are signs of a new scientific revolution emerging on the horizon, particularly in the field of low-dimensional electronics (LDE). LDE technology plays a crucial role in advancing electronic and mechatronic systems, leading to a major industrial breakthrough worldwide. This editorial highlights the most important issues and concepts in quantum geometry, including quantum mechanics and the discovery of the Attosecond, to achieve a new scientific leap. Quantum geometry is a science that uses quantum computing and topology, using coordinates, distances, angles, and shapes, to understand the physical properties of materials. Quantum mechanics relies on quantum entanglement and quantum superposition to describe various particle phenomena, meaning that a particle can assume two or more states simultaneously. Attosecond is a unique scientific discovery that has resolved the issue of observing electron motion to further understand the physical properties of materials with extreme precision and mastery. Integrating these concepts enables us to maximize efforts and optimism for a promising future in LDE technology, leading to enhanced quality of engineering industries in all areas of life, achieving scientific progress and economic prosperity for the well-being of society.

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Introduction

Scientific revolutions arise from the accumulation of valuable research and great discoveries in interpretation and the careful analysis of conceptual development and self-improvement over the years, especially when they have a direct connection to what benefits people's lives and society. Thanks to the efforts of dedicated explorers, researchers, and scientists, science has evolved over the years, from natural light at the beginning of creation to classical science and event physics, passing through engineering physics to quantum geometry and, most recently, to Attosecond. Long ago, and thanks to the scientific character of experiments in optics, achieved by the Arab encyclopedist Ibn al-Haytham at the beginning of the eleventh century AD [1]; thanks to the modern atomic theory formulated by the British chemist John Dalton in 1803; and thanks to the experimental results of the German scientist Max Planck in 1901, all of this laid the foundation for current scientific progress. The idea of the quantum theory began when some natural phenomena emerged that the laws of classical physics could not explain at that time. From these examples, when a tube of gas is heated, energy is released that can be sensed in the form of light and heat. When this tube is brought close to a prism, a prism is a prism-shaped piece made of a transparent material such as glass, but with flat surfaces at specific angles. When white light passes through a prism, it is refracted due to the different speed of light in the transparent material compared to air. A variety of colors are observed because the prism breaks white light down into its component colors of the spectrum. Each color has a different wavelength and therefore bends at a different angle as it passes through the prism. Therefore, we see a variety of colors, which contradicts the prevailing belief at the time that the energies emitted from objects are continuous. The German scientist Max Planck came to prove that these energies are emitted from objects in the form of specific units or "quanta" that can be measured using a simple equation: energy equals Planck's constant multiplied by frequency. This can be simplified to Planck's equation, which states that the energy of a photon is directly proportional to its frequency. Since then, talk about the concept of quantum geometry began.

The idea of converting a Femtolaser into an Attolaser also crystallized, i.e., converting the photons that make up the Femtolaser into high-energy, smaller, and much faster photons—a process known as high-harmonic generation (HHG), developed by Anne Lhuillier [2]. Combining the engineering physics of light, laser technology, and spectroscopy systems, the laser's operation relies on physical principles such as stimulated emission and radiation, making it a powerful tool in many applications. When this knowledge is combined with spectroscopy techniques, we obtain systems that excel at providing accurate information about the physical properties of materials by analyzing the emitted or absorbed light. These systems are used in various fields, helping to improve the accuracy of measurements and better understand the chemical and physical properties of materials. Prof. Mohamed Th Hassan (Egyptian) and his research team at the University of Arizona succeeded in developing a laser device that produces ultra-fast light pulses, enabling them to track the movement of electrons within insulating materials and transform them into electrically conductive materials [3]. This discovery represents a qualitative leap in the field of electronics and communications, as it is expected to increase the operating speed of electronic devices such as computers and mobile phones by 100 million times. In 2022, Professor Hassan and others were able to develop the world's fastest electron microscope, capable of detecting the movement of electrons within a billionth of a billionth of a second (Attoseconds) [3, 4]. It is worth noting that this was demonstrated by imaging and tracking the movement of electrons between carbon atoms in multilayer graphene at an unprecedented speed. This is in addition to the microscope's unique ability to perform three-dimensional imaging, which will help scientists in all fields' image electrons in samples of various materials in real time and space. The scientific community has recognized that this unique achievement opens the door to broad applications, not only in quantum geometry physics, but also in chemistry, biology, medicine, engineering, and all life sciences, bringing scientists closer to achieving the dream of determining the location and speed of electrons in real time and with extreme precision. Therefore, it can be said that Professor Hassan and his team were able to generate ultrafast photon pulses and use them to shape laser pulse waves generated by scattering light, modifying parts of the spectrum appropriately, and then recombining the light into a precisely engineered waveform. This was achieved by focusing light using advanced microscopy techniques to analyze lattice dynamics, helping to understand how the crystal structure affects the metal's electrical properties. The results also focused on studying the instability of charge density waves in Kagome metal, indicating the presence of complex interactions that may affect the material's physical properties. The results also indicated the presence of competition between different types of instability, which may affect the material's behavior under certain conditions. The study concluded that understanding charge dynamics in Kagome-structured materials may open new horizons in the field of advanced conductive materials and their applications. Therefore, it can be said that magnetism and electron correlations in kagomi magnets work together in a complex interaction. Magnetic effects have been shown to flow electrons around the material's structural triangles, and the electrons merge with each other in a collective wave, collectively carrying an electric current, akin to superconductivity. Based on how the atoms are arranged, the type of strongly selective band structure expected in a thin layer of kagomi magnets can be calculated. This is another promising path that may enable researchers to predict the topology of materials in future engineering designs. Further, researchers Minguo Kang and Ricardo Comin, along with others, have been able to discover the true shape (geometry) of moving electrons in kagomi magnets using angle-resolved photoelectron emission spectroscopy (ARPES) [5, 6]. ARPES is an ultra-advanced technique that enables the analysis of the angles and rotations of electrons emitted from a material to measure its quantum geometric matrix, providing unprecedented insight into its quantum geometric property. Providing unprecedented insight into their quantum geometry properties, the study revealed precise measurements of solid materials, enhancing understanding of the quantum properties of materials and improving their conductivity. This study is an important step toward developing the electrical and optical conductivity properties of solid materials, opening new horizons in the field of quantum geometry and its applications in future technologies [6].

Conclusion

Indeed, the accumulated studies and research have achieved significant progress and agreement between the concepts of engineering physics, quantum geometry, quantum mechanics, and the recent discovery of the Attosecond to produce materials with superconductive electrical and optical properties. This enhances the development of low-dimensional electronics systems, shaping the future of a new scientific revolution. The author also supports the importance of establishing specific laboratories focused on low-dimensional electronics at national metrological institutes and technological universities around the world. This is to achieve scientific progress and economic prosperity for the well-being of society and the people.

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