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From Precision Engineering and Quantum Geometry to Attosecond: A Promising Future in Electrnics Industries

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Abstract

Applied research and scientific discoveries have played a crucial role in advancing societies and improving the people's quality of life throughout the ages, especially when focusing on the physical properties of materials to achieve a leap in the electronics industry for economic prosperity. Electronics technology is now the driving force behind industrial progress in all aspects of life around the world.

Keyword: Precision Engineering and Quantum Geometry to Attosecond.

INTRODUCTION

Applied research and scientific discoveries have played a crucial role in advancing societies and improving the people's quality of life throughout the ages, especially when focusing on the physical properties of materials to achieve a leap in the electronics industry for economic prosperity. Electronics technology is now the driving force behind industrial progress in all aspects of life around the world. This editorial explores in depth the most important features of the development and discoveries of optics and engineering physics over time, including the scientific leap achieved during the last three years, from precision engineering and quantum geometry to the discovery of the Attosecond to observe and tracking electron motion, with the aim of understanding more about the superconductivity of materials. This enables us to maximize efforts and remain optimistic about a promising future for the electronics industry, extending to all engineering industries, to achieve progress and flourish economic for the benefit of all humanity.

As humanity sought a secure livelihood, the alternation of day and night was observed. Early astronomers needed to develop calendars to measure the passage of time. Around three thousand years BC, ancient cultural exchanges were recorded between the Indus River civilization in India and the Nile River civilization in Egypt. The civilization of the Pharaohs (ancient Egyptians) flourished, with the discovery of the sundial and the development of the sexagesimal system for measuring time. Three hundred years BC, the ancient Greek Euclid was interested in light. Meanwhile, during the sixth century AD, the Indian astronomer Aryabhata (476-550 AD) proposed ideas related to the Earth's rotation around its axis and considered relative motion to be the cause of sunrise and sunset. However, studies did not take on a scientific character until the Arab polymath Abu Ali al-Hasan Ibn al-Haytham (354-430 AH, corresponding to 965-1039 AD). His seven-volume book, "Al-Man?z?r" is a major scientific reference, containing a detailed description of his experiments and their results. He is thus called the father of modern optics, experimental physics, and scientific methodology.[1,2]

Today, efforts are increasingly being made to leverage modern engineering physics applications to overcome the current phase of the Fourth Industrial Revolution, such as the use of digitization and computing in the design and manufacture of environmentally friendly composite materials, smart materials, and high-precision coordinate automation, in preparation for the advent of the Fifth Industrial Revolution to achieve precise and highly accurate collaboration and harmony between humans and machines.[2-9] Salah Ali has contributed numerous scientific achievements that have influenced the engineering physics and mechatronics industries across several axes. His most significant contributions include the study of smart materials, the production and development of new environmentally friendly composite engineering materials, and the development of precise and ultra-precise metrological methods.[3] His contributions also include the production and characterization of carbon nanotubes and their polymer-supported composites, with the aim of improving various physical, mechanical, and electrical properties of the materials. These composites contribute to the manufacture of structural components of electronic devices, making them more flexible and durable, thus enhancing performance and efficiency in various applications. His achievements in the field of engineering metrology have contributed to understanding and improving the accuracy of measurement strategies while estimating the uncertainty associated with the manufacturing of complex engineering components at the micr- and nano-meter level, enhancing reliability in the mechanical and mechatronics industries, especially in automotive, aerospace, and biomedical applications. Furthermore, Prof. Salah Ali *et al.,* developed a newly innovative method for reverse engineering techniques using image processing and computer-aided design systems to improve the design and production of gears.[4] In another study, Prof. Ali *et al.,* developed an innovative method to precisely solve some important issues in the field of biomedical engineering.[5] Engineering physics, electric vehicles, and civil engineering also play a pivotal role in the design and performance improvement of new and smart underground cities by developing next-generation technologies.[6,7] In addition, Prof. Ali, through projects with his students, developed a microelectronic method to enhance the self-production of carbon nanotubes (CNTs).[8] Ali and his colleagues also developed CNT-reinforced polymeric materials to improve the mechanical and tribological properties of surfaces of new materials, thus meeting the aspirations of future generations.9 Numerous valuable contributions have been made by 2025, marking a new era of innovation for developing green hydrogen production systems to achieve economic balance.[10] These scientific achievements, as part of his plan for the coming year 2026, will contribute significantly to modern engineering industries, such as remote sensors, microprocessors, and actuators.[11,12] This is intended to achieve integration with engineering systems such as electronics, mechatronics, high-precision measurements, autotronics, and bioengineering. All of this will undoubtedly open new horizons in system design and the development of modern technologies to achieve high performance and greater progress in vehicle systems, as well as new generations in the communications, robotics, and public health industries for future generations.[9-12] All of this and more to come may accelerate the transition to the Fifth Industrial Revolution.

Attosecond, a new leap in future innovations: Thanks to the scientific breakthrough achieved in optics at the beginning of the eleventh century AD by the Ibn al-Haytham; and thanks to the ideas and achievements of numerous thinkers, researchers, and scientists, especially after John Dalton formulated his modern atomic theory in 1803; and after the concept of quantum geometry emerged in physics as a result of the experiments of the German scientist Max Planck in 1901. Following in the footsteps of scientists and explorers, Andre Geim, a Dutchman of Russian origin, and Konstantin Novoselov, a British man of Russian origin, conducted pioneering experiments in discovering graphene in the form of new sheets of carbon with a thickness equivalent to the diameter of one atom, for which they were jointly awarded the Nobel Prize in Physics in 2010. Graphene is a three-dimensional material with unique magical properties. The Egyptian scientist Ahmed Zewail invented the ultra-fast microscope, called Femtochemistry (10-15 seconds), which enabled scientists to photograph chemical reactions as they occurred at the atomic level, in a time of Femtoseconds. Prof. Ahmed Zewail was awarded the 1999 Nobel Prize in Chemistry for his invention of this revolutionary field, which has had huge applications in chemistry, medicine, and nanotechnology. This is in addition to explaining the concept of quantum entanglement, for which the trio John F. Clauser (American), Anton Zeilinger (Austrian), and Alain Aspect (French) were awarded the 2022 Nobel Prize in Physics for their achievements in the field of quantum mechanics, or as the Nobel Committee put it: for their experiments on quantum entangled photons. They confirmed the difference between the local reality of Albert Einstein's two theories and the quantum view. Local realism states that everything that can be measured has a specific value. Pierre Agostini (French), his supervisor Prof. Ferenc Krausz (Hungarian/Austrian), and Anne Lhuillier (French/Swedish) were awarded the 2023 Nobel Prize in Physics for their work in generating light pulses measured in Attoseconds. In the same year, for the discovery and synthesis of quantum dots, the Nobel Prize in Chemistry was awarded to Mongi G. Bawendi, Louis E. Bruce, and Alexei Yekimov. The research of Prof. Ahmed Zewail and Prof. Ferenc Krausz is a continuum, but their findings are distinct, based on distinct technological advances. Zewail's work relied on observations of the motion of molecules and atoms, which he conducted in the late 1980s, based on advances in Femtosecond laser technology. The development of the Attosecond laser was then considered in 1993. At that time, the discovery of the quantum geometry of subatomic particles led to a revolution in physics, as quantum theory described the behavior of microscopic particles, known as quantum mechanics. With the development of scientific cameras and microscopes, and the concept of quantum mechanics, together known as quantum geometry. Quantum geometry is a science that uses applications of quantum computing and topology in terms of coordinates, distances, angles, and shapes to understand more of the natural properties of materials. Therefore, it can be said that the development of natural sciences paved the way for modern engineering physics to achieve the quantum geometry of particles. The idea of ??transforming a Femtolaser into an Attolaser crystallized, i.e., converting the photons that make up a Femtolaser into high-energy, smaller, and much faster photons-a process known as high-harmonic generation (HHG), developed by Anne Lhuillier. Therefore, it can be said that Attosecond science relied on the development of Femtosecond technology. This means that the higher the energy of light photons, the faster their timescale. By amplifying the frequency and energy of Femtosecond photons, we obtain shorter laser pulses, called Attosecond, which can be used to monitor and study the movement of electrons.

By integrating engineering photophysics, laser technology, and spectroscopy systems, lasers operate based on physical principles such as stimulated emission and radiation, making them a powerful tool in a wide range of applications. When this knowledge is combined with spectroscopy techniques, we obtain systems capable of providing accurate information about material properties by analyzing the emitted or absorbed light. These systems are used in various fields such as chemistry, environment, and medicine, helping to improve the accuracy of measurements and understand the chemical and physical properties of materials. In 2017, Arab scientist Mohamed Tharwat Hassan and his research team 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. This discovery represents a quantum 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, Prof. Hassan and others were able to develop the fastest electron microscope in the world, capable of detecting the movement of electrons within a billionth of a billionth of a second, using what is called Attosecond technology (10-18 seconds).[13] As he became one of the youngest and most recent scientists in the world and the Arab world, we will give a brief overview of the stages of his scientific development. He was born in March 1983 in the Egyptian city of Fayoum (about 80 km southwest of the capital, Cairo). He obtained a Bachelor of Science in Chemistry from Fayoum University in 2003, and a Master's degree in Light and Optical Physics from the Institute of Laser Physics at Cairo University in 2008. He completed his studies at the Attosecond Physics Laboratory under the supervision of Prof. Ferenc Krausz in Germany to obtain a PhD from the Max Planck Institute for Quantum Optics in Munich in 2013. In 2016, he had the unique opportunity to pursue a postdoctoral fellowship at Caltech University in the United States under two giants in the fields of physics and chemistry, Nobel Prize winners Ahmed Zewail and Ferenc Krausz. After much effort, diligence, and perseverance, Prof. Hassan found his own space among leading scientists after he began working as a professor of physics and laser science at the University of Arizona in 2017, and established his research group there. His research made him one of the pioneers of Attosecond physics. Then, Attosecond became the quintillion is a unit of time in the International System of Units (SI). Imagine having a super-high-resolution camera that can capture the motion of an electron as it dances in its orbits around the nucleus, or moves between orbits or between atoms. This will undoubtedly allow scientists to see the electron in real time and space. Therefore, super-high-speed electron microscopes rely on emitting electron pulses in Attosecond, generating a series of images similar to the frames of a movie. Previously, scientists were unable to observe the interactions and changes that occur to the electron within these frames in real time and space. Prof. Hassan and his team were able to produce an Attosecond electron pulse, at the same speed as the electrons' motion, enabling the microscope to function as a super-high-speed, high-resolution camera capable of capturing the motion of electrons. This capability was demonstrated by imaging the movement of electrons between carbon atoms in multilayer graphene at unprecedented speeds. This, in addition to the microscope's unique ability to perform 3D imaging, will help scientist's image electrons in samples of various materials, particularly engineering and biological ones, in real time and space. Everyone agrees that this unique scientific achievement opens the door to broad applications, not only in geometrical quantum physics, but also in chemistry and biology, bringing scientists closer to achieving the dream of determining the location and speed of an electron in real time and with extreme precision. Therefore, it can be said that Prof. 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 reassembling the light into a waveform or engineered structure. This approach relies on spectral resolution and the overall spectral bandwidth. This enabled the team, led by Prof. Hassan, to overcome previous challenges and create an electric field for the Attosecond laser that extends from infrared to ultraviolet, passing through visible light. Measurements were also conducted to interpret the lattice dynamics of kagome metal and charge density waves in 2023.[14] Kagome metal (ScV6Sn6) is a solid metallic material with a crystalline structure, its internal structure consisting of interlocking triangles and hexagons. Its complex magnetic properties and unusually high electrical conductivity make it a candidate for study in electronics applications, especially with the presence of vanadium and scandium, which possess special magnetic properties based on the arrangement of electrons in the crystal structure and the interactions between atoms. The word "kagome" describes the geometric pattern of triangles and hexagons, and its name comes from a traditional Japanese lattice pattern known as the kagome pattern or kagome lattices. Advanced metrological techniques were used to analyze the lattice dynamics to help understand how the crystal structure affects the metal's electrical properties. The measurements focused on studying the instabilities of charge density waves in kagome metal, indicating the presence of complex interactions that may affect the physical properties of the material. The results also indicated the presence of competition between different types of instabilities, which may affect the behavior of the material under certain conditions. The study concluded that understanding the charge dynamics in kagome-structured materials is important, as it may open new horizons in the field of advanced materials and their applications. Therefore, it can be said that magnetism and electron correlations in kagome magnets work together in a complex interaction. Magnetic effects revealed the flow of electrons around the material's structural triangles, and the electrons merge with each other in a collective wave, collectively carrying an electric current, similar to superconductivity. Based on how the atoms are arranged, the type of strongly selective band structure expected in a thin layer of kagome magnet can be calculated, providing a good path for researchers to predict the topology of materials in future engineering designs. Further, researchers Mingoo Kang, Ricardo Comin, and others were able to discover the true shape (geometry) of the moving electron in Kagome using angle-resolved photoelectron emission spectroscopy (ARPES).[15-16] ARPES is an ultra-advanced metrological 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 feature. The study revealed precise measurements of solids, enhancing the understanding of the quantum properties of materials. This study is an important step toward developing the electrical and optical properties of solids, opening new horizons in the field of quantum physics and its applications in future technologies.[16]

On the other hand, after 10 years of research, a recent study by researcher Seongyong Lee and others at the Holmholtz Institute for Materials and Energy (HZB) in Germany has shown that complex quantum states such as spin liquids exist in complex crystals with different configurations of magnetic interactions, which may change our understanding of how quantum computing works. One of the most important of these was the development of magnetic correlations in a “spiral spin liquid” material.[17] Spiral spin liquid is a concept in fluid physics for the state of matter. It simply occurs, i.e., spinning or self-spinning, but in the quantum world it does not mean that the electron is physically rotating. In quantum computing, however, spiral spin liquid refers to a type of actual angular momentum, which simply describes how the electron behaves in terms of motion and order. The spin state of an electron is usually described as either “up”, “down”, or in a superposition state, i.e., in both states at the same time. The study showed how magnetic correlations change over two main stages across different temperatures in the development of magnetic interactions. The first stage is characterized by irregular frequencies and correlations, while the second stage shows greater stability in the magnetic spiral pattern. This analysis may contribute to understanding how complex patterns of magnetic motion are formed in spiral liquid materials. This may be It is important for the development of future quantum computers because spin liquids are one of the potential building blocks for carrying the smallest units of quantum information, known as quantum bits (Qubits). Therefore, I believe these researches could help in cryptography, chemical simulations, and complex data analysis and storage.

Economic Overview: Egypt's engineering industries witnessed remarkable development in 2024, with its engineering exports exceeding $5 billion for the first time in history, a 21.6% increase compared to the previous year, as part of the Egyptian Engineering Export Council's targets. The council also aims to reach $6 billion by the end of 2025. This is a step towards achieving the Egyptian government goal of increasing commodity exports to $145 billion by 2030.[18] India also witnessed remarkable growth in its engineering industries production during the 2023-2024 fiscal years, with its engineering exports exceeding $109 billion, a relative increase of 2.13% compared to the previous year. This is a step towards achieving the Indian government goal of are expected to continue their growth trajectory, potentially reaching $300 billion by 2030, according to the Business Standard.[19] This figure is expected to exceed $115 billion by the next fiscal year. Based on these indicators, it can be argued that continued support and development of the engineering industries is a fundamental pillar for achieving sustainable economic growth around the world, especially in Egypt and India, for example. This confirms that the largest electronics-producing countries in the world are currently, in order: China, South Korea, Taiwan, the United States, and Japan. The largest countries consuming electronics around the world, based on 2022 statistics, were: the United States (21.3%), Germany (10.5%), Japan (7.7%), the Netherlands (4.0%), Canada (3.7%), Russia (3.6%), Poland (3.4%), and France (3.3%).[20]

According to Global Insights, the electronics manufacturing sector is expected to witness significant progress in 2025, with growth ranging between 6% and 16%, based on various estimates from research and industry institutions. Gartner expects the semiconductor market to reach $717 billion in revenue in 2025, a 14% increase over the previous year. Meanwhile, the American company WSTS, based on its global semiconductor trade statistics, predicts a growth of 11.2%, bringing the market size to $697 billion.[21] This growth is attributed to the growing demand for expanding electronics infrastructure and 5G networks, driven by the increasing use of smart devices powered by artificial intelligence in homes, institutions, transportation systems, and in all other aspects of life, including the on-going digital wars. This is in addition to the largely unannounced developments in the defence industry, which I predict may have reached the tenth generation in complete secrecy.

CONCLUSION

The world is currently experiencing a new scientific leap, which may soon lead us to the Fifth Industrial Revolution, thanks to the anticipated advances in the electronics industry. Therefore, it can conclude the following:

Our new understanding of magnetism, in light of the level of electron movement and tracking within or between atoms, may help us understand more about the properties of superconductors and improve quantum computers. That is, we may soon be able to say, "I want to create a new material with specific behaviours and physical properties of superconductivity". This abundant qualitative momentum of efforts by scientists and explorers opens up promising opportunities for collaboration between physicists, chemists, engineers and materials scientists, representing a new step in advancing scientific and technological progress around the world. A better understanding of electron charge distribution may open the door to improving ultra-precision engineering metrology systems and post-nanometer technologies such as contact and non-contact sensors. This could also support the design and manufacture of more efficient, integrated, and microelectronic components and systems, saving significant amounts of effort, making them more efficient and sustainable in the future, thus contributing to the prosperity of the global economy. Eventually, the possession of natural resources, such as minerals and ores, is a valuable asset scientifically, economically, and politically. Academic institutions must also consider developing their curricula and research plans to understand and keep pace with recent scientific discoveries and developments, thus furthering students' knowledge, particularly in the fields of magnetism and the integrated nanoelectronics industry.

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