QUANTXCER BI-WEEKLY NEWS LETTER

QUANTUM PHYSICS NEWS LETTER 31-AUG-2024

QuantXCer.com

It is a quantum fractal algorithmic universe

TABLE OF CONTENTS

A New Approach To Fine-Tuning Quantum Materials

An MIT-led group shows how to achieve precise control over the properties of Weyl semimetals and other exotic substances.

Quantum materials — those with electronic properties that are governed by the principles of quantum mechanics, such as correlation and entanglement — can exhibit exotic behaviors under certain conditions, such as the ability to transmit electricity without resistance, known as superconductivity.

However, in order to get the best performance out of these materials, they need to be properly tuned, in the same way that race cars require tuning as well.

A team led by Mingda Li, an associate professor in MIT's Department of Nuclear Science and Engineering (NSE), has demonstrated a new, ultra-precise way to tweak the characteristics of quantum materials, using a particular class of these materials, Weyl semimetals, as an example.

Quantum mechanics, spintronics – artistic impression.

The new technique is not limited to Weyl semimetals. “We can use this method for any inorganic bulk material, and for thin films as well,” maintains NSE postdoc Manasi Mandal, one of two lead authors of an open-access paper — published recently in *Applied Physics Reviews* — that reported on the group’s findings.

The experiment described in the paper focused on a specific type of Weyl semimetal, a tantalum phosphide (TaP) crystal. Materials can be classified by their electrical properties: metals conduct electricity readily, whereas insulators impede the free flow of electrons. A semimetal lies somewhere in between. It can conduct electricity, but only in a narrow frequency band or channel. Weyl semimetals are part of a wider category of so-called topological materials that have certain distinctive features.

For instance, they possess curious electronic structures — kinks or “singularities” called Weyl nodes, which are swirling patterns around a single point (configured in either a clockwise or counterclockwise direction) that resemble hair whorls or, more generally, vortices. The presence of Weyl nodes confers unusual, as well as useful, electrical properties. And a key advantage of topological materials is that their sought-after qualities can be preserved, or “topologically protected,” even when the material is disturbed.

“That’s a nice feature to have,” explains Abhijatmedhi Chotrattanapituk, a PhD student in MIT’s Department of Electrical Engineering and Computer Science and the other lead author of the paper. “When you try to fabricate this kind of material, you don’t have to be exact. You can tolerate some imperfections, some level of uncertainty, and the material will still behave as expected.”

Like water in a dam

The “tuning” that needs to happen relates primarily to the Fermi level, which is the highest energy level occupied by electrons in a given physical system or material. Mandal and Chotrattanapituk suggest the following analogy: Consider a dam that can be filled with varying levels of water. One can raise that level by adding water or lower it by removing water. In the same way, one can adjust the Fermi level of a given material simply by adding or subtracting electrons.

To fine-tune the Fermi level of the Weyl semimetal, Li’s team did something similar, but instead of adding actual electrons, they added negative hydrogen ions (each consisting of a proton and two electrons) to the sample. The process of introducing a foreign particle, or defect, into the TaP crystal — in this case by substituting a hydrogen ion for a tantalum atom — is called doping. And when optimal doping is achieved, the Fermi level will coincide with the energy level of the Weyl nodes. That’s when the material’s desired quantum properties will be most fully realized.

For Weyl semimetals, the Fermi level is especially sensitive to doping. Unless that level is set close to the Weyl nodes, the material’s properties can diverge significantly from the ideal. The reason for this extreme sensitivity owes to the peculiar geometry of the Weyl node. If one were to think of the Fermi level as the water level in a reservoir, the reservoir in a Weyl semimetal is not shaped like a cylinder; it’s shaped like an hourglass, and the Weyl node is located at the narrowest point, or neck, of that hourglass. Adding too much or too little water would miss the neck entirely, just as adding too many or too few electrons to the semimetal would miss the node altogether.

Fire up the hydrogen

To reach the necessary precision, the researchers utilized MIT's two-stage "Tandem" ion accelerator — located at the Center for Science and Technology with Accelerators and Radiation (CSTAR) — and buffeted the TaP sample with high-energy ions coming out of the powerful (1.7 million volt) accelerator beam. Hydrogen ions were chosen for this purpose because they are the smallest negative ions available and thus alter the material less than a much larger dopant would. "The use of advanced accelerator techniques allows for greater precision than was ever before possible, setting the Fermi level to milli-electron volt [thousandths of an electron volt] accuracy," says Kevin Woller, the principal research scientist who leads the CSTAR lab. "Additionally, high-energy beams allow for the doping of bulk crystals beyond the limitations of thin films only a few tens of nanometers thick."

The procedure, in other words, involves bombarding the sample with hydrogen ions until a sufficient number of electrons are taken in to make the Fermi level just right. The question is: how long do you run the accelerator, and how do you know when enough is enough? The point being that you want to tune the material until the Fermi level is neither too low nor too high.

"The longer you run the machine, the higher the Fermi level gets," Chotrattanapituk says. "The difficulty is that we cannot measure the Fermi level while the sample is in the accelerator chamber." The normal way to handle that would be to irradiate the sample for a certain amount of time, take it out, measure it, and then put it back in if the Fermi level is not high enough. "That can be practically impossible," Mandal adds.

To streamline the protocol, the team has devised a theoretical model that first predicts how many electrons are needed to increase the Fermi level to the preferred level and translates that to the number of negative hydrogen ions that must be added to the sample. The model can then tell them how long the sample ought to be kept in the accelerator chamber.

The good news, Chotrattanapituk says, is that their simple model agrees within a factor of 2 with trusted conventional models that are much more computationally intensive and may require access to a supercomputer. The group's main contributions are two-fold, he notes: offering a new, accelerator-based technique for precision doping and providing a theoretical model that can guide the experiment, telling researchers how much hydrogen should be added to the sample depending on the energy of the ion beam, the exposure time, and the size and thickness of the sample.

Fine things to come with fine-tuning

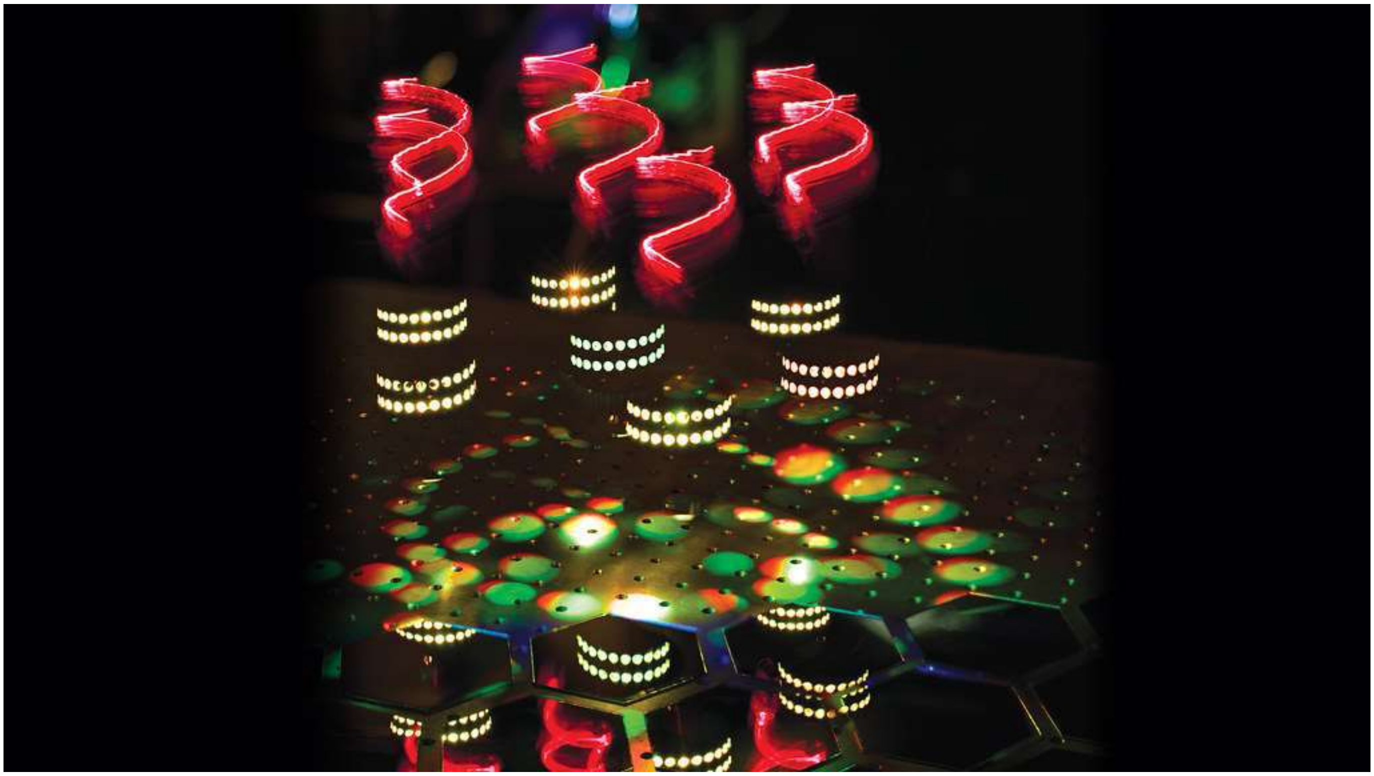
This could pave the way to a major practical advance, Mandal notes, because their approach can potentially bring the Fermi level of a sample to the requisite value in a matter of minutes — a task that, by conventional methods, has sometimes taken weeks without ever reaching the required degree of milli-eV precision.

Li believes that an accurate and convenient method for fine-tuning the Fermi level could have broad applicability. “When it comes to quantum materials, the Fermi level is practically everything,” he says. “Many of the effects and behaviors that we seek only manifest themselves when the Fermi level is at the right location.” With a well-adjusted Fermi level, for example, one could raise the critical temperature at which materials become superconducting. Thermoelectric materials, which convert temperature differences into an electrical voltage, similarly become more efficient when the Fermi level is set just right. Precision tuning might also play a helpful role in quantum computing.

Thomas Zac Ward, a senior scientist at the Oak Ridge National Laboratory, offered a bullish assessment: “This work provides a new route for the experimental exploration of the critical, yet still poorly understand, behaviors of emerging materials. The ability to precisely control the Fermi level of a topological material is an important milestone that can help bring new quantum information and microelectronics device architectures to fruition.”

Physicists Use Light To Probe Deeper Into The ‘Invisible’ Energy States Of Molecules

A new optical phenomenon has been demonstrated by an international team of scientists led by physicists at the University of Bath, with significant potential impact in pharmaceutical science, security, forensics, environmental science, art conservation and medicine.



Artistic representation of hyper-Raman optical activity. Image Credit: Ventsislav Valev and Kylian Valev, university of Bath

Molecules rotate and vibrate in very specific ways. When light shines on them it bounces and scatters. For every million light particles (photons), a single one changes colour. This change is the Raman effect. Collecting many of these colour-changing photons paints a picture of the energy states of molecules and identifies them.

Yet some molecular features (energy states) are invisible to the Raman effect. To reveal them and paint a more complete picture, ‘hyper-Raman’ is needed.

Hyper-Raman

The hyper-Raman effect is a more advanced phenomenon than simple Raman. It occurs when two photons impact the molecule simultaneously and then combine to create a single scattered photon that exhibits a Raman colour change.

Hyper-Raman can penetrate deeper into living tissue, it is less likely to damage molecules and it yields images with better contrast (less noise from autofluorescence). Importantly, while the hyper-Raman photons are even fewer than those in the case of Raman, their number can be greatly increased by the presence of tiny metal pieces (nanoparticles) close to the molecule.

Despite its significant advantages, so far hyper-Raman has not been able to study a key enabling property of life – chirality.

Optical activity

In molecules, chirality refers to their sense of twist – in many ways similar to the helical structure of DNA. Many bio-molecules exhibit chirality, including proteins, RNA, sugars, amino acids, some vitamins, some steroids and several alkaloids.

Light too can be chiral and in 1979, the researchers David L. Andrews and Thiruiappah Thirunamachandran theorised that chiral light used for the hyper-Raman effect could deliver three-dimensional information about the molecules, to reveal their chirality.

However, this new effect – known as hyper-Raman optical activity – was expected to be very subtle, perhaps even impossible to measure. Experimentalists who failed to observe it struggled with the purity of their chiral light. Moreover, as the effect is very subtle, they tried using large laser powers, but this ended up damaging the molecules being studied.

Explaining, Professor Ventsislav Valev who led both the Bath team and the study, said: “While previous attempts aimed to measure the effect directly from chiral molecules, we took an indirect approach.

“We employed molecules that are not chiral by themselves, but we made them chiral by assembling them on a chiral scaffold. Specifically, we deposited molecules on tiny gold nanohelices that effectively conferred their twist (chirality) to the molecules.

“The gold nanohelices have another very significant benefit – they serve as tiny antennas and focus light onto the molecules. This process augments the hyper-Raman signal and helped us to detect it.

“Such nanohelices were not featured on the 1979 theory paper and in order to account for them we turned to none other than one of the original authors and pioneer of this research field.”

Confirming a 45-year-old theory

Emeritus Professor Andrews from the University of East Anglia and co-author of the paper said: “It is very gratifying to see this work the experimental finally confirm our theoretical prediction, after all these years. The team from Bath have performed an outstanding experiment.”

This new effect could serve to analyse the composition of pharmaceuticals and to control their quality. It can help identify the authenticity of products and reveal fakes. It could also serve to identify illegal drugs and explosives at customs or crime scenes.

It will aid detecting pollutants in environmental samples from air, water and soil. It could reveal the composition of pigments in art for conservation and restoration purposes, and it will likely find clinical applications for medical diagnosis by detecting disease-induced molecular changes.

Professor Valev said: “This research work has been a collaboration between chemical theory and experimental physics across many decades and across academics of all stages – from PhD student to Emeritus Professor.

“We hope it will inspire other scientists and that it will raise awareness that scientific progress often takes many decades.”

Looking ahead he added: “Ours is the very first observation of a fundamental physical mechanism. There is a long way ahead until the effect can be implemented as a standard analytical tool that other scientist can adopt.

“We look forward to the journey, together with our collaborators from Renishaw PLC, a world-renowned manufacturer of Raman spectrometers.”

Dr Robin Jones, first-author for the new research paper and a PhD student at Bath until recently, said: “Performing the experiments that showed the hyper-Raman optical activity effect has been my most rewarding academic experience. In retrospect, it seems that almost every step of my PhD was like a piece of the puzzle which fell into place to achieve the observation.”

Milerd’s Innovative EMF Meter: Overview

EMF monitoring becomes important for keeping an environment safe. Phones and Wi-Fi routers, among others, emit electromagnetic fields, and this is becoming a health issue. Milerd’s innovative EMF detector presents an elegant solution for monitoring these radiation levels.

Created with precision to give accurate readings, Milerd’s gadget guarantees users can control their exposure to EMF, thus leading to healthier individuals. In this review, we will look at how Milerd’s battery-powered EMF meter is unique as a response to dealing with electromagnetic radiation conflict.

.

Main Features and Functions

Milerd’s EMF detector measures the full range of electromagnetic fields. It accurately identifies and measures electric, magnetic, and radio frequency fields, even with variable intensities. This ability makes it possible for the user to monitor different sources of radiation, from home appliances and power cables to Wi-Fi networks and other wireless devices. It has high sensitivity levels that enable precise measurements, thus enabling users to determine various sources of exposure to EMFs in the vicinity.

Color-Coded Threat Level Indicators

The EMF detector includes an intuitive color-coded indication system that makes it easy to assess radiation levels. These colors (red, yellow, green) show different threats:

- **Red**. This indicates very high levels of EMFs that could be dangerous to health, thus requiring immediate attention.
- **Yellow**. It shows moderate levels of EMF exposure, which may raise concerns when they continue over a long period of time; hence, caution is needed.
- **Green**. It represents low EMFs, meaning that the surroundings are well within safe limits for human beings.

With this visual system, users can quickly make sense of results obtained from measurements and choose whether they want to reduce their level of exposure.

Accumulated Dose Function

One feature worth noting about Milerd’s EMF detector is its Accumulated Dose function. This function automatically saves all data for cumulative radiation during a month. Users may understand their long-term patterns of exposure through tracking them; therefore, identifying potential issues might be helpful. Consequently, this information helps assess cumulative exposures and make necessary adjustments whenever needed to minimize such exposures accordingly.

Long Battery Life

Milerd’s electromagnetic field meter has been designed for extended use, with a battery life lasting up to 1 week in continuous monitoring mode. This longer battery performance ensures the device can operate as a consistent surveillance platform for electromagnetic fields without frequent recharges by its owner. It supports stable operation and long-term performance both in professional environments and everyday life, as its battery is durable. The lasting capacity of the battery is important as it provides continuous sensing, thus allowing the user to remain constantly aware of the EMF environment.

Advantages Over Other Meter

One of the main strengths of Milerd’s EMF detector is its user-friendly graphic display of measuring data. Unlike many others, which are only based on numbers, Milerd’s instrument presents information with clear and easy-to-understand graphs and visual displays. Adopting a graphical method allows users to grasp complex details at once by just looking at electromagnetic field levels over time in order for them to quickly detect, identify, and access patterns in such changes. Thus, this detector increases understanding by visualizing the raw data it produces, thereby facilitating informed decisions about EMF exposure.

Multi-Mode Operation: Versatile Usage Modes

Milerd’s EMF meter has some features that make it different from other meters regarding their functions. It can be used in several distinct modes depending on the type of monitoring required.

-
  - Search mode. This mode is aimed at discovering and identifying sources of EMFs at an initial stage so that one can quickly establish areas with high emitting levels for first scans.
  - Statistics screens. This mode gives a detailed statistical analysis of measurements taken concerning average, peak, and minimum radiation levels within some specified durations. It helps people track their exposure comprehensively.
  - LAB mode is intended for professional scientists because it provides sophisticated options for deep-level investigations, allowing detailed settings or high-resolution measurements during technical evaluations or research.

- Accumulated dose mode. This mode helps follow up on long-term emission level changes and, hence, evaluate possible health implications arising from prolonged exposures.

Examples of Using

- At home, Milerd’s EMF meter is invaluable for monitoring and managing electromagnetic radiation from everyday appliances. Users can check radiation levels from devices like cell phones, microwaves, and Wi-Fi routers to ensure their home environment is safe. By identifying high-emitting areas, users can make adjustments to reduce exposure, such as repositioning devices or using shielding materials.
- In the office. For office environments, the EMF meter helps assess emissions from office equipment like computers, printers, and wireless networks. It can be used to ensure that workspaces are within safe EMF limits, contributing to a healthier workplace. Employers and employees can use the meter to identify potential sources of excessive emissions and make necessary changes to improve workplace safety and comfort.
- During workouts. While exercising, whether at the gym or at home, Milerd’s EMF meter can be used to monitor EMF exposure from fitness equipment and electronic devices. Ensuring that workout areas are free from excessive electromagnetic radiation helps maintain a safe and healthy exercise environment. Users can also check emitting levels from personal fitness trackers and devices to ensure they are within safe limits.

- While traveling. When traveling, Milerd’s EMF meter is a practical tool for assessing EMF levels in various environments, such as hotels, rental accommodations, and public spaces. It helps travelers ensure that their temporary living spaces are free from high levels of electromagnetic emissions. Additionally, the devices compact size and long battery life make it convenient for on-the-go monitoring, allowing travelers to maintain their health and safety standards wherever they are.

Conclusion

The Milerd HiRange EMF detector is a state-of-the-art tool for professional and home use, with advanced functionality surpassing traditional EMF meters. It can measure low-frequency and high-frequency electric fields and magnetism, including that produced by 5G networks, enabling it to give a complete picture of the radiation levels in the environment. The broad measurement range of the HiRange from 0 Hz up to 8 GHz allows users to comprehensively evaluate exposure to radiation and its possible effects on health.

This makes HiRange useful in monitoring bedrooms or kitchens, while also being appropriate for office areas. Because this device is small, consumes less power, and has a battery life of almost one week, customers can carry it along when going out or use it at home or even at the office without difficulties. Furthermore, its ease of operation FCU usability.

Those concerned about their overall well-being and electromagnetic environment will find the Milerd HiRange necessary. We welcome you to purchase this highly developed EMF meter so that you can be responsible for your health and have a safer living condition full of knowledge.

New Technology Images Microbes In 3D

Caltech researchers have developed a new method to create three-dimensional images of complex communities of bacteria and plant roots. The technology synthesizes two traditional methods of imaging: visualizing microbes with fluorescence and a noninvasive technique called quantitative phase imaging.

Green plant growing in soil – illustrative photo. Image credit: Roman Synkevych via Unsplash, free license

This technology is a step toward understanding the complicated environment of the rhizosphere, the region of soil where a plant's roots interact with microorganisms. Bacteria in the rhizosphere help plants obtain crucial nutrients like phosphorous, but this environment has been difficult to study and image as it is underground.

The research is a collaboration between the laboratory of imaging specialist Changhuei Yang, the Thomas G. Myers Professor of Electrical Engineering, Bioengineering, and Medical Engineering, Heritage Medical Research Institute Investigator, and executive officer for electrical engineering; and the laboratory of biologist Dianne Newman, the Gordon M. Binder/Amgen Professor of Biology and Geobiology, and Merkin Institute Professor. A paper describing the study appears in the journal *Proceedings of the National Academy of Sciences*.

“It’s challenging to observe the dynamics in the rhizosphere because it’s naturally concealed beneath the opaque layers of soil,” says postdoctoral scholar Reinaldo Alcalde, a co-first author of the new study. “This was a motivation to develop better methods to image bacteria in these regions.”

Traditionally, researchers who want to study bacterial dynamics have genetically engineered bacteria to fluoresce under laboratory conditions, their artificial green glow visible with a microscope. However, not all microbial species can be engineered in this way. Another method to image bacteria, quantitative phase imaging, is able to detect miniscule differences in transparency without the use of fluorescence.

The new technology is a combination of these two techniques into a single optical setup. Called CFAST (Complex-field and Fluorescence microscopy using the Aperture Scanning Technique), the novel technique can create three-dimensional images of microbial communities much faster and with less damage than commercial microscopes.

“Through the 3D camera setup, the two techniques work simultaneously and seamlessly,” says postdoctoral scholar Oumeng Zhang, also a co-first author on the study.

As the work is still a proof of concept, the bacterial communities were imaged outside of soil under simplified conditions. The team aims to continue developing and improving the technology to be able to precisely image roots and bacteria together.

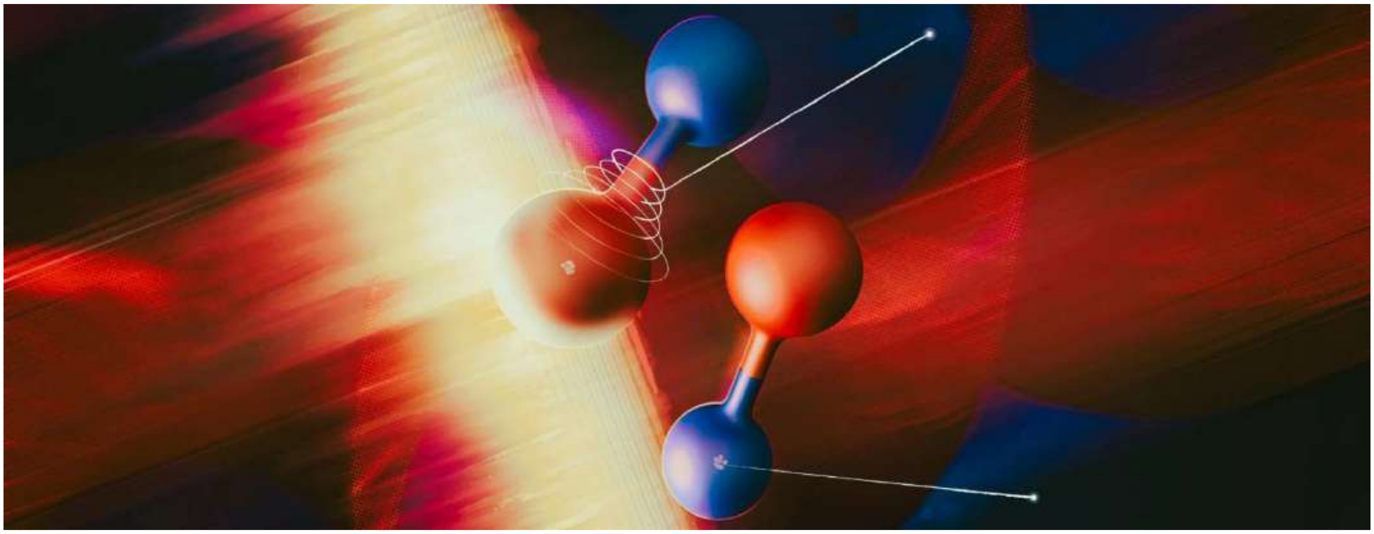
“This is a multidisciplinary collaboration that came out of curiosity and blending two fields of science to create something useful,” says Alcalde.

“There are many questions about what really goes on in soil, but there are few efforts aimed at developing good technologies for getting good data from the soil,” says Yang. “Hopefully, this project represents the start of an effort here on campus. Both Dianne and I appreciate the funding support from the Resnick Sustainability Institute.”

Physicists Shine New Light On Ultra-Fast Atomic Processes

An international team of scientists is the first to report small delays in a molecule's electron activity when the particles are exposed to X-rays.

.



Studying how atoms experience delays when they move can reveal structural and dynamical information about the universe.
Image credit: Gregory M. Stewart/SLAC National Accelerator Laboratory

The To measure these tiny high-speed events, known as attoseconds, researchers used a laser to generate intense X-ray flashes that allowed them to map the inner workings of an atom.

Their findings revealed that when X-rays eject electrons, they interact with another type of particle called the Auger-Meitner electron, causing a secondary pause that's never been detected before. These results have implications for a wide range of research fields, as learning more about these interactions can reveal novel ideas about complex molecular dynamics, said Lou DiMauro, co-author of the study and a professor of physics at The Ohio State University.

"X-rays are interesting probes of matter," DiMauro said. "You could use them to take a series of stop-action snapshots of a molecule as it evolves before or during a chemical reaction."

The study was recently published in *Nature.*

While there have been many noteworthy leaps in scientists' ability to study attosecond delays using ultraviolet light over the past two decades, for years it was a task made all the more challenging due to the scarcity of advanced tools needed to produce them.

It was so difficult that Pierre Agostini, an emeritus professor of physics at Ohio State, was awarded the 2023 Nobel Prize in Physics for his past work developing techniques to study electron dynamics using pulses of light that lasts for hundreds of attoseconds, a unit of time equivalent to one quintillionth of a second.

It wasn't until relatively recently that new technologies such as the Linac Coherent Light Source (LCLS), a massive free electron laser device at Stanford University's SLAC National Accelerator Laboratory, made these pulses much easier to create and visualize in the lab, said DiMauro.

Using the LCLS, the team studied how electrons inhabit a nitric oxide molecule, focusing on the electron particles that reside near the atom's oxygen core. They found that there were unexpectedly large delays that ranged up to 700 attoseconds, a pattern that suggests more complicated factors could be at play when determining what causes them, said Alexandra Landsman, a co-author of the study and professor of physics at Ohio State.

“We looked at what happens when you take out the electron from deep inside an atom, and what surprised me was how complex the dynamics of those deeply bound electrons were,” said Landsman. “This means that behavior is much more complex than scientists thought, and we need better theoretical descriptions to describe the light-matter interaction fully.”

Yet despite more research being needed to understand these interactions' structure further, uncovering formerly hidden details about them also gives scientists new insights to consider, said DiMauro.

For example, if scientists can get a better grasp on intra-particle behavior, some experts speculate that their discoveries could be vital to breakthroughs for early cancer detection technologies, such as being able to use molecular markers to diagnose blood cancers or detect malignant tumors.

Furthermore, this paper suggests that, combined with theoretical models, researchers could use advances in attosecond science to glimpse matter on some of the smallest scales imaginable, as well as study in greater detail many broader mysteries of the physical universe.

“I'm looking forward to seeing how we use attosecond pulses to learn more about science, engineering or nature in general,” said DiMauro. “Because what's described in this paper is an indication of a field that's really going to blossom.”

END OF NEWS LETTER

– QuantXCer.com