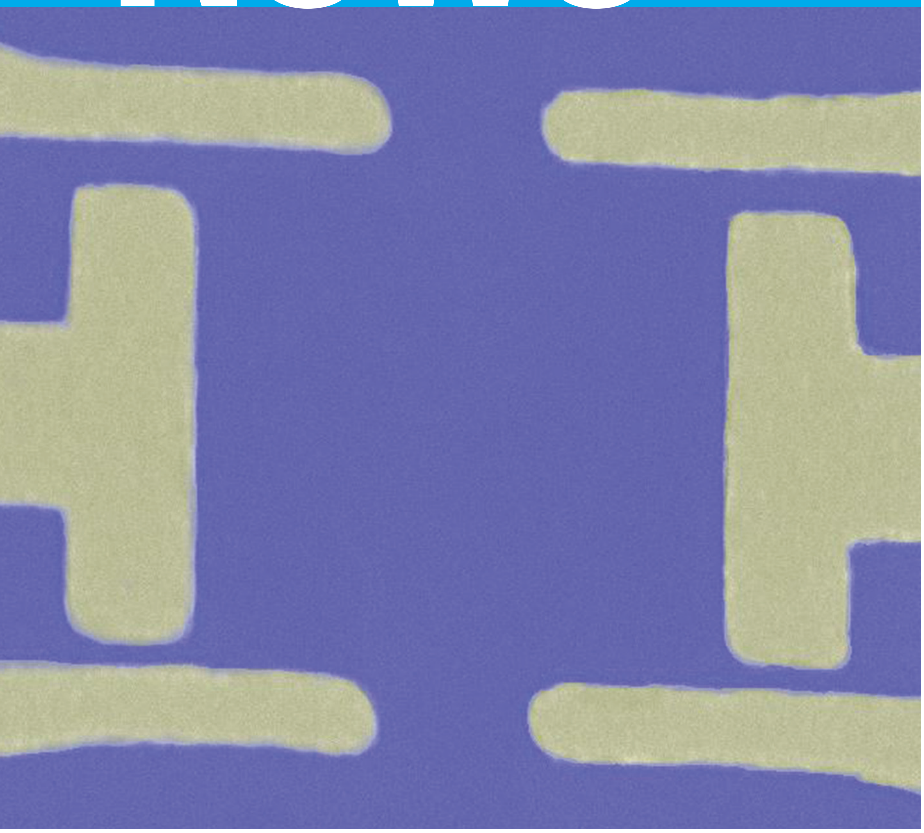
News



FRACTIONAL "PARTICLES" COULD MEAN NEW ELECTRONICS

Quasiparticles might lead to new kinds of quantum computers

Who knew you could get change for an electron?

Researchers have designed a nanoelectronic circuit that can tease into existence a strange new kind of quantum "particle." Its existence confirms decades of speculation about the behavior of electronic circuits in very low temperatures and high magnetic fields—and opens the door for possible applications in next-generation quantum computers.

However, this quasiparticle, or "anyon," carries only a fraction of an electron's charge. It is, to be clear, not substantively an actual single particle but rather more likely an ensemble of electrons acting collectively in certain extreme quantum environments. In other, significant ways, an anyon does behave like a particle. Much like an electron hole in conventional semiconductors, an anyon acts as its own discrete entity with its own characteristic mass, charge, and spin.

And, unlike the +1 charge of an electron hole, these newly studied anyons (whose name Nobel laureate Frank Wilczek jokingly coined after their seemingly "anything goes" nature) carry just one-third of an electron's charge.

James Nakamura, postdoctoral researcher in the lab of Michael Manfra at Purdue University, in Lafayette, Ind., says the quantum trajectories of the anyon are also curious. Its paths through the test circuit interact with other anyons—and indeed even with other quantum incarnations of itself moving through other elements of the

PARTLY PARTICLES: Purdue researchers have induced the appearance of exotic quasiparticles inside an interferometer at cryogenic temperatures.

PURDUE UNIVERSITY

circuit—and form interference patterns.

These interference patterns are analogous, Nakamura says, to the wavy patterns of ripples in a conventional laser interferometer. But instead of the patterns of light and darkness that a laser interferometer produces on a screen, this interferometer tracks anomalous shifts in conductance, as parameters like gate voltage and magnetic-field strength slowly vary.

The circuit—cooled to 10,000th of a degree above absolute zero (10 millikelvins) and immersed in a powerful magnetic field of 9 teslas—exhibits discrete jumps in its conductance. Manfra, Nakamura, and their coauthors infer from these observations the presence of the long-hypothesized anyon.

The finding recalls Robert A. Millikan's 1909 oil-drop experiments, which measured an electron's fundamental charge. Here, the Manfra group discovered a quantum of charge that's only 33 percent of the charge contained by the seemingly indivisible electron. The group, which published its findings in a recent issue of the journal *Nature Physics*, not only adduce the existence of these one-third-charged anyons but also track how the anyons evolve as they move through the interferometer.

"Quantum-mechanical phase is a very subtle thing," Nakamura said. "But there is a way you can see phases, and that's through interference measurements. . . . . Electrons, since they're quantum mechanical, have a phase. Also, these quasiparticles have a phase. And that's what we're studying."

Nakamura says the group's experiment and these fractionally charged anyons may not have immediate applications for any quantum technologies yet devised. However, he says, slightly weaker magnetic fields with slightly different conditions are also expected to produce an anyon with one-fourth of an electron's charge. This quasiparticle has already been discussed as a possible fault-tolerant qubit for an advanced "topological" quantum computer, which codes its quantum information in an anyon's changing state as it interacts with itself and other anyons moving through a circuit.

But all of that would depend on future experiments that begin by first doing what Manfra, Nakamura, and their coauthors did for the one-third-charged anyon: observing the quasiparticle and proving that you can track it through the circuits of a nanosize interferometer. Then it would be possible to discover what a universe composed of fractional charges could cook up. —MARK ANDERSON

A version of this article appears in our Tech Talk blog.

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NEWS

JOURNAL WATCH

New Form of Gallium Nitride Sets Up 6G

With 5G just rolling out and destined to take years to mature, it might seem odd to worry about 6G. But some engineers say that this is the perfect time to worry about it. One group, based at the University of California, Santa Barbara, has been developing a device that could be critical to efficiently pushing 6G's near-terahertz-frequency signals out of the antennas of future smartphones and other connected devices. They reported key aspects of the device—including an N-polar gallium nitride high-electron-mobility transistor (HEMT)—in two papers that recently appeared in *IEEE Electron Device Letters*.

Testing so far has focused on 94-gigahertz frequencies. "We have just broken through records of millimeter-wave operation by factors which are just stunning," says Umesh K. Mishra, an IEEE Fellow who heads the UC Santa Barbara group that published the papers. "If you're in the device field, if you improve things by 20 percent people are happy. Here, we have improved things by 200 to 300 percent."

A HEMT is formed around a junction between two materials having different bandgaps, in this case gallium nitride (GaN) and aluminum gallium nitride (AlGaN). At this heterojunction, gallium nitride's natural polarity causes a sheet of excess charge—a two-dimensional electron gas—to collect. The presence of this charge gives the device the ability to operate at high frequencies because the electrons are free to move quickly through it without obstruction.

Gallium nitride HEMTs are already contenders for 5G power amplifiers. But to efficiently amplify near-terahertz frequencies, the typical GaN HEMT needs to scale down in a particular way. Just as for a silicon transistor with a logic gate, bringing a HEMT's gate closer to the channel through which current flows—the electron gas in this case—lets it control the flow of current, thus using less energy and making the device more efficient. More specifically, explains Mishra, you want to maximize the ratio of the length of the gate versus the distance from the gate to the electron gas. That's usually done by reducing the amount of barrier material between the gate's metal and the rest of the device. But you can go only so far with that strategy. Eventually the material will be too thin to prevent current from leaking through, thereby harming efficiency.

But Mishra says his group has come up with a better way: They stood the gallium nitride on its head.

Ordinary gallium nitride is what's called gallium polar. That is, if you look down at the surface, the top layer of the crystal will always be gallium. But the UC Santa Barbara team discovered a way to make nitrogen-polar crystals so that the top layer is always nitrogen. It might seem like a small difference, but it means that the structure that makes the sheet of charge, the heterojunction, is now upside down.

This delivers a bunch of advantages. First, the source and drain electrodes now make contact with the electron gas via a lower bandgap material (a nanometers-thin layer of GaN) rather than a higher-bandgap one (AlGaN), thus lowering resistance. Second, the gas itself is better confined as the device approaches its lowest current state, because the AlGaN layer beneath acts as a barrier against scattered charge.

Devices made to take advantage of these two characteristics have already yielded record-breaking results. At 94 GHz, one device produced 8.8 watts per millimeter at 27 percent efficiency, says Mishra. A similar gallium-polar device produced only about 2 W/mm at that efficiency.

The UC Santa Barbara team plans to eventually test the new devices at even higher frequencies—140 and 230 GHz.

—SAMUEL K. MOORE

A version of this article appears on our website in the Journal Watch section.

YANN ARTHUS-BERTRAND/GETTY IMAGES

30-KILOMETER BLUETOOTH

Asset and inventory tracking demand that transmissions go to great lengths

When you think about Bluetooth, you probably think about things like wireless headphones, computer mice, and other personal devices that utilize the short-range, low-power technology. That's where Bluetooth has made its mark, after all—as an alternative to Wi-Fi, using unlicensed spectrum to make quick connections between devices.

But it turns out that Bluetooth can go much farther than the couple of meters for which most people rely on it. Apptricity, a company that provides asset- and inventory-tracking technologies, has developed a Bluetooth beacon that can transmit signals over 32 kilometers (20 miles). The company believes its beacon is a cheaper, more secure alternative to established asset- and inventory-tracking technologies.

A quick primer, if you're not entirely clear on asset tracking versus inventory tracking: There's some gray areas in the middle, but by and large, asset tracking refers to an IT department registering which employee has which laptop, or a construction company keeping tabs on where its backhoes are on a large construction site. Inventory tracking refers more to things like a retail store keeping correct product counts on the shelves, or a hospital noting how quickly it's going through its store of gloves.

Asset and inventory tracking typically use labor-intensive techniques like bar-code or passive RFID scanning, which are limited both by distance (a couple of meters at most, in both cases) and the fact that a person has to be directly involved in scanning. Alternatively, companies can use satellite or LTE tags to keep track of stuff. While such tags don't require a person to actively track items, they are far more expensive, requiring a costly subscription to either a satellite or LTE network.

So, the burning question: How do you send a Bluetooth signal over 30-plus km? Typically, Bluetooth's distance is limited because large distances would require a prohibitive amount of power, and its use of unlicensed spectrum means that the greater the distance, the more likely it will inter-

NEWS

WHEREVER YOU GO: Bluetooth-tracking beacons that send and receive signals for kilometers can help keep tabs on valuable assets, such as construction equipment.

fere with other wireless signals.

The key new wrinkle, according to Apptricity's CEO, Tim Garcia, is precise tuning within the Bluetooth spectrum. Garcia says it's the same principle as a tightly focused laser beam. A laser beam will travel farther without its signal weakening beyond recovery if the photons making up the beam are all as close to a specific frequency as possible. Apptricity's Bluetooth beacons use firmware developed by the company to achieve such precise tuning, but with Bluetooth signals instead of photons. Thus, the beacons can send and receive data without interfering with other wireless signals and without requiring unwieldy amounts of power.

Garcia says RFID tags and bar-code scanning don't actively provide information about assets or inventory. By contrast, not only can Bluetooth pinpoint where something is, it can also send updates about a piece of equipment that needs maintenance or just a routine checkup.

By its own estimation, Apptricity's Bluetooth beacons are 90 percent cheaper than LTE or satellite tags, specifically because Bluetooth devices don't require paying for a subscription to an established network.

The company's current transmission distance record for its Bluetooth beacons is 38 km (23.6 miles). The company has also demonstrated noncommercial versions of the beacons for the U.S. Department of Defense with broadcast ranges between 80 and 120 km.
—MICHAEL KOZIOL

A version of this article appears in our Tech Talk blog.

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spectrum.ieee.org/bluetooth-nov2020

ESTONIA'S PANDEMIC EDGE COMES FROM IT

Avoiding legacy IT has kept the country's online systems up and running

The COVID-19 pandemic has spotlighted the problems that legacy IT systems pose for companies, and how they especially affect governments. A story that discusses how government legacy IT systems in Japan are holding back that country's economic recovery further illustrates the magnitude of the problem.

Japanese economist Yukio Noguchi, quoted in a recent *Japan Today* story, warned that the country is "behind the world by at least 20 years" in administrative technology. This helps explain why, despite being the world's third-largest economy, Japan is now ranked only 34th out of 63 countries when it comes to digital competitiveness as measured by the IMD World Competitiveness Center, a Swiss business school.

By contrast, Estonia's IT systems have weathered the pandemic well. According to an article from the World Economic Forum, during the country's pandemic lockdown Estonia's online government services continued to be readily available. Further, its schools experienced little difficulty supporting digital learning, remote working seems to have been a nonissue, and its health-information systems were quickly reconfigured to provide information about newly diagnosed COVID-19 cases in near real time.

David Eaves, from the Harvard Kennedy School of Government, says Estonia is a prime example of being both "lucky" and "good." After the Baltic country won back its independence from Russia in August 1991 and the last Russian troops left in 1994, the country of 1.3 million people found itself desperately poor. The Russians "took everything," Eaves notes, but the country was "lucky" in that it was left with essentially a clean slate in terms of its IT and telecommunications environment.

And Estonia was "good," Eaves says, because its political leadership was savvy enough to recognize how important modern technology was, not only to its future economy but also its political stability and independence. Eaves says being poor meant that the country's leadership could not "afford to make bad decisions," like richer countries. Estonia began by modernizing its telecommunications infrastructure—mobile first because it was easiest and cheapest, followed by a fiber-optic backbone, and then, beginning in 2001, setting up public Wi-Fi areas across the country.

What's more, Estonia embarked on a program to digitize government operations and allow its citizens to communicate and interact with the government via the Internet. Eaves states that Estonia's political leadership also understood that to do so successfully required legal steps such as ensuring the protection of individual privacy, safeguarding personal information, and providing total transparency regarding how personal data would be used.

On top of that, Estonia set out to avoid being encumbered with old technologies that would bury it in IT system maintenance costs. With that in mind, the government decreed that "IT solutions of material importance must never be older than 13 years." While the 13-year period seems arbitrary, it serves the

IT SUPREMACY: Estonia's emphasis on having updated IT infrastructure served it well when COVID-19 forced the world to work, shop, and learn remotely.

KRISTI SITS/BRAND ESTONIA

purpose of a forcing function to ensure existing systems don't fall into the prevailing twilight world of technology maintenance.

Estonia proudly proclaims on its "e-governance" website that 99 percent of its public services are online 24/7: "E-services are only impossible for marriages, divorces, and real-estate transactions—you still have to get out of the house for those." Everything else, including voting and filing taxes, can easily be done securely and quickly online. And since the 2007 adoption of the nation's "once only" information policy, the Estonian government cannot ask citizens to enter the same information twice.

Scaling up Estonia's ecosystem of e-governance in larger countries might not be easy. However, there is still much to be learned about what an e-government approach can achieve, and which IT legacy modernization strategies might be quickly implemented, Eaves argues.

Yet, even in Estonia, there are a few dark clouds forming in the distance that could rain on its IT systems' parade. The government's chief information officer, Siim Sikkut, has repeatedly warned that while there has been funding available to build new online capabilities, the country's existing IT infrastructure has been chronically underfunded for several years. A September 2019 Organization for Economic Cooperation and Development report indicates that Estonia must spend approximately 1.5 percent of the state budget on its digitalization efforts, but is currently spending only around 1.1 percent to 1.3 percent.

Meanwhile, despite its seeming e-governance prowess, Estonia is surprisingly ranked only 28th by the IMD in global competitiveness. To improve that rank, the government will have to fund even more IT initiatives. But making up the shortfall will be challenging, given the pandemic's global economic impact.

So Estonia has reached an inflection point. It will be interesting to see whether the country will be able to find the funding for both new IT initiatives and IT modernizations, or if it will choose to fund the former over the latter—and end up stumbling into the legacy IT system trap that so many other countries have.

—ROBERT N. CHARETTE

A version of this article appears in our Risk Factor blog.

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spectrum.ieee.org/estonia-nov2020

NEWS

AI DIAGNOSES AUTISM EARLY

New tool likely to eliminate years of delay in treating small children

In September, Cognoa, a company based in Palo Alto, Calif., announced it will seek approval from the U.S. Food and Drug Administration (FDA) to market a first-of-its-kind autism spectrum disorder (ASD) diagnostic tool. Cognoa's technology uses artificial intelligence to make an ASD diagnosis within weeks of parents expressing concern—far faster than the current standard of care can achieve. If cleared by the FDA, the company says, it would be the first tool enabling primary care pediatricians to diagnose autism.

The approach is "innovative," says Robin Goin-Kochel, a clinical autism researcher at Baylor College of Medicine and associate director for research at Texas Children's Hospital's Autism Center. Goin-Kochel, who is not affiliated with Cognoa, says that the field absolutely needs a way to "minimize the time between first concerns about development or behavior and eventual ASD diagnosis."

The application of AI could enable more doctors to diagnose autism, thereby opening a critical bottleneck in children's health care. While most parents of children with autism notice developmental changes early on (within the first three years of life), the median age at which children in the United States are diagnosed is 4.3 years old. That's because families often wait months, even years, to see a specialist and get a diagnosis. The time lost during that period is critical: Numerous studies show that early intervention, before the syndrome is fully manifest, can reduce the severity of ASD and improve a child's brain and behavioral development.

Cognoa's technology comes out of the lab of company founder Dennis Wall, an associate professor of pediatrics at the Stanford University School of Medicine. "I went into this," says Wall, "with the hope of objectively asking the question: Can we reduce the complexity of the autism diagnostic process without loss of accuracy?"

By feeding electronic health-record data into a set of algorithms, Wall's team was able to identify key characteristics that are central to an ASD diagnosis. These include social and emotional behaviors, such as whether a child smiles in response to another person's smile or whether he or she can share attention toward an object, and the extent of traits such as creativity and imagination. The team's ASD diagnostic tool seeks to capture those features with three modules: a parent survey, home videos, and a clinician questionnaire.

David Happel, CEO of Cognoa, explains how the tool works: When a parent expresses concern at a pediatrician appointment, or a child fails an ASD screening questionnaire, the pediatrician gives the parent a code to access Cognoa's smartphone app. Once in the app, the parent answers a 15-minute questionnaire about the child's behavioral patterns, and then uploads two 1- or 2-minute home videos capturing the child's behavior in a natural environment. The videos are sent to a trained Cognoa professional who reviews them and answers pertinent questions. Those answers are fed into Cognoa's AI along with the parent's answers and a short questionnaire filled out by the pediatrician. Then the algorithm sends a result to the pediatrician, and the pediatrician renders a diagnosis.

The tool's algorithms are trained on data from hundreds of real cases across genders, races, and ethnic backgrounds, says Happel. "[The tool] has proven not only to accelerate the time of diagnosis but also to remove a lot of the biases that are inherent in the current system," he says. Today's standard ASD diagnostic tools, Happel notes, were constructed with health data from young Caucasian boys, so girls and children of nonwhite backgrounds are not well recognized by these tools, contributing to delays in diagnosis for those groups.

A Cognoa study published in March reported that an earlier version of its ASD diagnostic tool outperformed standard tools, including questionnaires answered by a parent, teacher, or clinician that flag some at-risk children.

Since then, the company has completed a pivotal, double-blind clinical trial at 14 sites around the United States. The trial involved 425 participants, aged between 18 months and 72 months, whose parents or doctors had expressed concern about their development but had not previously been evaluated for ASD, according to a press release. Each child was assessed twice–once using Cognoa's tool, and once by a specialist clinician based on criteria from the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5); that diagnosis was then validated by a second specialist clinician.

The results of the trial have yet to be published, so there is no specific data to report, but the company says the trial "surpassed its targeted benchmarks." Moreover, says Cognoa, the tool proved to be accurate regardless of gender or ethnicity.

SOONER THE BETTER: A new tool uses artificial intelligence to diagnose autism spectrum disorder within weeks of parents spotting signs of concern.

COGNOA

Because the study ran from July 2019 through May 2020, some of the children were evaluated this spring during the pandemic via telemedicine. The tool performed just as well when administered remotely as when it was used for in-office analysis, says Happel.

Happel, who confirms that the company plans to submit the full study for publication in coming months (and to the FDA as well), says Cognoa hopes to receive crucial regulatory approval in the second half of 2021. The company's timetable calls for it to be ready to launch the product into the hands of pediatricians two months after that.

If and when Cognoa's technology or others become available, "it will be really important to understand the plan for how new tools and technologies will be implemented in primary pediatric care," says Goin-Kochel. Doctors are often slow to adopt new models, especially for making diagnoses they may not feel comfortable making, she notes. New technologies raise practical questions, such as when they should be applied and whether insurance companies will pay.

"I'm very hopeful there is a near-term future where this product is available," says Cognoa's Dennis Wall, "covered by insurance, and made available to everybody as immediately as possible."
—MEGAN SCUDELLARI

A version of this article appears in our Human OS blog.

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