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Wed, 18 May 2022

पहली बार स्वदेशी एंटी-शिप मिसाइल का सफल परीक्षण, अब दुश्मन खाएगा धोखा

भारतीय नौसेना की ताकत और बढ़ने वाली है. आज यानी 18 मई 2022 को भारतीय नौसेना (Indian Navy) और भारतीय रक्षा अनुसंधान एवं विकास संगठन (DRDO) ने स्वदेश निर्मित नौसैनिक एंटी-शिप मिसाइल (Naval Anti-Ship Missile) का सफल परीक्षण किया. ये टेस्टिंग ओडिशा के चांदीपुर के तट के पास किया गया. भारतीय नौसेना के लिए पहली बार हवा से लॉन्च की जाने वाली नई स्वदेशी नौसैनिक एंटी-शिप मिसाइल (Naval Anti-Ship Missile) बनाई गई है. यह मिसाइल सी-स्किमिंग ट्रैजेक्ट्री (Sea Skimming Trajectory) पर चलते हुए सीधे टारगेट से जाकर टकराई. सी-स्किमिंग का मतलब ये है कि मिसाइल समुद्र की सतह से कुछ फीट या मीटर ऊपर तेजी से उड़ते हुए जाती है, जिससे वह राडार में पकड़ में नहीं आती.

मिसाइल पर आगे की तरफ लगे निशान से लगता है कि ये परमाणु हथियार ले जा सकती है. (फोटो: पीआरओ डिफेंस, हैदराबाद) उंचाई इतनी कम होने की वजह से दुश्मन उस मिसाइल को मारकर गिरा नहीं सकता. यह तकनीक भारत के पास ब्रह्मोस सुपरसोनिक क्रूज मिसाइल (BrahMos Supersonic Cruise Missile) में है. टेस्टिंग के दौरान मिसाइल की सटीकता, वेलिडेशन, नियंत्रण, गाइडेंस और मिशन संबंधी अन्य एल्गोरिदम की जांच की गई. सबकुछ एकदम सही निकला. मिसाइल के रास्ते में लगाए गए सेंसर ने मिसाइल की ट्रैजेक्ट्री और सभी इवेंट्स को सही से कैप्चर किया. समुद्र की सतह से चिपक कर चलने की टेक्नोलॉजी ब्रह्मोस मिसाइल के पास भी है. (फोटो: पीआरओ डिफेंस, हैदराबाद)

यह मिसाइल नौसैनिक हेलिकॉप्टर्स पर लगाई जाएगी. फिलहाल इसकी लॉन्चिंग सीकिंग 42बी हेलिकॉप्टर से की गई थी. इस मिसाइल में स्टेट-ऑफ-द-आर्ट नेविगेशन सिस्टम लगता है. इसके अलावा इंटीग्रेटेड एवियोनिक्स भी है. इस परीक्षण के दौरान डीआरडीओ के सीनियर वैज्ञानिक और भारतीय

नौसेना के अधिकारी मौजूद थे. रक्षामंत्री राजनाथ सिंह ने इस सफलता पर डीआरडीओ और इंडियन नेवी के अधिकारियों को बधाई दी है.

<https://www.aajtak.in/amp/india/news/story/drdo-indian-navy-sucessfully-tested-indigenously-developed-anti-ship-missile-tstrd-1465833-2022-05-18>



Fri, 20 May 2022

Private players can access govt facilities, says DRDO

DRDO chairman invited the private sector to tap opportunities in the defence sector as the govt aims to indigenise several defence items “India is now trying to shift its status from being one of the largest importers of defence products to one of the top exporters of defence items... The private sector can access government test systems and facilities, and for strengthening Indian defence industries, DRDO has facilitated access to more than 1000 patents without any royalty,” he said.

Satheesh Reddy, who is the secretary of the department of defence R&D, was talking at an event after inaugurating a facility of the 70,000-square feet advanced facility of SKM Technologies at Aerospace Park at Adibatla. SKM Technologies manufactures high precision components and assemblies for companies like Rafael, Pratt & Whitney, Dedienne Aerospace, Dassault Aviation, Magellan Aerospace Corporation, Nuclear Fuel Complex, Hindustan Aeronautics Ltd, DRDO, BDL and many others.

<https://www.deccanchronicle.com/amp/nation/current-affairs/200522/private-players-can-access-govt-facilities-says-drdo.html>



Fri, 20 May 2022

Visakhapatnam: Seminar on contemporary research held

It was inaugurated by academicians who chaired the panel boards, including Prof P Krishnan Kutty of IIT Madras, Prof N Prabhu of IIT Bombay, DD Ebenezer of CUSAT, Kochi and retired senior scientist of DRDO CVK Prasada Rao. As a part of 'Azaadi ka Amrit Mahotsav,' Naval Science and Technological Laboratory (NSTL), conducted a seminar on 'contemporary research in naval sciences and technologies' here on Thursday at NSTL. Organised in collaboration with the Naval Research Board (NRB), DRDO, the seminar was inaugurated by academicians who chaired the panel boards, including Prof P Krishnan Kutty of IIT Madras, Prof N Prabhu of IIT Bombay, DD Ebenezer of CUSAT, Kochi and retired senior scientist of DRDO CVK Prasada Rao.



Dignitaries inaugurating the seminar by lighting the lamp at NSTL in Visakhapatnam on Thursday

Addressing the gathering, officiating director of NSTL BVSS Krishna Kumar briefed about how NSTL evolved as the key designer and developer of underwater weapons with a primary objective of delivering products to the Indian Navy. He said that the systems being developed in NSTL were having a lot of interdependent subsystems that need thorough knowledge in the corresponding subjects with the help of academicians.

Scientist 'G' and member secretary of NRB Ashok Yadav explained the role of NRB, its organisational structure and composition. In his keynote address, Prof. Krishnan Kutty of IIT Madras gave an exclusive presentation on Development of Biometric Autonomous Underwater Vehicles (BAUVs) for Marine Surveillance. As many as 67 personnel from various academic institutions and naval organisations participated in the seminar.

<https://www.thehansindia.com/news/cities/visakhapatnam/visakhapatnam-seminar-on-contemporary-research-held-743843?infinitemscroll=1>

Defence News

Defence Strategic: National/International

The Tribune

Thu, 19 May 2022

Defence Minister Rajnath Singh flies in navy's P8I plane

Defence Minister Rajnath Singh today undertook a sortie on the Navy's P8I plane used for long-range maritime reconnaissance and anti-submarine warfare. The Navy demonstrated how long-range surveillance, electronic warfare and imagery intelligence works. The anti-submarine missions and search and rescue capabilities are used on this state-of-the-art plane that carries

specialised sensors. The P8I aircraft have significantly enhanced Navy's surveillance operations in the Indian Ocean Region.

<https://www.tribuneindia.com/news/nation/rajnath-singh-flies-in-navys-p8i-plane-396015>

THE ECONOMIC TIMES

Thu, 19 May 2022

Lt Gen Manjinder Singh reviews security situation in Jammu region

General Officer Commanding, XVI Corps, Lieutenant General Manjinder Singh on Thursday reviewed the security situation in the Jammu region ahead of the commencement of the annual Amarnath yatra next month, officials said. Thursday's meeting was held close on the heels of Northern Army Commander Lieutenant General Upendra Dwivedi's visit to forward areas in twin border districts of Rajouri and Poonch to review the security situation and operational preparedness in the region, they said. "A security review meeting chaired by Lt Gen Singh was held at Nagrota. The meeting was attended by Additional Director General of Police (ADGP) Mukesh Singh and senior officials of various intelligence agencies operating in the region," a defence spokesman said.

The meeting primarily focused on the prevailing security situation in the Jammu division, he said. The security measures for the forthcoming Machail as well as Amarnath yatra were also discussed in detail to ensure streamlined coordination between intelligence and security agencies, the spokesman said. The Amarnath yatra, scheduled to begin from June 30 to August 11, is taking place after a gap of two years.

https://m.economictimes.com/news/defence/lt-gen-manjinder-singh-reviews-security-situation-in-jammu-region/amp_articleshow/91663771.cms

THE ECONOMIC TIMES

Thu, 19 May 2022

New military tech: Russia uses new anti-drone laser tool in Ukraine

Russia has developed its own anti-drone laser tool and is already using it in Ukraine, Deputy Prime Minister Yury Borisov has claimed. It has a range of 5km and was nicknamed Zadira, or 'troublemaker' in Russian, Borisov said on Wednesday. He didn't disclose any other details about the new weapon. Borisov is also the points-person for India. The revelation came as Borisov was discussing the advanced weapons being developed in Russia. He compared the new weapon to Peresvet, a laser system first unveiled by President Vladimir Putin in 2018, the exact purpose of which was not explained at the time.

He noted that the Peresvet was designed to disable optic sensors, including on spy satellites orbiting the earth as high as 1,500 km. “While Peresvet blinds, the new generation of laser weapons causes physical damage to the target, burning it through,” he said. When asked about the timeline for the Russian armed forces to receive such systems, Borisov said they were already being supplied. When asked further whether the anti-drone laser was deployed in Russia’s military campaign in Ukraine, the minister acknowledged that the “first samples were used” there. According to military experts, lasers have several drawbacks as weapons, including massive power requirements and the deterioration of the beam caused by dust and water vapor in the air cause, among others.

However, they have a major advantage in terms of cost-per-shot compared to traditional anti-aircraft missiles. The advancement in drone technology, which has made the deployment of air assets more financially accessible, has compelled military planners worldwide to look for various ways to counter this threat without depleting their war chests. In the US, naval lasers were successfully tested against boats and drones this year, with the defeat of an aerial practice target by the Layered Laser Defense (LLD) in April described as “historic” by the authorities.

https://m.economictimes.com/news/defence/china-seeks-to-dominate-bay-of-bengal-through-myanmar-ports/amp_articleshow/91653661.cms



Thu, 19 May 2022

Top officers of Army, Navy, Air Force meet to review preparedness in East

Top officers of the Air Force, Navy and Army met in Shillong to review the operational issues and enhance interoperability among the forces in the eastern region, a defence spokesperson said on Thursday. The three-day Tri-Services Eastern Commanders–in-Chief Conference, held at the headquarters of the Eastern Air Command, concluded on Thursday. The commanders exchanged notes on the peculiarities of operations in their respective domains, identify each other’s strengths and arrive at mutually agreeable solutions to enhance interoperability and synergy between the three services,” the spokesperson said. They reviewed the progress made on various operational and logistic issues made since the last meeting, he said.

Commander-in-Chief of Andaman and Nicobar Command Lt Gen Ajai Singh, Flag Officer Commanding-in-Chief Eastern Naval Command Vice Admiral B Dasgupta and General Officer Commanding-in-Chief Eastern Command Lt Gen RP Kalita attended the meeting. The meeting was hosted by Air Officer Commanding-in-Chief Eastern Air Command Air Marshal DK Patnaik.

<https://www.financialexpress.com/defence/top-officers-of-army-navy-air-force-meet-to-review-preparedness-in-east/2530400/lite/>

Lasers, water landings, crewless ops: Upgrades are coming for the C-130 family

The most advanced versions of the military's long-running tanker-turned-death-dealer are expected to get even more toys under the direction of the special operations community. The MC-130J Commando II and the KC130J Super Hercules aircraft are experimenting with high-energy lasers, amphibious landing and takeoff, and potentially a crewless, fully automated cockpit, if U.S. Special Operations Command's work is successful. Program officers laid out the details of the C-130 family of aircraft on Wednesday at the Special Operations Forces Industry Conference, hosted in Tampa, Florida, by the National Defense Industrial Association.

The aircraft, first built in the 1960s, has served generations of troops in combat across the globe. But it's now facing contested airspace as it has never seen. "Threats are growing, it's just getting worse," said Rich Rodriguez, SOCOM technical director for its Program Executive Office Fixed Wing. Air Force Col. Ken Kuebler, head of the fixed-wing portfolio, told conference attendees that he's prioritizing autonomous technology to ease the burden of the flight crew. That was a running theme in nearly all of the air-, maritime- and data-focused panels this week.

Beyond the workload, the crew itself could see eventual trimming. "I need to be able to reduce the crew and able to reduce the crew workload," Kuebler said. "We've got a lot of data coming at us all the time." A less busy crew, he said, could then focus more on aircraft safety and combat missions. Rodriguez said SOCOM has already seen experiments by Air Force Special Operations Command on an unmanned cockpit integrated with a smaller aircraft platform. He did not specify which platform.



A rendering of a twin-float amphibious modification to an MC-130J Commando II is shown. Air Force Special Operations Command and private sector counterparts are developing a Removable Amphibious Float Modification for the MC-130J, allowing aircraft to take off and land in bodies of water as well as conduct runway-independent operations.

If successful, those initiatives could reach a massive plane like the C-130 variants, he said. Kuebler also wants to save space but add options. “I’ve got to be able to have a platform that’s truly a multimodal, modular system,” he said. That means payloads that can go on and off the aircraft easily and do more than one thing. Air Force Lt. Col. Kevin McClure, mobility division chief for PEO Fixed Wing, said the C-130 variants are receiving upgrades with a host of new gear. The goal is for the numerous variants to have common systems and to provide safer infiltration, exfiltration, resupply and refuel.

“But the big piece is in contested environments,” McClure said. “And that becomes a really hard problem we need [industry’s] help with.” They want better communication systems able to take in data from other platforms to increase situational awareness in real time. “Not only can we react and recover, but we can also share that back out into the community,” McClure said. That’s true for training, too. Program managers want augmented reality and virtual reality for immersive training on the C-130 variants and as many other aircraft as possible.

What’s going on with the MC-130J?

In terms of recapitalization, the U.S. is modifying the MC-130J with mission systems for special operations forces to improve low-level infiltration/exfiltration, airdrop, resupply and refueling in contested environments. Ongoing efforts include radar integration, airborne mission networking, radio frequency countermeasures, open mission systems integration, special mission processor tech refresh, tactical flight management system and cloud-based mission system integration. Planned efforts include automated mission systems functionality for joint all-domain operations, palletized munitions, active electronically scanned array radar, and augmented reality and virtual reality training.

The C-130 started its life as a tanker/transport plane. It continues to be a truck in the sky, but one that can collect data, sense targets and strike when needed. Lt. Col. Matt Foertsch, strike division chief for PEO Fixed Wing, said current work includes integrating the MC-130Js with a precision strike package and sensor systems for “next-generation” targeting. His work also includes retiring the “W” variant that preceded the “J” variant, which should conclude by July, he said.

The latest work on the AC-130 gunship

Ongoing efforts include sunsetting the AC-130W fleet, finishing AC-130J Block 30 production, retrofitting Block 20+ AC-130Js to Block 30, providing infrared suppression systems and bringing in defensive system upgrades. Planned efforts include crew reduction initiatives, taking on a modular, open-systems approach, and adopting augmented reality and virtual reality training. In other words, the gunship must maintain its close-in strike capability but also take on an integrated deterrence push, which the Pentagon assigned to the command.

To make that work, Foertsch said, personnel are eyeing air-delivered munitions primarily for the “best lethality.” An example of this approach, he explained, is an integrated weapons data link added to a 50-pound warhead class last year. Foertsch called the data link an “incredible capability” that allows the crew to fire and then communicate with the round in flight, issuing instructions. The link gives the user a “dud” command option, which can render the weapon inert midflight if a strike needs canceled. But that still needs improving, he said. To do, that they’re looking to industry to provide guidance and next-generation sensors that can work in GPS-denied environments. “We largely do laser targeting now,” he explained, and even that’s not

enough. They are also looking for optical or automated target recognition in modular, open systems.

But they want to do that by dropping in capabilities to their existing forms, rather than adding another, purpose-built round. And they want greater range and standoff. Work on that front is being done with two small business research grants, he said. Those involve testing a miniature cruise missile with electrical propulsion that fires past 100 nautical miles, and another small cruise missile that can go twice that distance. As if that isn't enough, they'd also like to get this 82-ton plane to land on water and take off again. That's important for Navy SEALs, Marine Raiders and other operators who need to get wet in far-flung locations. Rodriguez said Air Force special ops personnel are doing digital planning and working to place floatation assemblies on the platform for just that task.

<https://www.defensenews.com/news/your-military/2022/05/19/lasers-water-landings-crewless-ops-upgrades-are-coming-for-the-c-130-family/>



Fri, 20 May 2022

Israel launches Edge of tomorrow program to improve lethality, bring in new tech

Israel is putting its soldiers through a series of simulations and live drills as part of a program called Edge of Tomorrow, the government announced this month. The program falls under the Defense Ministry's Directorate of Defense Research and Development and is carried out with local defense company Elbit Systems. The program is meant to strengthen "the synergy between dismounted combat soldiers and their teams and [enable] optimal operational value through numerical and empirical processes based on research, simulation, live field scenarios, and more," according to a mid-May statement from the ministry. It also aims to supply new tools for the future battlefield through analysis of how technology can be integrated to "improve a range of mission capabilities including lethality, situational awareness, survivability, stamina, cognitive load, enemy exposure" and other issues faced by dismounted soldiers.

The ministry said the program will look at "augmented reality goggles, a computerized assault rifle system, a digital head-mounted display system, hostile fire detection technology, a location-tracking system in GPS-denied environments, tactile sleeves for navigation and command transmittance, and a voice command system (similar to systems used on smartphones)." In photos from a capability demonstration, soldiers are seen using Elbit Systems' SmartEye head-mounted eyewear as well as its E-LynX digital communications system, while wearing a tactile sleeve made by American firm TrekAce. Getting new technology to front-line forces is also a goal of the multiyear Momentum plan, launched by the Israel Defense Forces several years ago. This has included a new multidimensional unit as well as an increased use of artificial intelligence and swarm technology for aerial and ground drones. Israel is also rolling out new lasers for air defense, among a plethora of other technology across its armed services.

In comparing the two, Momentum is about moving new technology to the military, whereas Edge of Tomorrow focuses on simulating and evaluating the effectiveness of technology and choosing what should be deployed. A defense ministry source, who spoke on condition of

anonymity for security reasons, noted Edge of Tomorrow is a research and development program initiated four years ago, driven by a recognition that extremist militant groups have an advantage over traditional forces in modern urban warfare. The source noted the program “may help our dismounted troops to be superior in ‘chest to chest’ close-quarter battle situations.”

A senior manager at a local defense company with knowledge of the program who spoke on the condition of anonymity, as the individual was not authorized to speak to the media, said Edge of Tomorrow aims to bring a dramatic transformation to the military’s lethality. To understand how new technology can benefit units, the program is not only looking at replacing tech in the hands of the individual soldier, but it’s also objectively measuring platoon-level units. In other words, instead of individually asking soldiers what they think of new equipment, technology will be measured by how it improves a unit’s performance over time. Both the government and industry sources pointed out this differs from the past, when soldiers might have received new technology, but without a measurement of overall unit effectiveness.

The first evaluation round began a year ago and ended in April. The second round recently began and will result in an update to Israel’s concept of operations, the ministry source said. Edge of Tomorrow “offers a solid method for evaluating dismounted platoon-level optimization. So [the] IDF may use it for some parts of its multiyear [Momentum plan],” the ministry source added. The concept is to provide a base architecture for future abilities, which could involve a range of companies. Manned-unmanned teaming isn’t currently part of the program, but the architecture could eventually support those systems. The infrastructure that comes out of Edge of Tomorrow will be fully open to unmanned systems in the future, the industry source said.

Both sources stressed that key to this program is measuring the effectiveness of new tech to identify what’s worth developing — and what should be discontinued. “Because it is mature enough, that allows us to dramatically increase unit lethality, doing it in a way that is measurable,” the industry source said. Edge of Tomorrow is meant to ultimately deliver thousands of systems, as well as technology later developed based on those systems, for operational use, the industry source explained. All of this is to help commanders better see where their forces are in real time so soldiers can receive information from the communications network about threats, the source added.

Haim Delmar, executive vice president and general manager of C4I and cyber at Elbit Systems., said “the purpose of this program is to equip combat soldiers, teams and platoons with innovative capabilities that will significantly improve their survivability and transform their mission effectiveness.” It’s also meant to “enable optimal operational value for the dismounted combat soldiers by strengthening the synergy between them and their team,” noted Lt. Col. Shlomi Buskila of the Directorate of Defense Research and Development. According to the industry source, simulations are currently focused on the type of adversaries Israel has already faced, meaning they’re working on asymmetric warfare capabilities for dismounted forces in both urban and open terrain, where a large force might confront threats in a civilian-heavy environment.

<https://www.defensenews.com/global/mideast-africa/2022/05/19/israel-launches-edge-of-tomorrow-program-to-improve-lethality-bring-in-new-tech/>

Pentagon tech chief wants an ‘all in one’ sensor

One of the Pentagon’s top tech officials wants an “all in one” sensor for defense work. It is one of several critical technologies that Heidi Shyu, the undersecretary of defense for research and engineering, included in remarks Wednesday at the Special Operations Forces Industry Conference in Florida. “I’m interested in pushing the technology toward a single sensor that has the ability to listen, the ability to do jamming, the ability to communicate, the ability to inject, all in one,” Shyu said, without providing specific details of progress on such an advancement.

Some funding for that could come from the next defense budget, for which Shyu’s office requested \$377 million over the next five years for rapid experimentation projects, Defense News reported in April. Though that initiative awaits the threshing machine known as the congressional budget cycle, some money from last year is hitting the coffers for new technology. Shyu said Wednesday that the Pentagon received \$100 million specifically for “accelerated procurement and fielding” of innovating technology from small businesses. The goal is to help small companies move research work from the phase II to phase III levels in the government research process, she said.

She’s also hopeful about funding another initiative: a push in the budget proposal for \$52 billion to set up a microelectronics “foundry” in the United States. The COVID-19 pandemic highlighted the fact that the majority of the world’s microprocessors are manufactured in Taiwan. That’s a strategic chokepoint for everything from new pickup trucks to advanced satellite systems. An onshore foundry for microelectronics would add another source for such technology. It would also better allow university researchers and small U.S. companies to experiment with new materials for microelectronics, advancing the state of the art in that field, she said.

But Shyu faces other budgetary challenges. C4ISRNET reported earlier this week that many of the Pentagon’s \$5.7 billion laboratory wish list will likely remain unfunded in this budget cycle. That’s because, per a report obtained by Defense News that listed 126 high-priority projects, military services’ labs and testing facilities were excluded in the fiscal 2023 budget request for military construction.

<https://www.defensenews.com/smr/sofic/2022/05/19/pentagon-tech-chief-wants-an-all-in-one-sensor/>

Fri, 20 May 2022

Israel to hold military exercise simulating large-scale attack on Iran

The Israeli Air Force plans to conduct a military exercise later this month simulating a large-scale strike on Iran, according to *The Times of Israel*. The drill, dubbed Chariots of Fire, comes amid uncertainty about Iran's return to the 2015 nuclear deal, which involves the US, China, Russia, France, Germany, and the UK. According to the report, the simulation would focus on Iranian nuclear targets and take place over the Mediterranean Sea beginning on May 29. Nearly all Israel Defense Force (IDF) units are expected to participate. Apart from simulated strikes, Israel will focus on responding to potential retaliation by Iran and its allies.

Careful Planning

Last year, IDF Chief of Staff Aviv Kohavi said that the military had been instructed to create fresh attack plans against Iran and its nuclear assets. He further revealed that the Israeli armed forces had “greatly accelerated” preparations against Iran's nuclear program. Despite earlier claiming to have formulated a plan against Tehran's nuclear facilities, several defense analysts said that aspects of the strike plan could take a year to become fully actionable. One example is finding effective ways to strike Iranian facilities buried deep underground, as this requires specialized munitions and carefully-crafted tactics. Additionally, the Israeli Air Force must find ways to neutralize increasingly sophisticated Iranian air defenses to carry out a successful offensive.

Purported US Involvement

In a separate report, *The Times of Israel* said that the US would participate in the large-scale exercise. Citing Israeli TV channel *Channel 13*, the news outlet claimed that the US Air Force would only serve as a “complementary force” tasked with refueling Israeli planes as they simulate entering Iranian territory. The alleged Israel-US aerial collaboration is seen as a “potential message” to Iran amid negotiations on the potential return of the 2015 nuclear deal. However, a spokesman for the US Central Command has announced that the US Air Force refueling off the coast of Israel had no connection with the exercise.

<https://www.thedefensepost.com/2022/05/19/israel-exercise-attack-iran/>



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Ultrafast computers are coming: Laser bursts drive fastest-ever logic gates

Researchers have taken a decisive step toward creating ultrafast computers.

A long-standing quest for science and technology has been to create electronics and information processing that operate near the fastest timescales allowed by the laws of nature. A promising approach to achieve this goal involves using laser light to guide the motion of electrons in matter, and then using this control to develop electronic circuit elements—a concept known as lightwave electronics. Remarkably, lasers currently allow us to generate bursts of electricity on femtosecond timescales—that is, in a millionth of a billionth of a second. Yet our capacity to process information at such ultrafast timescales has remained elusive.

Now, researchers at the University of Rochester and the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) have made a decisive step in this direction by demonstrating a logic gate—the building block of computation and information processing—that operates at femtosecond timescales. The feat, reported on May 11 in the journal *Nature*, was accomplished by harnessing and independently controlling, for the first time, the real and virtual charge carriers that compose these ultrafast bursts of electricity. The researchers' advances have opened the door to information processing at the petahertz limit, where one quadrillion computational operations can be processed per second. That is almost a million times faster than today's computers operating with gigahertz clock rates, where 1 petahertz is 1 million gigahertz.

“This is a great example of how fundamental science can lead to new technologies,” says Ignacio Franco, an associate professor of chemistry and physics at Rochester who, in collaboration with doctoral student Antonio José Garzón-Ramírez '21 (PhD), performed the theoretical studies that lead to this discovery.

Lasers generate ultrafast bursts of electricity

In recent years, scientists have learned how to exploit laser pulses that last a few femtoseconds to generate ultrafast bursts of electrical currents. This is done, for example, by illuminating tiny graphene-based wires connecting two gold metals. The ultrashort laser pulse sets in motion, or “excites,” the electrons in graphene and, importantly, sends them in a particular direction—thus generating a net electrical current. Laser pulses can produce electricity far faster than any traditional method—and do so in the absence of applied voltage. Further, the direction and magnitude of the current can be controlled simply by varying the shape of the laser pulse (that is, by changing its phase).

The breakthrough: Harnessing real and virtual charge carriers

The research groups of Franco and of FAU's Peter Hommelhoff have been working for several years to turn light waves into ultrafast current pulses. In trying to reconcile the experimental measurements at Erlangen with computational simulations at Rochester, the team had a realization: In gold-graphene-gold junctions, it is possible to generate two flavors—"real" and "virtual"—of the particles carrying the charges that compose these bursts of electricity.

- "Real" charge carriers are electrons excited by light that remain in directional motion even after the laser pulse is turned off.
- "Virtual" charge carriers are electrons that are only set in net directional motion while the laser pulse is on. As such, they are elusive species that only live transiently during illumination.

Because the graphene is connected to gold, both real and virtual charge carriers are absorbed by the metal to produce a net current.

Strikingly, the team discovered that by changing the shape of the laser pulse, they could generate currents where only the real or the virtual charge carriers play a role. In other words, they not only generated two flavors of currents, but they also learned how to control them independently, a finding that drastically augments the elements of design in lightwave electronics.

Logic gates through lasers

Using this augmented control landscape, the team was able to experimentally demonstrate, for the first time, logic gates that operate on a femtosecond timescale. Logic gates are the basic building blocks needed for computations. They control how incoming information, which takes the form of 0 or 1 (known as bits), is processed. Logic gates require two input signals and yield a logic output. In the researchers' experiment, the input signals are the shape or phase of two synchronized laser pulses, each one chosen to only generate a burst of real or virtual charge carriers. Depending on the laser phases used, these two contributions to the currents can either add up or cancel out. The net electrical signal can be assigned logical information 0 or 1, yielding an ultrafast logic gate.

"It will probably be a very long time before this technique can be used in a computer chip, but at least we now know that lightwave electronics is practically possible," says Tobias Boolakee, who led the experimental efforts as a PhD student at FAU. "Our results pave the way toward ultrafast electronics and information processing," says Garzón-Ramírez '21 (PhD), now a postdoctoral researcher at McGill University. "What is amazing about this logic gate," Franco says, "is that the operations are performed not in gigahertz, like in regular computers, but in petahertz, which are one million times faster. This is because of the really short laser pulses used that occur in a millionth of a billionth of a second."

From fundamentals to applications

This new, potentially transformative technology arose from fundamental studies of how charge can be driven in nanoscale systems with lasers. "Through fundamental theory and its connection with the experiments, we clarified the role of virtual and real charge carriers in laser-induced currents, and that opened the way to the creation of ultrafast logic gates," says Franco. The study represents more than 15 years of research by Franco. In 2007, as a PhD student at the University of Toronto, he devised a method to generate ultrafast electrical currents in molecular wires exposed to femtosecond laser pulses. This initial proposal was later implemented

experimentally in 2013 and the detailed mechanism behind the experiments explained by the Franco group in a 2018 study. Since then, there has been what Franco calls “explosive” experimental and theoretical growth in this area.

“This is an area where theory and experiments challenge each other and, in doing so, unveil new fundamental discoveries and promising technologies,” he says. For more on this research, see [Laser Pulses for Ultrafast Signal Processing Could Make Computers 1 Million Times Faster](https://scitechdaily.com/ultrafast-computers-are-coming-laser-bursts-drive-fastest-ever-logic-gates/).

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Thermalization and information scrambling in a superconducting quantum processor

In recent years, physicists have carried out extensive studies focusing on quantum technology and quantum many-body systems. Two out-of-equilibrium dynamical processes that have attracted particular attention in this field are quantum thermalization and information scrambling. Thermalization, or "the relaxation to equilibrium," is a process through which quantum many-body systems achieve thermal equilibrium. Information scrambling, on the other hand, entails the scattering of local information into many-body quantum entanglements, which are distributed throughout a quantum many-body system.

Researchers at the University of Science and Technology of China, the Shanghai Research Center for Quantum Sciences, and the Chinese Academy of Sciences have recently observed both thermalization and information scrambling in a superconducting quantum processor. Their findings, published in a paper in *Physical Review Letters*, could pave the way towards new studies focusing on the thermodynamics of quantum many-body systems. "The non-equilibrium properties of quantum many-body systems is relevant to whether the integrability of the quantum system is broken," Xiaobo Zhu, one of the researchers who carried out the study, told Phys.org. "Specifically, thermalization and information scrambling fail during non-equilibrium dynamics of the one-dimensional free fermions as an integrable system."

Experimentally investigating thermalization and information scrambling in both integrable and non-integrable quantum systems can be particularly challenging, for two key reasons. Firstly, doing this requires the experimental implementation of both these type of systems on the same quantum simulator. In addition, to successfully conduct these experiments researchers need to be able to collect accurate and efficient measurements of entanglement entropy and tripartite mutual information. These measurements ultimately allow scientists to quantify thermalization and information scrambling, respectively, typically using an approach known as multi-qubit quantum state tomography.

"In our recent work, using a programmable ladder-type superconducting circuit consisting of 24 qubits, we experimentally studied thermalization and scrambling in the 12-qubit chain and ladder, performing quantum simulations of the 1D XX model, which can be mapped to free

fermions, a typical integrable system, and the XX-ladder model as a non-integrable system," Zhu explained. "We observed two distinct dynamical behaviors of the qubit array chain and ladder, demonstrating that integrability plays a key role in thermalization and information scrambling."

Zhu and his colleagues decided to study quantum thermalization and information scrambling in a superconducting quantum processor characterized by a high programmability. By tuning all qubits to the same interacting frequencies, they were able to experimentally study the non-equilibrium dynamics of the qubit chain and ladder. "After the time evolution, we can measure the local observables by projecting all qubits to the Z projections," Zhu said. "We also used high-precision multi-qubit quantum state tomography to measure the entanglement entropy and the tripartite mutual information (TMI). The ladder-type architecture of the superconducting circuit allowed us to study the integrable 1D chain and the non-integrable ladder in the same quantum processor."

Zhu and his colleagues first investigated thermalization and information scrambling in their highly programmable superconducting circuit's qubit array chain and ladder. Their observations suggest that integrability significantly impacts the properties of out-of-equilibrium quantum many-body systems. "We also observed a stable negative value of TMI in the non-integrable system, which is the first experimental signature of information scrambling, characterized via TMI, laying down the foundation for further experimental studies on TMI in other platforms," Zhu said. In addition to gathering interesting insight about the relevance of a system's integrability in determining its out-of-equilibrium properties and unveiling a signature of information scrambling, Zhu and his colleagues were among the first to study quantum many-body systems using a highly programmable quantum processor.

In the future, the size of the circuit they used could be expanded further, to carry out computations that would be harder to perform using classical computers. In their next studies, the researchers would like to expand on their recent work, pursuing two main research directions. "Firstly, we plan to include more qubits to form a larger many-body system," Zhu added. "Secondly, we plan to improve the programmability of the quantum processor. On the state-of-the-art superconducting quantum processor 'Zuchongzhi 2.0', we have successfully demonstrated the quantum advantage. We plan to use this processor to demonstrate more exciting phenomena in many-body physics."

More information: *Qingling Zhu et al, Observation of Thermalization and Information Scrambling in a Superconducting Quantum Processor, Physical Review Letters (2022). DOI: [10.1103/PhysRevLett.128.160502](https://doi.org/10.1103/PhysRevLett.128.160502)*

<https://phys.org/news/2022-05-thermalization-scrambling-superconducting-quantum-processor.html>

