A steady place to hold the new maser

The diamond crystal has become home to a microwave laser that works at room temperature

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The first laser was in the microwave region, and was called the maser. Lasers, which are the same thing in the optical region, were developed soon after, but they outpaced the maser in applications and specialisation. An important reason is that masers need low pressure gas or work at low temperature, conditions restricted special laboratories, while lasers are used everywhere.

But the microwave region is important and the want was felt of masers for general use. In 2012, Jonathan D Breeze and Neil McN Alford of Imperial College, London collaborated with Mark Oxborrow, from the UK National Physical Laboratory in Teddington, in creating a first room temperature maser that worked in pulses.

Breeze and Alford, with Enrico Salvadori, Juna Sathian, and Christopher W M Kay, from University College, London, London Centre for Nanotechnology, Queen Mary University of London and University of Saarland, Germany now report, in the Journal, Nature, a more versatile, continuous wave, room temperature maser, where the operative part is held steady in a diamond lattice.

The laser, or the maser, is a device that generates high frequency electro-
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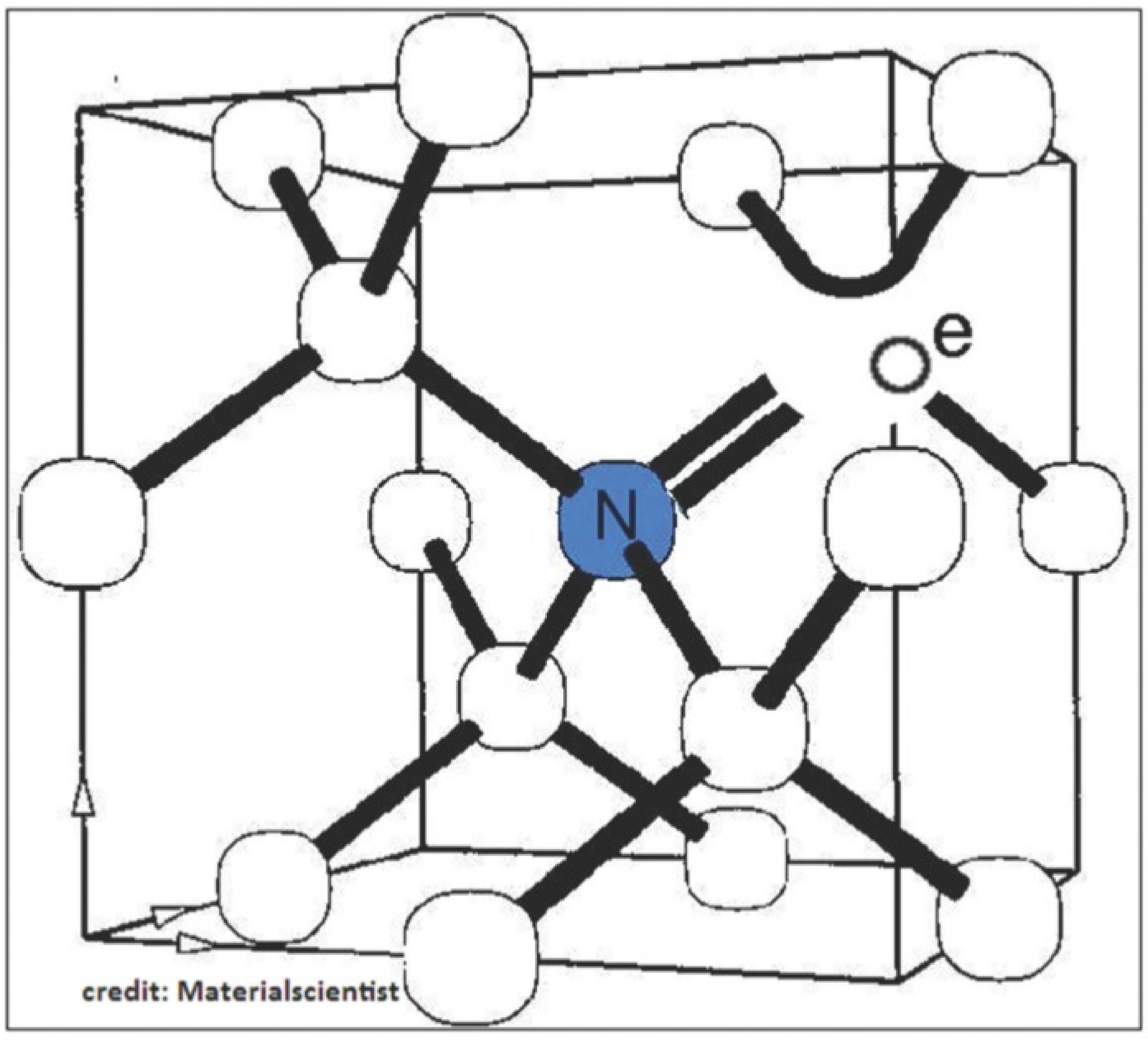
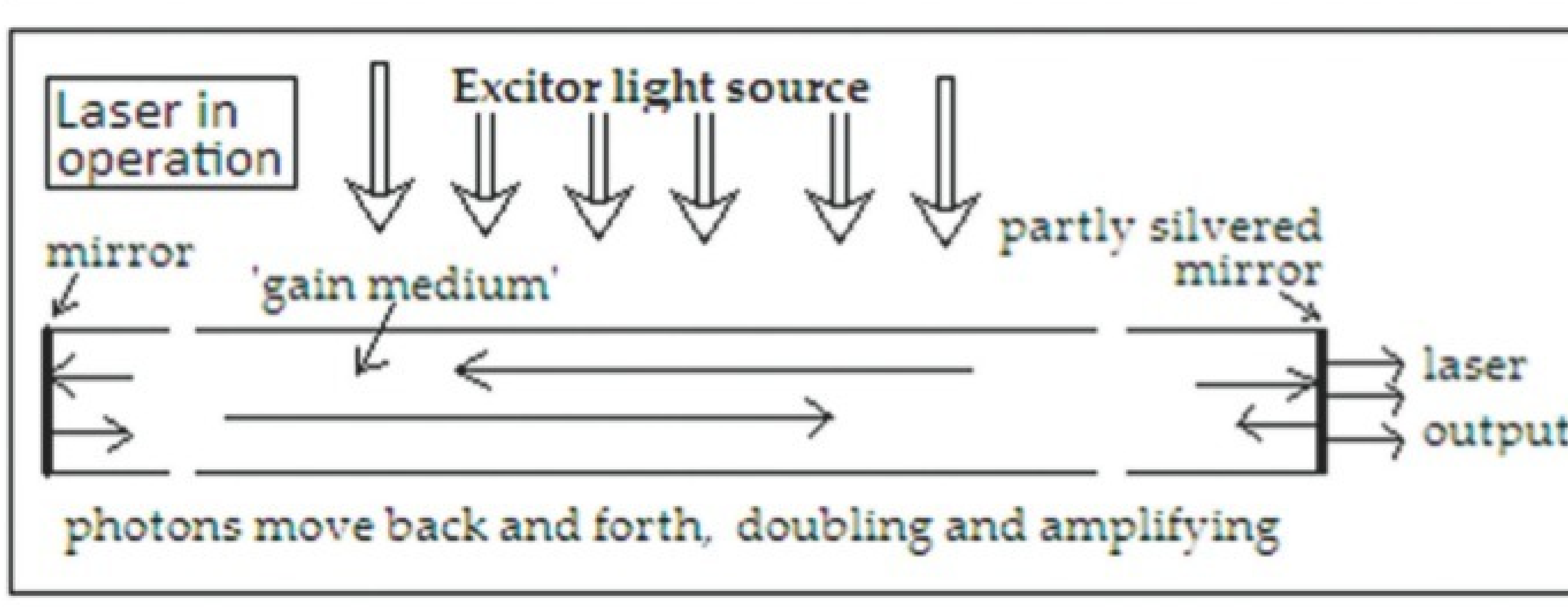
but they cannot work at the dimensions of very short waves. Here, we need to harness emission from the interior of the atom. Any warm object does emit electromagnetic waves, in the infra red or the visible part, but these waves are emissions from physical vibrations of atoms. They are hence of different frequencies and not in step.

Even where the em radiation is from changes in the energy levels of atoms, as in the fluorescent light, the radiation is reasonably of the same colour, but the waves are not in step or directional. In the laser an excited atom is stimulated to emit light by another particle of the same frequency. The two particles of light are hence of the same frequency and, as they set out together, they are in step. The arrangement to create these conditions calls for accurate back and forth reflection of light waves, which makes for a highly directional beam.





The laser has hence found use in research, in communications and in generating powerful beams to melt things. The trick in creating lasers is a condition when there are excited atoms waiting to be stimulated into emission. As excited states are unstable and decay, atoms are mostly in the ground state and excited atoms, which can be stimulated to emit, are rare. In materials suitable for lasers, however, there is an excited state that stays put for a short while before spontaneously de-exciting. It is hence possible to create a condition of more atoms in the excited state than in the normal, or a "population inversion".

Now, if the material is placed between a pair of parallel mirrors, particles of light emitted spontaneously, would reflect back and forth are likely to meet excited atoms, when they would "stimulate" another particle of light, which would be "in step", to be emitted. The pair could then stimulate other atoms and a back and forth surge of light particles of the same frequency, in step and in the same direction. Light in the visible part of the spectrum is emitted by electronic transitions in atoms. These are when the electrons that orbit atoms move to higher orbits, when excited, and emit light corresponding to the difference in energy, when they de-excite. Microwaves, however, are very low energy waves that arise ether from low energy molecular transitions or from atomic transitions between energy levels that are very close to each other.

Such close packed energy states in atoms arise not from the orbit of electrons, but when the electron spin flips from one direction to another. When the atom is in a magnetic field, the electron spin can be either in the same direction or in the opposite direction. With a pair of electrons, thus, the spin can be ½ + ½ = 1 or ½ - ½ = 0 or (-½) + (- ½) = -1 (as the unit of spin of the electron is ½). Any one flip of an electron would thus cause a change in the state by "1", corresponding to the energy of microwaves.

The practical difficulty in making use of such electron spin states is that excited states are sensitive to disturbances, like collisions of atoms in a gas or vibrations of atoms in solids. The first maser, which used ammonia gas, thus used the gas at very low pressure, a near vacuum, and solids that have been used for masers need to be kept at very low temperatures, nearly absolute zero, where there are very little thermal vibrations.

Masers for everyday use have thus not been possible. The first room-temperature maser was in 2012, with an organic material called pentacene. The molecules of pentacene could configure in a way that allowed maser action. A crystal with pentacene was "pumped" by a yellow light, optical laser, which brought about "population inversion" and a shot of microwaves set off a cascade of stimulated emission.

The shortcoming, however, was that the organic material could not withstand continued "pumping" and the maser could emit a flash of coherent microwaves only for every short spell of exposure to the laser. This was a form of "pulsed" working, rather than producing a continuous maser beam, which is needed for many applications.

The success now reported is of a maser that is both at room temperature and operates continuously. The maser medium was a diamond lattice with nitrogen atoms in place of some of the carbon atoms. The carbon atom has four electrons in its outer shell and in the lattice each of these pairs with one of the neighbouring atom, create a stable lattice. The nitrogen atom, in contrast, has three outer shell electrons. If a nitrogen atom takes the place of carbon in the lattice and there is a vacant lattice position, the Nitrogen - vacancy lattice defect, as it is called, gives rise to two unpaired electrons. These then have three possible spin states - 1, 0 or 1.

Now, a magnetic field was applied, so that vacancy centres with spin 0 had more energy than centre with spin -1. And then, a laser pump created an excess of vacancy centres with spin 0, than spin -1. The diamond lattice protects the states from being corrupted, without the need for low temperatures. The excited spin states, when stimulated by a microwave particle, then decayed from spin 0 to spin -1, emitting more microwave particles, and then continuous maser action. The maser has an important application as an amplifier of very weak microwave signals.

In normal methods of amplification, there are disturbances that create noise and distort the signal. The maser, however, would amplify with no noise and this has application in a range of instrumentation, for astronomy and medical applications.

The maser beam would also be a great medium for communication with distant spacecraft. The optical laser is high frequency and the beam gets scattered. A microwave beam would scatter to a much lesser extent.

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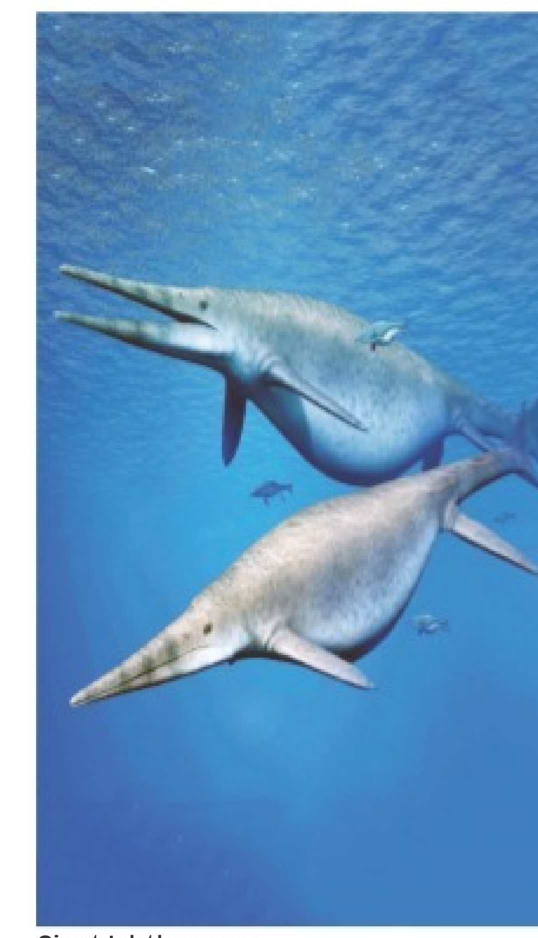
PLUS POINTS

Prehistoric connect



Giant Ichthyosaur

A jaw bone belonging to a gigantic underwater reptile has been identified as belonging to "one of the largest animals ever".

Founded by fossil collector Paul de la Salle in Lilstock, Somerset, the 205 million-year-old remains have now been analysed by an international team of palaeontologists. They concluded it belonged to a type of fish-like predatory reptile called Ichthyosaur, and its discovery suggests other fossils found in the UK could belong to even larger creatures. "Initially, the bone just looked like a piece of rock but, after recognising a groove and bone structure, I thought it might be part of a jaw from an ichthyosaur," said De la Salle.

He made contact with ichthyosaur experts Dean Lomax, of the University of Manchester, and Professor Judy Massare, of Suny College at Brockport, who both expressed an interest in studying the bone.

They compared the fossil - an incomplete bone called a surangular from the lower part of the animal's jaw - with several other ichthyosaur specimens.

Notably, they looked at the bone in relation to a specimen held at the Royal Tyrrell Museum of Palaeontology in Canada, belonging to a species called Shonisaurus sikanniensis. Measuring 21 metres, Shonisaurus was a true monster, and the largest known ichthyosaur.

However, the palaeontologists' analysis suggested the bone found by Mr De la Salle belonged to a similar animal that was even bigger.

In their paper describing the discovery in the journal PLOS One, the scientists also suggested the new bone could be a sign that prehistoric Britain was home to many more of these enormous creatures.

The Independent

Insightful discovery

A sauropod footprint discovered at Brothers' Point on the Isle of Skye in Scotland

Dozens of rare footprints belonging to dinosaurs made some 170 million years ago have been discovered on Scotland's Isle of Skye, offering an important insight into the Middle Jurassic era, scientists said recently.

"The more we look on the Isle of Skye, the more dinosaur footprints we find," said Dr Steve Brusatte of the University of Edinburgh's School of GeoSciences.

"This new site records two different types of dinosaurs - long-necked cousins of Brontosaurus and sharp-toothed cousins of T-Rex - hanging around a shallow lagoon, back when Scotland was much warmer and the dinosaurs were beginning their march to global dominance", he added.

The find is globally important as it is rare evidence of the Middle Jurassic period, from which few fossil sites have been found around the world, the university said on its website. The footprints were difficult to study owing to tidal conditions, the impact of weathering and changes to the landscape, it added. But researchers managed to identify two trackways in addition to many isolated footprints.

They used drone photographs to make a map of the site while other images were collected using a paired set of cameras and tailored software to help to model the prints. The study, carried out by the University of Edinburgh, Staffin Museum and Chinese Academy of Sciences, was published in the Scottish Journal of Geology.

The Straits Times

Secrets of early human migration

Discovery of oldest confirmed homo sapiens fossil outside of Africa and Levant suggests early colonisation of 'expansive region of south-west Asia'

JOSH GABBATISS

A single finger bone found in the Saudi Arabian desert has provided unprecedented insight into the early migration of our species out of Africa. At 90,000 years old, the bone is the oldest confirmed Homo sapiens fossil found outside Africa and the Levant.

It contradicts received wisdom concerning the history of humanity, suggesting instead that people were spreading far and wide 30,000 years earlier than previously thought. The discovery is "a dream come true" for Professor Michael Petraglia, an archaeologist at the Max Planck Institute for the Science of Human History, who led the project that found the bone.

Found at a site known as Al Wusta in the middle of the hyper-arid Nefud desert, the bone is the culmination of a decade's work by Prof Petraglia and his colleagues. During this period they scoured the region for signs of early humans, seeing it as a natural "stepping stone" for humans leaving Africa. "We found many archaeological sites; many animal fossils, but one thing was always missing - ancient human fossils," said Dr Huw Groucutt, an archaeologist at the University of Oxford who directed the field work that led to the discovery. That all changed with the discovery of the Al Wusta finger bone.

Following the fossil's discovery in 2016, the scientists spent two years subjecting it to rigorous tests determining its age and confirming that it did, indeed, belong to a member of the Homo sapiens species. The gender and age of the bone's owner are unknown, but based on their analysis of the site the archaeologists think they belonged to a flourishing community in what would have once been lush grassland.

Hundreds of animal fossils were found at the site, including those belonging to hippopotamus, as well as plenty of stone tools made by humans. These findings were outlined in a study published in the journal Nature Ecology and Evolution. Though measuring no more than 3cm, the finger bone has big implications for our understanding of early human history.

"Traditionally the movement of modern humans — our species, Homo sapiens - out of Africa has been conceived of as a single rapid movement 60,000 years ago," said Professor Petraglia, noting that this view was supported by genetic evidence.

"These groups - so the theories have gone would have been moving on the coastlines out of Africa and subsisting on marine resources, and would have been using very advanced technologies." In recent years, however, this outlook has been challenged by findings in Israel's caves that suggest humanity began to take its first tentative steps out of Africa far earlier.

The Al Wusta site in Saudi Arabia, where the finger bone was discovered

Prior to the Al Wusta discovery, however, early dispersals into the Levant were thought to have been unsuccessful, and confined to the forested Mediterranean regions. Now, archaeologists have evidence of humans successfully striking out into the unknown, early in our species' history.

"This discovery for the first time conclusively shows that early members of our species colonised an expansive region of south-west Asia and were not just restricted to the Levant," said Dr Groucutt.

"The ability of these early people to widely colonise this region casts doubt on long-held views that early dispersals out of Africa were localised and unsuccessful." The researchers predict this fossil will be the first of many tracing the path of human migration across Asia.

The finger bone is the oldest confirmed Homo sapiens fossil outside of Africa and the Levant

"What we are arguing for here is that there were multiple dispersals out of Africa, so the process of the movement and colonisation of Eurasia was far more complicated than our textbooks tell us," said Professor Petraglia.

The Independent