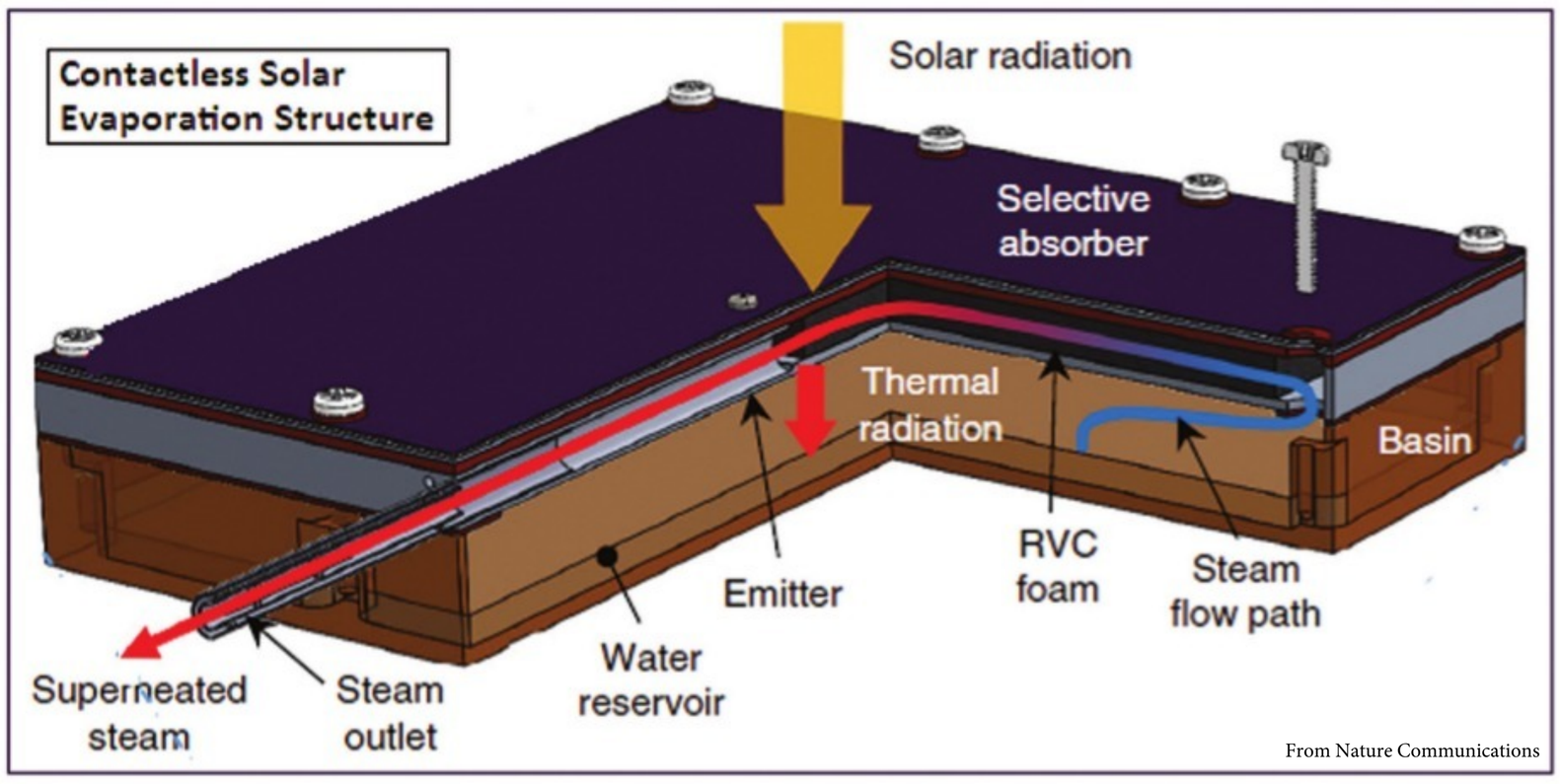
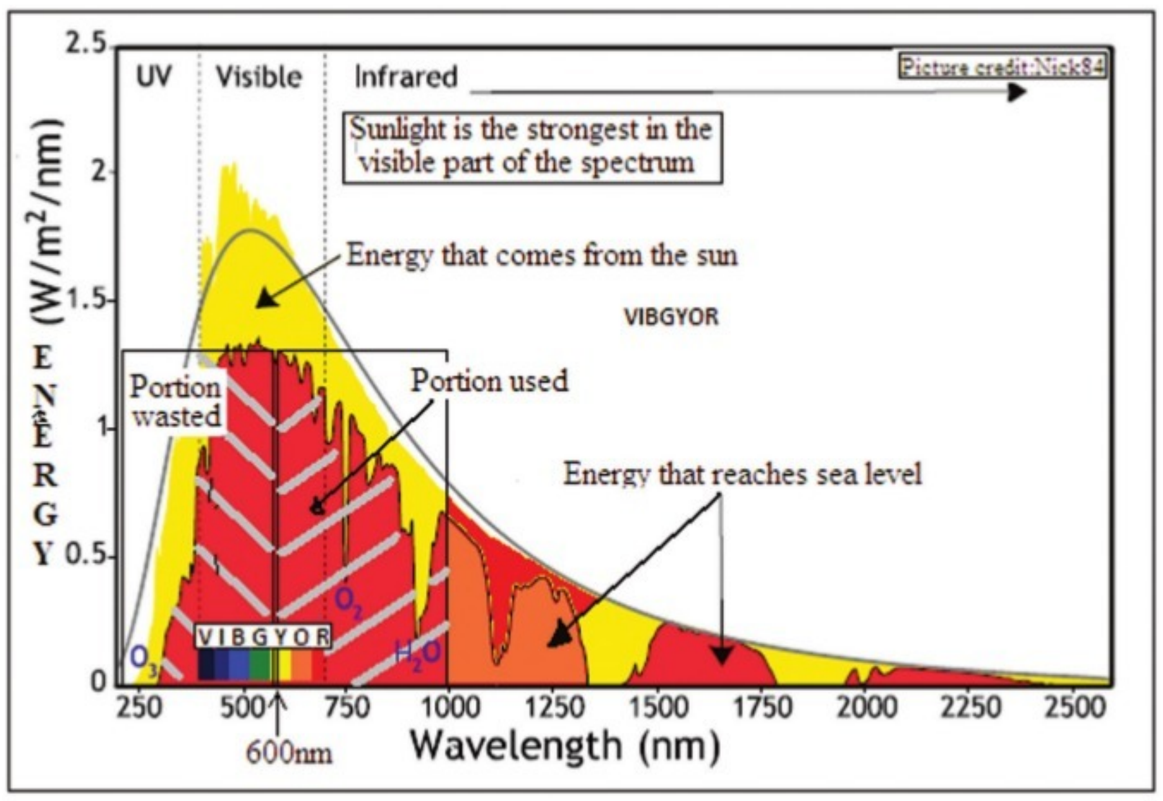
Catch sunlight and pin it down

Its rays can be harnessed for accelerated evaporation of water and the production of vapour at high temperature

S ANANTHANARAYANAN



From Nature Communications



While it is the sun's energy that drives all processes on the earth, sunlight itself is usually not a suitable industrial energy source. We need to use "stored sunlight", as energy found in fossil fuels or indirectly, as the energy in the wind, or in water at higher altitudes, for hydroelectricity. The exception is the case of the solar cell, which uses direct sunlight, but this is a case of considerable complexity.

Thomas A Cooper, Seyed H Zandavi, George W Ni, Yoichiro Tsurimaki, Yi Huang, Svetlana V Boriskina and Gang Chen, from MIT, USA, describe in the journal, Nature Communications, a simple method to harness sunlight to cause accelerated evaporation of water, even production of water vapour at high temperature.

The most visible effect of sunlight is the gentle warmth that causes evaporation. Huge quantities of water from the oceans evaporate and bring about the water cycle, which provides fresh water. Life forms, habitation, even the topography of the earth have evolved because of this effect of sunlight. The fresh water actually available for humans to use, however, is a small fraction, as the bulk is locked as polar ice. With rising demand for water, finding ways to use sunlight for local distillation of sea water or other, impure water has become important.

A problem with using sunlight to evaporate water is that water is transparent to the frequencies of light which contain most of the energy in sunlight. Sunlight thus gets absorbed by water only when light penetrates to a depth of 20 to 40 meters, the MIT paper says. There is hence negligible heating of the mass of water and little evaporation. Ways have hence been found to increase the heat absorbed, by introducing particles in the water, or blackening the container. But with these, the paper says, the water, which is usually brackish water, is in contact with the heat absorbing material, and this leads to deposit of salts or impurities on the material. The material is hence degraded, or corroded, and needs to be cleaned or replaced. There have been developments in materials or structures that can stay clean, but "fouling remains a fundamental challenge inherent to all solar absorbers in direct contact with the water surface", the paper says.

Another limitation of evaporation using sunlight absorbers that are in contact with water is that the absorber can get only as warm, at best, as the boiling point of water. Sunlight can thus cause evaporation, but it cannot create steam at temperatures above 100°C. While we think of using sunlight for producing potable water in remote places, another need in such places, where there may be no electricity, is a way to sterilize surgical instruments. This application sometimes needs super-heated steam, at 121°C to 135°C which is not possible with solar heaters in contact with water. This has been once done, the paper says, with a composite- material absorber floating on water, but it called for a twenty-fold concentration of sunlight.

The new approach by the MIT team tackles both the problems with solar evaporation - that water is transparent to sunlight and the need to keep the heating material out of contact with the water. The arrangement is a slab of material that absorbs heat from sunlight, but is not in contact with water, just above the surface of water. While the material warms up in the sun, it radiates heat to the water in the infra red. The energy coming in from the sun at visible (and ultra violet) frequencies is thus converted to energy in the infra red. Now, unlike in the case of visible light, water is opaque to infra red. 90 per cent of the energy from normal warm objects is absorbed by the top 100 microns (a tenth of a millimeter) of the water, the paper says. Compared to absorption by 20 meters for normal sunlight, this conversion to infra red, which is absorbed at the surface of the water, amounts to a great increase in heating effect.

This naturally increases the rate of evaporation and the efficiency of the arrangement with distillation of bad water, to create exceedingly good quality water, in good quantity, with no power input other than sunlight. But what is more, with the concentrated input of energy into a paper-thin wafer of water, the water need not just warm and vaporise, but can superheat and give off steam at high temperatures. In a demonstration of the device on the rooftop of MIT, water in a reservoir was seen to heat up to its boiling point within an hour and half and superheated steam, at more than 146°C, was generated over three and a half hours, the paper says.

And then, the other feature of the arrangement is that the absorbing-radiating material is not in contact with water. There is hence no deposit of salts and impurities, no fouling. To demonstrate the extent of fouling resistance, laboratory experiments were conducted using sea water, which has 3.5 per cent salt content. Even after continuous operation for eight hours, there was no sign of fouling. This is indeed a major advantage, as corrosion and surface degradation are problems that lead to high costs, or water treatment or maintenance, in all technologies where material is in contact with water.

This principle of converting visible sunlight to the more useful, lower frequency, or 'down-conversion', has also been applied with ultra violet light and electric solar cells. While the bulk of the energy in sunlight is in the visible range, there is a considerable part in the higher frequency, and more energetic, ultra violet. As solar cells are most effective with light at the red end of the spectrum, this higher frequency component of sunlight is lost. What is more, energetic ultra violet damages and degrades the solar cell material.

In 2015, Jingwen Ding, Jie He and Challa V Kumar, at the University of Connecticut reported a simple material, derived from albumin and coconut fat, as a cover for solar cells, which doubled the output of the solar cells. The principle was a dyestuff that had the property of absorbing energy in the ultra violet and then emitting the energy at a lower frequency. The result of draping a film of this material on a solar cell was two-fold. First, to convert the energy at high frequencies to a form that the solar cell could use. And second, to use up the high frequency radiation and protect the solar cell from damage.

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The forgotten quantum Indian

Scientist Satyendra Nath Bose, along with Albert Einstein, defined the general properties of bosons that occupy half the universe

BINAY MALAKAR

There has been no other scientist in the world other than Satyendra Nath Bose whose name is indissolubly linked with Albert Einstein in Physics text books. This is simply due to Bose-Einstein statistics which revolutionised quantum physics and lead to the greatest scientific discovery of this generation -the Higgs Boson (popularly known as God particle) and the Bose Einstein condensate (BEC).

Bose was born on 1 January 1894 in Calcutta. He joined as lecturer in the physics department of the University of Calcutta in 1916. During this time, he and professor Meghnad Saha translated Einstein's works on general relativity into English from German and published them as a book. In 1921 Bose joined the physics department of Dacca University. In 1924 while teaching a class on quantum physics, Bose had a eureka moment.

Actually, Bose had been very dissatisfied with the way Plank's quantum law of energy distribution was being derived. Earlier Ludwig Boltzmann had developed a mathematics (Boltzmann law) using probability and statistics. Bose applied the statistics in a novel way to predict the number and probability of Einstein's photons.

He decided to send his paper to Einstein and overnight became a celebrity. Einstein was delighted to receive his paper and was very positive about it.

He translated Bose's paper in German and published it in Zeitschrift fur Physik. Einstein adopted Bose's idea and extended it to atoms and this lead him to predict which now we call Bose Einstein condensate (BEC)

What Bose showed in his paper was that in the case of photons, classical statistics does not hold much relevance - it's a new statistics which is now called Bose statistics. He assumed that the photons are identical and indistinguishable unlike classical gas molecules.

Bunching probability for indistinguishable photons is more likely (if we toss two distinguishable coins the probability of bunching i.e. two heads (H) or two tails (T) coming up is 1/4=25 per cent as in this case the probable results are (H,H),(T,T).(H,T) and (T,H) but when the coins are indistinguishable the probable results are (H,H),(T,T) and (H,T) and the bunching probability is 1/3=33 per cent so probability of bunching increases from 25 to 33 per cent). Einstein realised how radical Bose's proposition was.

BEC is a quantum phenomenon, characteristic of boson particles, where macroscopically large number of particles condenses at very low temperature to ground state. Though the 1924 theory suggests that BEC does exist but it was not until 1995 when Eric Cornell, Carl Wieman and Wolfgang Ketterle verified it experimentally for which they got the 2001 Nobel Prize in Physics.

In the year 1964, Peter Higgs of Edinburg University, proposed the existence of Higgs field and Higgs boson. Theory has it that as the universe cooled after the Big Bang, an invisible force field known as Higgs field formed which pervades the entire universe.

This field can be pictured as a pool of molasses that "sticks" to otherwise massless fundamental particles that travel through the field, converting them into particles with mass. The more strongly the particle interacts with the field, the heavier it becomes. Massless particles such as photons are those that do not interact at all with the Higgs field.

Higgs boson accounts for why everything in the universe has mass. Higgs boson was detected by LHC (large Hadron Collider) experiment in the year 2012 and Peter Higgs was awarded Nobel Prize in the year 2013.

Thus we see that to detect Higgs boson it takes only 48 years (1964 - 2012) whereas BEC was detected after 71 years (1924 -1995). The question is why it takes so long time to verify BEC in the laboratory.

The reason is that the sophisticated instruments needed to verify BEC in the laboratory were not available before 1980s when laser cooling was invented and then in early 1990s magnetic evaporative cooling was invented and all these ultra cooling techniques make things happen.

Cornell,Wieman and Ketterle took rubidium (Rb87) atoms and cooled them at chilling temperature of 20 nanokelvin. In fact, BEC is the ultimate low temperature phase of weakly interacting gas.

SN Bose with Albert Einstein

We know that our universe started cooling down from the time of Big Bang explosion and the average back ground temperature at present is 2.7 Kelvin. So any temperature below 2.7 Kelvin is artificial.

Now to make Bose Einstein condensate to happen we need temperature of the order of 20 nano Kelvin which is much below the present average back ground temperature (2.7 K).

If the verification of BEC could have happened before 1974, Bose should have been awarded the Nobel Prize. But according to the Nobel Foundation Committee, a Nobel Prize cannot be awarded posthumously.

Bose passed away in 1974. He is regarded as a forgotten hero but a man of his calibre can never be forgotten as his name is associated with one half the particles in this world.

Since there are two kinds of particles in the universe - Bosons and Fermions, so half the particles in this universe are Bosons. As long as there is light in this universe, there will be Bosons everywhere - Bose thus becomes a household name.

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PLUS POINTS

Driven to extinction

Exploding stars 2.6 million years ago may have contributed to a mass extinction event that swept earth's prehistoric oceans wiping out creatures like the giant shark known as the Megalodon, according to a new scientific paper.

Cosmic particles from these supernovae showered the planet's surface at such high levels the researchers from the University of Kansas say they may have caused cancers in large marine creatures.

The theory was laid out by a team led by Adrian Melott, a physicist at the University of Kansas. To arrive at this hypothesis, Melott drew on his knowledge of historic supernovae and the impact they had on earth.

Ancient seabed deposits of iron-60 isotopes - radioactive forms of iron - provided a crucial clue. Publishing the findings in the journal Astrobiology, Melott claimed there was no other way for these materials to have arrived on earth except from a supernova, meaning they provided the "slam dunk" evidence for these events taking place.

Further support came from the structure of the surrounding universe. Earth sits on the edge of something termed the "local bubble"— an enormous region of hot, dense gas that astronomers think resulted from a series of supernovae explosions - the explosion of stars that have reached the end of their life.

Due to the structure of this bubble, it is possible that earth could have been bathed in cosmic rays, as the explosion bounced off the edges, for up to 100,000 years.

During this time, particles called muons would have fallen in large numbers on the planet. With muon exposure increasing by hundreds of times Melott and his colleagues think this could have led to an increase in rates of mutation and cancer.

Larger animals would have been particularly susceptible as they would have caught a greater dose of radiation.

Melott said his work clarifying the impact of these star explosions during this key period in earth's history was "another puzzle piece".

Often, mass extinction events are linked with dramatic changes to the earth's climate, such as "The great dying" 252 million years ago.

Though cosmic rays bombarding the atmosphere could also be linked to a changing climate, the authors of the study admit this is "a controversial claim".

The independent

Selfie by InSight

The United States National Aeronautics and Space Administration's InSight lander is not camera-shy. The spacecraft has used a camera on its robotic arm to take its first selfie - a mosaic made up of 11 images. This is the same imaging process used by Nasa's Curiosity rover mission.

Visible in the selfie are the lander's solar panel and its entire deck, including its science instruments.

Mission team members have also received their first complete look at InSight's "workspace". The spacecraft designed to unveil the Red Planet's inner mysteries — marked the eighth successful landing on Mars in Nasa's history.

In the coming weeks, scientists and engineers will go through the process of deciding where in this workspace the spacecraft's instruments should be placed.

They will then command InSight's robotic arm to carefully set the seismometer and heat-flow probe in the chosen locations.

The straits times/ann