Fifty years on…

… And for the Laser it's only just begun, writes **S Ananthanarayanan**

THE first functioning version of this phenomenal light generating device of our times now found in research labs, industry, communications, data processing and entertainment was developed in 1960 at Hughes Research Laboratories, Malibu, USA, by Theodore H Maiman, then all of 33 years old. His work was the practical form of an idea some eight years in the making, starting from Charles Townes and Arthur Schawlow's Microwave Amplification by Stimulated Emission of Radiation. The successful demonstration validated much theoretical work that had gone before and became the start of a tidal wave of new things in different fields.

In recognition of this 50 years of progress, the journal *Nature* has published a feature called *Milestones*, where the stages in our understanding of the nature of light is captured, the Light Amplification by Stimulated Emission of Radiation being the 10th, since the start in the 17th century.

Laser light

This is usually described as different from ordinary light in the same way that a jostling crowd is different from a marching column of soldiers. The crowd also advances but the sound of advance is just a roar, unlike the soldiers who march in step. Ordinary light comes from the random de-excitation of billions of atoms with no regard for the photon, which has a wave nature, from one atom being "in step" with other photons. In Laser light, in contrast, the emission of the photons is linked with other photons and the photons are all "in step".

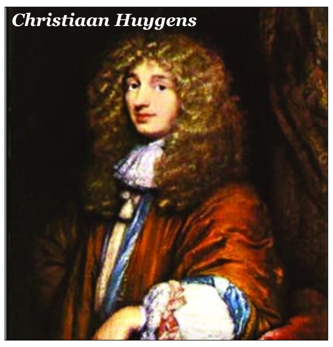
This analogy, although exact, does not bring out what difference this quality makes. We know that bridges, particularly suspension ones, oscillate and movement on the bridge at the natural frequency of the construction can be dangerous. Well, the jostling crowd could rush across the bridge with all their energy and do no harm. But a column of just a few soldiers marching at the right rhythm could bring the bridge (and themselves) down!

The laser beam, by this precision in frequency, phase and direction finds application in sensitive optical arrangements for research in communications as the carrier of digital information in glass fibre cables, as the stylus in DVDs, as the scalpel in microsurgery, the welding torch in engineering and in displays that call for powerful light beams in different colours.

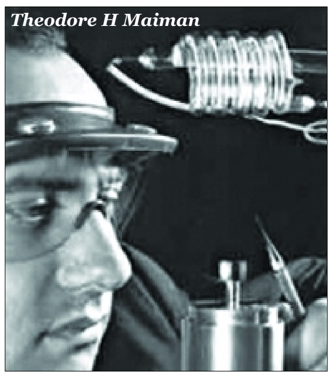
Development

The origin of the Maser, which is a Laser in the microwave region, was at the Bell Telephone Laboratories, in work for improved military radar. The need was for radio waves of shorter wavelengths so that radar beams could be more directional and the antennae on the aircraft could be smaller. And Townes, a physicist, had bent his mind to the problem.

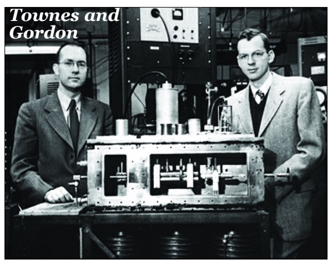
After the war, he worked with the interplay of radiation with molecules of gases and this work required the use of radio waves of very short wavelengths, indeed. Now, when building a device to generate such short



Christiaan Huygens



Theodore H Maiman



Townes and Gordon

HJ Zeiger

wavelengths became difficult, Townes got the idea of using molecules themselves to generate the waves.

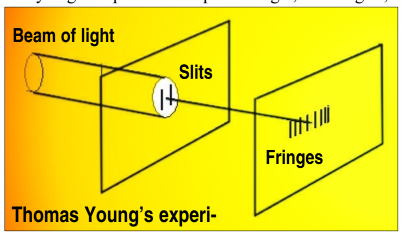
Towns, Gordon Gould and HJ Zeiger used the ammonia molecule, which has two energy levels separated by the energy of microwave photon. They rigged up a container with mirrors at two ends so that microwaves could flash back and forth exciting ammonia molecules to the higher energy level. When there were more excited molecules than ground level ones, the photons were more likely to cause *decay* and emission of a photon than absorption and excitation. When this happened, there was a cascade of *stimulated emissions*. In this kind of emission, the photon given off is just in step with the photon that causes the emission, which leads to two photons *in phase*. The geometry of the container is also adjusted so that the photons remain in phase and the result is a burst of laser light. As it was first done with microwaves, it was called Maser.

Townes and company went on to develop the idea for use in the optical region which would employ atoms in place of molecules, and they published an important paper in 1598. There was also similar work by Alexander Prokhorov in the Soviet Union and Gould, a student in Columbia University, mainly about the kind of cavity for the Laser.

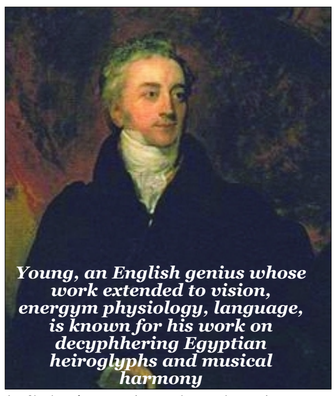
The Laser

The method used for the optical region is to use a gas or a crystal doped with a trace of an impurity to make it work. The material is excited to a higher energy level that readily decays to an intermediate level. This level stays stable for a short while and, over time, can be more populated than the ground state. This is the condition for laser action, brought about by light from decay of the intermediate state, reflecting back and forth either at the silvered ends of the crystal or mirrors at the ends of the container, in the case of a gas. One of the mirrors is made partially transmitting to get the laser light out of the system.

This basic design has been perfected over the last 50 years and now we have lasers at many large frequencies that produce light, not



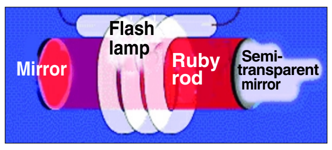
Thomas Young's experi-



Young, an English genius whose work extended to vision, energym physiology, language, is known for his work on decyphhering Egyptian heiroglyphs and musical harmony

in flashes but continuously, as the active element is *pumped up* to the higher level and laser light is harvested from regular decay and cascade.

There are heavy duty arrangements that consume huge power and need elaborate cooling arrangements and there are lasers that



have to operate very steadily for long periods for transmitting data through kilometers of glass fibre cables. And there are lasers that provide intense and precisely directed beams for eye surgery. Then again, there's the laser in every CD or DVD drive that shines its beam on the tracks to detect the *pits* and the digital signal.

Photon history

The laser, of course is the culmination of our understanding of light itself. *Timeline* published by *Nature* describes the early debates that favoured a corpuscular theory of light, mainly because light moved in straight lines. The classic work of Christiaan Huygens, to explain light in the form of waves, could not prevail over the champions of the corpuscular theory, the greatest being Isaac Newton. In his *Optics* of 1704, Newton considered that the colour of light should correspond to the mass or the velocity of the particles, which also helped explain the splitting of colours when refracted through a prism.

The experiment of Thomas Young in the early 1800s, where light passing through two narrow slits produces a series of dark and bright fringes, may be a turning point towards the wave theory. Augustin-Jean Fresnel's work on diffraction, soon after, resurrected Huygen's first theory, and when, in 1821, he showed that polarisation was explained if light were a transverse wave, Newton was supplanted.

Clerk Maxwell's elegant mathematical structure, to explain all optical phenomena and even predict the existence of electromagnetic waves, seemed to place the wave theory of light as the last word. But again, the distribution of radiation from a warm object over different wavelengths ran into serious difficulties with the wave theory. New kinds of radiation, like X-rays and Alpha rays had been discovered and atoms that emitted light of specific colours were found to have a structure that played a role.

The result was the discovery of the photon, or the quantum of energy, radiated as electromagnetic waves, which Max Plank showed exactly described black body radiation. This also explained curious phenomena like the photoelectric effect (Albert Einstein got the Nobel prize for this).

The corpuscular theory seemed to be back — but with a difference — so that even "real" particles like electrons were found to have "wave-like" properties. The result was the new field of quantum mechanics which has now been validated in every possible way and verified to incredibly accurate limits. And the result is the laser, the transistor, all kinds of solid state devices, nanotechnology, atomic energy, theories of how the universe began…

It was Einstein who was not finally fully convinced that quantum mechanics, which uses *probabilities and uncertainties* in its calculations, was a sound theory. But, curiously, it was Einstein, in his work of rederiving Max Plank's formula of radiation on the bases of probabilities of absorption and emission of quanta, who laid the foundation for the discovery of the Laser, which is a showpiece of quantum mechanics in action.

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For a richer yield

Decontamination of seeds from pathogens of plant diseases can be performed in a variety of ways. **Tapan Kumar Maitra** explains a few of the most preferred

DECONTAMINATION of seeds from pathogens of plant diseases transmitted through them can be performed in a variety of ways. Seed treatment makes it possible to control loose smut and common bunt of wheat, loose and covered smut of barley, flag and covered smut of rye, loose and covered smut of oats and loose smut of millet. It also diminishes the harm caused by fusarial wilt, helminthosporiosis and bacteriosis of cereals, black root of sugar beets, bacterial blight of cotton, root rot and ascochitosis of small grain and bean crops, pyriculiariosis and root rot of rice and sclerotinosis of sunflowers.

It also helps retain the planting properties of seeds in storage and protects planted seeds and shoots from growing mouldy in the soil; reduces the damage to seedlings by soil-dwelling pests; increases the energy of seed sprouting and their field germination rate; stimulates the growth and development of plants; and improves winter crops, which ensures a normal density of the shoots thereby increasing the harvest.

Depending on the kind of pesticide and also in accordance with the biology of the pathogen, dry, semi-dry and moist treatment are used. Moist treatment has a restricted use.

In dry treatment, powdered formulations are mixed with the grain. This method, though, has many shortcomings. The sanitary conditions of work become worse because of an increased dust content in the air, which further accentuates by growth in the losses of the formulation. And these, in addition, are retained poorly on dry seeds.

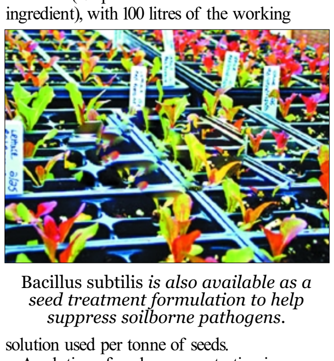
The shortcomings of dry treatment can be eliminated by using aqueous solutions of pesticides for decontamination of seeds, or with the simultaneous moistening of the seeds and the powder in the course of treatment. In the treatment of seeds with suspensions of powdered formulations, the rate of use of the liquid is 10-15 litre/tonne. The dose of the formulation remains the same as in the dry method of treatment, but it is difficult to prepare a homogeneous suspension. This is why it is better to use treatment with moistening.

To improve the effectiveness of treatment and the sanitary conditions of work, various adhesives should be used — liquid sulphite and alcohol slops (0.7-1 kg/tonne), a concentrate of solid slops (0.5- 0.7 kg/tonne) and silicate glue (150-200 g/tonne).

When treating sugar beet seeds, it is good to use liquid slops as the adhesive (three kg/tonne). Sugar beet seeds are treated in type APS-4 machines.

When the seeds of grain crops are treated with moistened formulations or suspension of ethyl mercury chloride, thiram or carboxin together with a growth promoting substance, water is replaced with an aqueous solution at a rate of four to six litres of a 60 per cent solution of the growth promoting substance per tonne. Water is added up to 10-15 litre/tonne. The rate of use of the protectant is not changed.

Semi-dry treatment of barley and oat seeds is performed with a 1.25 per cent solution of 40 per cent formalin (0.5 per cent relative to the active ingredient.) The rate of use of the working formalin solution is 30 litre/tonne for oats and 15-20 litre/tonne for barley. After being wetted, the seeds are held under a canvas for three to four hours. Greatly infected millet seeds are decontaminated with a 0.33 per cent solution of 40 per cent formalin (0.11 per cent relative to the active ingredient), with 100 litres of the working



Bacillus subtilis *is also available as a seed treatment formulation to help suppress soilborne pathogens.*

solution used per tonne of seeds.

A solution of such a concentration is suitable for decontaminating only one batch of millet seeds, after which holding under a canvas for two hours is obligatory.

Formalin is to be used for treatment only prior to sowing. The pre-sowing storage period of treated seeds is five days.

Treated seeds of sugar beets, flax, corn, vegetable crops and cotton at their conditioned moisture content can be stored for several years. The seeds of all agricultural crops brought up to the sowing condition may be treated in good time.

The treatment of seeds of pod cultures with ethylmercury chloride in good time is especially effective against smut diseases. To increase the effectiveness of controlling covered and loose smut of pod cultures, the seeds are treated after two or three weeks before sowing with moistening and the use of adhesives. Mercury toxicants used to treat seeds with moisture content of over 16 per cent upon prolonged storage after treatment may cause lowering of germination and deformity of the shoots. Wheat, oat and barley seeds with an increased moisture content may be treated with ethylmercury chloride only as an exception and certainly not earlier than three days before sowing.

If oat and barley seeds are not treated in good time, they are processed with formalin in the semi-dry way not before 35 days from sowing. Freshly harvested seeds of winter crops should be subjected to air and heat processing and dried to the conditioned moisture content prior to treatment.

When winter wheat is infected with common bunt and winter rye with flag smut, and also when wheat seeds are infected with fuzariosis and helminthosporiosis and with their increased moisture content, it is good to treat them with formulations based on thiram in conventional doses. Seeds intended for processing with bacterial fertilizers should be treated with toxicants of the mercury group, at least 20 to 30 days before bacterisation. In treatment with systemic fungicides (benomyl), nitrogenation may be performed simultaneously. However, in almost all the cases, sealed worm and chamber-treating machines should be used for treatment.

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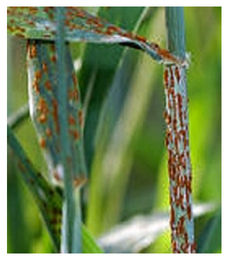
Red menace

And India's on the threatened route

FIRST discovered in Uganda 12 years ago, Ug99 – a deadly stem rust-causing fungus blighting African wheat — has since snowballed through Kenya, Ethiopia, Sudan and now Yemen. "I look at Yemen as the gateway into West Asia and Asia," says David Hodson of the Food and Agriculture Organisation. Indeed, fears are rife that Ug99 is headed for Punjab, south Asia's most important breadbasket that feeds hundreds of millions.



Ug99, a deadly fungus, causes stem rust on wheat crops that threatens food security in developing countries.

Researchers are trying to develop wheat strains that contain insurmountable genetic barriers for the fungus, but it is mutating, allowing a way to overcome the barriers put up by resistant genes in today's crops. Four variants of Ug99 are able to "knock out" such resistance genes.

In Njoro, Kenya, wheat breeders are working on promising varieties in the hope that one of these can outwit Ug99. And a two-year project to sequence the fungus genome hopes to identify the specific wheat-destroying genes so that new wheat breeds can be screened for Ug99 resistance. More farfetched dreams include the insertion of genes that can scramble Ug99 spores' "topographical sense" so that they cannot burrow into wheat.

Staying with Njoro, in a wheat field ringed by barbed wire, a dozen men wearing white polyethylene jumpsuits stand in a tight huddle, eyes fixed on the green-and-amber stalks that graze their knees. They chat in foreign tongues — Urdu, Farsi, Chinese — that are rarely heard amid the acacia trees and donkey carts of Kenya's Rift Valley. The men's *hazmat*-style safety gear suggests they might be hunting down one of the infamous viruses that flourish in this part of the world — Ebola, perhaps, or Marburg. Then the leader of the huddle, Harbans Bariana, a rotund Australian in an undersize safari hat, begins reading aloud from his clipboard. "Wylah?" he asks.

His colleagues bend down to examine some flaccid plants flecked with red splotches. A lanky Pakistani with a salt-and-pepper beard rakes a finger along one of the mottled stalks and an iodine-like residue rubs off on his skin. "40 S," he calls out.

The men move three steps right to a slightly more robust clump of wheat. The Australian asks: "Yandanooka?"

"25 MR?" comes the tentative reply from a mustachioed Nepali in a green baseball cap. They slide over to inspect another stalk, and then another.

These specialists have come to Njoro to study the Ug99 scourge that is destroying acres of Kenyan fields.

This distinct new race of *P. graminis*, dubbed Ug99 after its country of origin (Uganda) and the year of christening (1999), is storming east, working its way through Africa and West East and threatening India and China. More than a billion lives are at stake. "It's an absolute game-changer," says Brian Steffenson, a cereal-disease expert at the University of Minnesota who travels to Njoro regularly to observe the enemy in the wild.

— SciDev.Net

Breakthrough

Blood test on newborns could prevent disability. **Jeremy Laurence** reports

A BLOOD test to assess the risk of brain damage in vulnerable newborn babies could save lives and prevent disability, scientists say.

Measuring the pH level of umbilical cord blood can give insights into future health.

The test, carried out on blood taken from the umbilical cord immediately after birth, measures its acidity (the pH level). Blood with a low pH (more acid) indicates a lack of oxygen at birth, which is the commonest cause of brain damage, cerebral palsy and death.

Current guidelines suggest that measuring the pH level of umbilical cord blood is worthless as a predictor of how the baby will fare, because the association is inconsistent. But doctors based in Birmingham reviewed 51 studies involving almost 500,000 babies and found a low pH in the cord blood was strongly linked with serious outcomes.

Based on their findings, published in the *British Medical Journal*, they call for increased surveillance of babies born with low cord blood pH and for further research to explore the cost-effectiveness of doing the test on all babies.

In an accompanying editorial, James Neilson, professor of obstetrics and gynaecology at the University of Liverpool, said, "We should aim to reduce the number of babies born with a low cord pH, without increasing unnecessary obstetric intervention."

Andy Shennan, professor of obstetrics at St Thomas' Hospital in London welcomed the study into the relationship between low pH and future health. "Lack of oxygen to the baby during labour will result in a low pH in the umbilical cord," he said. "If it is prolonged, irreversible neurological damage can occur, although this is rare."

The Independent, London