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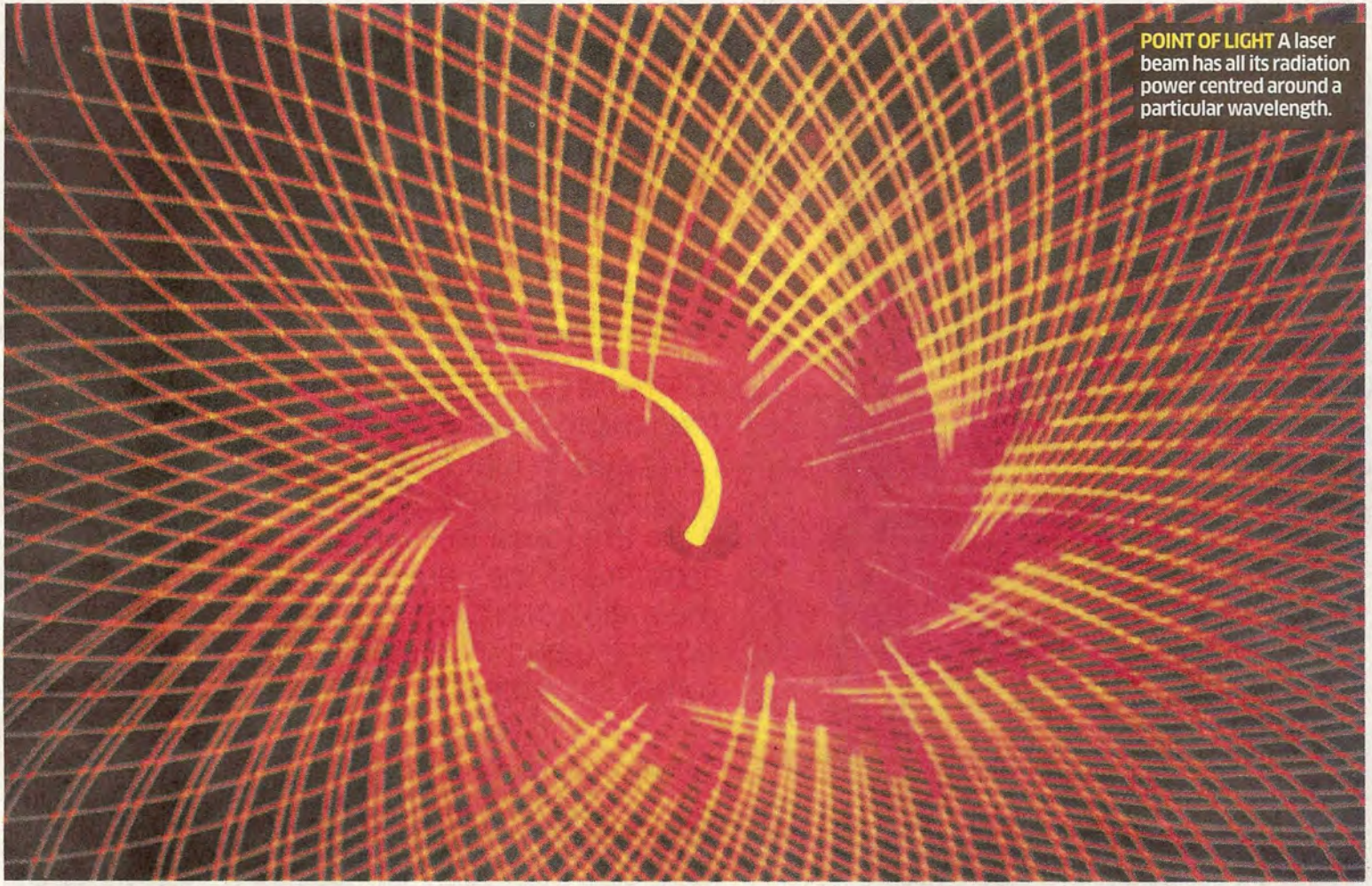

POINT OF LIGHT A laser beam has all its radiation power centred around a particular wavelength.

Intense beam of light

PHYSICS Lasers have revolutionised every area of science and technology, finding applications in LEDs, DVDs, instant communication and entertainment. Next generation lasers may allow creation of new states of matter, compressing and heating it to densities and temperatures present at cores of massive stars, writes **C Sivaram**

It was about mid-May in 1960, exactly fifty years ago that Theodore Mainman of Hughes Laboratories produced the world's first laser; an intense ruby red beam (induced using excited levels in ruby). The laser is an acronym for Light Amplification by Stimulated Emission of Radiation. It has revolutionised every area of science and technology finding applications from laser eye surgery, LEDs, DVDs, laser separation of nuclear isotopes, instant communication via optic fibres, studying femtosecond chemical reactions, environment monitoring, triggering of nuclear reactions, entertainment, manufacturing of most items (including textiles and ceramics) etc. Lasers have stimulated all areas of basic and applied research.

It was preceded by the MASER (Microwave Amplification of Stimulated Emission of Radiation). Masers were conceived and developed in the 1950s by people like Charles Townes and the Russian Scientists' Basov and Prokhorov. All three shared the Nobel Prize for physics in 1964 for these contributions.

The idea for the laser actually goes back to Einstein in 1916, when he introduced the concept of stimulated emission in atomic transitions. If in an atomic system, more electrons are "pumped up" (by an external source) to occupy higher energy levels, then a monochromatic beam of radiation having the right frequency (corresponding to the energy difference in the levels) passing through the system can stimulate the electrons to transit to the lower level producing radiation of the same frequency as the incoming radiation and thus amplifying it. This can be repeated several times by having mirrors to reflect the beam back and forth, for instance. Thus this finally results in the production of an intense beam of monochromatic (i.e. having only one frequency) radiation.

Focusing light on one spot

Laser light thus differs from ordinary sources of light like a candle or sunlight, by having all its radiation power centred around a particular wavelength (in the optical or infrared), i.e. in a narrow bandwidth. Again, it is a so-called coherent source, with all the photons being "in step" in amplitude or phase. This is what gives the laser its intensity. Its spectral intensity in a narrow bandwidth would be far greater than sunlight. For instance it can be focused in a narrow beam thus concentrating all the light power in a small spot. Thus laser beams can be bounced back from the moon with reflectors left behind by the Apollo astronauts and also by unmanned Russian moon probes.

This has enabled the distance between the earth and moon to be now determined to within a few millimetres, confirming the prediction (from tidal theory) that the moon is moving away from the earth at about three centimetres per year. Lasers thus find application in ultra precision distance and time measurements.

In the near future, laser based clocks with their ultra precision will measure possible changes in fundamental constants as the universe evolves and expands and could discriminate and challenge the latest fundamental theories on the origin of the universe and unification of interactions.

Within a decade, lasers may emit beams with spot sizes of a nanometre, about that of a molecule and microscopes using laser sources with apertures the size of a single molecule will result in fast direct sequencing of DNA, RNA and other bio-molecules. They could also lead to hard disc storage at several hundred times the present day capabilities, i.e. several petabytes in a PC.

Unprecedented miniaturisation

Holographic data storage and processing would lead to unprecedented miniaturisation and ultrarapid processing. Next generation lasers would allow creation of new states of matter, compressing and heating matter to densities and temperatures present at cores of massive stars. The resulting fusion reactions would one day lead to unlimited source of carbon free power with the oceans containing vast amounts of deuterium, the thermonuclear fuel, releasing ten times the energy as that of fission reactors.

It was pointed out long back by laser pioneers Towns and Schalow, that a 10kW continuous laser when beamed through a five-metre telescope would be visible over ten light years.

This suggestion has led to searches for advanced ETs (extra terrestrials) who may be beaming powerful laser beams in our direction. The world's most powerful Nova laser beamed through the ten-metre Keck telescope could be seen over a few thousand light years. More than 500 sun-like stars have been monitored with the Keck to look for sharp ultra bright spectral features which would stand out. So far, results are negative but this opens up a new avenue for such search called OSETI (Optical Search for Extraterrestrial Intelligence).

It was even suggested by some eminent astronomers that a powerful gamma ray laser could be used to trigger stellar explosions! Powerful lasers, so called chemical lasers, have been developed. X-ray lasers have been tested for 'strategic defence' based in space. Antiballistic laser beams could shoot down incoming missiles. Free electron lasers which can operate a wide range of wavelengths, called tuneable lasers, have many applications. Carbon-dioxide and Nd (neodymium) glass lasers are among the most powerful. Lasers based on Raman effect, plasma lasers (spasers) have all been developed.

Laser particle accelerators could accelerate particles to very high energies. Lasers can be used to produce the highest temperature in the universe as well as the lowest with laser cooling.

Lasers can already separate isotopes for use in nuclear reactors. SILEX is the newest device which could rival other techniques like the gas centrifuge.

The applications and developments in laser technology in the next few years are likely to be even more mind boggling than the past fifty years.

(The author is with the Indian Institute of Astrophysics.)

LASER SHARP!

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