

## American Physical Society celebrates a centennial

A number of Societies of Physicists have been around for more than a century; these include Societe' Francaise de Physique founded in 1873, Physical Society in UK from around 1874, Italiana di Physica founded in 1897 and so on. The American Physical Society joins this group of centenarians now.

The American Physical Society was founded on 20 May 1899 by holding its first meeting at the Columbia University, New York City. According to A. Pais in *Inward Bound*, 'In 1899, the American Physical Society was founded by 38 physicists. In 1900, the world wide number of academic physicists of all ranks was about 1000. The number of theoretical physicists was 8 in Germany, 2 in USA, one in Holland and none in the British Empire. The emergence of theoretical physics as a semi-autonomous discipline is a 20th century phenomenon'. As Pais states, around 1895, 'none of the fundamental particles had yet been found, cosmic rays had not been discovered, the only accelerator was a cathode ray tube and relativity theory and quantum theory were yet to come'. At the 20 May 1899 meeting, the physicists elected from their midst two

colleagues of international reknown as Senior Officers: Henry Rowland as President and Albert Michelson as Vice-President. Neither Rowland nor Michelson had formally earned a Ph D degree.

Today American Physical Society is one of the foremost bodies that is active and has to its credit several achievements. It has over 40,000 members and it is one of the ten member societies of American Institute of Physics founded in 1931 'for the purpose of coordinating various societies whose interests are primarily in the field of physics and for the purpose of supporting their publications'.

A special issue of *Reviews of Modern Physics* was published in March 1999 in honour of this centenary of the American Physical Society. In the Preface to this issue Benjamin Benderson of the American Physical Society states 'this American Physical Society issue can be considered as a companion volume to the collection entitled *The First Hundred Years* edited by H. Henry Stroke, containing about 1000 articles reprinted in hard copy and by CD-ROM in 1997, published by the American Institute of Physics to commemorate the centenary of *Physical*

*Review* whose birth preceded that of American Physical Society by three years'.

The special issue of *Reviews of Modern Physics* contains about 50 articles covering historical developments, astrophysics, nuclear physics, atomic, molecular and optical physics, condensed matter physics, statistical physics and fluids, plasma physics, chemical physics and biological physics and application of physics to other areas. The section on historical developments contains articles, more like eye-witness accounts prepared by persons who played important roles in their developments like Hans Bethe, A. Pais and W. Kohn. Each one of these articles brims with personal ring-side view of developments and helps to provide a proper perspective of growth of important topics of physics. In a short introduction, Hans Bethe says 'a hundred years ago, some of the great physicists in England and Continental Europe predicted that physics was at an end. We know what actually happened and we are proud of the contribution of American Physical Society.... Looking at the predictions of 100 years ago, it would be foolish to make predictions for the next 100 years.'

## RESEARCH NEWS

### Evidence of electrochemiluminescence as a pumping mechanism for a dye laser

*Sushil Mujumdar*

An important advancement in the technology of continuous wave dye lasers was reported by a group of scientists at NTT Basic Research Laboratories, Japan<sup>1</sup>. They claim to have realised an idea, proposed about twenty five years ago, of improvising the process of pumping a dye laser, thereby making the family of dye lasers easier to maintain, cost effective, and user-friendly.

For any medium to act as a laser, it is essential that the number of molecules

in the excited state exceeds the number of molecules in the lower state. This condition is called 'Population Inversion'. In ordinary circumstances, the energy levels are populated according to the Maxwell Boltzmann distribution. This distribution rules that the population of any energy level is inversely proportional to the exponential of its energy. Furthermore, the excited states have a very short lifetime, and the molecules in the excited state decay

rapidly to the lower state, destroying the population inversion. So, to hold a large number of molecules in the excited state, one is required to supply a lot of energy. The minimum energy required to invert the population is called the threshold energy. The obvious sources of such large energies are flashlamps. However, flashlamps can deliver energies only in short pulses, and cannot perform continuously. They are used, therefore, in pulsed dye lasers. And this

is where continuous wave dye lasers run into problems.

The active medium in dye lasers is a fluorescent dye, the molecules of which absorb energy in the blue part of the spectrum, and emit in the red part. Every electronic energy level of the dye consists of a stack of vibrational levels which are closely spaced and almost form a continuum of states. Hence both the absorption and emission spectra are continuous. That makes the dye lasers tunable, i.e. one can obtain a laser emission at any wavelength within the fluorescence spectrum. This is a powerful advantage over other lasers.

Dye lasers, being the tunable type, are vastly used in areas such as spectroscopy, light scattering and find applications in medicine, communications etc. However, these dye lasers can prove to be a liability than an asset, because of the pumping requirements.

The source which can deliver high energies continuously is a laser itself. So, to build a continuous wave dye laser, other lasers are used as pumping sources. Effectively, the maintenance of such a dye laser involves the maintenance of two lasers, and this also renders it unreasonable pricewise.

One of the solutions to this disadvantage was conceived and proposed about twenty five years ago<sup>2-4</sup>. It was suggested that energy obtained by the process of electrochemiluminescence (ECL) can be used as a pump for such dye lasers. Efforts were made to realise this idea, but the maximum energy generated was two orders of magnitude lower than the threshold. Recently, Hirouchi *et al.*<sup>1</sup> succeeded in building a device which enhances the efficiency of ECL leading to observation of laser action.

When the anion and cation radicals of a species react with each other, the electron transfer between them excites the atom that absorbs the electron. The energy carried off by the electron is equal to the energy that is expended in creating the two radicals. The excited atom then decays by radiating this energy as light. This is called chemiluminescence. If the radicals are electrochemically generated, that is, under the influence of an electric field, the process is called electrochemiluminescence. Clearly, it is the energy of the electric field that is converted into light energy.

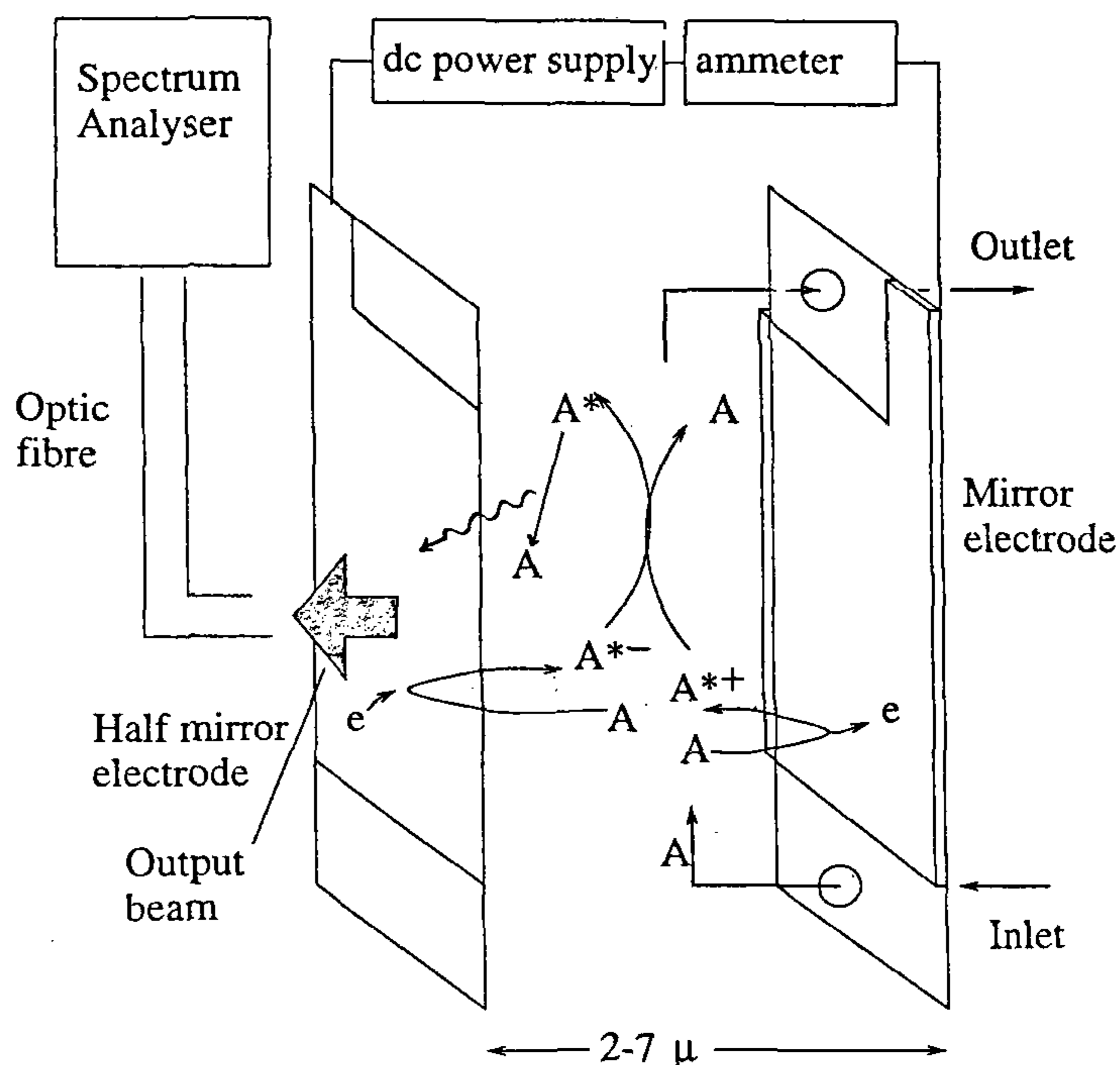


Figure 1. The dye is allowed to flow between the electrodes. The schematic of the chemical reaction is shown in the figure. A, A\*, A\*<sup>-</sup> and A\*<sup>+</sup> stand for the ground state, excited state, anion radical and cation radical states of the dye molecule respectively.

The dye used in the experiment of Hirouchi *et al.*<sup>1</sup> was Diphenylanthracene (DPA) dissolved in Dimethylformamide (DMF). This dye, when used as a lasing medium, is pumped by a nitrogen laser<sup>5</sup>. The oxidation potential of the molecule of this dye is 1.3 V and the reduction potential is -1.7 V. Both these numbers are with reference to Ag/AgCl. The energy given out when the two radicals combine is equal to the potential difference, which is 3 V. The wavelength corresponding to this energy is ~400 nm, that lies in the blue region of the spectrum. The dye molecules can absorb this energy and fluoresce.

A special cell was engineered to drive the chemiluminescent reaction (Figure 1). A thin layer of platinum was deposited on two quartz substrates (each of area 2 mm × 2 mm). The thickness of the deposition was such that one of them was totally reflecting, and the other had 99.2% reflectance. These two substrates formed the opposite faces of a rectangular cell. The separation between the two faces was about 2-7 microns. The platinum layers also acted as electrodes. The dye was allowed to flow through this cell, and an optical fibre was placed outside the semireflecting mirror to collect the light generated.

The electric field electrolysed the ground state molecules into anion and

cation radicals. These radicals released energy in the form of fluorescent radiation on recombination according to the fluorescence spectrum of the dye. The spectrum peaked at 445 nm. Moreover, the fluorescence showed some special features.

The fluorescence spectrum of the dye was seen to be modulated by thin sharp equidistant peaks, which were detected to be the Fabry Perot resonances of the cavity formed by the two mirrors. These resonances occur when light is repeatedly reflected between two parallel mirrors, and the separation between the two mirrors enables certain wavelengths to interfere constructively, resulting in intense lines at corresponding wavelengths.

The dependence of ECL on the current was examined. The intensity of the peaks in the fluorescence spectrum, was measured at different current values in a steady state. Theoretically, the ECL intensity should be proportional to the square of the current. However, the observed intensity could not be represented as a quadratic function of the current. Initially, the intensity showed a very gradual increase with current, up to about 0.45 mA. After that, it grew rapidly with current, showing a clear threshold at 0.45 mA. This dependence of intensity on current is similar to the

one observed in semiconductor lasers. An empirical relation was used to estimate the threshold current to be 0.41 mA for the cell, which fairly matched with the experimental value of 0.45 mA.

Two spectra were obtained at two different current values, one above the threshold and the other below the threshold. The peak positions were almost the same for the two spectra, however, the peak heights of the spectrum above threshold were much greater than those below threshold, and the envelope of the spectrum above threshold nar-

rowed. This envelope narrowing effect is similar to that observed in ordinary lasers. This happens because the peaked wavelength starts growing in intensity at the cost of other wavelengths, which are consequently suppressed. This narrowing, called 'line narrowing' is a clear indicator of laser action.

These observations confirm that the emission from the cell was indeed a 'laser', driven by an electrochemical reaction. Thus, ECL can prove to be an easier alternative to pump continuous wave dye lasers in the near future.

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## DNA structure: Yet another avatar?

*Manju Bansal*

Everytime the story of DNA structure seems to reach a conclusion, it bounces back to centre stage by appearing in yet another incarnation. The latest avatar to manifest itself is a stretched and overwound form of DNA reported recently by a French group<sup>1</sup>, working with single DNA molecules. When a moderately large stretching force (of about 3 piconewtons) is applied, the DNA molecule apparently becomes highly twisted and extended, but even more amazingly it takes up an 'inside-out structure' in which the phosphodiester chain is on the inside and the bases are exposed (Figure 1a). Precisely such a structure was proposed in 1953 by Pauling and Corey<sup>2</sup> (albeit with three strands), making use of 'the general principles of molecular structure', which they had applied with such spectacular success in predicting the  $\alpha$ -helix and  $\beta$ -structure for proteins<sup>3</sup>. While they were convinced that the DNA structure was a helix, they did not make use of the already available chemical data of Chargaff, which demonstrated that although the base composition of DNA varies widely, certain bases were always present in equal numbers (viz. Adenine = Thymine and Guanine = Cytosine), clearly suggesting some kind of pairing between the bases. So in their model building studies, when they considered the question of arranging more than one

chain about the helix axis, they made the wrong choice. As shown schematically in Figure 2, the helix axis can be located either to the left or to the right of the polynucleotide backbone. An axis to the right of the chain, as shown in the top right of Figure 2, results in a structure with phosphates near the helix axis and the bases farther away from the axis and 'fanning' out. Watson and Crick on the other hand placed the helix axis on the left side of the chain, resulting in the arrangement shown in the top left of Figure 2, with the phosphates on the outside and the bases inside. This arrangement for a two chain molecule readily explains Chargaff's data, if a specific base-base interaction is postulated between the bases A and T, as also between G and C. The two chains can be either parallel or antiparallel to each other. The antiparallel arrangement was chosen, rather arbitrarily, since it was consistent with the pseudo-two-fold symmetry of the basepairs, but has subsequently been confirmed by biochemical studies. Thus, the canonical Watson-Crick structure for hydrated DNA, which gives the B-form X-ray fibre pattern, a two-strand right-handed helix, with ten planar A:T or G:C basepairs of nearly equivalent shape and size arranged in a spiral arrangement, almost perpendicular to the fibre axis, came into existence<sup>4</sup>. The currently accepted

detailed structure<sup>5</sup> for the B-form of DNA retains the essential features of the original Watson-Crick model and is shown in Figure 1b. Since this structure was observed when the molecule was fully hydrated and it also immediately suggested a possible copying mechanism for the genetic material and the semiconservative replication of DNA, it was readily accepted as being the 'biologically relevant structure' for DNA. This corollary was repeatedly emphasized, since even before the structure of DNA was known, X-ray fibre diffraction and spectroscopic data had clearly shown that it is quite a pliable molecule, readily undergoing interconversion between various forms (arbitrarily classified as A, B, C, etc.) when ionic or humidity conditions are changed. All these related structures were considered as relatively unimportant minor variants, or distorted versions, of the B-form, which occupied the centre-stage for nearly a quarter century after it was first proposed.

Once the Watson-Crick model for DNA became an accepted fact, the double helix came to be regarded merely as a safe storage device for the genetic information encoded in the nucleotide sequence, that could only be accessed after unwinding of the helix. Hence the double stranded DNA molecule was treated as being a very stable, intrinsi-