

## C. V. Raman memorial lecture\*

*To Raman, scientific activity was the fulfillment of an inner need. His approach to science was one of passion, curiosity and simplicity. It was an attempt to understand. To him science was based on independent thought, combined with hard work. Science was a personal endeavour, an aesthetic pursuit and above all a joyous experience.*

S. Ramaseshan<sup>1</sup>

The C. V. Raman memorial lecture series was instituted by the Indian Institute of Science (IISc), Bangalore in honour of its first Indian Director. The first lecture in the series on 'C. V. Raman' was delivered in 1978 by S. Ramaseshan<sup>1</sup>, in the 50th anniversary year of the discovery of the Raman effect. Raman was awarded the Nobel Prize in Physics in 1930 for 'his work on the scattering of light and for the discovery of the effect named after him' ([http://nobelprize.org/nobel\\_prizes/physics/laureates/1930/](http://nobelprize.org/nobel_prizes/physics/laureates/1930/)).

In his talk, Ramaseshan quoted Raman: 'When we want to achieve – whether it be in science or in anything else we must first learn to use the resources we have in plenty. As a nation what are the resources we have in plenty – human beings of whom at least a third are young. This is our real strength. If they are enthused and if they are instilled with a spirit of adventure, the sleeping giant will wake up and we can conquer the world'<sup>1</sup>.

Raman himself was a great inspiration both in his research and in his speeches. He was a breathtaking lecturer. According to Ramaseshan<sup>1</sup>, 'To him (Raman), giving a lecture was clearing up things in his own mind. He talked of only those things about which he felt intensely, of those things which he understood or wanted to understand. He saw things in their simplest and most basic elements. He made the audience feel that they could have seen it all by themselves (which of course they had not)'.

The C. V. Raman memorial lectures have encompassed a wide range of topics over the years. The second lecture (in 1980) by Sukhdev was on 'Research and development in the chemical industry'; the third (in 1983) by C. N. R. Rao on 'Man, minerals and microscopes'; the fourth (in 1986) by R. Narasimha on 'Order and chaos in fluid flows'; the fifth (in 1988) by S. Chandrasekhar on 'Optical phenomena in liquid crystals'; the sixth (in 1990) by Govind Swarup on 'Radio astronomy and the structure of the universe'; the seventh (in 1992) by M. S. Valiathan on 'Cardiac surgery – an offspring of experiment'; the eighth (in 1995) by V. J. Modi on 'Satellites, space shuttles and space stations: evolution and challenges'; the ninth (in 1996) by Ramanath Cowsik on 'My meanderings in search of neutrino mass'; the tenth (in 1999) by Narendra Kumar on 'Quantum Zeno effect: slowing down of reactions by fast perturbations'; the eleventh (in 2002) by D. Balasubramanian on 'Molecular and cellular approaches to understand and treat some diseases of the eye', and the twelfth lecture (in 2007) by Michael. E. Fisher was on 'Molecular motors – observation and theory'<sup>2</sup>.

The thirteenth lecture on 'Electrons in semiconductor nanostructures: the engineering of physics' was delivered by Michael Pepper (University College London (UCL), UK) on 13 July 2010 at IISc. Pepper has delivered other famous lectures such as the Mountbatten memorial lecture of the Institution of Engineering and Technology, UK and the Bakerian lecture of the Royal Society, London. He was a collaborator in the discovery of the (integer) Quantum Hall Effect (QHE) for which Klaus von Klitzing received the Nobel Prize in Physics in 1985. Pepper was chosen as Honorary Professor of Pharmaceutical Science in the University of Otago in 2004 for his work on the application of terahertz technology in pharmaceuticals. He is now Pender Professor of Nanoelectronics and Honorary Professor of Physics at UCL.

In his talk at IISc, Pepper pointed out that there has been a progressive increase in the complexity and technology in the structure of materials used for develop-

ment. He cited Moore's Law: 'The complexity for minimum component costs has increased at a rate of roughly a factor of two per year'. Every two years, the number of transistors on a chip doubles, the minimum feature size becomes  $\times 0.7$  times, and the cost of a manufacturing plant doubles. Projecting the semiconductor economics for 2020, Pepper said that electronics would equal world economy if the present trend continues and there would be no money for food! To cope with this unsustainable growth, there has been a search for new technologies.

He called attention to the implications of Moore's Law. In economics: the cost of building fabrication plant doubles approximately every 3 years. By 2035, it will exceed the gross domestic product of the entire planet. In physics: the electrons per device and the transistors per chip are reducing. The problem with making conventional devices small is that below a certain number of electrons, fluctuations and tunnelling dominate. This leads to non-uniform transistors and poorly performing circuits.

Pepper said that after the CMOS (complementary metal oxide semiconductor), there would be new materials, oxides with high electron mobility, spins and magnetics, logic and memory, quantum data processing and then more CMOSs! The CMOS concept and applications are expected to continue for many more decades.

Pepper then discussed the construction of nanostructures. There are two main methods of fabricating nanostructures: (i) electrostatically squeezing the electrons and (ii) self-assembly. The former is used in electronic applications, whereas the latter is employed for optical uses. The reduced dimensionality, confining a carrier in at least one spatial dimension at a scale of the order of de Broglie wavelength, leads to quantum size effects. Pepper presented examples of electron density of states in different structures such as bulk, quantum well, quantum wire and quantum dot. He indicated that when devices become very small, the strong electron repulsion gives a blockade. A radius of 0.1 micron

\*A report on the 13th C. V. Raman memorial lecture on 'Electrons in semiconductor nanostructures: the engineering of physics', organized by and held at the Indian Institute of Science, Bangalore on 13 July 2010.

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corresponds to a repulsion energy of 100 K.

He mentioned an application of single electron transport in the triangle of quantum constants, which involves the Josephson Effect, QHE and the Single Electron Tunnelling Effect. He also touched upon quantum pumping of a single electron, two-dimensional electron gas, the production of tailor-made high-quality gallium arsenide heterostructures

using molecular beam epitaxy and the quantization of resistance.

Pepper concluded that the future would include applications in quantum information, manipulation of electron waves and an Aharonov Bohm device with quantum dots.

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1. Ramaseshan, S., C. V. Raman memorial lecture; <http://dspace.rii.res.in/bitstream/>

[2289/1508/1/1978Ramaseshan\\_CVRamanLecture.pdf](#)

2. IISc – Profile: 2009–10, Indian Institute of Science, Bangalore, 2009.

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