Bose–Einstein Condensate (BEC) : Resurrection of Satyendra Nath Bose

Bose-Einstein Condenstate (BEC) theory stole the limelight in the Nobel parlour of Physics last year. The scientific souls of Albert Einstein (1879-1955) and Satyendranath Bose (1894 - 1974) were resurrected. It looked like the Easter Monday resurrection of Jesus Christ (4. B. C. – 29 or 30 A.D.) in the realm of science ! Three physicists [Eric A. Cornell (1961 –), Carl E. Wieman (1951-), both of the U.S.A., and Wolfgang Ketterle (1957 –), a German working in USA], who first created independently a new ultra solid state of matter that both Albert Einstein, Nobel Physics Laureate, 1921, and Satyendranath, in their Bose-Einstein Condensation theory, had predicted independently some 70 years ago, were jointly awarded the Nobel Prize in Physics, 2001, for their production in 1995 of the so-called Bose-Einstein Condensate (BEC).

Satyendranath was a theoretical physicist and it is probably because of that, he was not considered for a Nobel Prize. The same thing is also said of Stephen W. Hawking (1924 -), the English theoretical physicist and author of the popular science masterpiece - "A Brief History of Time : From The Big Bang to Black Holes" (1988), who currently holds the Isaac Newton's (1642 - 1727) Chair as Lucasian Professor of Mathematics at the University of Cambridge, England. Even Einstein was not awarded the Nobel Prize for his epoch-making theoretical hypothesis ('Special Theory of Relativity', Annalen der Physik, Vol. 17, p. 891-921, 1905) but was given the Prize for his work on photoelectricity ('On a Heuristic Point of View Concerning the Production and Transformation of Light', 1905). 'Laser' (Light Amplification by Stimulated Emission of Radiation) technology of today is one of the practical applications of Einstein's work on photoelectricity.

The genesis of the quantam statistical mechanics of gases – what we now call Bose-Einstein statistics for gases is interesting. Satyendranath, at that time teaching in the Physics Department of Dacca University (Dhaka - now in Bangladesh – originally East Bengal), had sent to Einstein a short manuscript in English in 1924 with a request to translate it into German for publication in a leading physics journal in Germany if he agreed with the theme of his paper (Letter to Albert Einstein, June 4, 1924 : A photocopy of the original letter printed in – 'Bose and His Statistics', by G. Venkataraman, Vignettes in Physics, Sangam Books, University Press (India) Ltd. 1992, p. 13). Einstein was impressed with the work and accepted his request, and translated the paper into German and got it published in the leading physics journal of the day – 'Zeitschrift fur Physik' under Bose's name as the author in 1924, with his comment that the paper was important (Planck's Law and the Hypothesis of Light Quanta'). Einstein started working on Bose's concept himself. All this changed Bose's destiny from being an obscure physicist of colonial India to one with a place in the Hall of Fame in the International arena of Physics.

Satyendranath met Einstein in Berlin during 1925 - 1926. Einstein was then Director of Kaiser Wilhelm Physical Institute in Berlin (1914 - 1933). In 1926, Bose also briefly worked with the Polish-French physicist, Madame Marie Curie (1867 - 1934) – Double Nobel Laureate : Physics, 1903; Chemistry, 1911, in her Radium Institute in Paris, France.

In 1924 Bose derived Karl Ernst Ludwig Max Planck's (1858-1947), (Nobel Physics Laureate, 1918), black body radiation law without the use of classical electro-dynamics which Planck needed to use. Bose's paper – 'Planck's Law and the Hypothesis of Light Quanta', published in 1924 with Einstein's comment, led Einstein to seek him for collaboration. In 1924, Bose was granted two years' study leave with expenses, by the University of Dacca to go to France and Germany for research.

In 1924 Bose made important theoretical calculations about the nature of light particles or photons. The phenomenon of the propagation of light in discrete packets of energy travelling through space had already been recognized. Bose, in his above-mentioned paper presented an alternative derivation of a law about the behaviour of photons that had been developed earlier by the German physicist, Max Planck. These kinds of particles obeying Bose's description eventually were named 'BOSON' in his honour.

'BOSON' is a class of subatomic particles having integer spin, considered to be carriers of basic physical properties. In theory, a force is transmitted from one particle to another by a carrier-field, which is embodied in a corresponding 'BOSON'. Force-carrying particles such as photons, gluons and gravitions are all 'BOSONS'. They have a property that allows them to congregate without number, occupying the same quantam state at the same time.

Bose's work focussed on particles such as photons that have no rest mass. Einstein extended it to particles that have mass, such as atoms in a dilute gas. He theoretically predicted that if a sufficient number of such atoms get close enough together and move slowly enough, they will undergo a phase transition into a new state. That new state of matter became known as a 'Bose-Einstein Condensate' (BEC).

Physicists recognized the keys to achieving a 'BEC'. The major challenge was to make the gas very cold, above a tenth of millionth of a degree of absolute zero (-273.15^0C or -459.67^0F) to slow down the motion of the atoms without causing them to condense to a liquid. Atoms in gases usually move about in an uncontrolled way, ricocheting off each other and nearby objects. Under the specific conditions described by Einstein, however, the atoms 'sense' one another and transform from a mass of uncoordinated individuals to a coherent group that acts like a single giant atom (the BEC).

The three Nobel Physics Laureates (2001) independently succeeded in forming the BEC. Cornell and Wieman, working at the University of Colorado, in 1995, used a combination of Laser and magnetic techniques to slow, trap and cool about 2,000 rubidium atoms to form a BEC. Ketterle, working independently at Massachusetts Institute of Technology (M.I.T.) created a BEC from sodium atoms. Ketterle's BEC, which comprised a larger sample of atoms, was used to carry out additional studies of the BEC, including an interfering experiment that provided the first direct evidence of the coherent nature of a BEC. Those first successes led to a flurry of experiments in other laboratories, in which physicists expanded the roster of BEC-forming gases and used BECs to produce 'Atom Lasers' that emit coherent beams of matter, rather than light.

In 2001 about 20 groups all over the world were conducting BEC experiments, which were providing new insights into the laws of physics and pointing to possible practical uses of BECs. Until 2001 condensates of elements such as rubidium, lithium and sodium had been prepared by cooling a dilute gas of atoms in their ground states (just above absolute zero). During 2001, separate research groups at the University of Paris XI, Orsay, and the Ecole Normal Superieure, Paris, succeeded in making a condensate from a gas of excited helium atoms. Because no existing Lasers operated in the far-ultraviolet wavelength needed to excite helium from the ground state, the researchers used an electrical discharge to supply the excitation energy.

Although each helium atom possessed an excitation energy of 20 eV (which was more than 100 billion times its thermal energy in the condenstate), the atoms within the condensate were stabilized against release of this energy by polarization (alignment) of their spins, which greatly reduced the probability that excited atoms would collide. When the condenstate came into contact with some other atoms, however, all the excitation energy in its atoms was released together. This suggested a new kind of laser that emits in the far ultraviolet.

Pactical devices based on such advanced techniques of atomic and optical physics were coming closer to realization. During 2001 again, another team at the U.S. National Institute of Standards and Technology, Boulder, Colorado, used the interaction between a single cooled mercury atom and a Laser beam to produce the world's most stable clock, with a precision of about one second in 100 million years. Such precision could well be needed in future high-speed data transmission.

In the Nobel Physics award the Swedish observed :

"Revolutionary applications of BEC in lithography, nanotechnology and holography appear to be just around the corner."

The cycle which Satyendranath and Einstein initiated jointly in 1924 appears to be complete in a full circle and immortality of Bose shines in every ring of it. It is best expressed by Satyendrath himself. In January, 1974, the University of Calcutta organised an international seminar in honour of Satyendranath Bose. Many leading physicists from all over the world came for the seminar. Bose was also present but frail and weak in health. He was asked to say a few words. He tried to speak standing, but had difficulty. He therefore delivered his address seated. He concluded with these words :

"Well, after all, if one has lived through so many years of struggle, and if at the end he finds that his work has been appreciated, he feels that he does not need to live long."

Prophetic words indeed ! For Bose passed away soon after, on 4th February, 1974. Bose is no more, but BOSONS and BEC will be there for ever to sing the song of his immortality in the world of science.

Nobel Prize, or no Nobel Prize, Bose was a genius. Incidentally, Jean-paul Sartre (1905 -1980) one of the most original thinkers of the twentieth century - a genius, and the founder of French existentialism, was awarded the Nobel Prize for Literature in 1964, but declined. A genius is above such earthly award or reward. Amidst the names of physicists that crowd the columns of history of quantum physics, Planck, Einstein, Henreich David Neils Bohr (1885 - 1962), the name of Satyendranath shines, and shines as a glittering star.

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* Physiology (1955-57)