Japan Academy Prize to:

Akira HASEGAWA

CEO, Soliton Communications
Professor Emeritus, Osaka University

for "Discovery of Optical Soliton Properties in Fibers and of Self-organization of Plasma Turbulence"

Outline of the work:

One important achievement in theoretical physics in the twentieth century is the discovery of coherent collective phenomena in nonlinear continuous media, represented by solitons and self-organizations. The theoretical foundation was made possible during the latter half of the twentieth century owing to the development of super computers.

Solitons are seen primarily in one-dimensional waves in a medium with dispersion and nonlinearity, while self-organizations are seen primarily in two-dimensional turbulence. It has long been believed that nonlinearity would induce incoherent and random phenomena through generation of higher harmonics and turbulence and contributes to the increase of entropy. However, it was discovered recently that the nonlinearity in media with infinite degrees of freedom could produce coherent phenomena contrary to the previous expectations. The discoveries of solitons and self-organizations are representatives of these phenomena. In particular, the theoretical discovery that waves in nonlinear and dispersive media can be described by an ensemble of solitons illustrates the fact the solitons are elementary modes in nonlinear media as the Fourier modes are so in linear media. Meanwhile, the self-organizations are seen primarily in two-dimensional fluids, where existence of more than two conserved quantities is essential in generating the self-organization. The phenomena of self-organization are attracting interests because they seem to violate the law of entropy increase, although they do not.

Important contributions of Dr. Hasegawa are related to understanding of these nonlinear phenomena in continuous media. Dr. Hasegawa has long been involved in the study of nonlinear phenomena of electromagnetic waves in optical fibers and in plasmas and produced a large number of original and innovative results well known internationally. Among them the best recognized are: 1. derivation of the master equation that describes optical information transfer in optical fibers (the nonlinear Schrödinger equation) and discovery of the optical soliton as well as the development of soliton based on ultra-high speed optical communication systems and 2. derivation of the fundamental equation that describes the plasma turbulence (the Hasegawa-Mima equation) and discovery of zonal flow in magnetized plasmas.

In the field of optical communications, during the early days of development of fiber based on optical communication initiated by Dr. Nishizawa in 1965, Dr. Hasegawa has recognized importance of the fiber nonlinearity, whereby the index of refraction increases in proportion to the light intensity, and derived in 1973, the master equation that describes the information transfer in fibers and showed that added some elbium following in glass laser for nuclear fusion in Lebedev Research Institute, a stable soliton solution exists. Here, he also proposed the use of solitons for optical communications. This work was published jointly with Dr. Fred Tappert and attracted over 1000 citation. It precedes almost two decades the practical development of long distance optical communication systems, yet the master equation is still used extensively in the design of such systems. Optical solitons in a modified forms are presently used as fundamental information carriers in ultra-high speed long distance communications. For this contribution, Dr. Hasegawa was awarded various internationally acclaimed prizes including the British Rank Prize, the French Da Vinci Excellence Prize, the US Quantum Electronics Prize and the Japanese C&C Prize.

In the field of plasma turbulence, by recognizing that magnetically confined plasma is inherently turbulent, Dr. Hasegawa, together with Dr. Kunioki Mima, derived the most fundamental equation (called the Hasegawa-Mima equation) that describes turbulent field in magnetized plasmas. The work has been cited by over 500 papers and widely used worldwide for the study of fusion plasma behavior. Dr. Hasegawa subsequently has made prediction of generation of zonal flow in the azimuthal direction of toroidal plasmas as a consequence of the self-organization of the turbulence. Generation of such zonal flows is now recognized as a fundamental process in Tokamak plasmas that influences plasma confinements. For this contribution (and others), Dr. Hasegawa won the Maxwell Prize from the American Physical Society, as a major contributor for magnetic fusion research.

Relevant publications

[1] A.Hasegawa and F.Tappert, "Transmission of Stationary Nonlinear Optical Pulses in Dispersive Dielectric Fibers I. Anomalous Dispersion", Appl. Phys. Lett. 23, 142-144 (1973).

[2] A.Hasegawa and K.Mima, "Pseudo-Three-Dimensional Turbulence in Magnetized Nonuniform Plasma", Phys. Fluids 21, 87-92 (1978).

[3] A.Hasegawa and M.Wakatani, "Self-Organization of Electrostatic Turbulence in a Cylindrical Plasma", Phys. Rev. Lett. 59, No.14 (October) 1581-1584 (1987).