Professor Mima's Achievements in Nonlinear Plasma Physics and Future Prospects

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Professor Kunioki Mima, who was a pioneer of nonlinear plasma physics and produced many significant results through elucidating key plasma processes in both magnetically confinement fusion plasmas as well as laser fusion plasmas, passed away in January 2025.

Professor Mima studied under the laboratory of Professor Kyoji Nishikawa at the Faculty of Science, Kyoto University in 1965, and received his doctorate in 1973 for his work on "Modification of weak turbulence theory due to perturbed orbit effects". After Prof. Nishikawa moved to Hiroshima University, Prof. Mima also moved there and began his brilliant research career. During that time, Prof. Mima studied abroad at Bell laboratory, where he discovered so called Hasegawa-Mima equation, which is now widely known in the field of magnetically confined plasmas, and studied variety of nonlinear plasma physics, such as parametric instabilities and nonlinear plasma waves. Prof. Mima's research career can be said to have been dedicated to nonlinear plasma physics.

In 1980, I was a student of Prof. Nishikawa at Hiroshima University, working on the topic of nonlinear wave propagation in plasmas exceeding the critical density, where we encountered the phenomena of complete transmission of electromagnetic field via structure resonance. Through the topics given by Prof. Nishikawa, who was the supervisor of Prof. Mima, I had the opportunity to interact with Prof. Mima and had the honor of studying under him [1].

I conducted theoretical and computational research on fast ion production in laser-produced plasmas under Prof. Mima and am proud to have published a paper co-authored with my two respective supervisors, Prof. Nishikawa, and Prof. Mima [2]. Following that research, also under the supervision of Prof. Mima, we tackled the problem of nonlinear heat conduction under steep temperature gradients, which was one of key issues in laser fusion research at the time, and conducted research on an approach based on a differential form associated with the Chapman-Enskog perturbation expansion [3] and an approach based on an integral representation that renormalizes all terms in the perturbation expansion [4].

These studies with Prof. Mima formed the basis of my subsequent research career, including the turbulent transport processes in tokamaks, and I am deeply grateful for his guidance.

The last time I had a discussion with Prof. Mima was for the paper I wrote with my colleague on the relativistic ion acceleration by high-intensity lasers. In the paper, we discussed the possibility of restoring "linearity" in the plasma oscillations ω_p that govern laser propagation in plasmas in the strongly nonlinear region of high-intensity lasers. This is considered to result in the cancelation between the ponderomotive nonlinearity that causes electron density modulation δn and the relativistic nonlinearity $\delta\gamma$ that causes the electron mass modulation., i.e. $\delta\omega_p \propto (\delta n/ \delta\gamma)^{1/2}$. In linear or quasi-linear regimes, a coherent structure can be seen. while as the nonlinearity becomes stronger, the coherence is broken, leading to highly distorted (random) characteristics. However, as the nonlinearity becomes even stronger, the coherence is restored due to the cancellation between δn and $\delta\gamma$, which may be referred to as *frozen-in* condition, so that an orderly structure appears [4].

I enjoyed this discussion with Prof. Mima on this issue, which we had in September 2024, when we worked together for the duty related to AAPPS-DPP 2024. I would like to dedicate this research to Professor Mima, who loved the nonlinearity of plasma. As one of Prof. Mima's students, I am saddened by his passing and pray for his soul to rest in peace.

References

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