So far I have engaged myself in the research on superstring theories and M-theory as the only viable candidate for a consistent unified theory including quantum gravity. In the past years, I have studied non-perturbative string physics and string dualities in order to geometrically reformulate them in the light of the spacetime supersymmetry.

1. Two-dimensional Black Hole [1,2]
We examined $SL(2,\mathbb{R})/U(1)$ gauged Wess-Zumino-Witten (WZW) model, which is a string theory on a Two-dimensional black hole, and derived the physical states taking account of the representation theory of the current algebra. As a result, we found that there are new physical states with a ghost number ranging from -1 to 2, in addition to the discrete states of the $c = 1$ two-dimensional gravity.

2. Universal String Theory [3,4]
We showed that all string theories, which have the N-fold supersymmetry and the linearized W-symmetry, say w-symmetry, on the world-sheet, can be formulated as the $N = \infty, w_\infty$ string theory. This enables us to interpret various string theories as symmetry broken phases of the $N = \infty, w_\infty$ two-dimensional field theory.

3. New Geometrical Formulation of Branes [8-12,14]
New geometrical formulation of branes in type-II superstring theories was given in a superspace democratic way. We constructed the space-time superalgebras including new generators with spinorial indices. Using supercurrents on the group manifold corresponding to the space-time superalgebra, (D)p-brane actions including the Wess-Zumino(WZ) term were shown to be manifestly space-time superinvariant. The Born-Infeld U(1) gauge field on the world-sheet is expressed in terms of the group coordinate dual to the new fermionic generator. We extended this formulation to a superstring on the Anti-de-Sitter (AdS) space. In addition, we classified the usual (D)p-brane actions as non-trivial elements of the Chevalley-Eilenberg cohomology.

4. Tachyon Condensation and Space-time Supersymmetry [13,15]
It was shown that the superstrings constructed above describe the degrees of freedom of the open string end-points. We discussed using this model how broken supersymmetries can be restored under the tachyon condensation. It is known that the condensation affects not only the space-time supersymmetry but also the space-time geometry. In order to examine this process, needed is the superstring field theory which is off-shell formulated, contains Ramond string fields as well as Neveu-Schwarz string fields and is formulated background independently. We provided a background independent formulation of the WZW-type superstring field theory, which is the only consistent theory of covariant string fields including Ramond fields.

5. Penrose Limit and super-AdS algebras [16,17,20-22]
The plane-wave geometry has attracted great interests because the Green-Schwarz string theory on this background was shown to be exactly solvable and the string/gauge theory correspondence conjecture was examined beyond the supergravity level. In order to clarify the relation to the AdS geometry and to make the discussion coordinate independent, we showed that the superisometry algebra of the plane-wave geometry can be derived from that of the AdS geometry as an Inönü-Wigner(IW) contraction, and gave a map between generators of the plane-wave algebra and those of the AdS algebra. This clarifies the relation between theories in the plane-waves and those in the AdS space.

6. Superstrings on the plane-waves and the AdS spaces [18,19]

We proposed a covariant bi-linear superstring action on the plane-wave as well as the AdS space. This action has the manifest space-time supersymmetry, the κ-invariance and the correct flat limit, and reproduces the correct string charge in the superalgebra. It is hard to rewrite the ordinary action in the bilinear form and thus to examine it. It is expected that our alternative action should be useful in the analysis.

7. Brane Classification from a Covariant Open Supermembrane [23,25,26]

We classified Dirichlet branes of a covariant open supermembrane in the plane-wave and the AdS space, examining the κ-invariance of the action. So far the classification was incomplete because of the difficulty of solving the supermembrane equation of motion in a covariant manner. Our approach leads to the complete covariant classification.

8. M(atrix) theory on a time-dependent plane-wave [24]

A time-dependent system contains rich physics while it is difficult to analyze them. We constructed a matrix theory on a time-dependent plane-wave and examined the supersymmetry of this model. We also constructed various classical solutions such as fuzzy ellipsoidal sphere, fuzzy hyperboloid and so on, and examined the energy and supersymmetry.