ISSN 0915-633X

NATIONAL INSTITUTE FOR FUSION SCIENCE

New Stationary Solutions of the Nonlinear Drift Wave Equation

Y. Nejoh

(Received - Jan. 5, 1995)

NIFS-342 Feb. 1995

RESEARCH REPORT
NIFS Series

This report was prepared as a preprint of work performed as a collaboration research of the National Institute for Fusion Science (NIFS) of Japan. This document is intended for information only and for future publication in a journal after some rearrangements of its contents.

Inquiries about copyright and reproduction should be addressed to the Research Information Center, National Institute for Fusion Science, Nagoya 464-01, Japan.

NAGOYA, JAPAN

New stationary solutions of the nonlinear drift wave equation

Yasunori Nejoh

Hachinohe Institute of Technology
88-1, Obiraki, Myo, Hachinohe, 031

Abstract:

A new type of nonlinear wave modes which occur as the electrostatic drift waves in an inhomogeneous magnetized plasma is presented. The existence of a new type of spiky solitary wave and an explosive mode with the negative potential are predicted as stationary solutions of this equation. These solutions are a consequence of a density gradient and not connected with a temperature gradient. Using these nonlinear wave modes, the solitary structure and the explosive event concerning nonlinear drift waves propagating in interplanetary space and the Earth's magnetosphere, are understandable.

Key words: nonlinear drift w1ave equation, new type of nonlinear wave modes, spiky solitary wave, explosive mode

1. Introduction

Drift waves in the inhomogeneous magnetized plasmas have been studied experimentally and theoretically in the context of vortexes and solitary waves. The drift solitary waves have been experimentally observed in the Q-machine [1]. Simple two-dimensional drift wave turbulence models based on wave-wave nonlinear coupling have been examined with numerical techniques [2]. Recently, Lakhin *et al.* theoretically studied the low frequency drift solitary wave [3]. In the situation where the nonlinear drift wave propagates in interplanetary space, it may be possible that spiky solitary waves and explosive (bursting) events are detected by satellites [4]. Hendel *et al.* suggest that mode stabilization occurs because the mode density perturbations affect the diamagnetic drift [1]. Hence, it is possible for new type of nonlinear wave modes to occur in drift waves. Zakharov stresses the importance of the higher-order nonlinearity with regard to the collapse of Langmuir waves, and mentions that the waves with negative energy have the explosive instability [5]. On the other hand, several studies of the nonlinear evolution equation have been made in the context of nonlinear plasma waves [6-8]. Su *et al.* show plasma waves associated with the exponential nonlinearity [9-10]. However, the new type of nonlinear drift waves have not yet been shown.

In this paper, we consider a nonlinear drift wave equation in an inhomogenious magnetized plasma as a model equation, that is, Hasegawa-Mima equation. The purpose of this investigation is to demonstrate a new type of spiky solitary wave and an explosive mode of the nonlinear drift wave equation. It will be expected that these solutions extend the scheme of well established nonlinear evolution equations and this investigation may be applied to explaining the behaviour of larger amplitude nonlinear waves propagating in plasmas. We do not compare the present results to collisional plasmas.

The layout of this paper is as follows. In section 2, we consider the stationary nonlinear drift wave equation propagating in an inhomogeneous magnetized plasma. A nonlinear evolution equation is derived by several approximations. In section 3, new stationary wave solutions of this equation are shown. These are a spiky solitary wave and an explosive mode. The last section is devoted to concluding discussion.

2 . Derivation of a nonlinear evolution equation

We begin by considering a nonlinear drift(Hasegawa-Mima) equation [11,12] as a model:

$$\frac{\partial}{\partial t}(\nabla^2\phi-\phi)-(\nabla\phi\times\vec{i}_z)\cdot\nabla(\nabla^2\phi-\log n_0)=0 \quad . \tag{1}$$

We take the following assumptions:

1. the magnetic field $B=B_0\vec{i}_z$ is assumed to be constant and homogeneous.
2. the density n_0 is inhomogeneous in the x-direction and depends strongly on the spatial variation.
3. the drift wave is not connected with the temperature gradient.
4. the nonlinearity competes with the dispersion effect.

When the density $n_0=n_0(x)$ varying in a direction perpendicular to the magnetic field $B=B_0\vec{i}_z$ in the z-direction, eq.(1) is reduced to

$$\frac{\partial}{\partial t}(\nabla^2\phi-\phi-\log n_0)+[\phi,\ \nabla^2\phi-\phi-\log n_0]=0 \tag{2}$$

where

$$[\alpha,\beta]=\frac{\partial\alpha}{\partial x}\frac{\partial\beta}{\partial y}-\frac{\partial\alpha}{\partial y}\frac{\partial\beta}{\partial x}\ .$$

In order to obtain stationary wave solutions, we put

$$\phi=\phi(x,\eta)$$
$$\eta=y-ut\quad . \tag{3}$$

Then eq.(2) becomes

$$[\phi-ux,\ \nabla^2\phi-\phi-\log n_0]=0\quad . \tag{4}$$

Equation (4) has the integral

$$\nabla^2\phi-\phi-\log n_0=F(\phi-ux) \tag{5}$$

where $F(\phi-ux)$ is an arbitrary function of the argument. Such solutions travel with the velocity u in the y direction. In the case of solitary localized solutions, $F(\phi-ux)$ is determined from the condition that $\phi\to 0$ at $|y|\to\infty$ for the fixed values of x.

Then we obtain, from eq.(5),

$$\nabla^2\phi-\phi+\log\left[n_0\left(x-\frac{\phi}{u}\right)\right]-[\log n_0(x)]=0 \tag{6}$$

We expand $\log[n_0(x-\phi/u)]$ in the power series of ϕ as follows

$$\log\left[n_0\left(x-\frac{\phi}{u}\right)\right]-\log n_0(x)$$

$$
= -\frac{\phi}{u}\left[\frac{\partial}{\partial x}\log n_0\right]_{x=0} - x\frac{\phi}{u}\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0}
$$

$$
+\frac{\phi^2}{2u^2}\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0}
$$

$$
+\left[-\frac{1}{2}x^2\frac{\phi}{u}+\frac{1}{2}x\frac{\phi^2}{u^2}-\frac{1}{6}\frac{\phi^3}{u^3}\right]\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0}
$$

$$
+\left[-\frac{1}{6}x^3\frac{\phi}{u}+\frac{1}{4}x^2\frac{\phi^2}{u^2}-\frac{1}{6}x\frac{\phi^3}{u^3}+\frac{1}{24}\frac{\phi^4}{u^4}\right]
$$

$$
\times\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}+\cdots\cdots
$$

$$
= -\left\{\left[\frac{\partial}{\partial x}\log n_0\right]_{x=0} + x\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0}\right.
$$

$$
\left.+\frac{1}{2}x^2\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0}+\frac{1}{6}x^3\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\}\frac{\phi}{u}
$$

$$
+\frac{1}{2}\left\{\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0}+x\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0}\right.
$$

$$
\left.+\frac{1}{2}x^2\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\}\frac{\phi^2}{u^2}
$$

$$
-\frac{1}{6}\left\{\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0}+x\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\}\frac{\phi^3}{u^3}
$$

$$
+\frac{1}{24}\left\{\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\}\frac{\phi^4}{u^4}
$$

$$
+\ O(\phi^5)\ +\ \cdots\cdots \tag{7}
$$

Substituting eq.(7) into eq.(6), one obtain

$\nabla^2\phi$

$$
\begin{aligned}
&= \Bigg[1 + \frac{1}{u} \Bigg\{ \left[\frac{\partial}{\partial x} \log n_0 \right]_{x=0} + x \left[\frac{\partial^2}{\partial x^2} \log n_0 \right]_{x=0} \\
&\quad + \frac{1}{2} x^2 \left[\frac{\partial^3}{\partial x^3} \log n_0 \right]_{x=0} + \frac{1}{6} x^3 \left[\frac{\partial^4}{\partial x^4} \log n_0 \right]_{x=0} \Bigg\} \Bigg] \phi \\
&- \frac{1}{2} \frac{1}{u^2} \Bigg\{ \left[\frac{\partial^2}{\partial x^2} \log n_0 \right]_{x=0} + x \left[\frac{\partial^3}{\partial x^3} \log n_0 \right]_{x=0} \\
&\qquad\qquad + \frac{1}{2} x^2 \left[\frac{\partial^4}{\partial x^4} \log n_0 \right]_{x=0} \Bigg\} \phi^2 \\
&+ \frac{1}{6} \frac{1}{u^3} \Bigg\{ \left[\frac{\partial^3}{\partial x^3} \log n_0 \right]_{x=0} + x \left[\frac{\partial^4}{\partial x^4} \log n_0 \right]_{x=0} \Bigg\} \phi^3 \\
&- \frac{1}{24} \frac{1}{u^4} \Bigg\{ \left[\frac{\partial^4}{\partial x^4} \log n_0 \right]_{x=0} \Bigg\} \phi^4 \ . \\
&\quad + O(\phi^5) + \cdots\cdots
\end{aligned}
\tag{8}
$$

Since the behaviour of stationary wave solutions is determined largely by the spatial dependence of the density $n_0 = n_0(x)$, we assume a simple exponential density profile,

$$n_0(x) \sim \exp(-\varepsilon_n x) \ ,$$

and constant temperature. Here ε_n is the usual drift theory expansion parameter $\varepsilon_n = \rho_0 / L_n$, where $\rho_0 = c_s/\omega_i = (\kappa T_e/m_i)^{1/2} / (eB/m_i)$ is the Larmor radius, and L_n is the density gradient scale length.

As is seen in the observation, c_s and ω_i are the sound velocity and the ion cyclotron frequency.

Using this model, we can describe eq.(8) to

$$\nabla^2\phi = c_1(x)\phi + c_2(x)\phi^2 + c_3(x)\phi^3 + c_4(x)\phi^4 + O(\phi^5) + \cdots, \tag{9}$$

where the coefficients are determined to

$$c_1(x) = 1 + \frac{1}{u}\left\{\left[\frac{\partial}{\partial x}\log n_0\right]_{x=0} + x\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0} + \frac{1}{2}x^2\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0} + \frac{1}{6}x^3\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\},$$

$$c_2(x) = -\frac{1}{2u^2}\left\{\left[\frac{\partial^2}{\partial x^2}\log n_0\right]_{x=0} + x\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0} + \frac{1}{2}x^2\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\},$$

$$c_3(x) = \frac{1}{6u^3}\left\{\left[\frac{\partial^3}{\partial x^3}\log n_0\right]_{x=0} + x\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\},$$

$$c_4(x) = -\frac{1}{24u^4}\left\{\left[\frac{\partial^4}{\partial x^4}\log n_0\right]_{x=0}\right\},$$

where $c_1(x)>0$, $c_2(x)<0$, $c_3(x)>0$ and $c_4(x)<0$.

Since eq.(9) heavily depends on x, we can approximate

$$\left|\frac{\partial\phi}{\partial\eta}\right| \ll \left|\frac{\partial\phi}{\partial x}\right| .$$

Then the left hand-side of eq.(9) is reduced to $\nabla^2\phi \simeq (\partial^2\phi/\partial x^2)$. This means that we consider the quasi-one dimensional case. Using these approximations and integrating eq.(9), we obtain

$$\left[\frac{\partial\phi}{\partial x}\right]^2 = c_1(x)\phi^2 + \frac{2}{3}c_2(x)\phi^3 + \frac{1}{2}c_3(x)\phi^4 + \frac{2}{5}c_4(x)\phi^5$$

$$\equiv -\mathcal{U}(\phi)$$

$$= \phi^2\,(a_1 - a_2\phi - a_3\phi^2 - a_4\phi^3) \qquad (10)$$

where

$$a_1 = c_1(x) \quad ,$$

$$a_2 = -\frac{2}{3}c_2(x),$$

$$a_3 = -\frac{1}{2}c_3(x) \; ,$$

$$a_4 = -\frac{2}{5}c_4(x) \; .$$

If $a_4\phi^5 \approx 0$ in eq.(10), the solution is already shown. However, the solution of this equation which includes the nonlinear term $a_4\phi^5$ has not yet been solved.

3. Stationary solutions of eq.(10)

In order to obtain stationary wave solutions of eq.(10), we transform eq.(10) to

$$\left(\frac{\partial \phi}{\partial x} \right)^2 \equiv -\mathcal{U}(\phi)$$

$$= A\phi^2(\varphi_0 - \phi)^3 \quad , \tag{11}$$

because the solutions of eq.(10) exist only in the region of $-\mathcal{U}(\phi) > 0$, where we determine that

$$A = a_4 \quad , \qquad\qquad \varphi_0 = -\frac{a_3}{3a_4} \quad .$$

A relationship between the potential function $-\mathcal{U}(\phi)$ and ϕ is shown in Fig.1. One can understand that the proper localized solutions are obtained in the upper region of the horizontal axis. According to eq. (11), $d\phi/dx$ is finite everywhere ϕ is finite. It should be noted that the potential function $\mathcal{U}(\phi)$ is finite in the region $\phi > 0$, but is infinite in the region $\phi < 0$. As a result of this, we have to integrate eq.(10) independently in the two regions.

Imposing the boundary conditions ϕ, $d\phi/dx$, $d^2\phi/dx^2 \to 0$ at $|x| \to \infty$, we have, from eq.(11),

$$\pm A^{1/2}(x - x_0) = \int \frac{d\phi}{\phi(\varphi_0 - \phi)^{3/2}}$$

$$= \begin{cases} \displaystyle\int_{\phi}^{\phi_0} \cdots\cdots & \text{in the region } 0 < \phi < \varphi_0 \qquad (12) \\ \displaystyle\int_{\phi}^{0} \cdots\cdots & \text{in the region } -\infty < \phi < 0 \qquad (13) \end{cases}$$

where ϕ_0 denotes the maximum amplitude of the drift wave at $x \to x_0$.

We should note the sign of the coefficients of eq.(10). If the coefficients $a_1>0$, $a_2>0$, $a_3<0$, $a_4>0$, then $u>0$ and $\varphi_0>0$.

Integrating eq.(12) and using the boundary conditions, we have

$$\pm\frac{A^{1/2}}{2}\varphi_0^{3/2}(x-x_0)$$

$$=-\left[\frac{\varphi_0}{\varphi_0-\phi_s(\varphi_0,\phi_0,x)}\right]^{1/2}+\operatorname{arctanh}\left[\frac{\varphi_0-\phi_s(\varphi_0,\phi_0,x)}{\varphi_0}\right]^{1/2}$$

$$+\mathscr{H}_1(\varphi_0,\ \phi_0)\ , \tag{14}$$

where

$$\mathscr{H}_1(\varphi_0,\ \phi_0)=\left[\frac{\varphi_0}{\varphi_0-\phi_0}\right]^{1/2}-\operatorname{arctanh}\left[\frac{\varphi_0-\phi_0}{\varphi_0}\right]^{1/2}.$$

We obtain the solution of eq.(12) as follows

$$\phi_s(\varphi_0,\phi_0,x)$$

$$=\varphi_0\ \mathrm{sech}^2\left[\left[\frac{\varphi_0}{\varphi_0-\phi_s(\varphi_0,\phi_0,x)}\right]^{1/2}\pm\frac{A^{1/2}}{2}\varphi_0^{3/2}(x-x_0)\right.$$

$$\left.-\mathscr{H}_1(\varphi_0,\ \phi_0)\right] \tag{15}$$

Since $\mathscr{H}_1(\varphi_0,\ \phi_0)$ of eq.(15) connects the wave profile in $x>0$ with that in $x<0$, the wave profile of $\phi_s(\varphi_0,\phi_0,x)$ is continuous and finite at $x\rightarrow x_0$. Equation (15) forms a new type of spiky solitary wave. $\phi_s(\varphi_0,\phi_0,x)$ is the amplitude of the spiky solitary wave. We illustrate the wave profile of eq.(15) in Fig.2.

Similarly, calculating eq.(13), we get

$$\pm\frac{A^{1/2}}{2}\varphi_0^{3/2}(x-x_0)$$

$$=-\left[\frac{\varphi_0}{\varphi_0-\phi_E(\varphi_0,\phi_0,x)}\right]^{1/2}+\text{arccoth}\left[\frac{\varphi_0-\phi_E(\varphi_0,\phi_0,x)}{\varphi_0}\right]^{1/2}$$

$$+\mathscr{H}_2(\varphi_0,\ \phi_0)\quad, \tag{16}$$

where

$$\mathscr{H}_2(\varphi_0,\ \phi_0)=\left[\frac{\varphi_0}{\varphi_0-\phi_0}\right]^{1/2}-\text{arccoth}\left[\frac{\varphi_0-\phi_0}{\varphi_0}\right]^{1/2}.$$

We then obtain the solution of eq.(13), from eq.(16), as

$$\phi_E(\varphi_0,\phi_0,x)$$

$$=\varphi_0\coth^2\left[\left[\frac{\varphi_0}{\varphi_0-\phi_E(\varphi_0,\phi_0,x)}\right]^{1/2}\pm\frac{A^{1/2}}{2}\varphi_0^{3/2}(x-x_0)-\mathscr{H}_2(\varphi_0,\ \phi_0)\right] \tag{17}$$

The potential function $\mathscr{U}(\phi)$ is infinite in the region $\phi<0$ in Fig.1. Hence, it is predicted that eq.(13) has no finite solutions. Calculating eq.(17) numerically, we can obtain the solution that the amplitude becomes infinite. $\phi_E(\varphi_0,\phi_0,x)$ denotes the amplitude of the explosive solution. Equation (17) takes an explosive profile at $\pm(1/2)A^{1/2}\varphi_0^{3/2}(x-x_0)\rightarrow\mathscr{H}_2(\varphi_0,\ \phi_0)$, which is illustrated in Fig.3.

4. Concluding discussion

We present new type of nonlinear wave modes associated with in nonlinear drift waves. We show that a new nonlinear evolution equation is derived from nonlinear drift wave equation, assuming the spatial dependence of the density and using a quasi one-dimensional approximation. This equation has the fifth-order nonlinear potential term. The behaviour of the plasma physical system in which the fifth-order nonlinearity competes with the dispersion effect is described by eq. (10). The stationary wave solutions of eq. (10) with the nonlinear potential term ϕ^5 is shown for the first time in this investigation. The solution of eq. (11) is integrable according to the selection of the proper boundary conditions and the proper integration region. The stationary wave solutions of this equation are obtained due to the fifth-order nonlinearity, and bear a spiky solitary wave solution and an explosive solution. These solutions are first shown in drift waves. It should be noted that the explosive solution eventually will make the ordering in the derivation of the higher-order nonlinear evolution equation break down. In addition, the explosive solution is associated with the wave with negative potential. It is worth noticing that the explosive mode presented here is similar to those derived in the potential structure of Zakharov.

In actual situations, spiky solitary waves and solar radio burst events are frequently observed in interplanetary space. Hence, referring to the present spiky solitary waves and explosive(bursting) modes, we can understanding the properties concerning the new nonlinear wave modes of nonlinear drift waves in space plasmas. Although the author has not examined the application of these results to a specific observational result, this investigation is important in discussing the nonlinear wave modes which occur in plasmas. This theory is therefore applicable to another nonlinear waves in physical systems.

Acknowledgement

The author would like to thank Dr. H. Sanuki for valuable suggestion. This work was a joint research effort with the National Institute for Fusion Science.

References

[1] H.W.Hendel, T.K.Chu, and P.A.Politzer, "Collisional drift waves-Identification, stabilization, and enhanced plasma transport", *Phys. Fluids,* Vol.11, p.2426, 1968.

[2] R.E.Waltz, "Numerical study of drift wave turbulence with simple models for wave-wave nonlinear coupling", *Phys. Fluids,* Vol.26, p.169, 1983.

[3] V.P.Lakhin, A.B.Mikhailovskii, and O.G.Onishchenko, "Drift solitons" *Plasma Phys. Controll. Fus.*, Vol.30, p.457, 1988.

[4] A.Hasegawa, "Self-organization processes in continuous media", *Adv. Phys.*, Vol.34, p.1, 1985.

[5] V.E.Zakharov, "Wave Collapse", *Sov. Phys. Usp.*, Vol.31, p.672, 1988.

[6] Y.Nejoh, "Association between weakly relativistic ion modulation modes in a collisionless plasma", *Phys. Fluids,* Vol.31, p.2914, 1988.

[7] Y.Nejoh, "Modulational instability of relativistic ion-acoustic waves in a plasma with trapped electrons", *IEEE Trans. Plasma Sci.*, Vol.20, p.80, 1992.

[8] Y.Nejoh, "Double layers, spiky solitary waves, and explosive modes of relativistic ion-acoustic waves propagating in a plasma", *Phys. Fluids B*, Vol.4, p.2830, 1992.

[9] X.N.Su, W.Horton, and P.J.Morrison, "Drift wave vortices in inhomogeneous plasmas", *Phys. Fluids* B, Vol.3, p.921, 1991.

[10] X.N.Su, W.Horton, and P.J.Morrison, "Drift wave vortices in nonuniform plasmas with sheared magnetic fields", *Phys. Fluids* B, Vol.4, p.1238, 1992.

[11] A.Hasegawa, and K.Mima, "Pseudo-three-dimensional turbulence in magnetized nonuniform plasma", *Phys. Fluids*, Vol.21, p.87, 1978.

[12] E.W.Laedke, and K.H.Spatchek, "Drift vortices in inhomogeneous plasmas:Stationary states and stability criteria," *Phys. Fluids*, Vol.31, p.1492, 1988.

Captions of figures

Fig. 1 The potential function $-\mathcal{U}$ versus potential ϕ.

Fig. 2 The profile of a spiky solitary wave described by eq. (15).

Fig. 3 The profile of an explosive solution described by eq. (17).

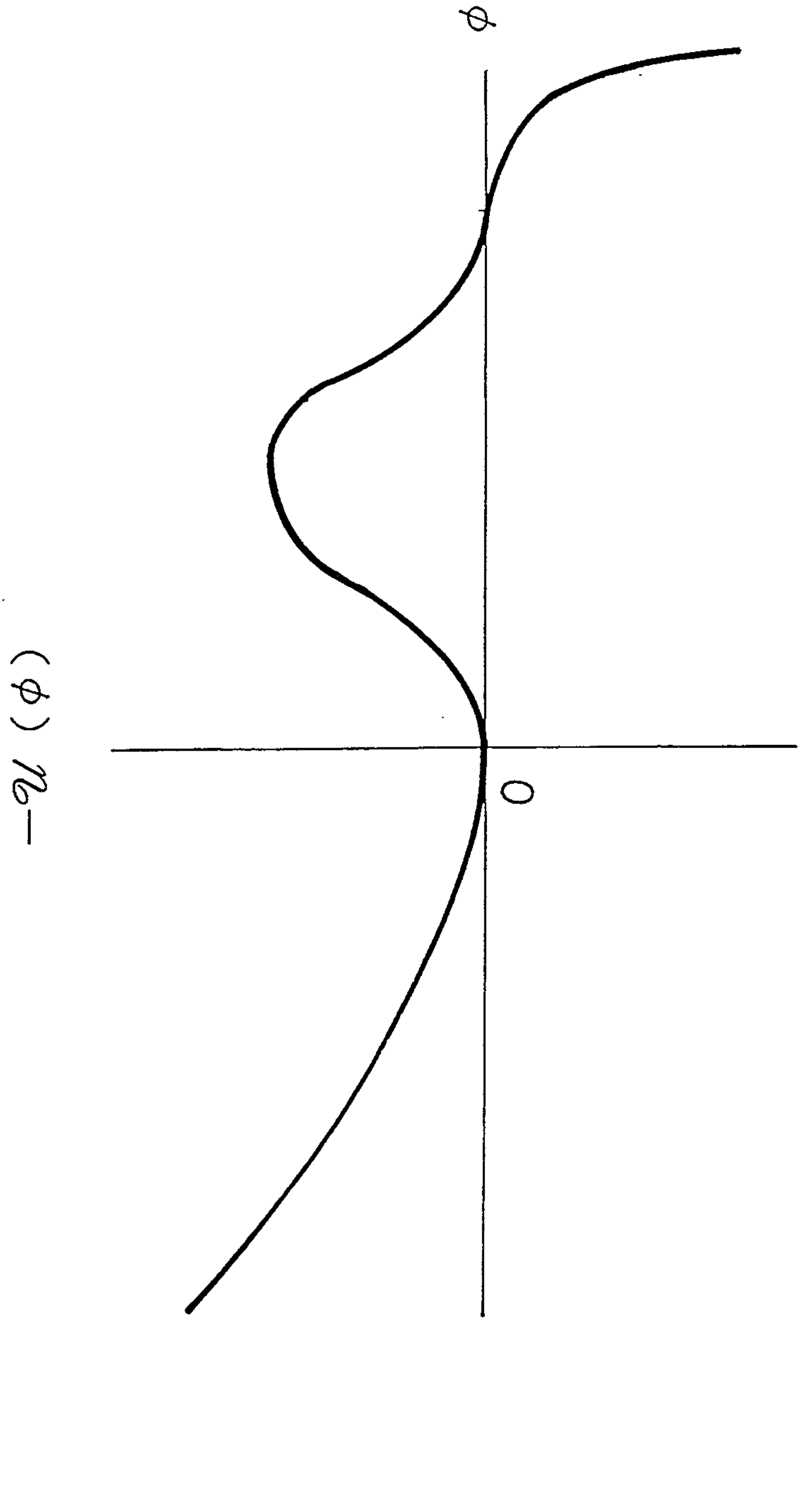


Fig.1

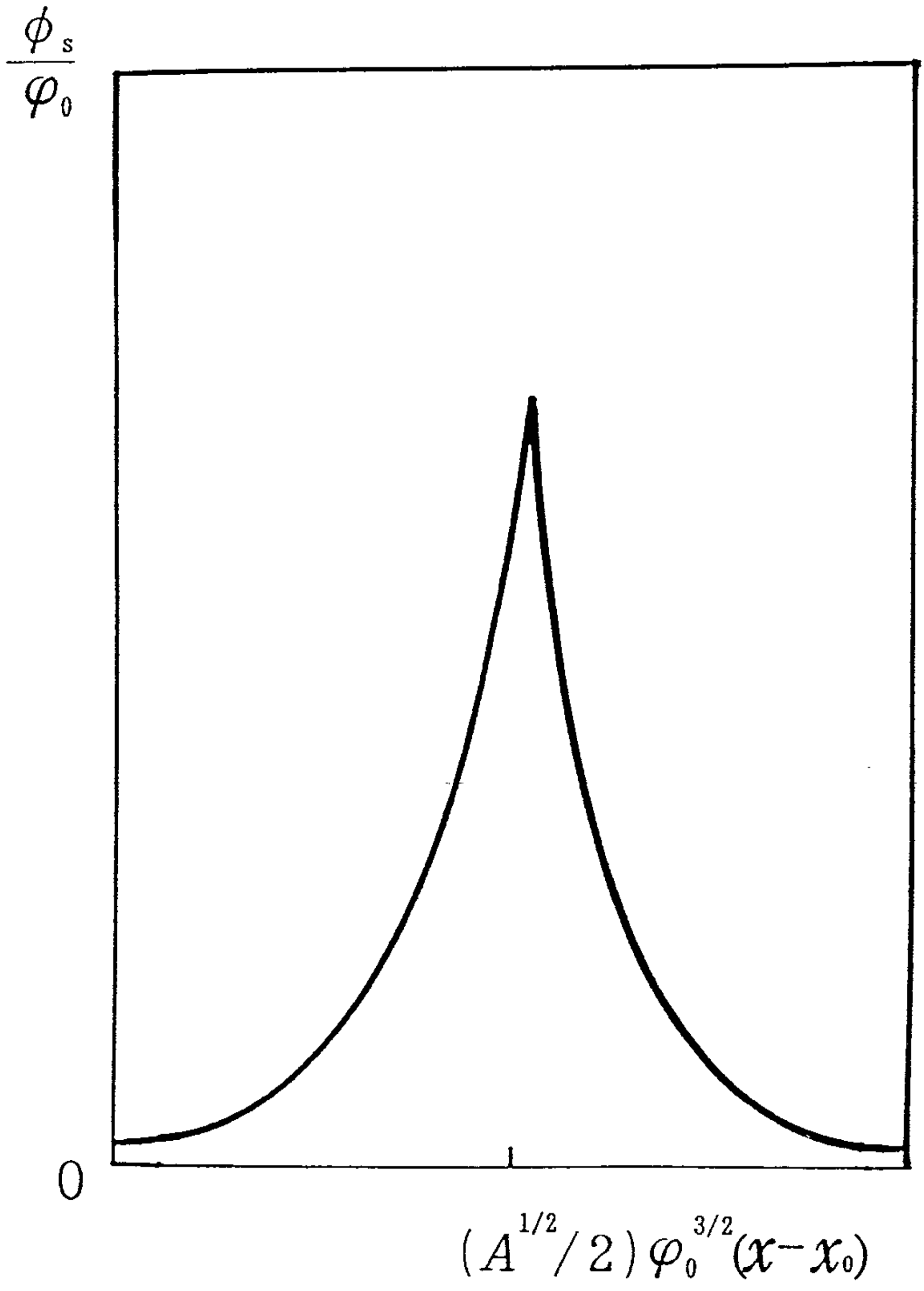
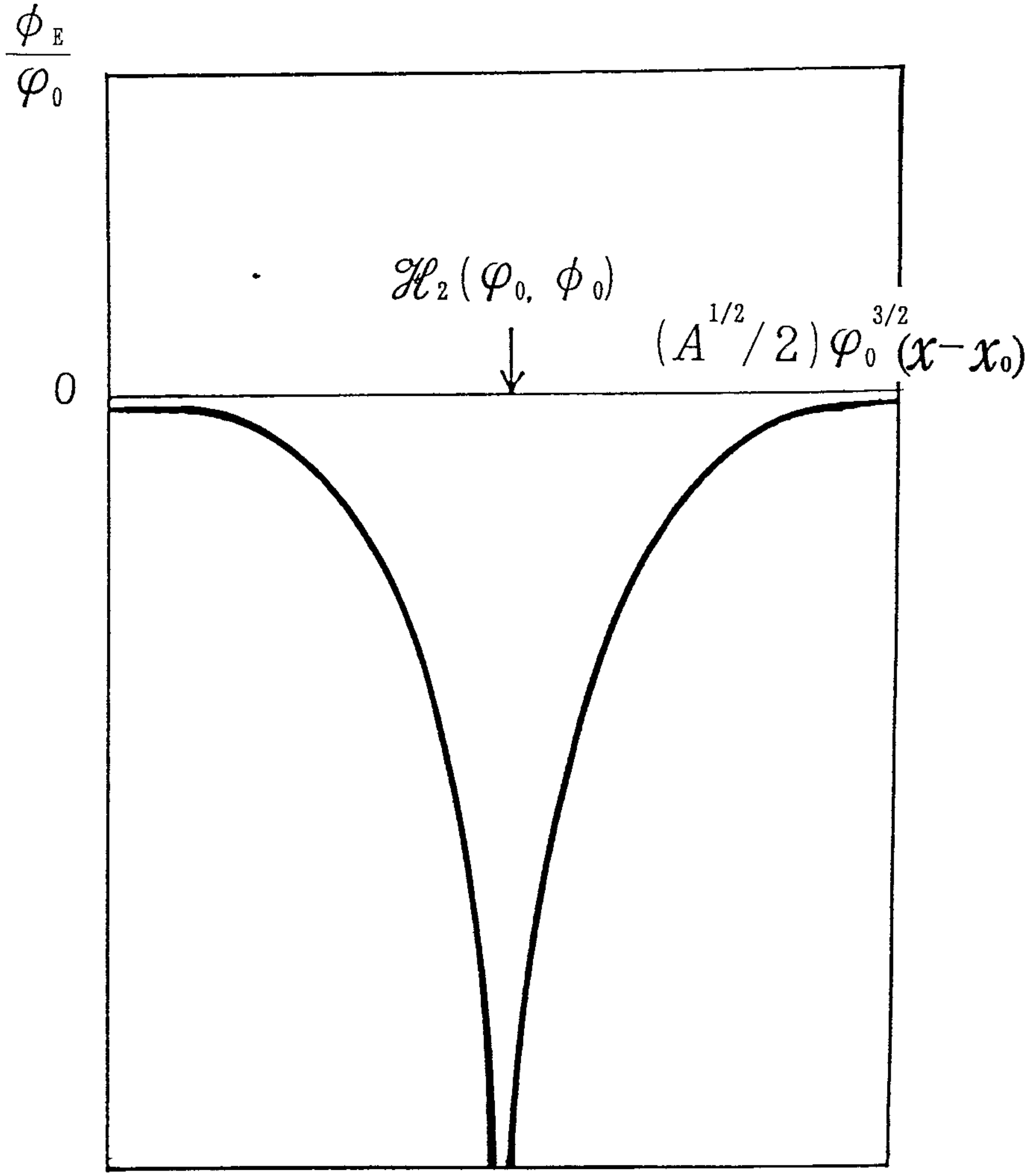


Fig.2



$\frac{\phi_E}{\varphi_0}$
$\mathscr{H}_2(\varphi_0, \phi_0)$
$(A^{1/2}/2)\varphi_0^{3/2}(x-x_0)$
0

Fig.3

Recent Issues of NIFS Series

NIFS-300 H. Sugama and W. Horton,
Dynamical Model of Pressure-Gradient-Driven Turbulence and Shear Flow Generation in L-H Transition; Aug. 1994 (IAEA/CN-60/D-P-I-11)

NIFS-301 Y. Hamada, A. Nishizawa, Y. Kawasumi, K.N. Sato, H. Sakakita, R. Liang, K. Kawahata, A. Ejiri, K. Narihara, K. Sato, T. Seki, K. Toi, K. Itoh, H. Iguchi, A. Fujisawa, K. Adachi, S. Hidekuma, S. Hirokura, K. Ida, M. Kojima, J. Koog, R. Kumazawa, H. Kuramoto, T. Minami, I. Negi, S. Ohdachi, M. Sasao, T. Tsuzuki, J. Xu, I. Yamada, T. Watari,
Study of Turbulence and Plasma Potential in JIPP T-IIU Tokamak; Aug. 1994 (IAEA/CN-60/A-2-III-5)

NIFS-302 K. Nishimura, R. Kumazawa, T. Mutoh, T. Watari, T. Seki, A. Ando, S. Masuda, F. Shinpo, S. Murakami, S. Okamura, H. Yamada, K. Matsuoka, S. Morita, T. Ozaki, K. Ida, H. Iguchi, I. Yamada, A. Ejiri, H. Idei, S. Muto, K. Tanaka, J. Xu, R. Akiyama, H. Arimoto, M. Isobe, M. Iwase, O. Kaneko, S. Kubo, T. Kawamoto, A. Lazaros, T. Morisaki, S. Sakakibara, Y. Takita, C. Takahashi and K. Tsumori,
ICRF Heating in CHS; Sep. 1994 (IAEA-CN-60/A-6-I-4)

NIFS-303 S. Okamura, K. Matsuoka, K. Nishimura, K. Tsumori, R. Akiyama, S. Sakakibara, H. Yamada, S. Morita, T. Morisaki, N. Nakajima, K. Tanaka, J. Xu, K. Ida, H. Iguchi, A. Lazaros, T. Ozaki, H. Arimoto, A. Ejiri, M. Fujiwara, H. Idei, A. Iiyoshi, O, Kaneko, K. Kawahata, T. Kawamoto, S. Kubo, T. Kuroda, O. Motojima, V.D. Pustovitov, A. Sagara, C. Takahashi, K. Toi and I. Yamada,
High Beta Experiments in CHS; Sep. 1994 (IAEA-CN-60/A-2-IV-3)

NIFS-304 K. Ida, H. Idei, H. Sanuki, K. Itoh, J. Xu, S. Hidekuma, K. Kondo, A. Sahara, H. Zushi, S.-I. Itoh, A. Fukuyama, K. Adati, R. Akiyama, S. Bessho, A. Ejiri, A. Fujisawa, M. Fujiwara, Y. Hamada, S. Hirokura, H. Iguchi, O. Kaneko, K. Kawahata, Y. Kawasumi, M. Kojima, S. Kubo, H. Kuramoto, A. Lazaros, R. Liang, K. Matsuoka, T. Minami, T. Mizuuchi, T. Morisaki, S. Morita, K. Nagasaki, K. Narihara, K. Nishimura, A. Nishizawa, T. Obiki, H. Okada, S. Okamura, T. Ozaki, S. Sakakibara, H. Sakakita, A. Sagara, F. Sano, M. Sasao, K. Sato, K.N. Sato, T. Saeki, S. Sudo, C. Takahashi, K. Tanaka, K. Tsumori, H.Yamada, I. Yamada, Y. Takita, T. Tuzuki, K. Toi and T. Watari,
Control of Radial Electric Field in Torus Plasma; Sep. 1994 (IAEA-CN-60/A-2-IV-2)

NIFS-305 T. Hayashi, T. Sato, N. Nakajima, K. Ichiguchi, P. Merkel, J. Nührenberg, U. Schwenn, H. Gardner, A. Bhattacharjee and C.C.Hegna,
Behavior of Magnetic Islands in 3D MHD Equilibria of Helical Devices; Sep. 1994 (IAEA-CN-60/D-2-II-4)

NIFS-306 S. Murakami, M. Okamoto, N. Nakajima, K.Y. Watanabe, T. Watari, T. Mutoh, R. Kumazawa and T. Seki,
Monte Carlo Simulation for ICRF Heating in Heliotron/Torsatrons; Sep. 1994 (IAEA-CN-60/D-P-I-14)

NIFS-307 Y. Takeiri, A. Ando, O. Kaneko, Y. Oka, K. Tsumori, R. Akiyama, E. Asano, T. Kawamoto, T. Kuroda, M. Tanaka and H. Kawakami,
Development of an Intense Negative Hydrogen Ion Source with a Wide-Range of External Magnetic Filter Field; Sep. 1994

NIFS-308 T. Hayashi, T. Sato, H.J. Gardner and J.D. Meiss,
Evolution of Magnetic Islands in a Heliac; Sep. 1994

NIFS-309 H. Amo, T. Sato and A. Kageyama,
Intermittent Energy Bursts and Recurrent Topological Change of a Twisting Magnetic Flux Tube; Sep.1994

NIFS-310 T. Yamagishi and H. Sanuki,
Effect of Anomalous Plasma Transport on Radial Electric Field in Torsatron/Heliotron; Sep. 1994

NIFS-311 K. Watanabe, T. Sato and Y. Nakayama,
Current-profile Flattening and Hot Core Shift due to the Nonlinear Development of Resistive Kink Mode; Oct. 1994

NIFS-312 M. Salimullah, B. Dasgupta, K. Watanabe and T. Sato,
Modification and Damping of Alfvén Waves in a Magnetized Dusty Plasma; Oct. 1994

NIFS-313 K. Ida, Y. Miura, S -I. Itoh, J.V. Hofmann, A. Fukuyama, S. Hidekuma, H. Sanuki, H. Idei, H. Yamada, H. Iguchi, K. Itoh,
Physical Mechanism Determining the Radial Electric Field and its Radial Structure in a Toroidal Plasma; Oct. 1994

NIFS-314 Shao-ping Zhu, R. Horiuchi, T. Sato and The Complexity Simulation Group,
Non-Taylor Magnetohydrodynamic Self-Organization; Oct. 1994

NIFS-315 M. Tanaka,
Collisionless Magnetic Reconnection Associated with Coalescence of Flux Bundles; Nov. 1994

NIFS-316 M. Tanaka,
Macro-EM Particle Simulation Method and A Study of Collisionless Magnetic Reconnection; Nov. 1994

NIFS-317 A. Fujisawa, H. Iguchi, M. Sasao and Y. Hamada,
Second Order Focusing Property of 210° Cylindrical Energy Analyzer; Nov. 1994

NIFS-318 T. Sato and Complexity Simulation Group,
Complexity in Plasma - A Grand View of Self- Organization; Nov. 1994

NIFS-319 Y. Todo, T. Sato, K. Watanabe, T.H. Watanabe and R. Horiuchi,
MHD-Vlasov Simulation of the Toroidal Alfvén Eigenmode; Nov. 1994

NIFS-320 A. Kageyama, T. Sato and The Complexity Simulation Group,
Computer Simulation of a Magnetohydrodynamic Dynamo II: Nov. 1994

NIFS-321 A. Bhattacharjee, T. Hayashi, C.C.Hegna, N. Nakajima and T. Sato,
Theory of Pressure-induced Islands and Self-healing in Three-dimensional Toroidal Magnetohydrodynamic Equilibria; Nov. 1994

NIFS-322 A. Iiyoshi, K. Yamazaki and the LHD Group,
Recent Studies of the Large Helical Device; Nov. 1994

NIFS-323 A. Iiyoshi and K. Yamazaki,
The Next Large Helical Devices; Nov. 1994

NIFS-324 V.D. Pustovitov
Quasisymmetry Equations for Conventional Stellarators; Nov. 1994

NIFS-325 A. Taniike, M. Sasao, Y. Hamada, J. Fujita, M. Wada,
The Energy Broadening Resulting from Electron Stripping Process of a Low Energy Au^- Beam; Dec. 1994

NIFS-326 I. Viniar and S. Sudo,
New Pellet Production and Acceleration Technologies for High Speed Pellet Injection System "HIPEL" in Large Helical Device; Dec. 1994

NIFS-327 Y. Hamada, A. Nishizawa, Y. Kawasumi, K. Kawahata, K. Itoh, A. Ejiri, K. Toi, K. Narihara, K. Sato, T. Seki, H. Iguchi, A. Fujisawa, K. Adachi, S. Hidekuma, S. Hirokura, K. Ida, M. Kojima, J. Koong, R. Kumazawa, H. Kuramoto, R. Liang, T. Minami, H. Sakakita, M. Sasao, K.N. Sato, T. Tsuzuki, J. Xu, I. Yamada, T. Watari,
Fast Potential Change in Sawteeth in JIPP T-IIU Tokamak Plasmas; Dec. 1994

NIFS-328 V.D. Pustovitov,
Effect of Satellite Helical Harmonics on the Stellarator Configuration; Dec. 1994

NIFS-329 K. Itoh, S-I. Itoh and A. Fukuyama,
A Model of Sawtooth Based on the Transport Catastrophe; Dec. 1994

NIFS-330 K. Nagasaki, A. Ejiri,
Launching Conditions for Electron Cyclotron Heating in a Sheared Magnetic Field; Jan. 1995

NIFS-331 T.H. Watanabe, Y. Todo, R. Horiuchi, K. Watanabe, T. Sato,
An Advanced Electrostatic Particle Simulation Algorithm for Implicit Time Integration; Jan. 1995

NIFS-332 N. Bekki and T. Karakisawa,
Bifurcations from Periodic Solution in a Simplified Model of Two-dimensional Magnetoconvection; Jan. 1995

NIFS-333 K. Itoh, S.-I. Itoh, M. Yagi, A. Fukuyama,
Theory of Anomalous Transport in Reverse Field Pinch; Jan. 1995

NIFS-334 K. Nagasaki, A. Isayama and A. Ejiri
Application of Grating Polarizer to 106.4GHz ECH System on Heliotron-E; Jan. 1995

NIFS-335 H. Takamaru, T. Sato, R. Horiuchi, K. Watanabe and Complexity Simulation Group,
A Self-Consistent Open Boundary Model for Particle Simulation in Plasmas; Feb. 1995

NIFS-336 B.B. Kadomtsev,
Quantum Telegragh : is it possible?; Feb. 1995

NIFS-337 B.B.Kadomtsev,
Ball Lightning as Self-Organization Phenomenon; Feb. 1995

NIFS-338 Y. Takeiri, A. Ando, O. Kaneko, Y. Oka, K. Tsumori, R. Akiyama, E. Asano, T. Kawamoto, M. Tanaka and T. Kuroda,
High-Energy Acceleration of an Intense Negative Ion Beam; Feb. 1995

NIFS-339 K. Toi, T. Morisaki, S. Sakakibara, S. Ohdachi, T.Minami, S. Morita, H. Yamada, K. Tanaka, K. Ida, S. Okamura, A. Ejiri, H. Iguchi, K. Nishimura, K. Matsuoka, A. Ando, J. Xu, I. Yamada, K. Narihara, R. Akiyama, H. Idei, S. Kubo, T. Ozaki, C. Takahashi, K. Tsumori,
H-Mode Study in CHS; Feb. 1995

NIFS-340 T. Okada and H. Tazawa,
Filamentation Instability in a Light Ion Beam-plasma System with External Magnetic Field; Feb. 1995

NIFS-341 T. Watanbe, G. Gnudi,
A New Algorithm for Differential-Algebraic Equations Based on HIDM; Feb. 13, 1995