Ion acoustic cnoidal waves in electron-positron-ion plasmas with q-nonextensive electrons and positrons and high relativistic ions

By:

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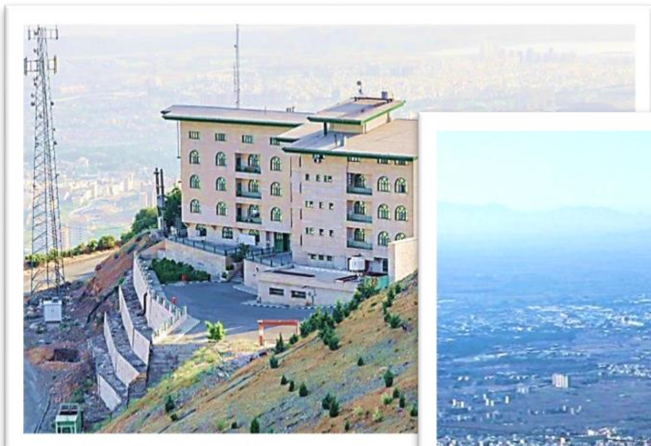
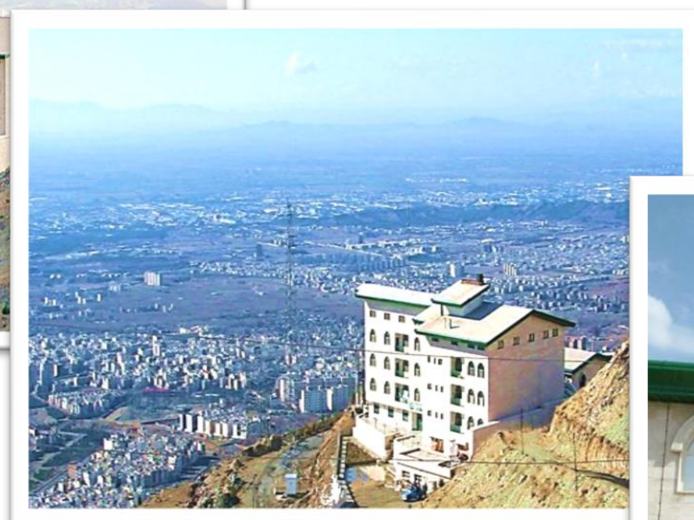
XXIV international Baldin Seminar

Outline

. Introduction
. Basic equations
. Derivation of KdV equation
. Results and discussion
. Conclusion

PART 1:
PLASMA PHYSICS RESEARCH CENTER





Plasma Physics Research Center
Tehran
1993
Science and Research Campus
Islamic Azad University

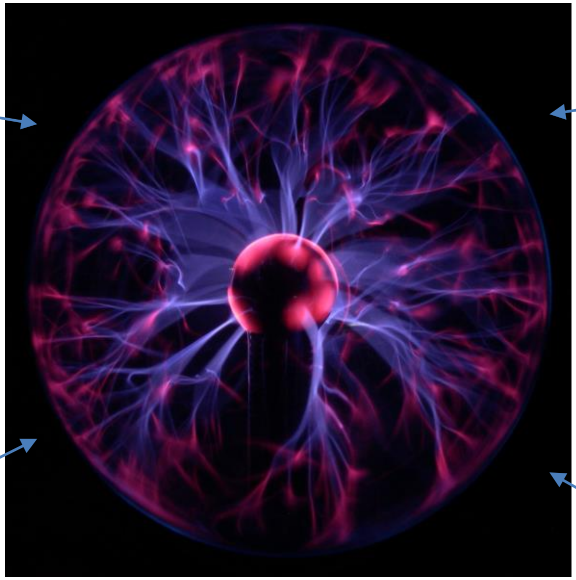
- The Department was established by I.A.U Science and research branch in **1993**, and includes some of the most advanced facilities of its kind.

- Our faculty members specialize in various field of science and technology-Namely **Plasma Physics, Laser-Optics, Nano-Technology, Nano-Optoelectronics, Condensed Matter, Solid State Physics and ... .**

- This department consists of about **74 PhD students**, and **500 students** that follow bachelor and master degrees in Physics and Engineering Physics (Laser, Plasma and Condensed matter.

Waste Disposal

Clean Energy



Material Sciences

Medical Sciences

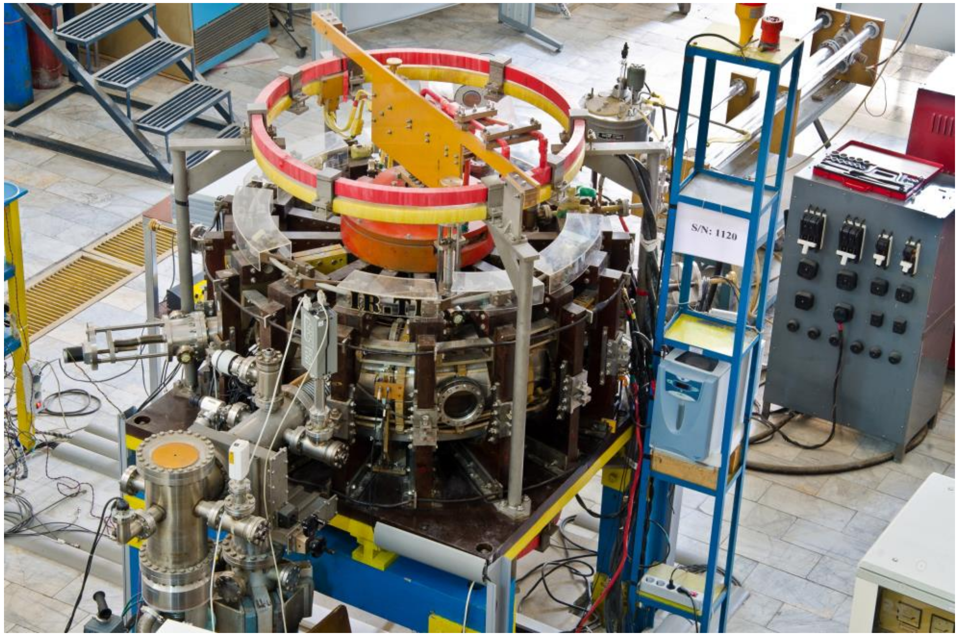
Research at PPRC organized around following theme:

1. Magnetic Confinement Fusion (Tokamak, Plasma Focus)
2. Inertial Confinement Fusion
3. Laser applications (Laser medicine, Laser ablation, …)
4. Surface Physics (Thin film structures, ion implantation, ion beam assisted deposition, …)
5. Nanotechnology applications (CVD , TCVD , PECVD , HFCVD , …)
6. Semiconductors
7. Optoelectronics
8. Biophysics and Plasma medicine
9. Plasma application in textile and polymers
10. Thermal Plasma and its application (waste disposal)

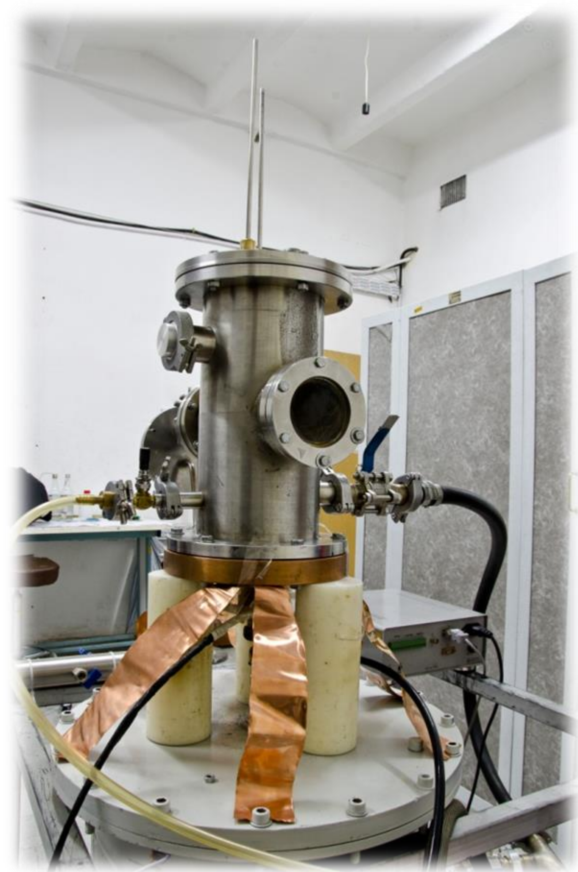
…

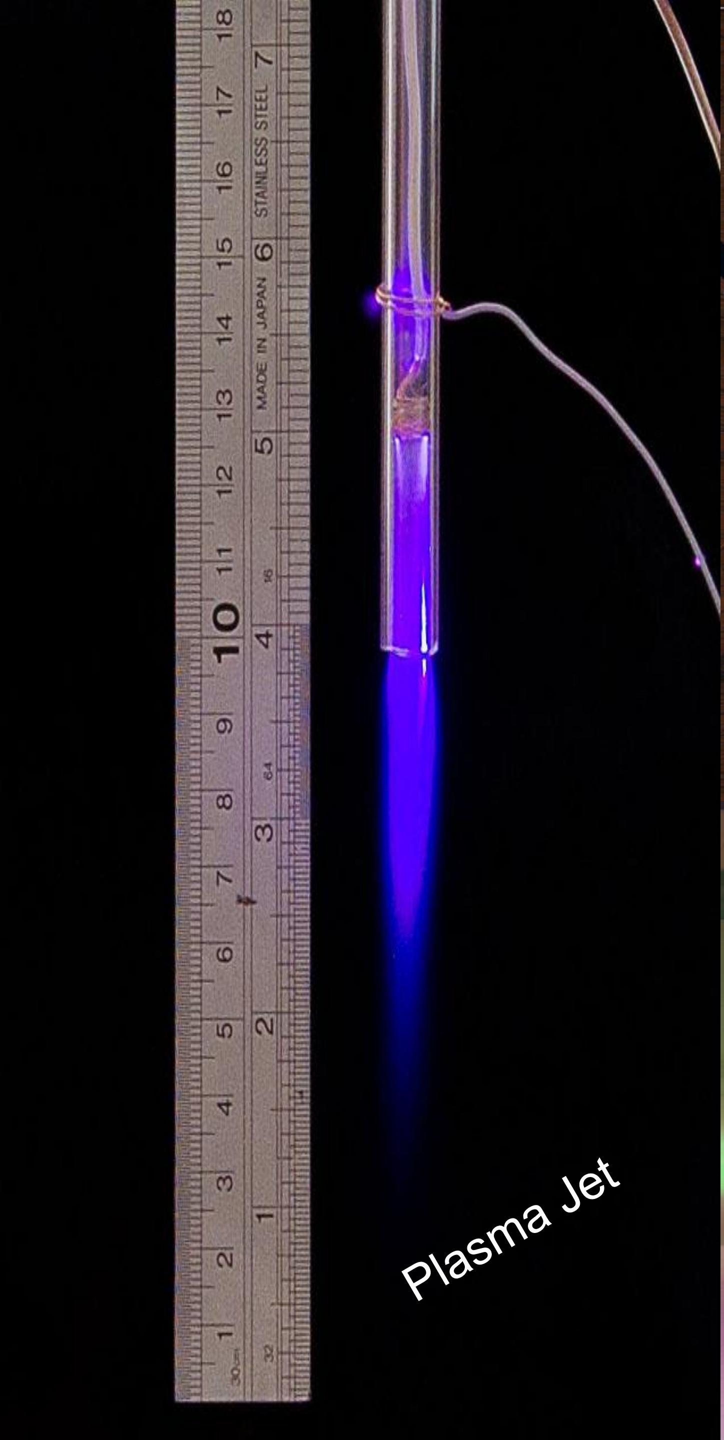
Workshop

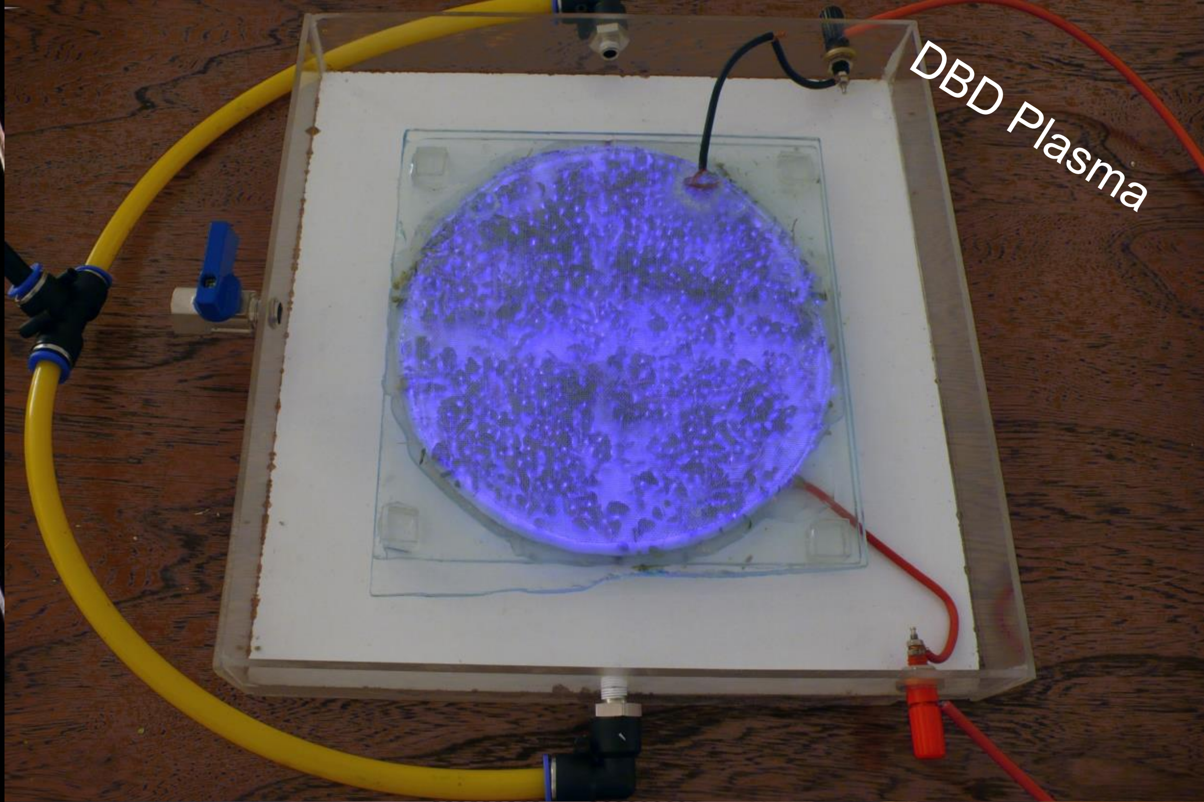
IR-T1 Tokamak

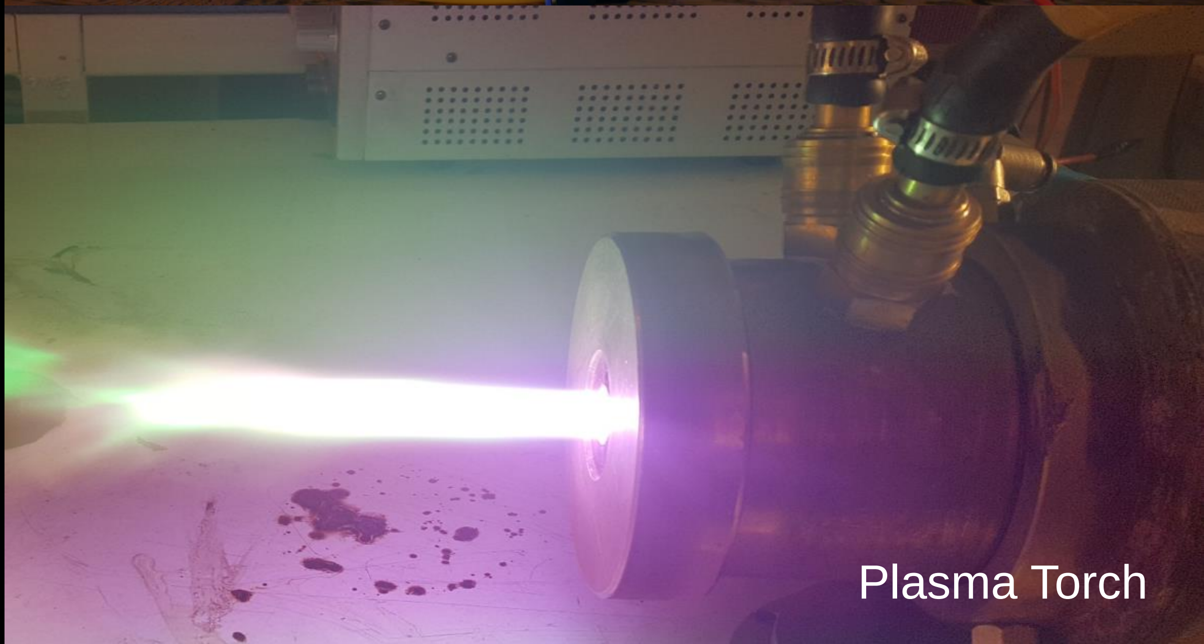


Dense Plasma Focus

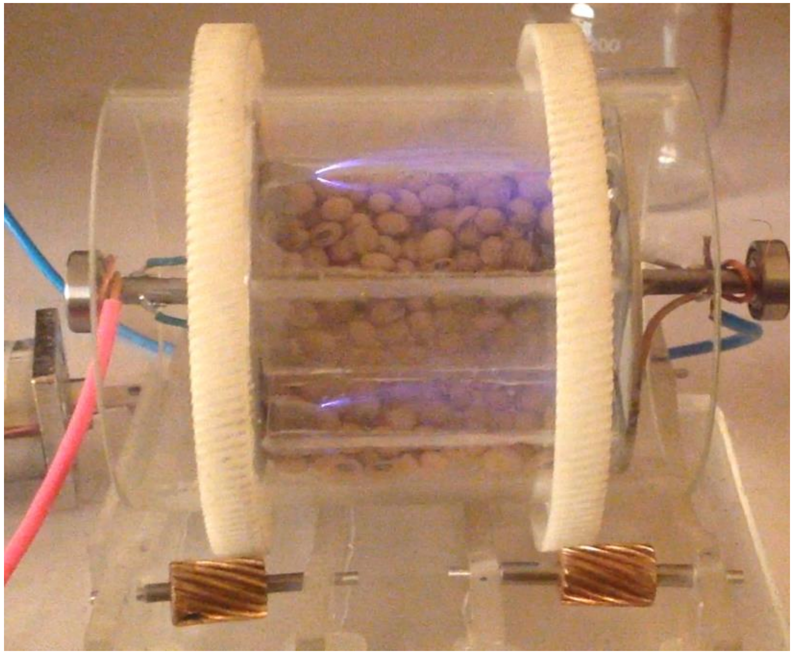



STAINLESS STEEL
MADE IN JAPAN
Plasma Jet


DBD Plasma

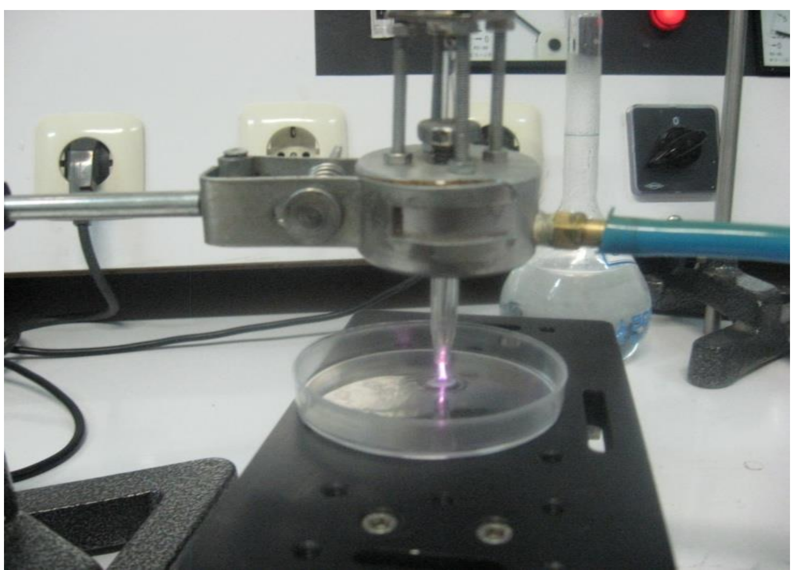

Plasma Torch

Seed treatment



Bedsore treatment

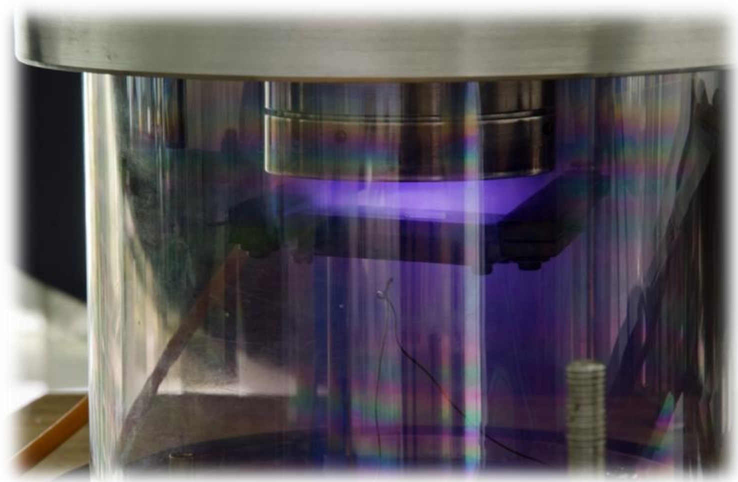
Antibacterial treatment



Medical waste treatment

Ion Implantation & Ion Beam

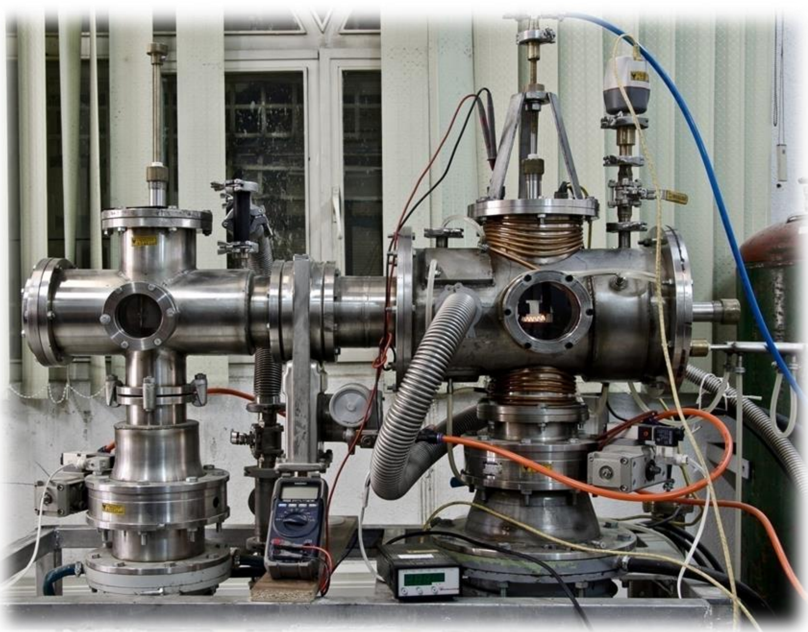
Various Sputtering Systems



TCVD

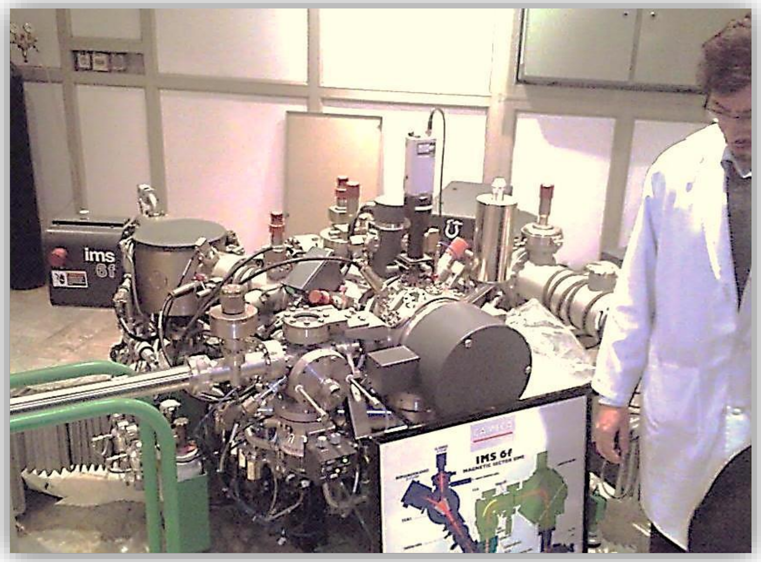
PECVD

HFCVD



RF Plasma

Secondary Ion Mass Spectrometry (SIMS)

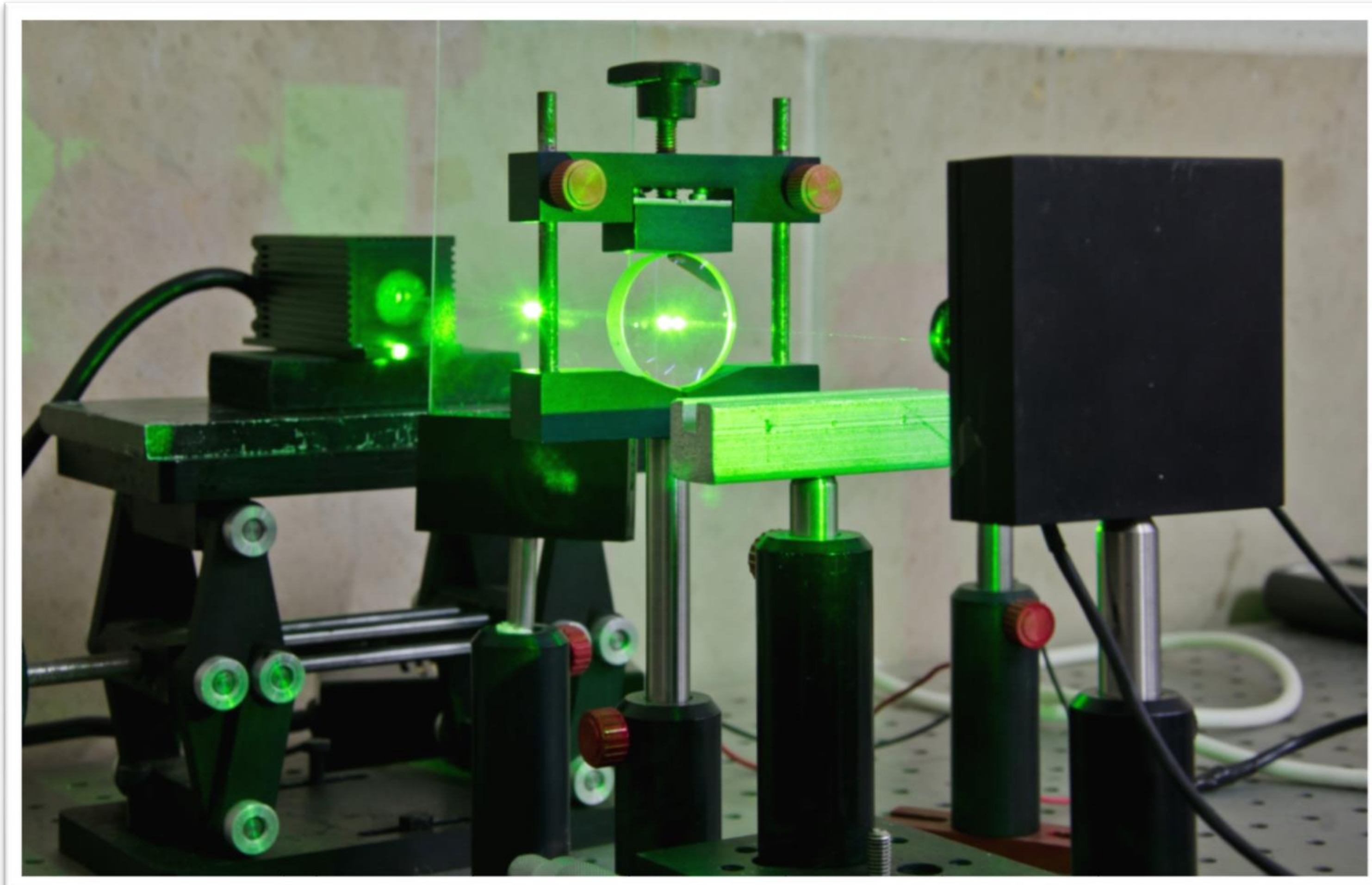


UV-Vis-NIR Spectroscope

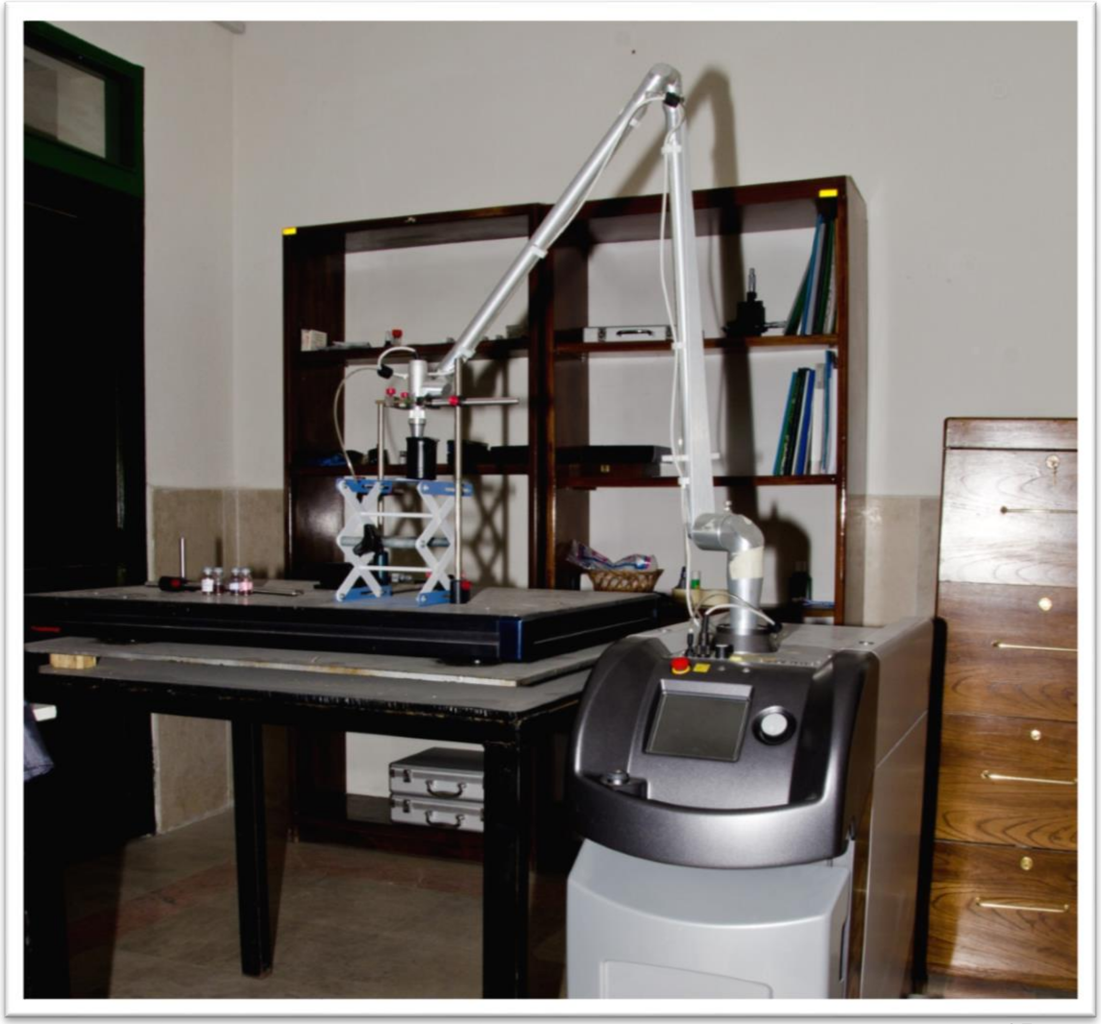
SPM-AFM

XRD & SCXRD

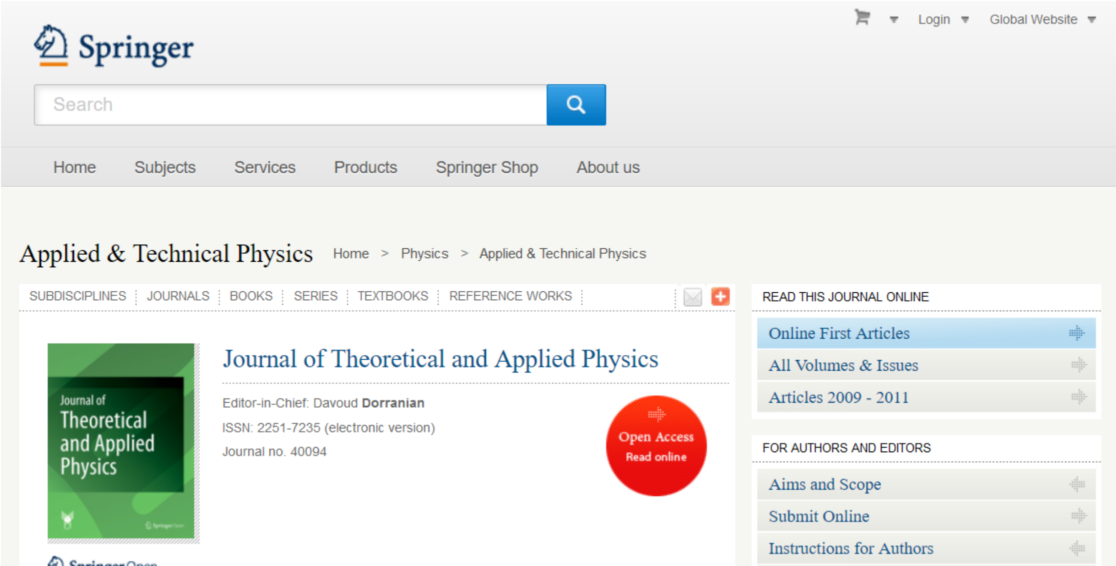
Laser Labs



Laser Lab



Laser Lab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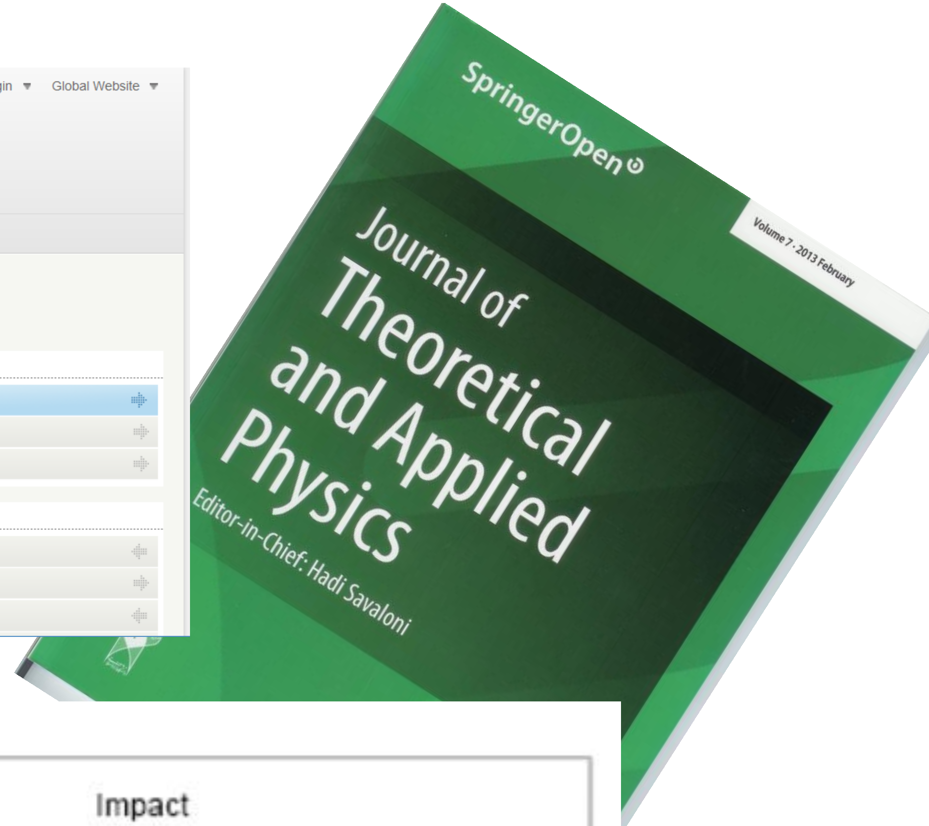
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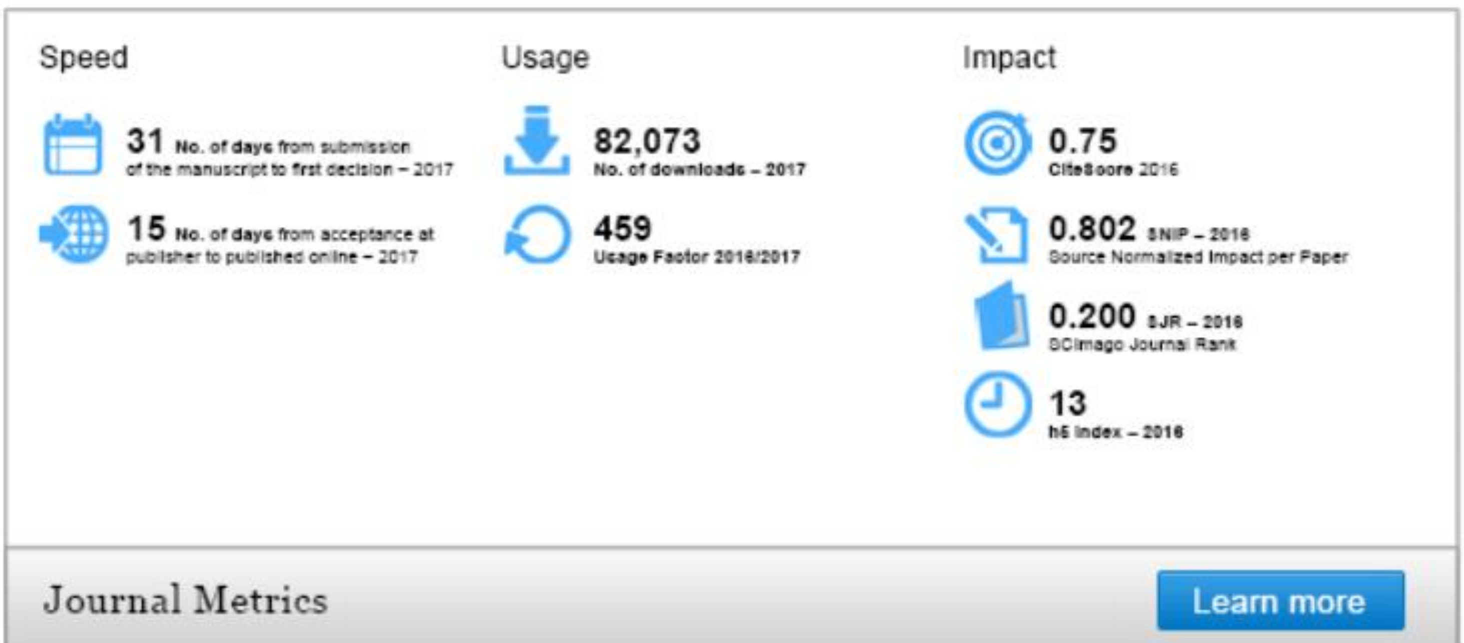
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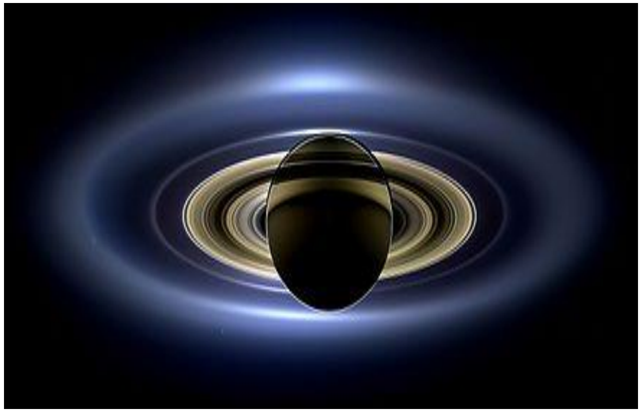
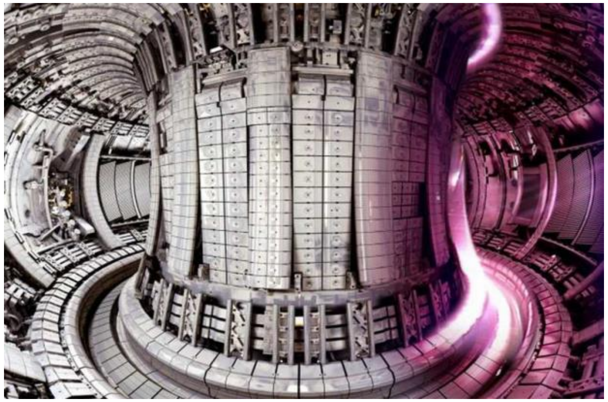
0.802 SNIP – 2016 Source Normalized Impact per Paper
0.200 SJR – 2016 SCImago Journal Rank
13 h5 index – 2016
Journal Metrics
Learn more

In this work, we study **ion acoustic cnoidal waves (IASW)** in **electron–positron-ion plasma** with **nonextensive** electrons and positrons and high **relativistic** ions. Our aim in this study is therefore to recognize the effects of plasma nonextensivity and relativity on the IACW.

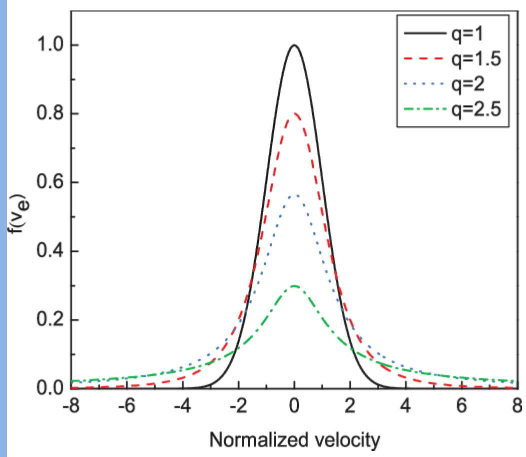
Applications





Introduction:

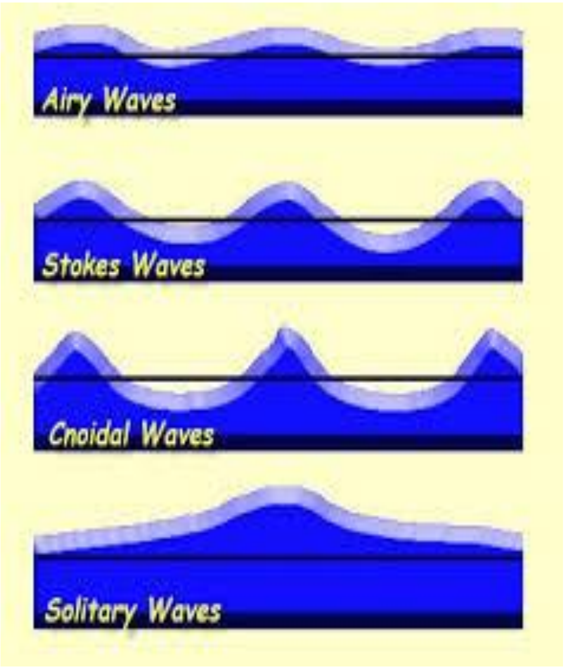
Nonextensive distribution function



$$n_e = [1 + (q-1)\phi]^{\frac{q+1}{2(q-1)}}$$

For example this normalized density distribution function

Common nonlinear waves in plasmas



Electron+positron+ion plasma

GAS+Energy→ PLASMA

Electric charge conservation

Electron-Ion plasma:

$$n_e + Zn_i = 0$$

Electron-Ion-Positron plasma:

$$n_e + Zn_i + n_p = 0$$

Relativistic effects

$$\frac{\partial(\gamma u)}{\partial t} + u\frac{\partial(\gamma u)}{\partial x} = -\frac{\partial \phi}{\partial x}$$

$$\gamma = \left(1 - \frac{u^2}{c^2}\right)^{-\frac{1}{2}} \cong 1 + \frac{u^2}{2c^2} + \frac{3u^4}{8c^4}$$

2. Basic equations

$$\frac{\partial n}{\partial t} + \frac{\partial}{\partial x}(nu) = 0$$

$$\frac{\partial(\gamma u)}{\partial t} + u\frac{\partial(\gamma u)}{\partial x} = -\frac{\partial \phi}{\partial x}$$

$$\frac{\partial^2 \phi}{\partial x^2} = n_e - pn_p - (1-p)n$$

$$n_e = [1+(q-1)\phi]^{\frac{q+1}{2(q-1)}}$$

$$n_p = [1-(q-1)\sigma\phi]^{\frac{q+1}{2(q-1)}}$$

$$\gamma = \left(1-\frac{u^2}{c^2}\right)^{-\frac{1}{2}} \cong 1+\frac{u^2}{2c^2}+\frac{3u^4}{8c^4}$$

σ:The temperature ratio of electron to positron.

T_p: The temperature of positron

T_e: The temperature of electron

n_e: The density of electron

n_{e0}: The equilibrium density of electron

n_p: The density of positron

n_{p0}: The equilibrium density of positron

n: The density of ion

ϕ: The electrostatic potential

k: Boltzmann's constant

2. Basic equations

The normalization

$$
\begin{cases}
u \longrightarrow u \,/\, (kT_e/m)^{1/2} \;, \\
\phi \longrightarrow \phi\, \mathrm{e} / kT_e \;, \\
\mathrm{t} \longrightarrow \mathrm{t} \,/\, (\mathrm{m}\varepsilon_0/\mathrm{n}_0\mathrm{e}^2)^{1/2}, \\
\mathrm{x} \longrightarrow \mathrm{x}/(k\, \varepsilon_0 T_e \,/ n_0 e^2)^{1/2}
\end{cases}
$$

2. Derivation of KdV equation
Reductive perturbation method

$\xi = \varepsilon^{1/2}(x - V_0 t)$ $\tau = \varepsilon^{3/2} t$

Dependent variables are expanded :

$$\begin{cases} n = 1 + \varepsilon n_1 + \varepsilon^2 n_2 + \varepsilon^3 n_3 + \ldots \\ u = u_0 + \varepsilon u_1 + \varepsilon^2 u_2 + \varepsilon^3 u_3 + \ldots \\ \phi = \varepsilon \phi_1 + \varepsilon^2 \phi_2 + \varepsilon^3 \phi_3 + \ldots \end{cases}$$

2. Derivation of KdV equation

The set of equations at the lowest order is;

$$-V_0 \frac{\partial n_1}{\partial \xi} + \frac{\partial (u_1 + n_1 u_0)}{\partial \xi} = 0$$

$$-(V_0 - u_0)\gamma_1 \frac{\partial u_1}{\partial \xi} + \frac{\partial \phi_1}{\partial \xi} = 0$$

$$\phi_1 \left(\frac{q+1}{2}(1 + p\sigma) \right) - (1-p) n_1 = 0$$

$$n_1 = \left[\frac{\left(\frac{q+1}{2} \right)(1 + p\sigma)}{1-p} \right] \phi_1$$

$$u_1 = (V_0 - u_0) \left[\frac{\left(\frac{q+1}{2} \right)(1 + p\sigma)}{1-p} \right] \phi_1$$

$$V_0 = \left[\frac{1-p}{\left(\frac{q+1}{2} \right)(1 + p\sigma)\gamma_1} \right]^{\frac{1}{2}} + u_0$$

2. Derivation of KdV equation

The next higher-order equations are;

$$\begin{cases} -(V_0-u_0)\dfrac{\partial n_2}{\partial \xi}+\dfrac{\partial n_1}{\partial \tau}+\dfrac{\partial u_2}{\partial \xi}+\dfrac{\partial (n_1 u_1)}{\partial \xi}=0 \\ -(V_0-u_0)\gamma_1\dfrac{\partial u_2}{\partial \xi}+\gamma_1\dfrac{\partial u_1}{\partial \tau}+[\gamma_1-2\gamma_2(V_0-u_0)]u_1\dfrac{\partial u_1}{\partial \xi}+\dfrac{\partial \phi_2}{\partial \xi}=0 \\ \dfrac{\partial^2 \phi_1}{\partial \xi^2}=\left(\dfrac{q+1}{2}(1+p\sigma)\right)\phi_2+\left(\dfrac{(3-q)(q+1)}{4}(1-p\sigma^2)\right)\dfrac{\phi_1^2}{2}-(1-p)n_2 \end{cases}$$

$$\gamma_1=1+\frac{3u_0^2}{2c^2}+\frac{15u_0^4}{8c^4}$$

$$\gamma_2=\frac{3u_0}{2c^2}+\frac{30u_0^3}{8c^4}$$

After some algebraic manipulations, second order quantities are eliminated and ϕ_1 is found to satisfy the following KdV equation

2. Derivation of KdV equation

After some algebraic manipulations, second order quantities are eliminated

and f_1 is found to satisfy the following KdV equation:

$$\frac{\partial \phi_1}{\partial \tau} + a\phi_1 \frac{\partial \phi_1}{\partial \xi} + b\frac{\partial^3 \phi_1}{\partial \xi^3} = 0$$

which is the required KdV equation and describes the evolution of the first order perturbed potential . The coefficients and are given by:

$$a = \frac{3}{2\gamma_1(V_0 - u_0)} + \frac{V_0 - u_0}{2}\left[\frac{(3-q)\left((1-P\sigma^2)\right)}{2(1+P\sigma)}\right] - \frac{\gamma_2}{\gamma_1^2}$$

$$b = \frac{1}{2}\left[\frac{V_0 - u_0}{\left(\frac{q+1}{2}\right)(1+p\sigma)}\right]$$

2. Derivation of KdV equation

Cnoidal wave solution of KdV equation

$$\phi(\eta) = \alpha_1 + (\alpha_0 - \alpha_1) cn^2 (D\eta, m)$$

The α_0, α_1, and α_2 are the real roots of Sagdeev potential $V(\phi_1) = \frac{a}{6b}\phi_1^3 - \frac{u}{2b}\phi_1^2 + \rho_0\phi_1$

$$m^2 = \frac{\alpha_0 - \alpha_1}{\alpha_0 - \alpha_2} \qquad D = \sqrt{\frac{a}{12b}(\alpha_0 - \alpha_2)}$$

the amplitude $A = \alpha_0 - \alpha_1$

the wavelength $\lambda = 4\sqrt{\frac{3b}{a(\alpha_0 - \alpha_2)}} K(m)$

K(m) is the first kind of complete elliptic integral

3. Results and discussion

Cnoidal wave may generate and propagate in plasma medium only if Sagdeev potential has three real roots. In this case the domain of real roots should be found from the inequalities $\Delta = (u/a)^2 - \rho_0\ (b/a) > 0$ and $0 < ((\alpha_0 - \alpha_1)/(\alpha_0 - \alpha_2))^{0.5} < 1$

The acceptable values for q in which Sagdeev potential has three real roots are shown in Fig. 1

This figure shows that for all values of q> -1 periodic wave (Cnoidal) may be formed

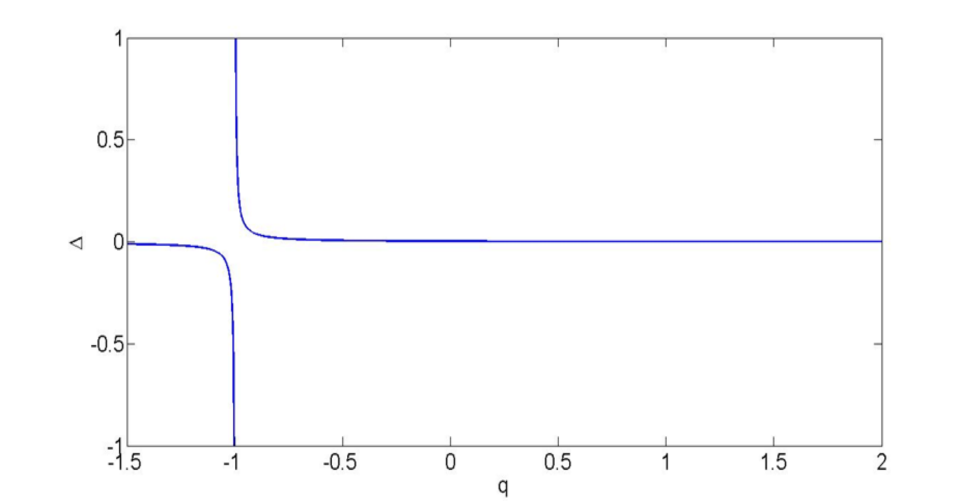


Fig1.Plot of Δ versus q, having σ=0.1, p=0.1,U=0.0075, ζ=0.8 and ρ_0=–0.002

Δ versus $\zeta = u_0/c$ is shown in Fig. 2. Ion relativity does not make any effect on the formation of IACW and for all magnitudes of ζ periodic wave may generate and propagate in plasma medium.

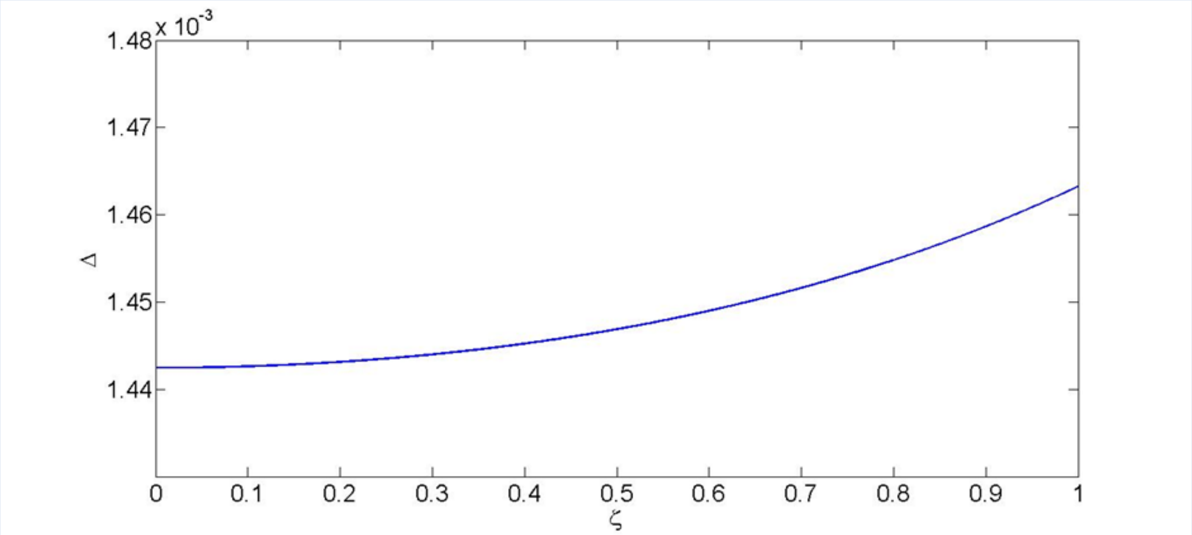


Fig2. Plot of Δ versus ζ, having σ=0.1, p=0.1, U=0.0075, q=0.1 and ρ_0=–0.002

This figure shows that by increasing plasma nonextensivity the width and depth of the potential well decrease.

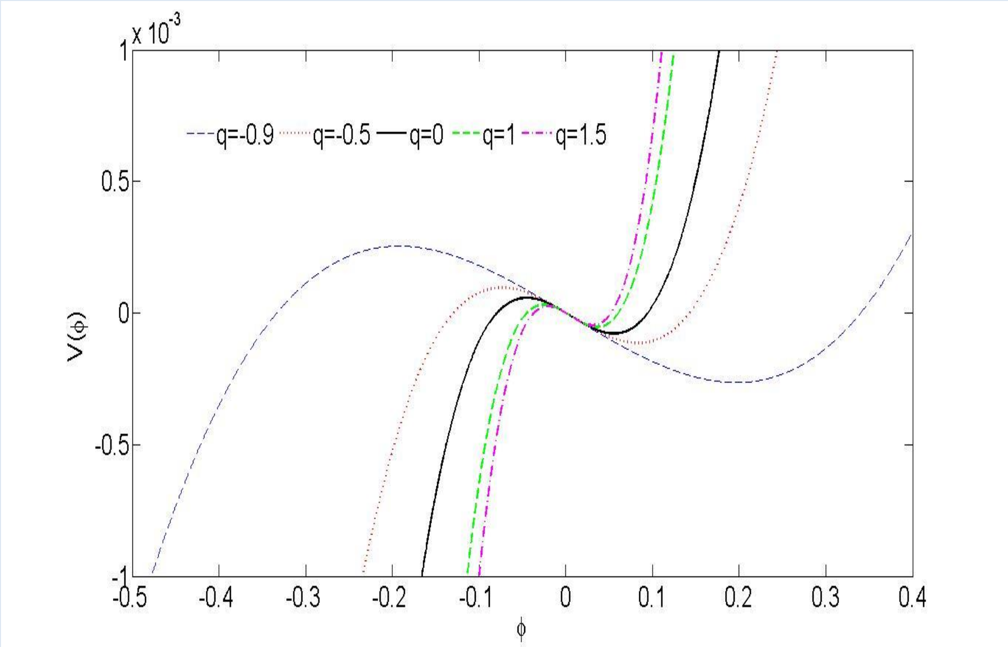


Fig3. Plot of V (ϕ) versus ϕ for different qs, having σ=0.1, p=0.1, U=0.0075, ζ=0.8 and ρ_0=−0.002

In Fig. 4 the frequency of ion acoustic periodic wave (cnoidal) versus $\zeta = u_0/c$ for different *q*s has been plotted. By increasing *q* and ζ the frequency of periodic wave (cnoidal) will decrease.

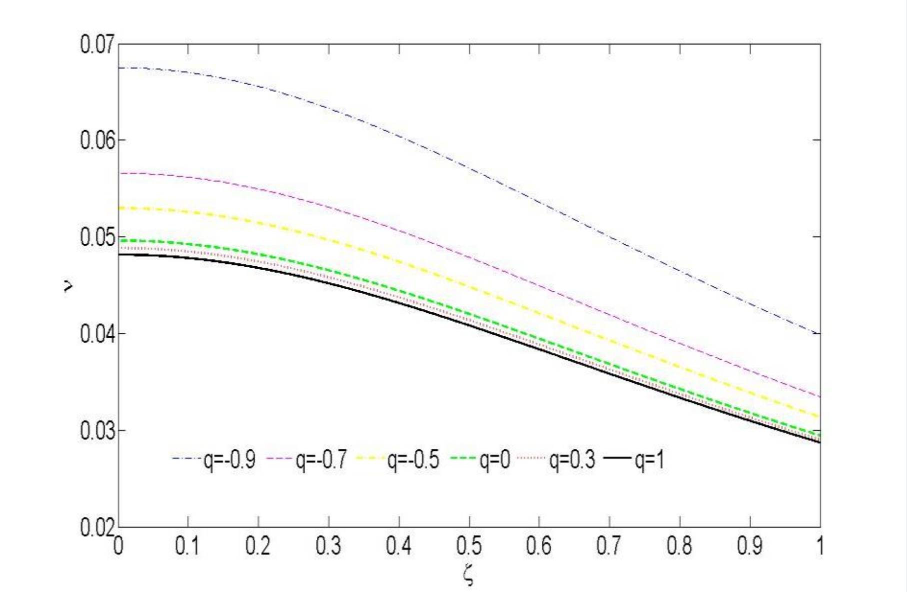


Fig4. Plot of frequency of periodic wave (cnoidal) versus ζ for different *q*s, having σ=0.1, *p*=0.1, *U*=0.0075 and ρ_0=–0.002

By increasing the nonextensiivity of plasma the amplitudeof periodic wave (cnoidal) will decrease. Variation of the amplitude of IACW mainly occurs in the super extensive regime when $q<1$

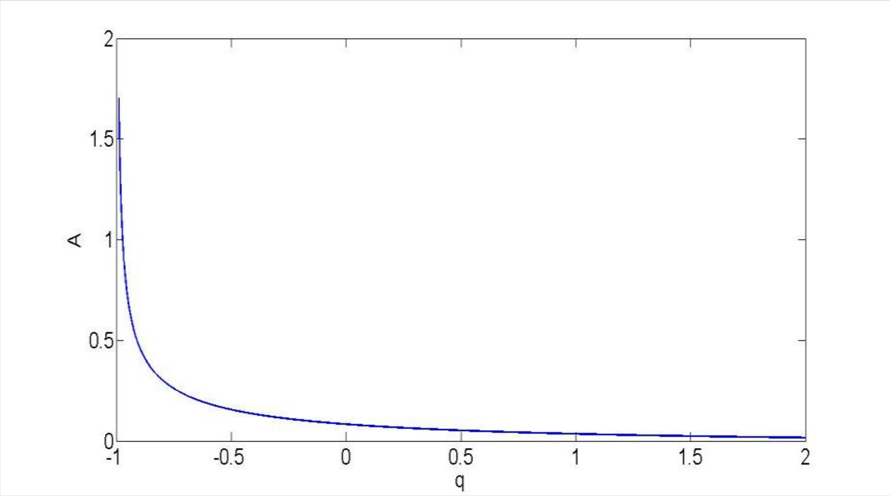


Fig5. Plot of amplitude of periodic wave (cnoidal) versus q, having σ=0.1, p=0.1, U=0.0075, ζ=0.8 and ρ_0=−0.002

By increasing $\zeta = u_0/c$, the amplitude of periodic wave (cnoidal) slightly increased.

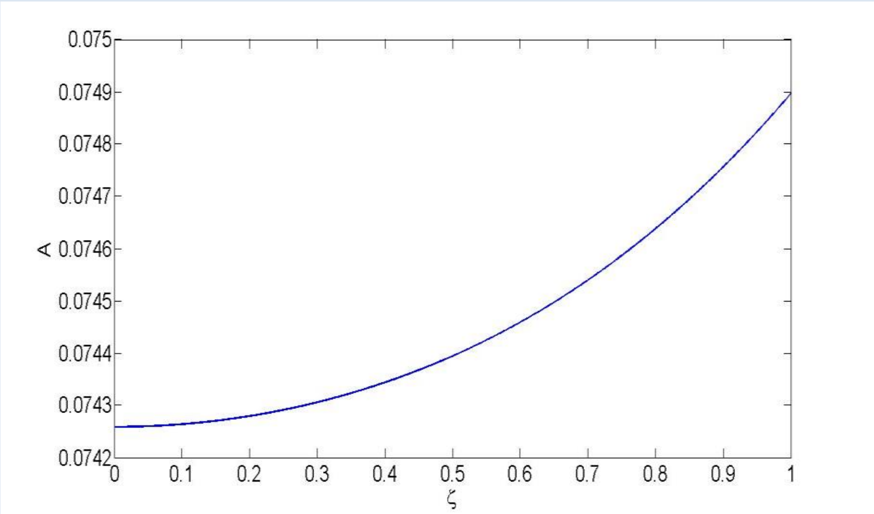
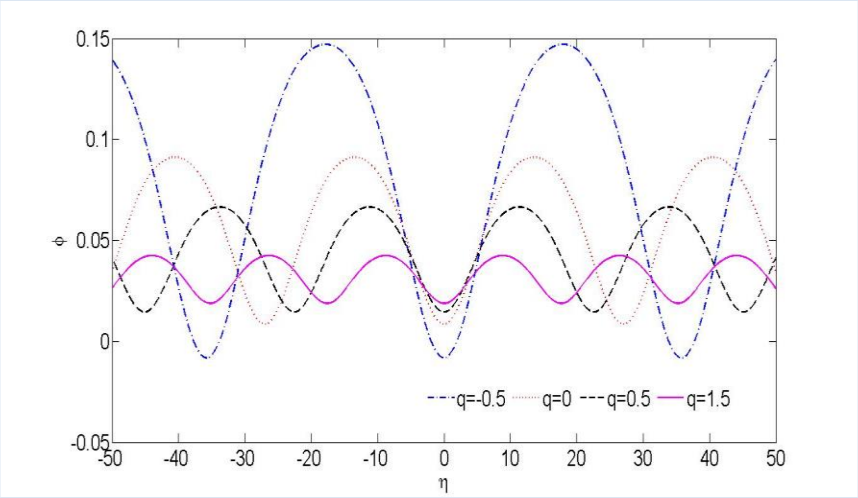


Fig6. Plot of amplitude of periodic wave (cnoidal) versus ζ , having σ=0.1, p=0.1, U=0.0075, q=0.1 and ρ_0=–0.002

Effects of ζ and q on the wave pattern of IACW are presented in Figs. 7 and 8. In any case for all magnitudes of q and ζ, IACW is compressive



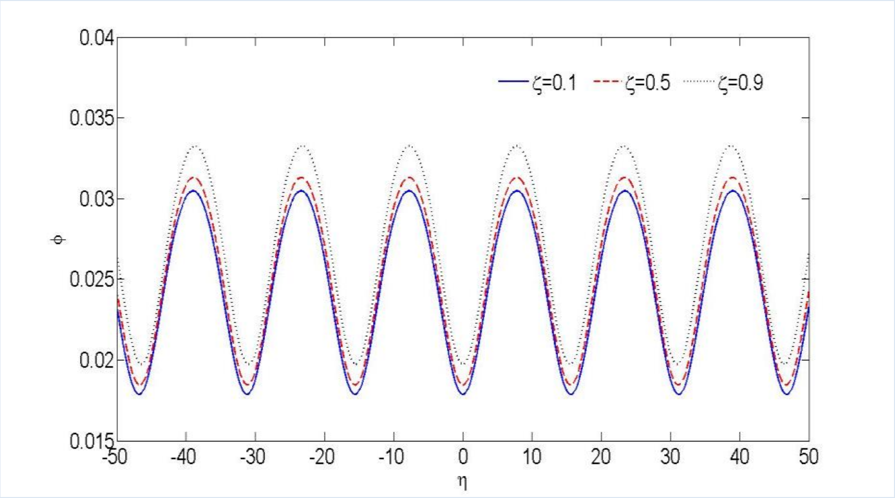


Fig8.Plot of the potential of the cnoidal wave ϕ versus η for different qs,having σ=0.1, p=0.1, U=0.0075, ζ==u_0/c=0.8 and ρ_0=–0.002

Fig7. Plot of the potential of the cnoidal wave ϕ versus η for different ζs, having σ=0.1, p=0.1, U=0.0075, q=0.1 and ρ_0=–0.002

4. Conclusion

- Propagation of IACW in collisionless, unmagnetized high relativistic plasmas with nonextensive electrons and positrons has been studied.
- Amplitude of the cnoidal wave and its width has been derived as functions of plasma parameters.
- Only positive cnoidals can be generated in the plasma medium.
- Amplitude of IACW increases with increasing the relativistic parameter ζ.
- Presence of nonextensive electrons decreases the amplitude of IACW.
- Width of IACW increases with ζ.

PLASMA

Thank you for your attention