B R A Z I L – J I N R F O R U M - 2 0 1 5

PHASE DYNAMICS OF LONG JOSEPHSON JUNCTIONS

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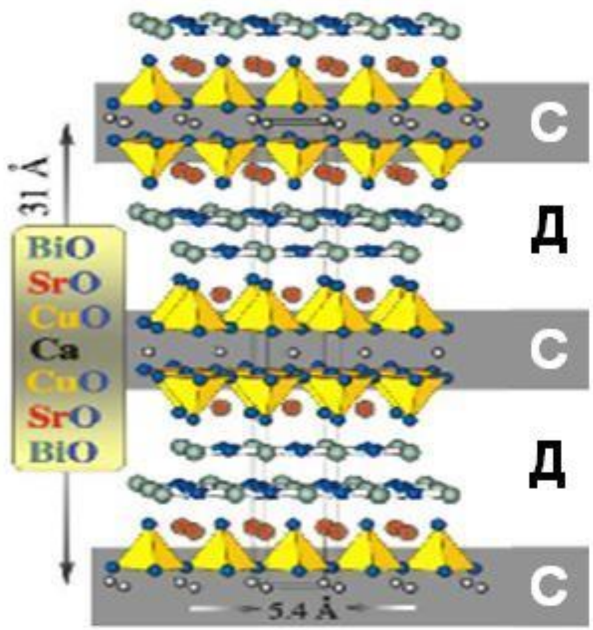
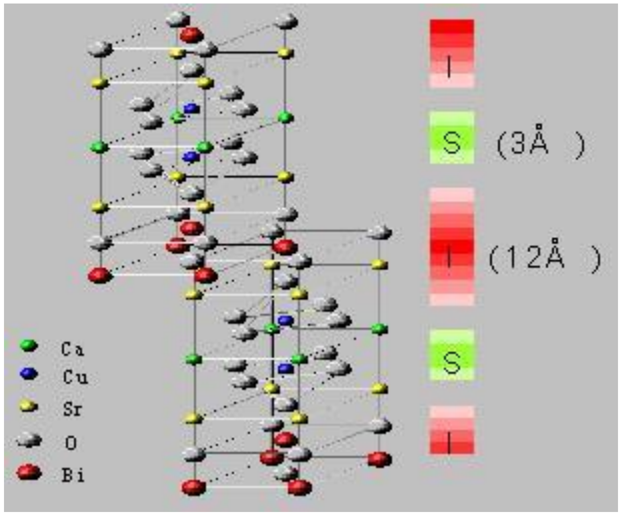
Outline

Introduction

Intrinsic Josephson junctions

$Bi_2Sr_2CaCu_2O_{8+\delta}$





1. Intrinsic Josephson effect was observed in 1992

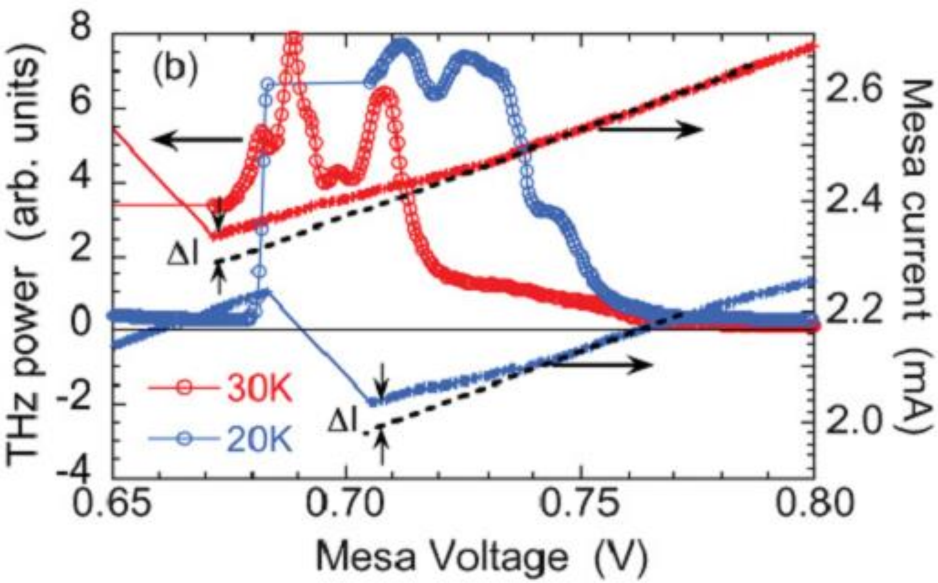
[R. Kleiner, F. Steinmayer, G. Kunkel P. Müller, Phys. Rev. Lett. 68 (1992) 2394]

It was investigated in the several work

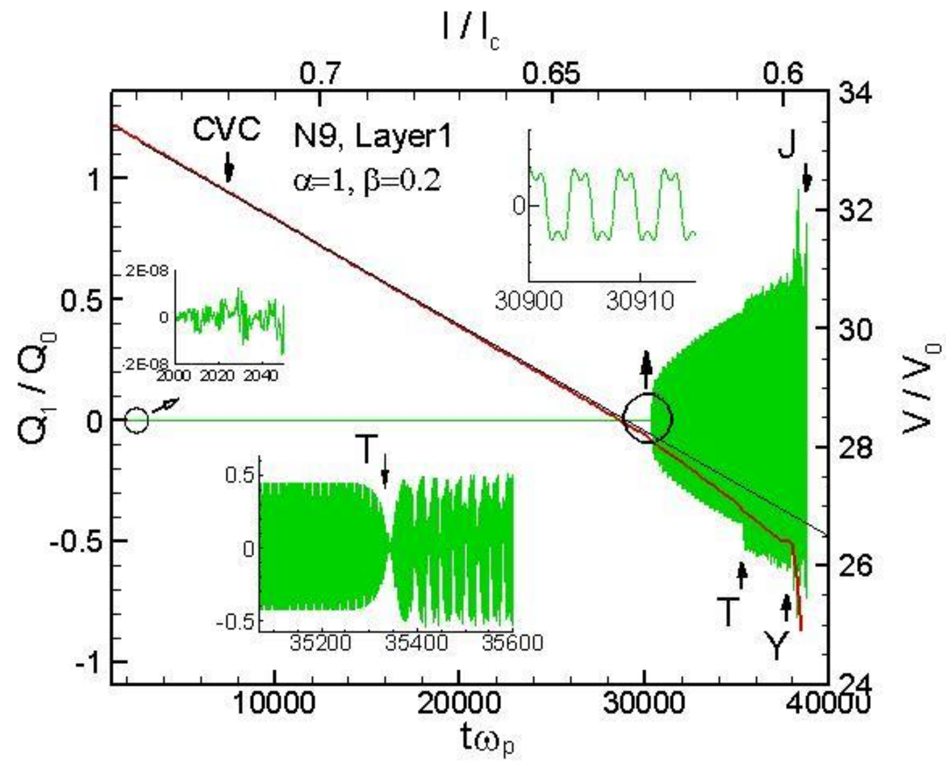
[A. A. Yurgens, Super. Science Technol., 13 (2000) R85]

[Xiao Hu, Shi-Zeng Lin] Super. Science Technol., 23 (2010) 053001]

Experimental and simulated current voltage characteristics



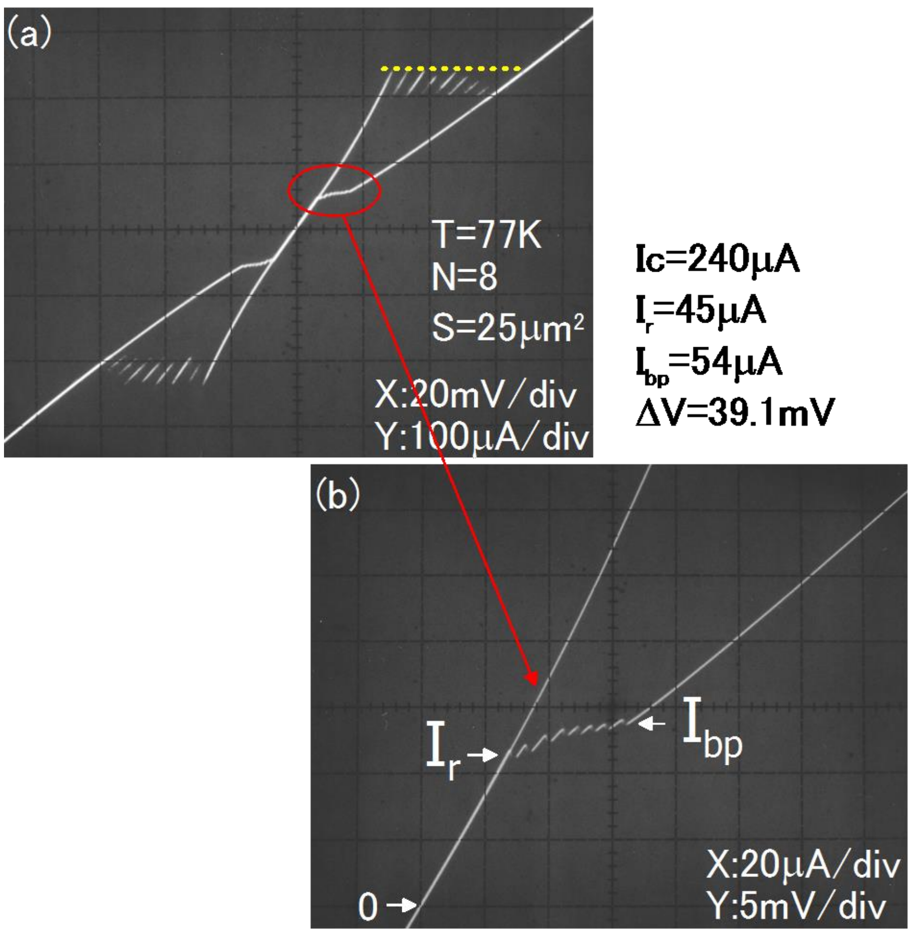
T. M. Benseman, A. E. Koshelev et al. «Tunable terahertz emission from $Bi_2Sr_2CaCu_2O_{8+\delta}$ mesa devices», Phys. Rev. B 84, 064523 (2011).

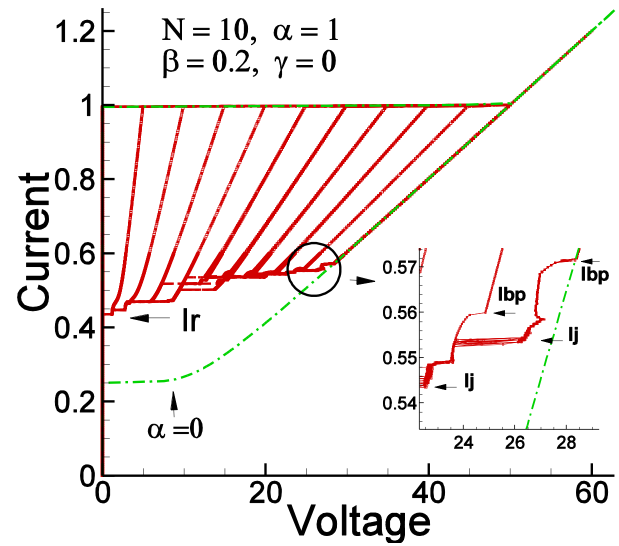


Yu. M. Shukrinov, I.R. Rahmonov and M.El Demery, *«Phase Dynamics in IJJ: Comparative Study in Different Models»*, abstracts book of International Symposium«**PLASMA 2010**», p. 2010.(Hirosaki, Japan)

Parametric resonance and breakpoint region

Sample:Nm1−11



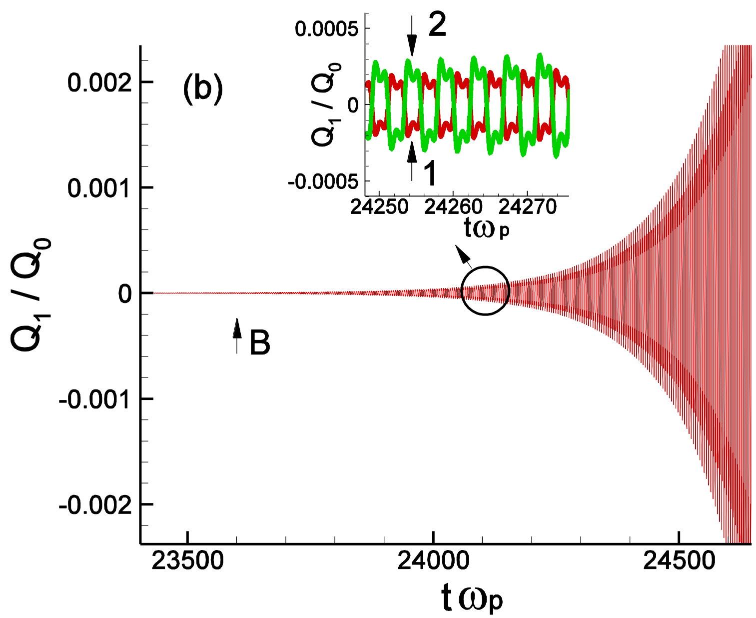


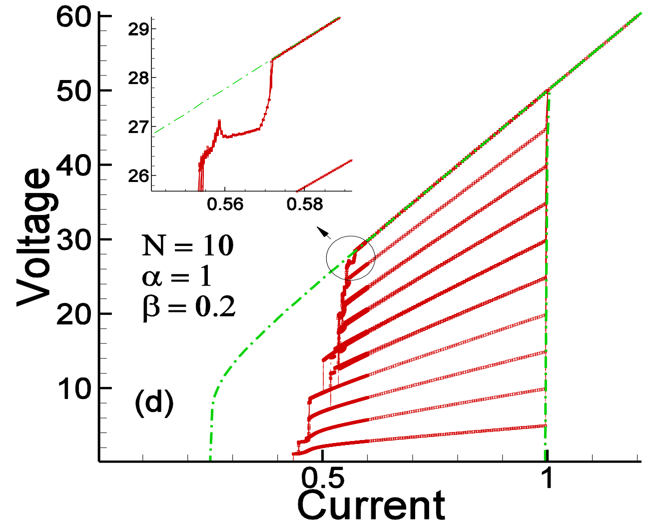
Experimental results: Utsunomiya university

A. Irie, Yu. M. Shukrinov, and G. I. Oya, Appl. Phys. Lett. 93, 152510 (2008).

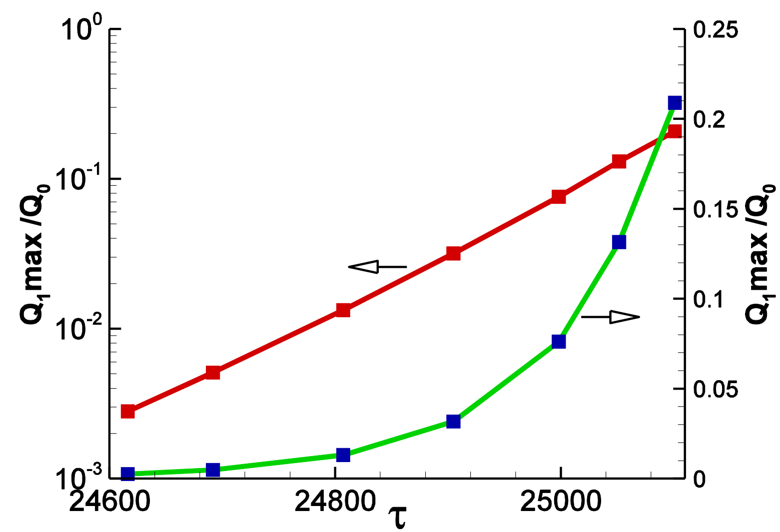
Parametric resonance and breakpoint region

Charge oscillations near the breakpoint in the stack with 9 JJ



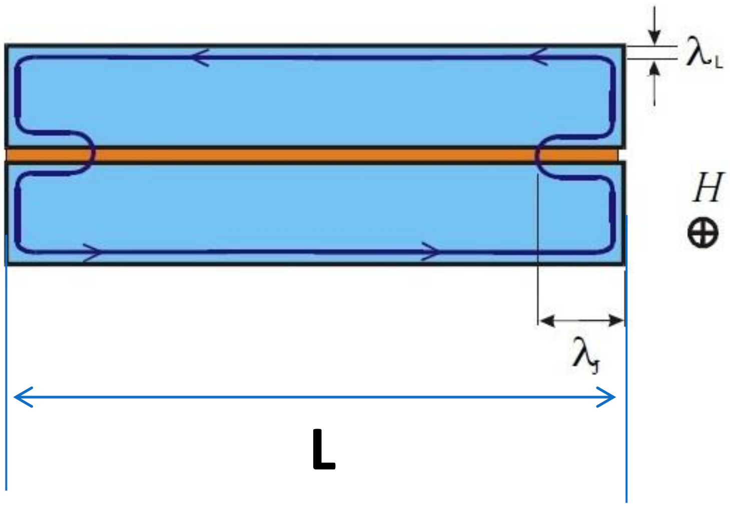


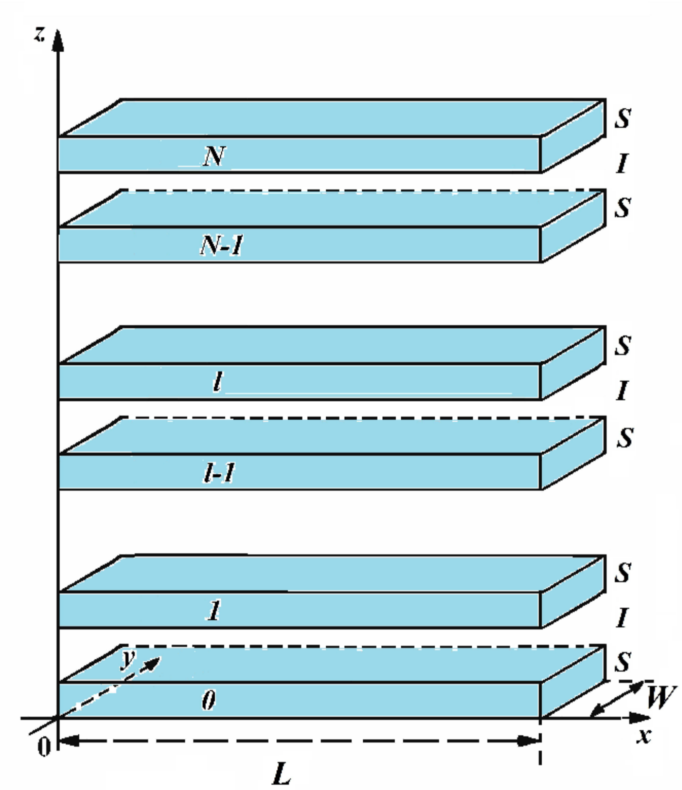
Test of the exponential dependence of charge amplitude.



Yu.M.Shukrinov, F.Mahfouzi, M.Suzuki Phys.Rev.B 78, 134521 (2008).

Simulation model





$$\varphi_l = \theta_l - \theta_{l-1} - \frac{2e}{\hbar c} \int_{z_{l-1}}^{z_l} A_z dz$$

$$\frac{\hbar}{2e} \frac{\partial \varphi_l}{\partial t} = D^C E_l + s^C E_{l+1} + s^C E_{l-1}$$

$$\frac{\hbar c}{2e} \frac{\partial \varphi_l}{\partial x} = D^L B_l + s^L B_{l+1} + s^L B_{l-1}$$

Simulation model

$$\begin{cases} \dfrac{\partial \varphi_l}{\partial t} = D_c V_l + s_c V_{l+1} + s_c V_{l-1} \\ \dfrac{\partial V_l}{\partial t} = \sum_{n=1}^{N} \left(\pounds^{-1}_{l,n} \dfrac{\partial^2 \varphi_n}{\partial x^2} \right) - \sin \varphi_l - \beta \dfrac{\partial \varphi_l}{\partial t} + I \end{cases}$$

$$D_c = 1 + \frac{2\lambda_e}{d_I} \coth\left(\frac{d_s}{\lambda_e}\right) \qquad s_c = -\frac{\lambda_e}{d_I \sinh(d_s/\lambda_e)}$$

$$\hat{\pounds} = \begin{pmatrix} 1 & S & 0 & \ldots & & & & S \\ S & 1 & S & 0 & \ldots & & & \\ 0 & S & 1 & S & 0 & \ldots & & \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ & & & \ldots & 0 & S & 1 & S \\ S & & & & \ldots & 0 & S & 1 \end{pmatrix}$$

$$S = s_{\pounds}/D_{\pounds}$$

$$D_{\pounds} = d_I + 2\lambda_L \coth\left(\frac{d_s}{\lambda_L}\right)$$

$$s_{\pounds} = -\frac{\lambda_L}{\sinh(d_s/\lambda_L)}$$

$$\lambda_j = \sqrt{\frac{\hbar c^2}{8\pi e j_c D_{\pounds}}} \qquad \frac{j_B}{j_c} = I \qquad \omega_p = \sqrt{\frac{8\pi d_I e j_c}{\hbar \varepsilon}} \qquad V_0 = \frac{\hbar \omega_p}{2e}$$

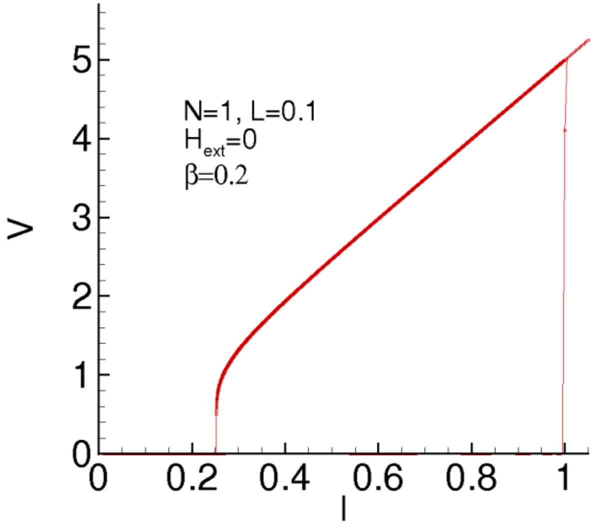
M. Machida, S. Sakai, Phys. Rev. B 70 (2004) 144520

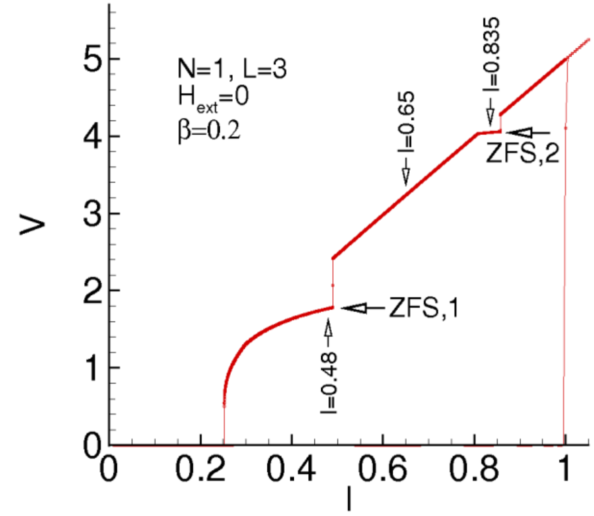
S. Sakai, P. Bodin, N. F. Pedersen, J. Appl. Phys. 73 (1993) 2411

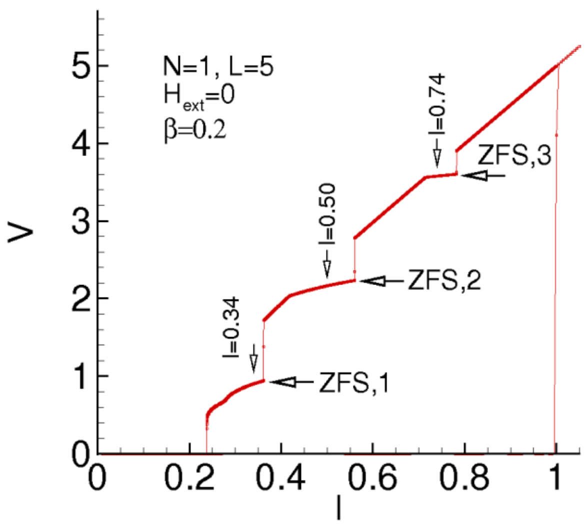
I.R. Rahmonov, Yu.M. Shukrinov, A. Irie, JETP Lett. 99, № 11, 735-742 (2014) (russian)

The main features of the single long JJ

The main features of the single long Josephson junction







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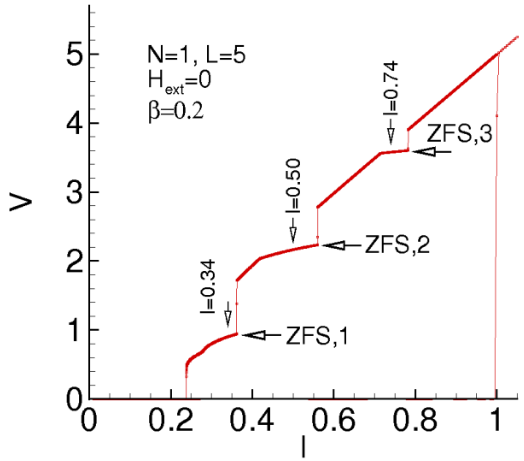
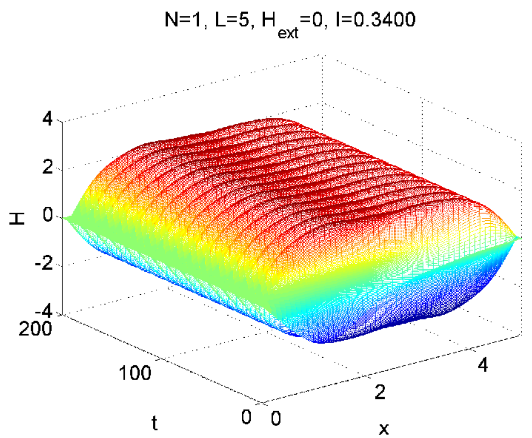
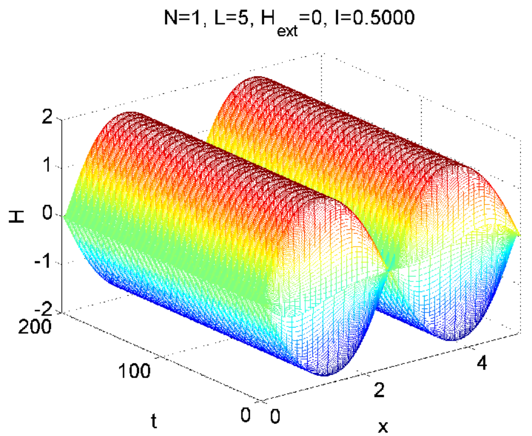
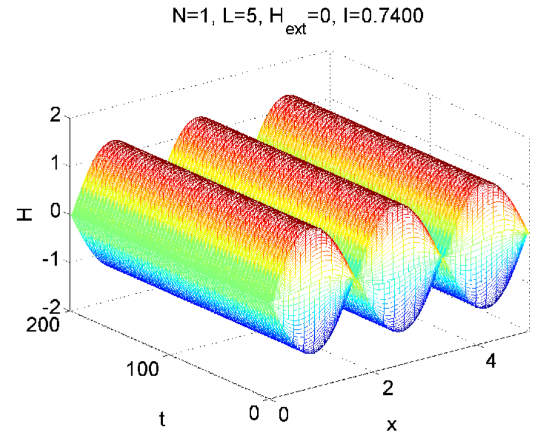
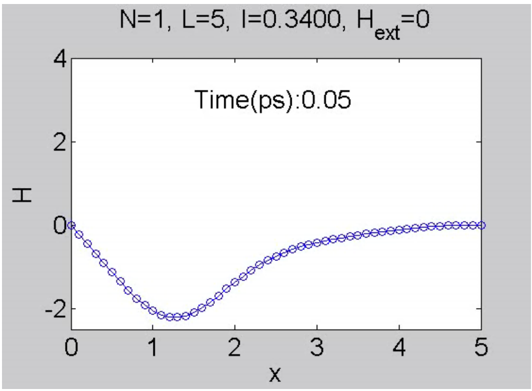
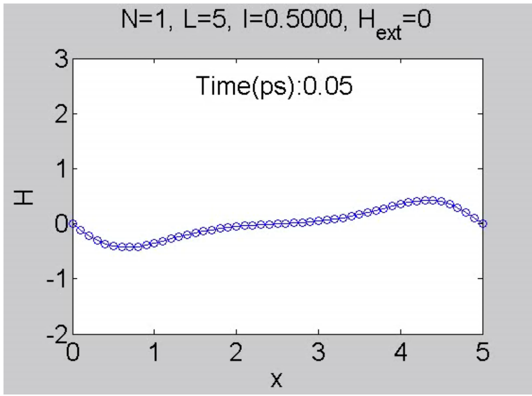


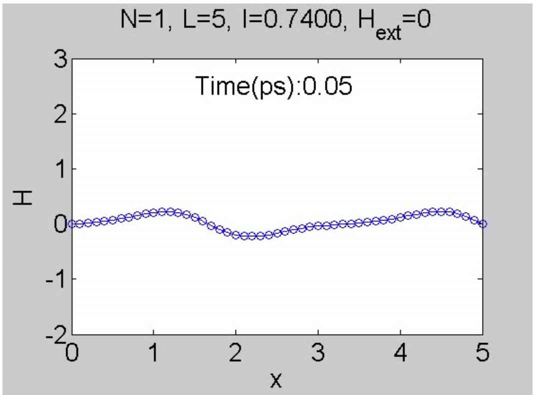






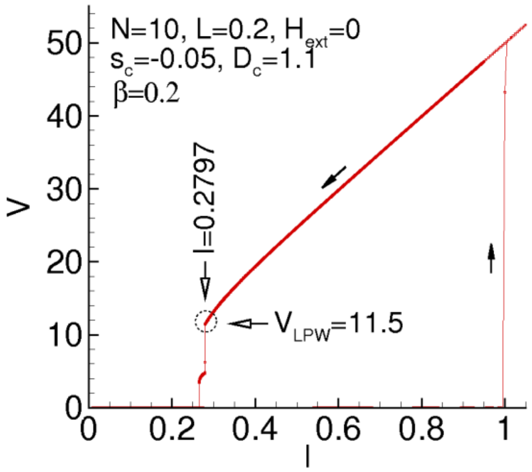


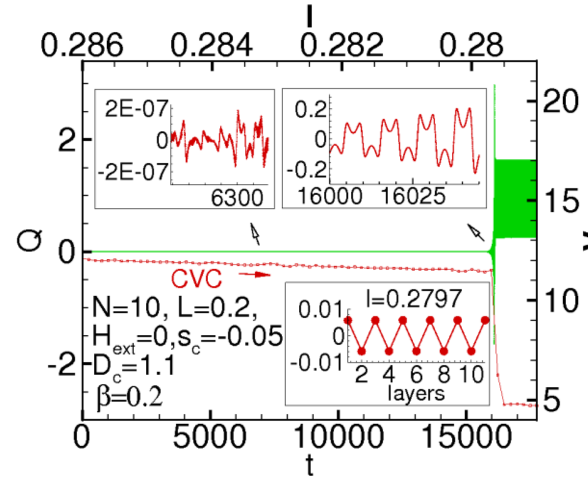


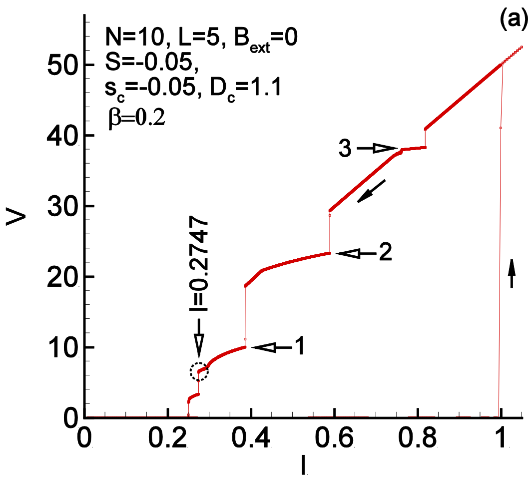


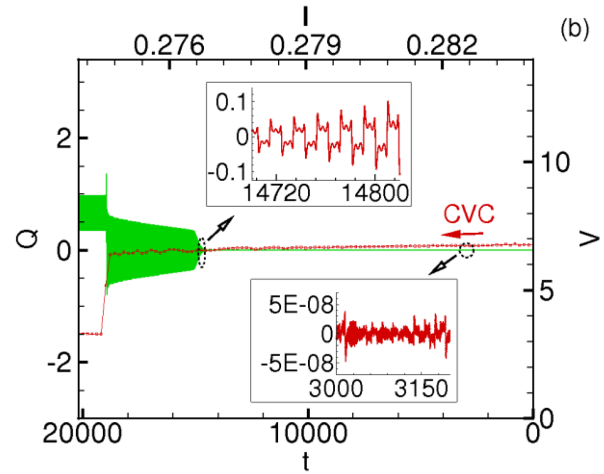
Parametric resonance in the stack of long JJ

Parametric resonance and longitudinal plasma wave in the stack of long Josephson junctions









I.R. Rahmonov, Yu.M. Shukrinov, A. Irie, JETP Lett. 99, № 11, 735-742 (2014) (russian)

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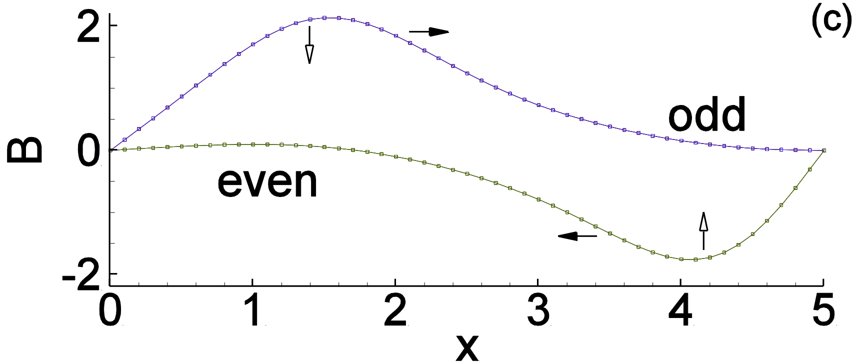

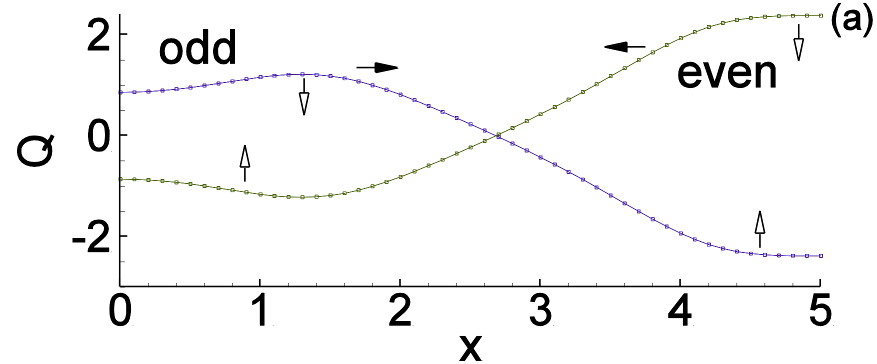

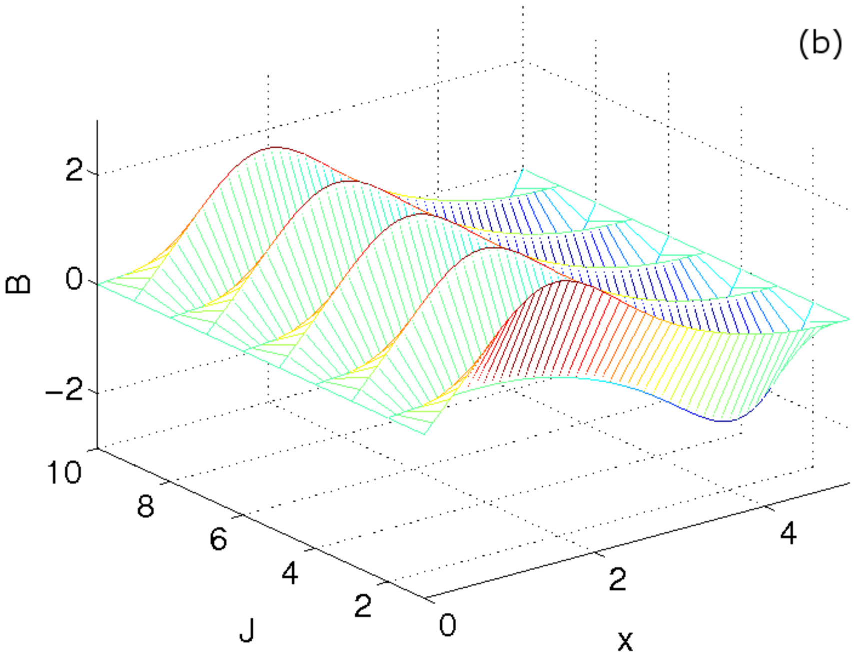

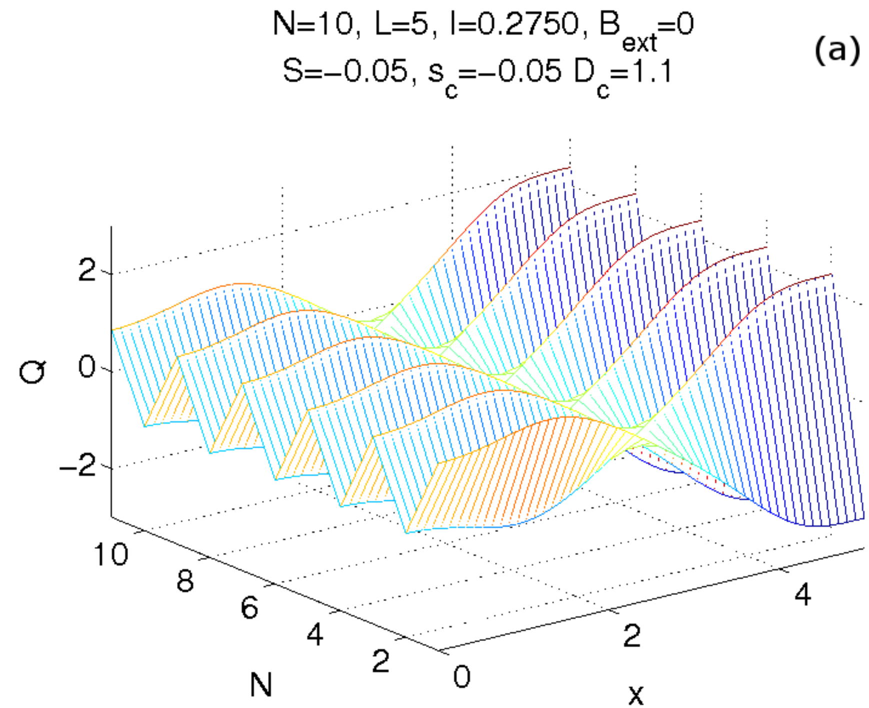

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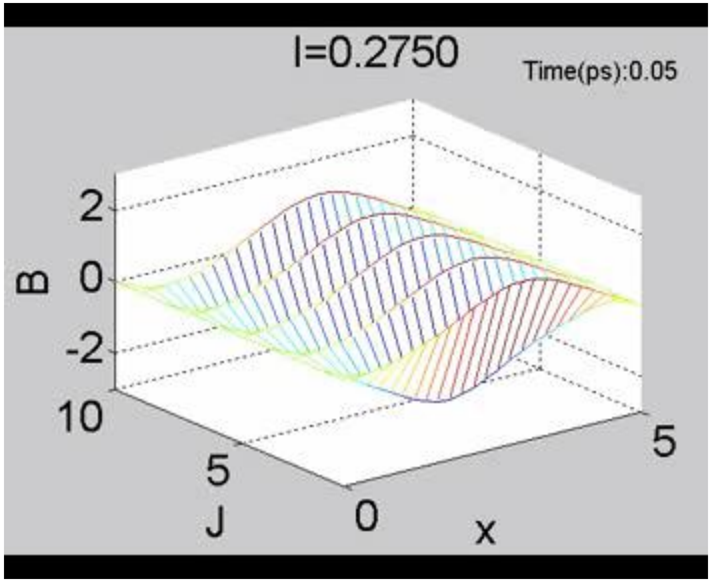

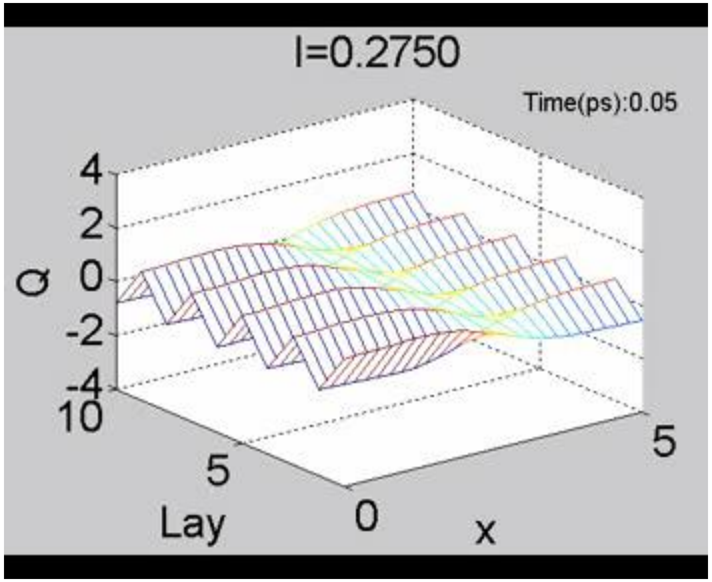

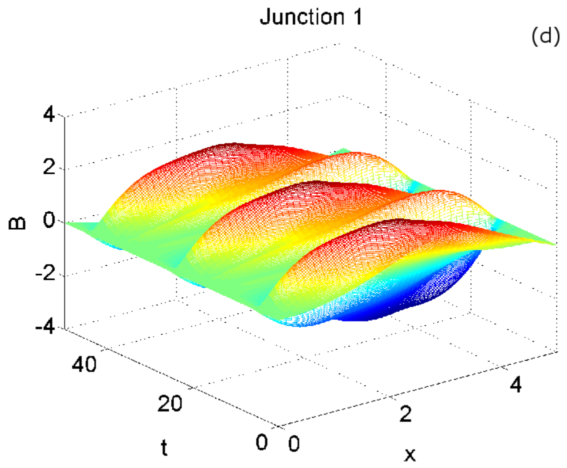

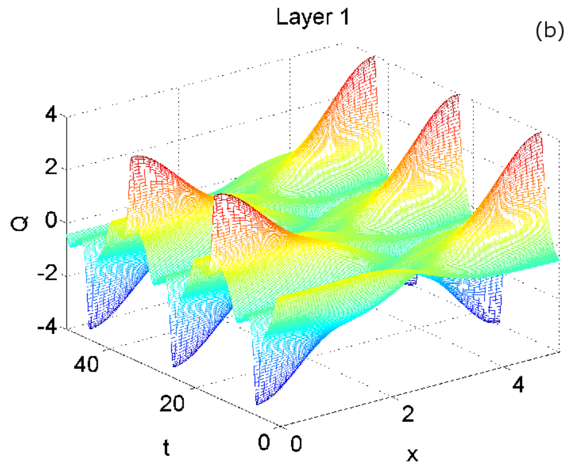

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Charge traveling wave in the stack of long JJ

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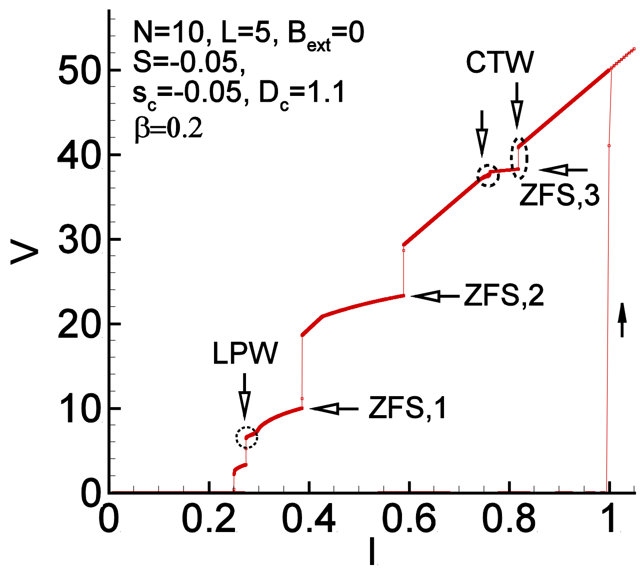
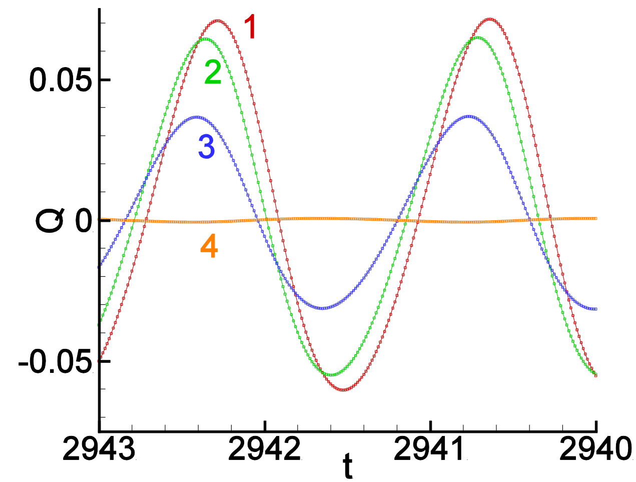
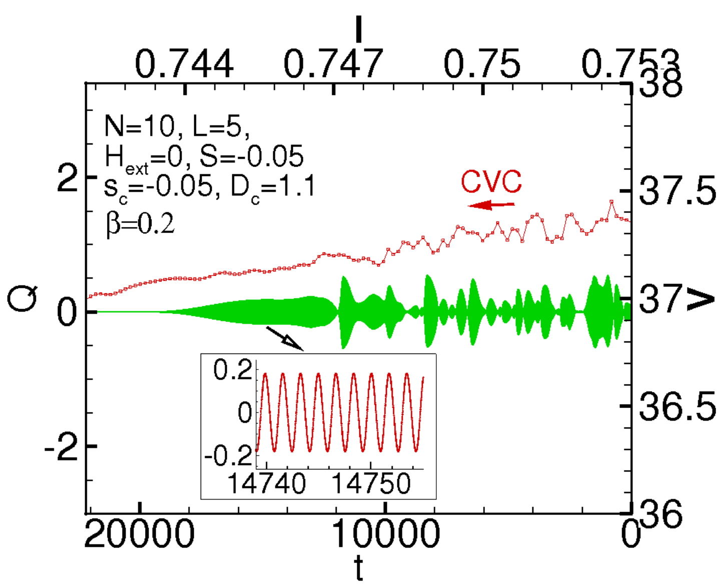
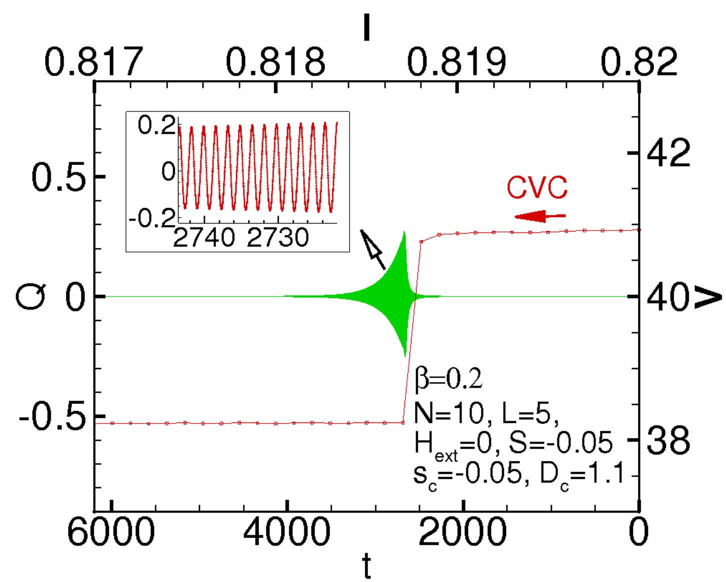
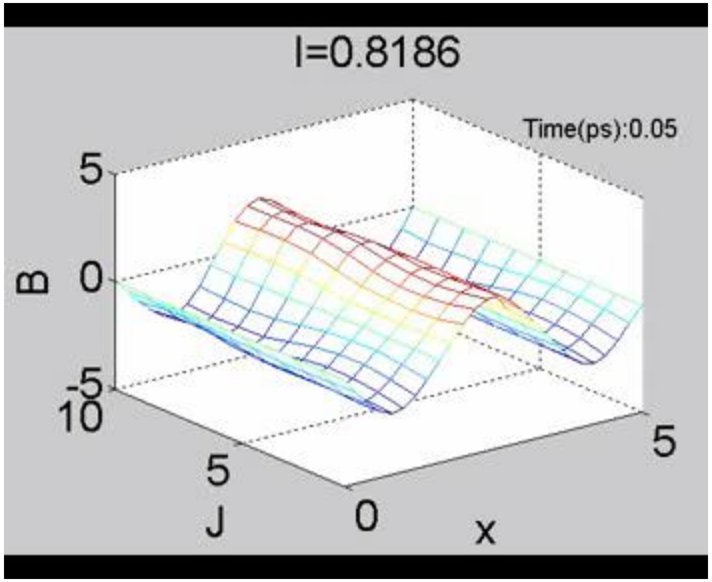


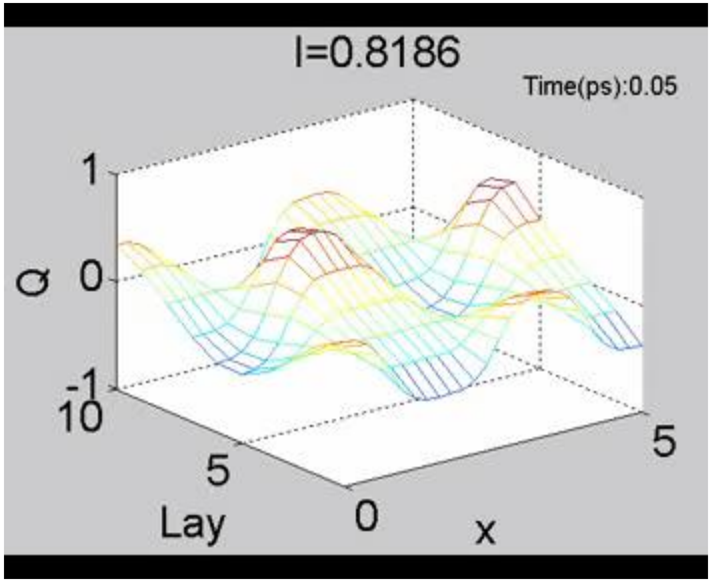


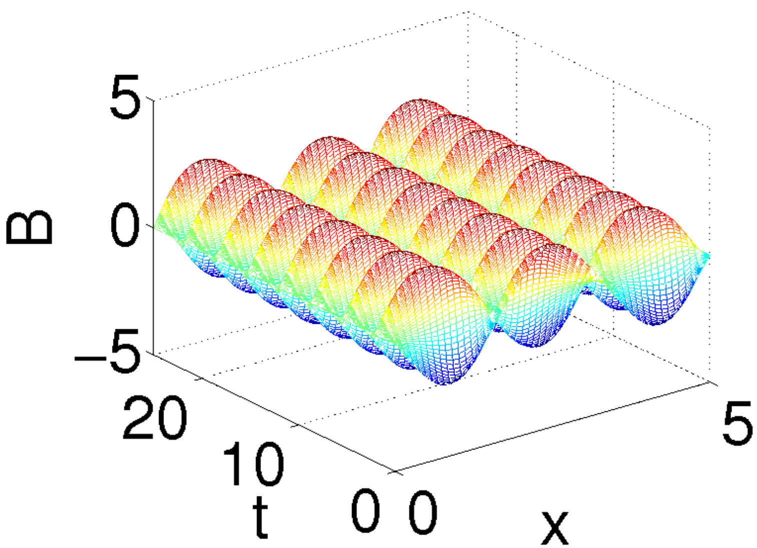


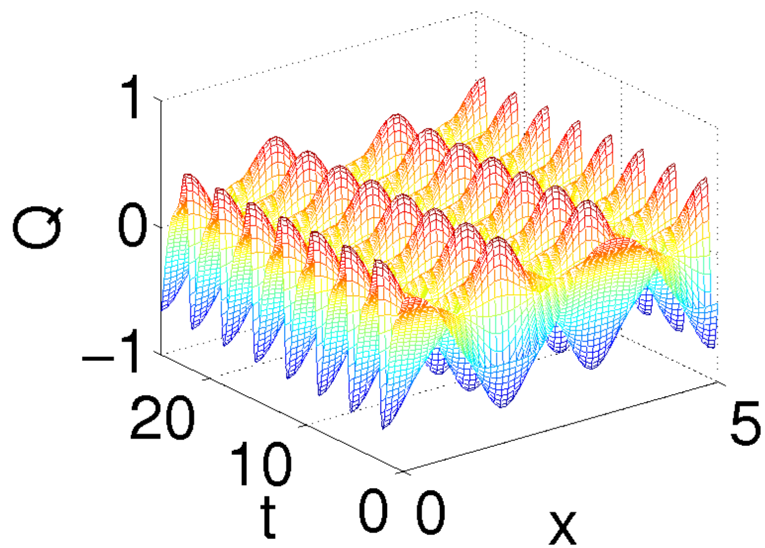


Charge traveling wave in the stack of long Josephson junctions









Conclusions

► **We demonstrate the possibility of realization of parametric resonance in the stack of long Josephson junctions.**

► **In the parametric resonance region observed coexistence of the longitudinal plasma wave and fluxons.**

► **At the border of zero field steps we observe coexistence of the charge traveling wave and fluxons.**

► **This observed behaviors can be interpreted as a new stable collective excitation.**

Thanks for your attention