Switching phenomena and pulsed operation in long Josephson devices

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Group presentation

INTRODUCTION

Non-equilibrium in Josephson junctions is a promising field for future applications involving fast devices designed to interact with optical signals [1,2].

This implies the study of transistor-like devices [3] and bi-stable devices [4] to investigate what is the behavior of Josephson junction subjected to (fast) signals, both electronical and optical, which alter the equilibrium distribution of charge carriers (quasiparticles and Cooper pairs).

Josephson electrodynamics under Fast Pulsed Signals

Model no.1 (Single junction with modulated critical current)

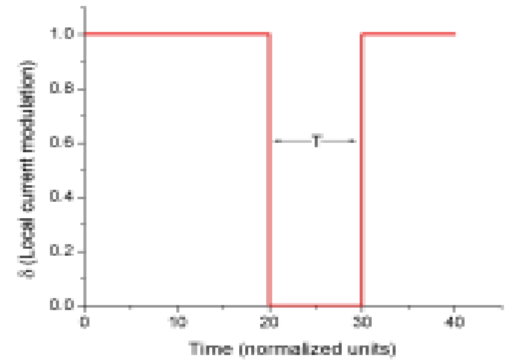
$$\phi_{tt}-\phi_{xx}+\delta(x,t)\sin\phi+\alpha\phi_t=\gamma_B+\gamma_P(x,t)+\gamma_N(x,t) \qquad (1)$$

Model no.2 (Double stack subject to electronic pulses)

$$\begin{aligned}\varepsilon\partial_{xx}\varphi-\partial_{xx}\psi+\partial_{tt}\psi+\alpha\partial_t\psi+\sin\psi+\gamma_P(x,t)+\gamma_N(x,t)&=0\\ \varepsilon\partial_{xx}\psi-\partial_{xx}\varphi+\partial_{tt}\varphi+\alpha\partial_t\varphi+\sin\varphi+\gamma_B+\gamma_N(x,t)&=0\end{aligned} \qquad \textbf{(2)}$$

Driving waveforms

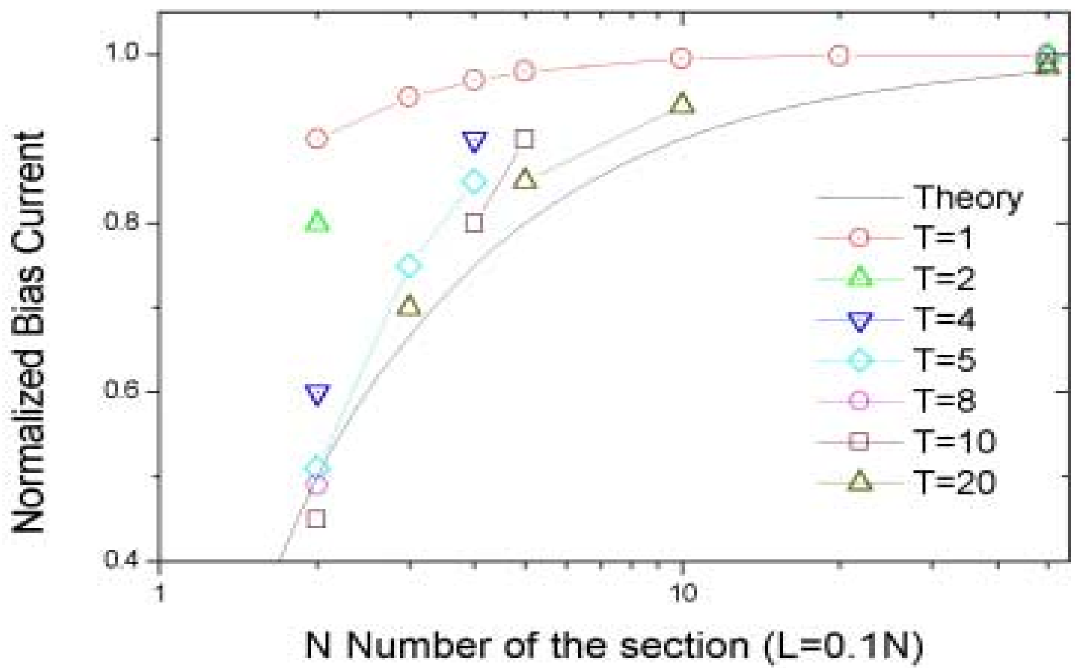
Model no.1 => fast local depression of Josephson current



Model no.2 => electronic pulse trains pumping

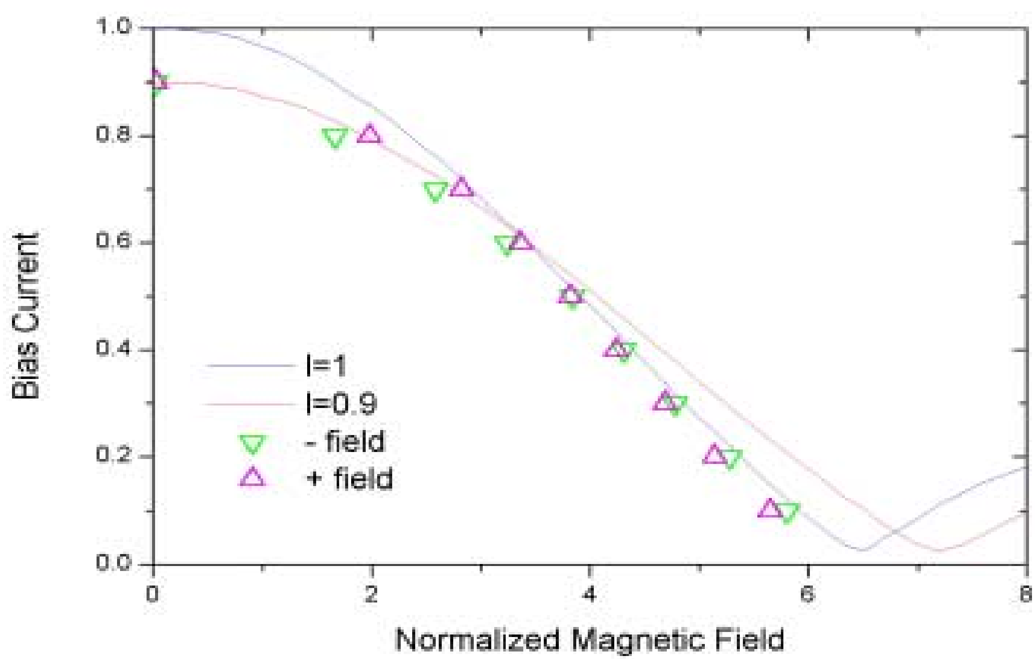
$$\gamma_P(x,t) = \begin{cases} \Gamma h_1\left(\frac{x}{l}\right)\left(\frac{t}{T_1}\right) & for\ 0 \le t \le T_1 \\ \Gamma h_2\left(\frac{x}{l}\right)\left(1-\frac{t-T_1}{T_2}\right) & for\ T_1 \le t \le T_1 + T_2 = T \\ 0 & for\ T \le t \le T_p \end{cases}$$

Model no.1: results



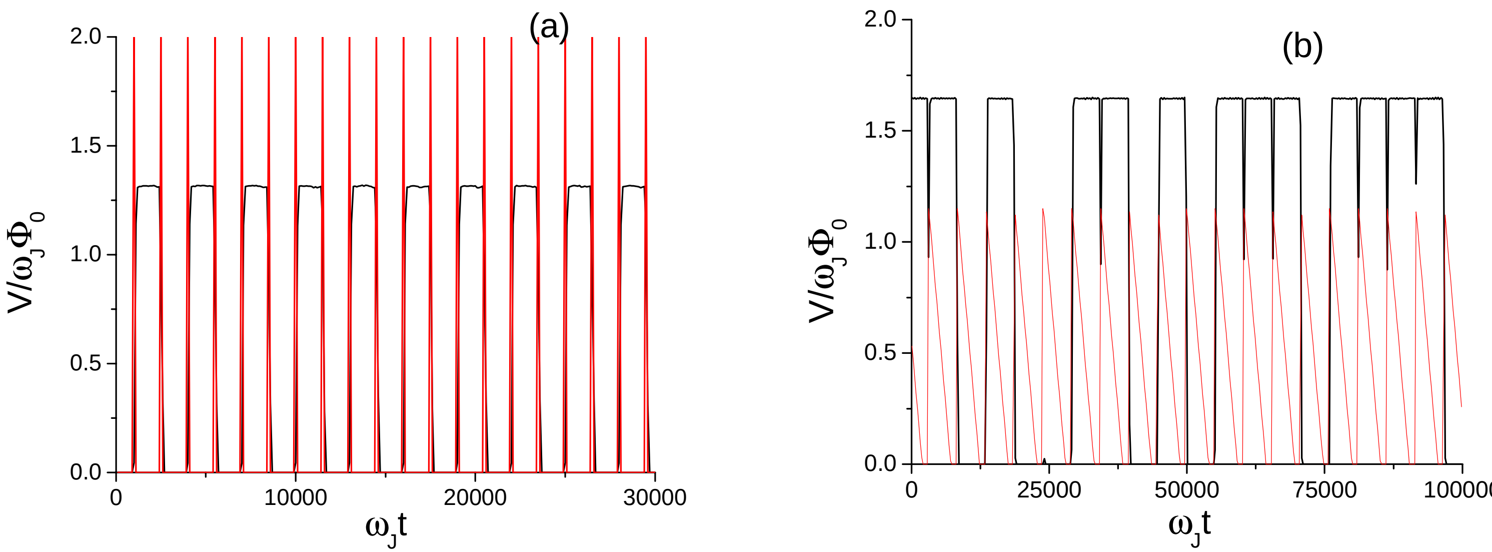
Successful switches to resistive state vs. the junction length of a JJ (overlap) with the Josephson current of an end section of length 0.1 suppressed by a variable time T. The theoretical curve represents the critical current of the reduced length junction γ_c=(N-1)/N. For T>20 there is no substantial change to this picture. For l=5 the difference becomes very small hindering the effect in very small fractions of critical current (1% - 2%).

Model no.1: results



The effect of magnetic field over a JJ of normalized length l=1 with the Josephson current of an end section of length 0.1 suppressed by a time T=10 u.t.. Each point represents the first successful switch over the resistive state. For comparison are shown also the l=1 lobe (blue) and the l=0.9 lobe (red). Field behavior shows also a difference in sign because only one end of the junction is subject to the current suppression.

Model no.2: results: Statistical Flip-Flop SFF

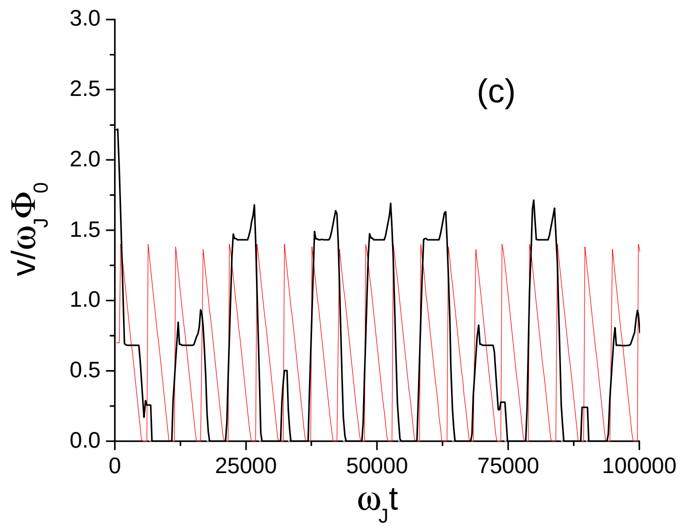


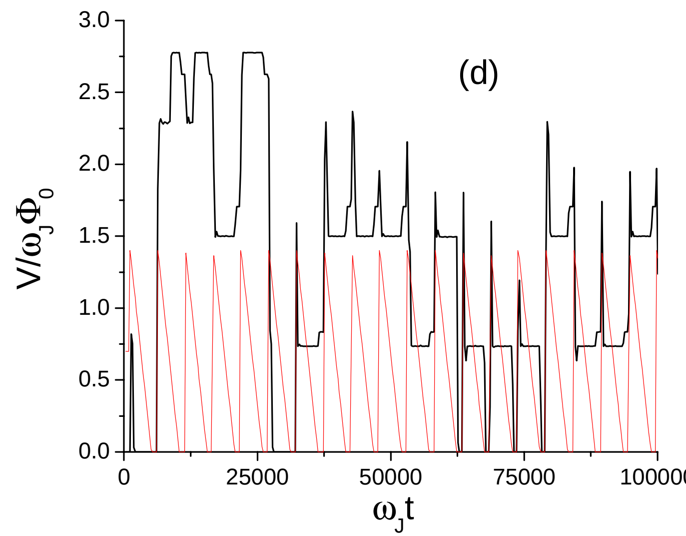
Simulated SFF transitions in different stacked systems:

a) l=1, α=0.15, ε=-0.85, γ_B=0.23, Γ=21, short pulses, T=100 u.t.;

b) l=2.5, α=0.05, ε=-0.2, γ_B=0.0875, Γ=46, asymmetric pulses, T_1=50 u.t. and T_2=2000.

Model no.2: results: Statistical Flip-Flop SFF



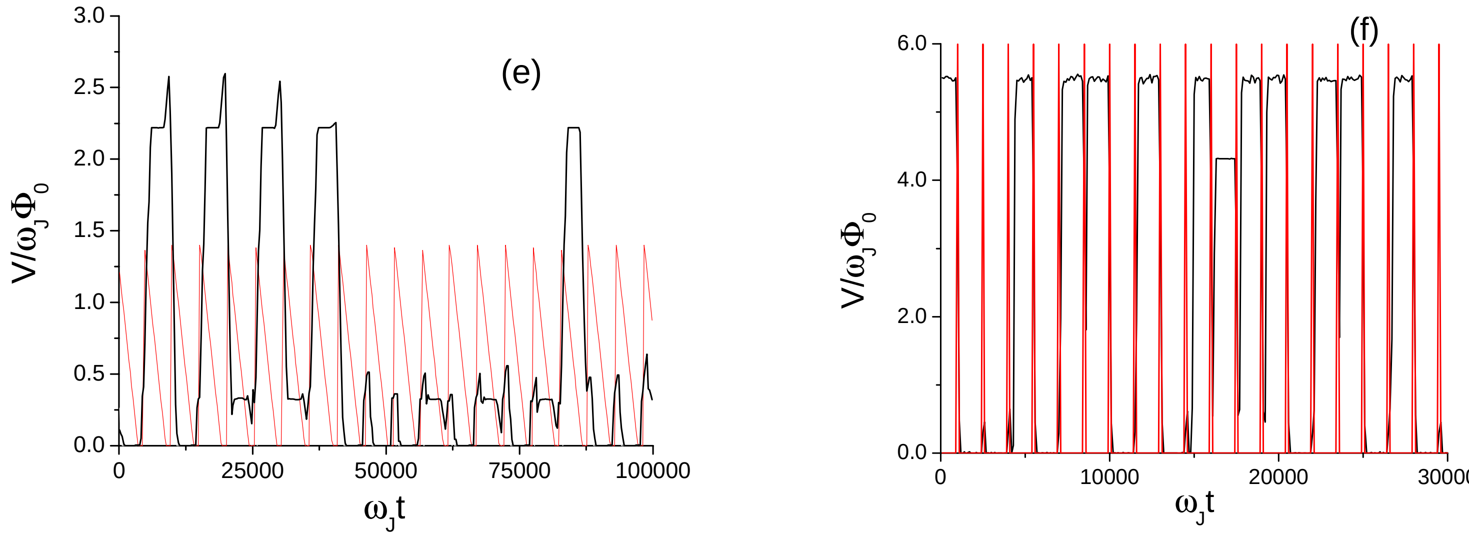


Simulated SFF transitions in different stacked systems:

c) l=5, α=0.1, ε=-0.55, γ_B=0.23, Γ=56, asymmetric pulses with T_1=50 u.t. and T_2=2000;

d) l=5, α=0.1, ε=-0.55, γ_B=0.28, Γ=56, asymmetric pulses with T_1=50 u.t. and T_2=2000.

Model no.2: results: Statistical Flip-Flop SFF

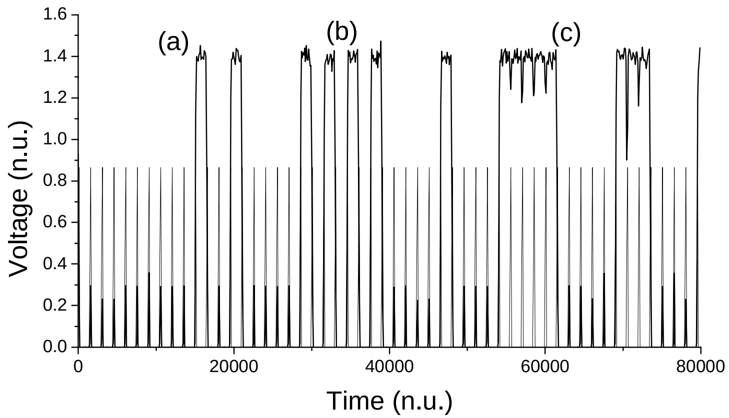


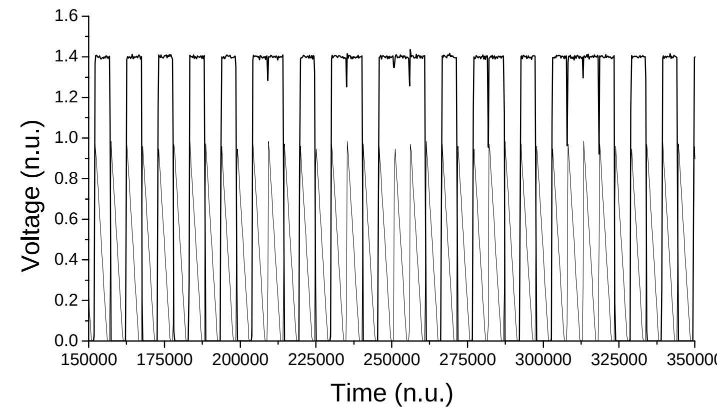
Simulated SFF transitions in different stacked systems:

e) l=5, α=0.1, ε=-0.55, γ_B=0.28, Γ=56, asymmetric pulses with T_1=50 u.t. and T_2=2000, magnetic field at boundary η=1.0;

f) l=2, ω_g=8ω_J, ε=-0.55, γ_B=0.18, Γ=60, triangular short pulses with T=100 u.t. some instability and also an intermediate state occurs due to low dissipation under the gap. This last is modeled via a patchwork model as in Ref.[9].

Model no.2: results: Statistical Flip-Flop SFF



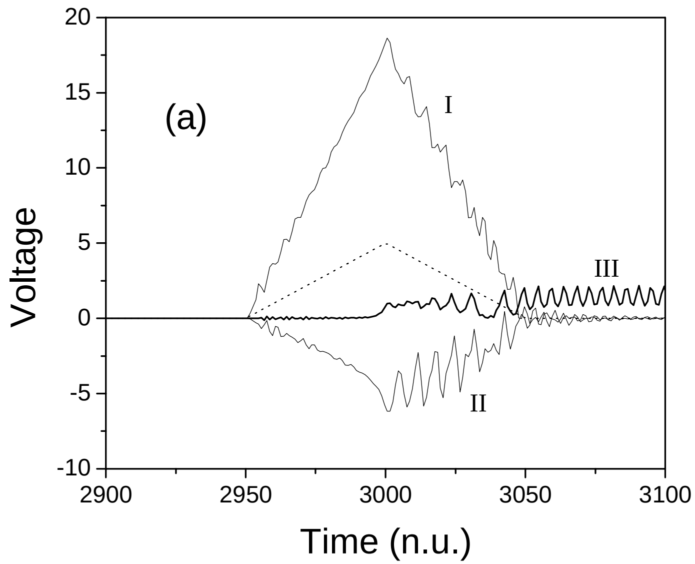


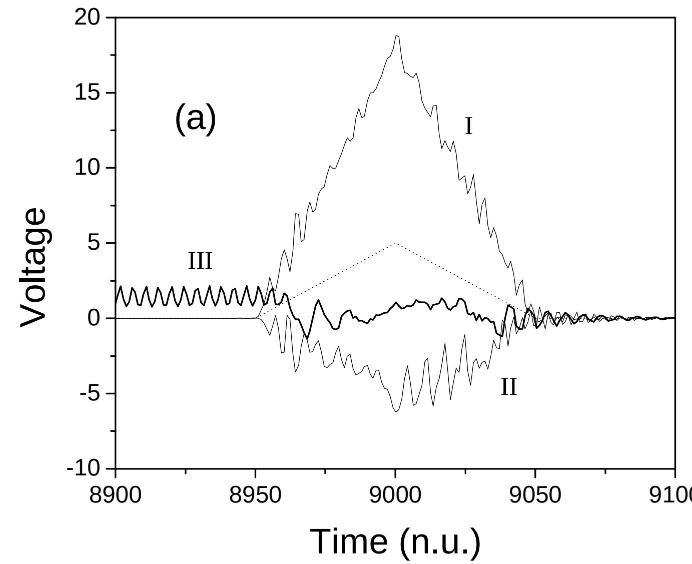
Simulated SFF transitions in different stacked systems:

e) l=2, α=0.1, ε=-0.3, γ_B=0.145, Γ=50, symmetric pulses with T=100 u.t.;

f) l=2, α=0.1, ε=-0.3, γ_B=0.155, Γ=50, asymmetric pulses with T_1=50 u.t. and T_2=1500.

Model no.2: results: Dynamics of switching

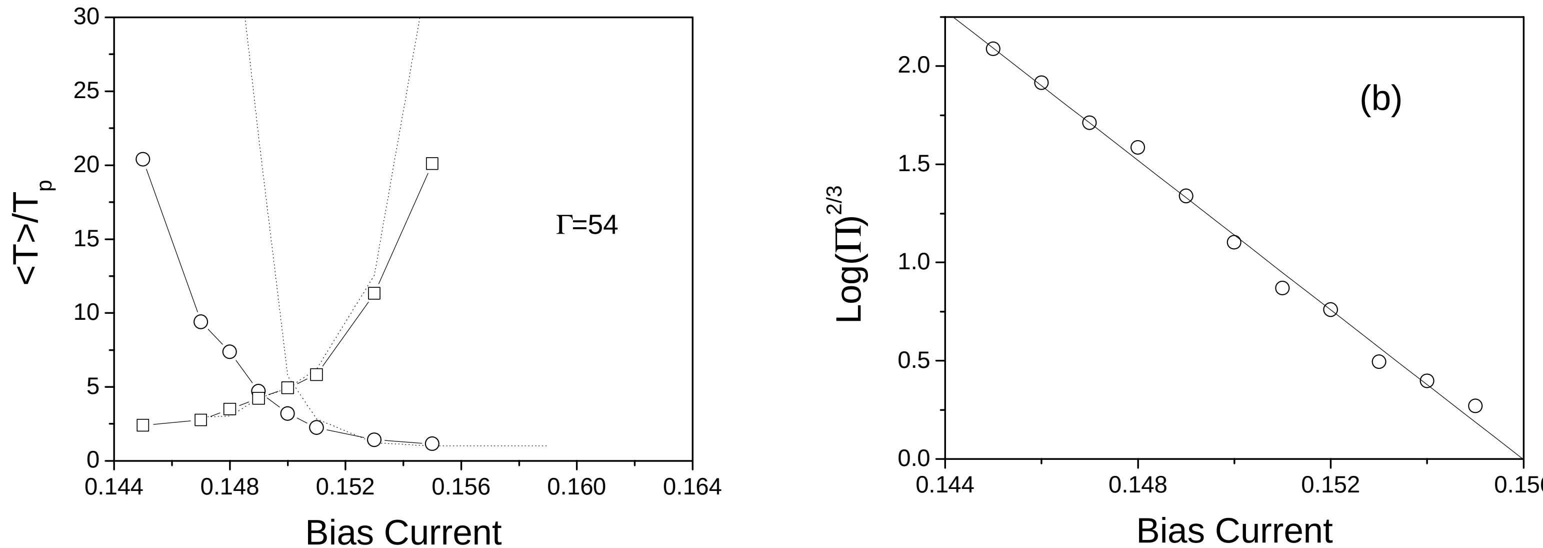




Switching dynamics in a stacked with I=2, ε=-0.26, α=0.1, T=4.2 K

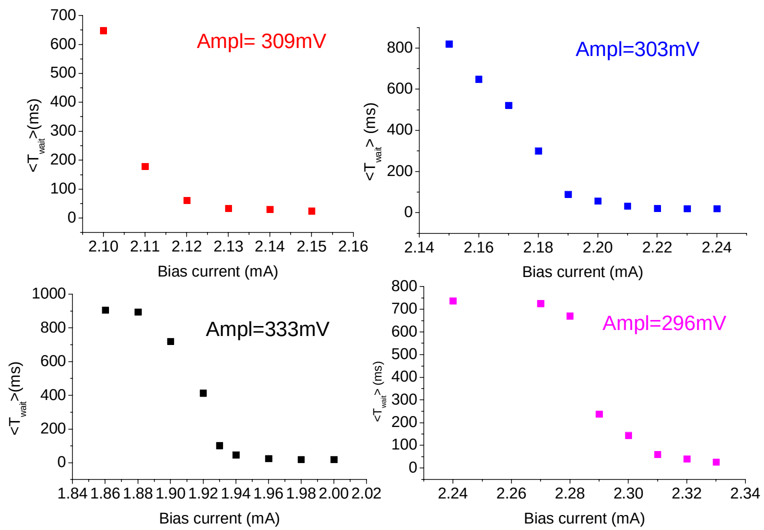
Model no.2: results: Thermal Lifetimes

There are evidences that pulsed assisted escape from zero voltage is very similar to standard thermal escape [5]) on the other hand the reset pulse appears related to the non-linear dynamics effects involved in Eq.s (2).

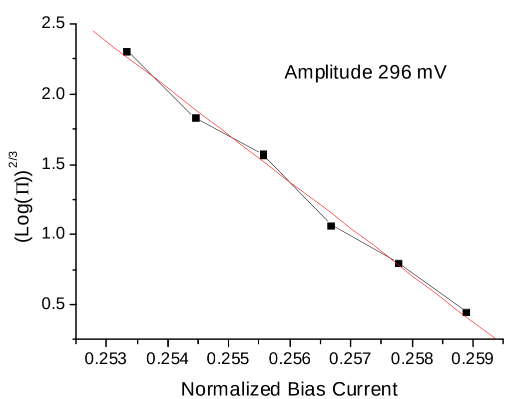


Average lifetimes and logarithmic escape rate in a stacked with /=2, ε=-0.26, α=0.1, T=4.2 K (T=1 K dotted line)

Model no.2: some experimental result



Lifetimes for
Different amplitudes



Thermal regime analysis

Conclusions

Several experiments have been devised to demonstrate SFF in different devices (cf.Ref.[4,5,6,8,9]).
We note that the possibility of having long deterministic flip-flop series is again to be proved.
Progress in obtain a deterministic FF have been made using magnetic control line as reported in [6] (see SATT11 Poster Session B, R.Latempa et al.).

More promising appears the possibilities of use ultrafast (20 ps to 100 fs) laser pulses to pump detector junctions away from zero voltage state for the developing of a fast opto-superconducting electronics.

Acknowledgements

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