Dear Mrs. Catherine Werner,

I would like to present a Final Report on the exchange grant

"Influence of lateral vibration on the mechanism of nanoscale friction"

Reference number: **149**

in frame of which my research visit to Tel Aviv University (groups of Profs. J. Klafter and M. Urbakh) for two months in April-June, 2004 is supported.

Sincerely yours,
A. Filippov

Final report
to the exchange grant
" Influence of lateral vibration on the mechanism of nanoscale friction"

A.E. Filippov1, J.Klafter2 and M. Urbakh2

1Donetsk Institute for Physics and Engineering of NASU, 83144, Donetsk, Ukraine,
2School of Chemistry, Tel Aviv University, 69978 Tel Aviv, Israel.

The grant has been awarded for a financial support of the research visit of Prof. A. E. Filippov (Ukraine) to Tel Aviv University (groups of Profs. J. Klafter and M. Urbakh) for two months in April-June, 2004.

During the visit we studied the effect of lateral oscillations of the cantilever on friction. The main goal was to treat theoretically an effect of reduction of friction which has been observed experimentally (Phys.Rev. Lett. 91, N 084502 (2003)). We started from a consideration of 1D model that describes an externally driven motion of AFM tip under the application of external oscillations and focused on the relationship between surface diffusion and macroscopic frictional dynamics.

In particular, we investigated diffusion properties of the system with periodic cosine potential under the influence of lateral oscillations at different combinations of the parameters. As result, complete 2D maps of the diffusion coefficient in the plane amplitude-frequency have been obtained. These maps are shown in the Figs.1a and 1b for the simulations performed at presence and without normal motion (in z-direction, which is orthogonal to a surface) respectively.

The regions where a significant enhancement of the effective diffusion appears have been found. The enhancement takes place when the oscillation amplitude and the frequency are appropriately chosen to force the "particles" (representing statistical realizations of the of AFM tip position) systematically visit a vicinity of maximums of the periodic potential. It causes a divergence of the trajectories even at very weak random noise. As a result, the system intensively reacts on the external force fext . Typical distribution of the trajectories in such a resonance regime is presented in the Fig.2a - b

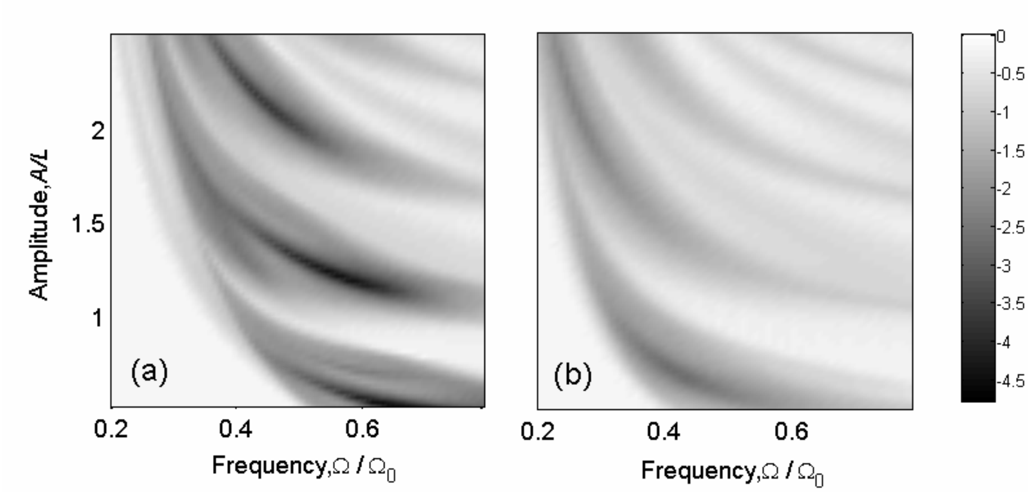


Figure 1. Gray-scale maps of the diffusion coefficient at presence (b) of normal motion respectively.

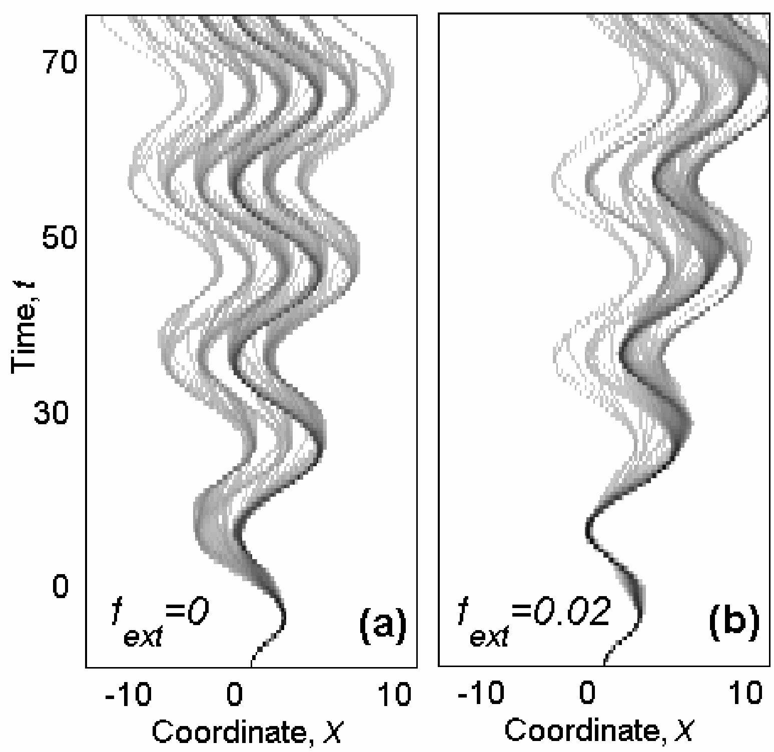
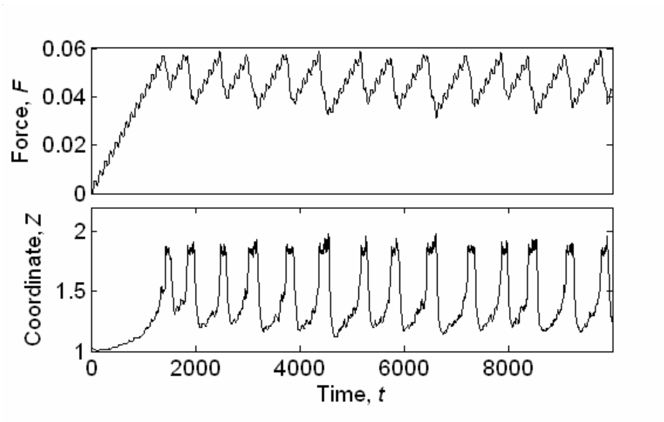
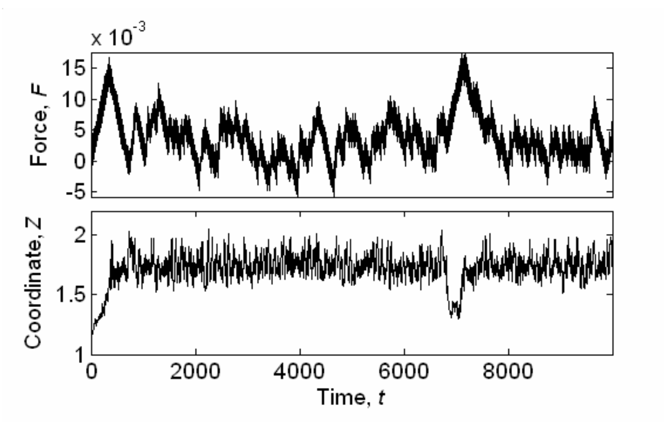


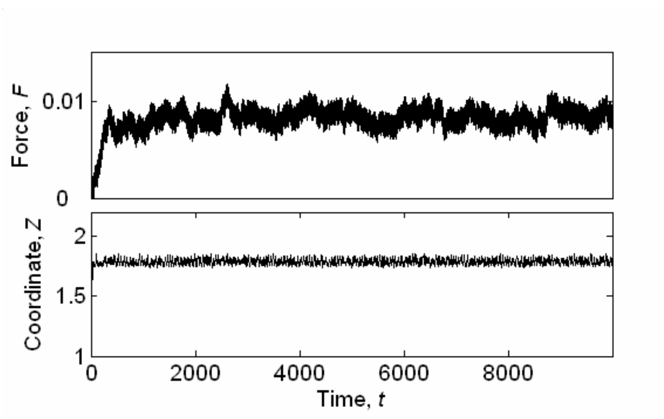
Figure 2. . Typical distribution of the trajectories in a resonance regime at zero (a), and nonzero (b) external force respectively.



(a)



(b)



(c)

Figure 3. Typical time series for the frictional forces and normal to the surface z-coordinate obtained for the lateral oscillations with the frequencies lower (a), higher (c) and close (b) to the resonance reduction of friction. The bold black line corresponds to the time-averaged difference between maximal and minimal force at zero and nonzero external force respectively.

One can check that the process is equivalent to normal diffusion with a giant effective diffusion coefficient. The width of the "trajectories" in the Fig.2 gives an estimation for the intensity of random noise (temperature), which is responsible for a normal impact to the diffusion.

Using these observations we performed an investigation of the dynamics of friction in the described system for different combinations of the frequencies and amplitudes of the oscillation. It is proven that at resonance conditions the giant diffusion effect is accompanied by a significant suppression of friction. Some typical variants of the time behavior are shown in the Figs.3 a-c.

During the visit we have studied these phenomena in details. We have calculated the dependence of the mean frictional force on frequency and amplitude of lateral oscillations for a wide range of system parameters

In particular, we considered in details the coupled lateral-normal motion of the AFM tip under the application of lateral oscillations. It is found that for a given normal load lateral oscillations will lead to an increase of a distance between the tip and the surface, and as a result influence essentially the frictional response. Corresponding distributions of the z-coordinates are presented in the Fig.4

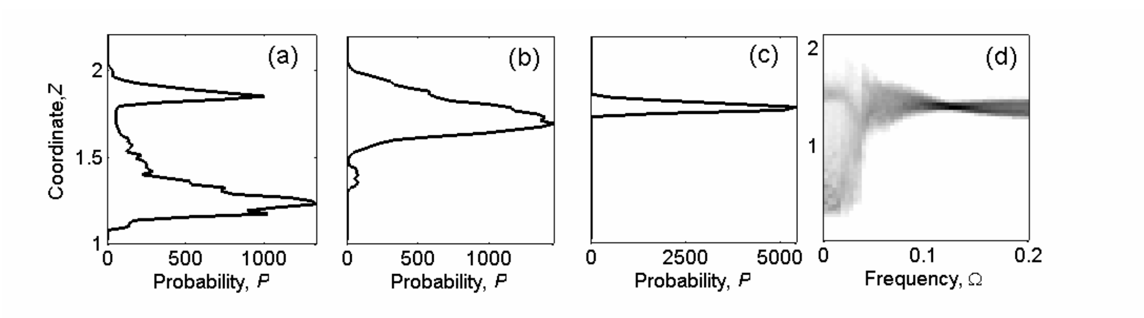


Figure 4 . Typical distributions of the distributions of the z-coordinates calculated for the same frequencies as in the Fig.3 are shown in the subplots (a)-(c). Complete distribution of the z-coordinate at different frequencies is presented in (d) by a gray-scale map.

We expect that the performed research will stimulate the development of new experimental methods to control and modify dynamics of friction applying external oscillations.

The results of this study are summarized in an article which we plan to publish in one of the international physical journals.