Poster

TOWARD CONTROLLED SURFACE MANIPULATION AT THE NANOMETER SCALE BY ATOMIC FORCE MICROSCOPY

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The controlled manipulation and surface modification at the nanometer scale is a subject of great importance for scientific and technological applications. Although different nanomanipulation methods have been proposed, systems based on scanning probe microscopy offer the most versatile approach due to its high positioning precision and the high aspect ratio of the tip. Among them, the atomic force microscopy (AFM) has the widest range of application, both for imaging and manipulation [1]. However, standard AFM systems present some restrictions. The working areas are small and the operating speed efficiency is low. Additionally, the operation of the AFM during manipulation using standard methods is limited to straightforward manipulation without possibility to perform online control of the manipulation process.

To enhance and expand the capabilities of the AFM for manipulation we have developed a combined system [2]. In this system, we conjugate an AFM for high resolution imaging and manipulation with video microscopy and non-contact ablation by an ultraviolet (UV) microbeam laser for large scale manipulation of biological specimen. In Figure 1, the combined system is depicted. To control the manipulation process we use two different approaches. The first one is to give control of the system to the user through a haptic interface, in our case, a force-feedback joystick [3]. The second approach is the *offline* operation of the AFM, setting *a priori* the manipulation parameters. To improve the manipulation perfomance it is necessary to investigate the real-time control of manipulation forces.

Actually there is a lack of understanding of the system dynamics governing the interaction of the AFM cantilever and nanoscale components. This is not a trivial issue considering the fact that the AFM cantilever is a distributed system and its interaction with a surface presents a high non-linear character. The knowledge of the tip-sample interaction is a critical issue for the control of the manipulation process. To solve this problem, the application of modern system control theory offers a very interesting approach. A study of the theoretical transfer function based on the distributed model of the freely vibrating cantilever is needed in order to know which control methods can be applied to the system [4]. A realistic state space description of the AFM cantilever interacting with a surface allows the use of modern system control for nanomanipulation applications.

We have obtained the transfer functions for different system inputs and outputs acting on the cantilever: a) point force acting on the tip of the cantilever (Figure 2 shows the frequency response of the system); b) distributed linear force; c) cantilever base excitation; d) electrostatic excitation of the cantilever. The zeros dynamics obtained from the transfer function are analyzed to obtain the optimal configuration for control of the AFM during manipulation.

Additionally, an observer based on the state-space description of the AFM [5] has been developed to obtain a real-time estimation of the transient force applied by the AFM cantilever on a surface. The obtained observer can be applied for nanomanipulation to optimize the process by the regulation of the estimated transient force.

References:

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[5] R. W. Stark, G. Schitter, M. Stark, R. Guckenberger, A. Stemmer, Physical Review B, **69** **(8)** (2004) 085412.

Figures:

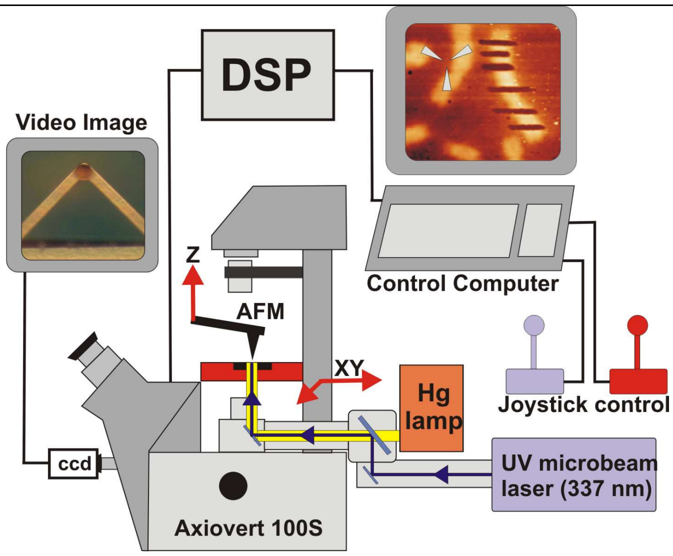

Fig. 1. Diagram of the nanomanipulator combining non-contact laser ablation, AFM, video- microscopy and robotic control.

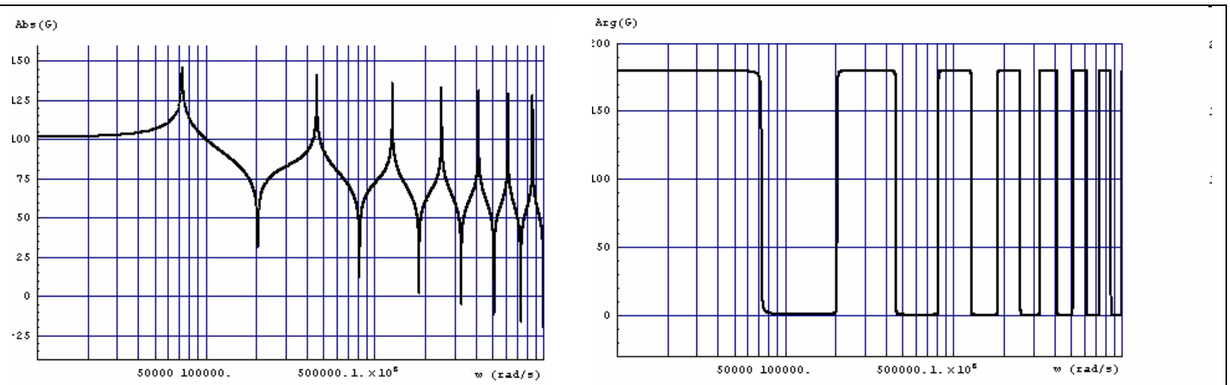

Fig. 2. Frequency response of the cantilever deflection to a force acting at the end of the cantilever obtained from the theoretical transfer funtion.