13 Physics of Biological Systems

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This project is currently in the process of being established. It is devoted to employing physics tools and concepts to understand and modify molecular objects with a main emphasis on the physics of biological systems. Questions related to Structural Biology and the interfacing of bio-molecules with silicon microstructures to obtain novel physical objects that exhibit new and useful properties are among the central themes of our efforts.

Our electron point source exhibits unique properties in respect to brightness and coherence. We employ the coherent electron waves to image and manipulate bio-molecules in a lens-free holographic microscope, that we named the LEEPS (Low Energy Electron Point Source) microscope.

The low energy of the electrons, although a great benefit in avoiding radiation damage as commonly observed in conventional electron microscopes, makes this tool also susceptible to external ac-magnetic fields and building vibrations. In order to achieve optimal resolution, well below the nanometer regime, the coherent electron waves have to be protected from external disturbances. Construction work for a suitable laboratory environment is presently planned and we expect that the beginning of the winter-semester 2000 completes it.

The holographic record of an individual molecule contains the complete information about the amplitude and the phase of the object wave and it is thus possible to gather 3-dimensional information about the object. In collaboration with scientists from a CNRS laboratory in Marseille, we plan to develop a fast numerical algorithm for the hologram reconstruction to obtain the full object information during the experiment in an on-line modus. With this, a proper constructed laboratory environment and a newly designed electron detector, we expect to be able to routinely address questions of structural biology. One of the important goals will then be to work on appropriate sample preparation methods in collaboration with colleagues from the biochemistry department of our University to obtain structural details on specific proteins.

In-situ studies of the growth of clusters on carbon nanotubes, their charging properties as well as the direct observation of the dynamics of charge hopping processes in quasi insulating bio-polymers are other topics of our current interests.

We could recently obtain the first direct evidence for the electrical conductivity of DNA molecules, which has triggered quite some expectations to use DNA molecules in molecular devices. At the March meeting 2000 of the American Physical Society, there is a special session on DNA conductivity and a related press conference on possible future DNA based electronic devices. While we will not be in the position to employ sophisticated silicon technology, we still plan and hope to maintain a leading role in this emerging field since we have the unique ability to actually see the "DNA-wires" on a device. In view of silicon device fabrication, we are assured of the assistance of the mesoscopic physics groups at the University of Basel as well as of the ETH Zrich. A small biotechnology company in Jena has recently offered its assistance in providing us with partially structured membrane chips that they produce specific to our needs by optical lithography. The final structuring of the membranes on a sub-micron scale, the arrangements of the DNA molecules and the contacts to them should then take place in our laboratory once we shall have an ion-milling instrument available.

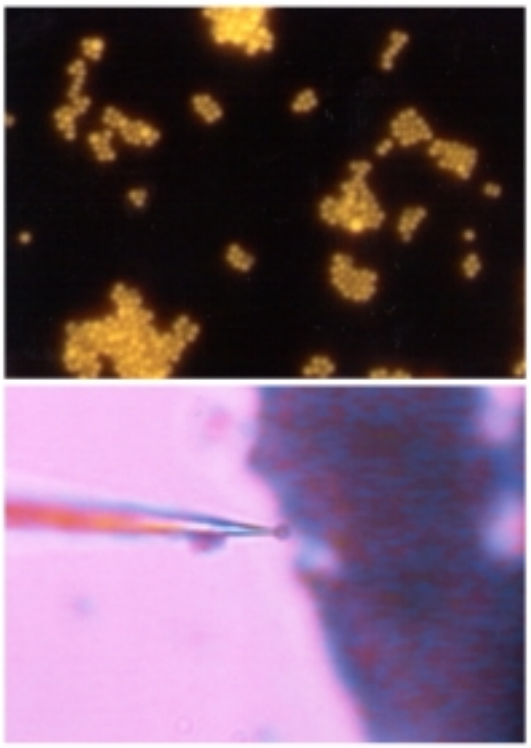

Figure 13.1: Light optical microscopy images of one-micron diameter fluorescent latexspheres clustered on a silicon nitride membrane (top). Manipulation of a single latex sphere with a glass pipette (bottom). At a later stage, the latex spheres should be attached to the end of DNA molecules via a biotin streptavidin bond. The mechanical manipulators will then be used to move the spheres (and the "invisible DNA) to the desired places on the membrane. Holographic imaging of the DNA and electrical measurements will subsequently be carried out in the LEEPS microscope.

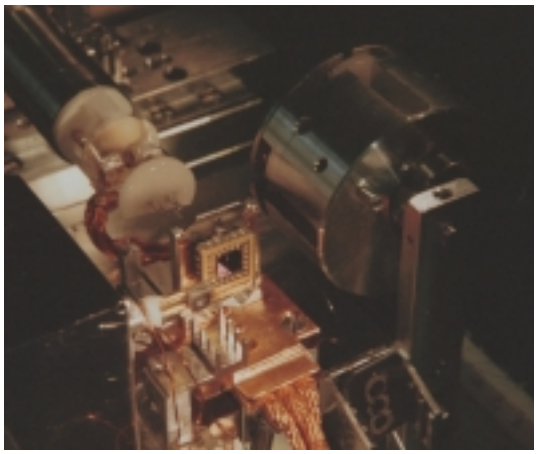

Figure 13.2: Inside view of the Low Energy Electron Point Source (LEEPS) Microscope for imaging and manipulating individual molecules.