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November 2005

Fabricating 3D Microstructures and High-Resolution Imaging Using NI LabVIEW

Author(s):
Mr. Michael Ross Vanner, Dr. Martin Straub, and Prof. Min Gu
Centre for Micro-Photonics, Swinburne Univerisity of Technology

Industry:
Research, University/Education

Product:
GPIB & Instrument Control, High-Speed Digital I/O, LabVIEW, PXI/CompactPCI

The Challenge:
Controlling a piezoelectric nanopositioning stage for 3D microstructure fabrication and photon-counting optical tomography.

The Solution:
Using National Instruments LabVIEW software to develop an efficient 3D scanning program with a convenient graphical user interface.

3D Polymer Microstructure Fabrication and Low-Light Level Optical Tomography

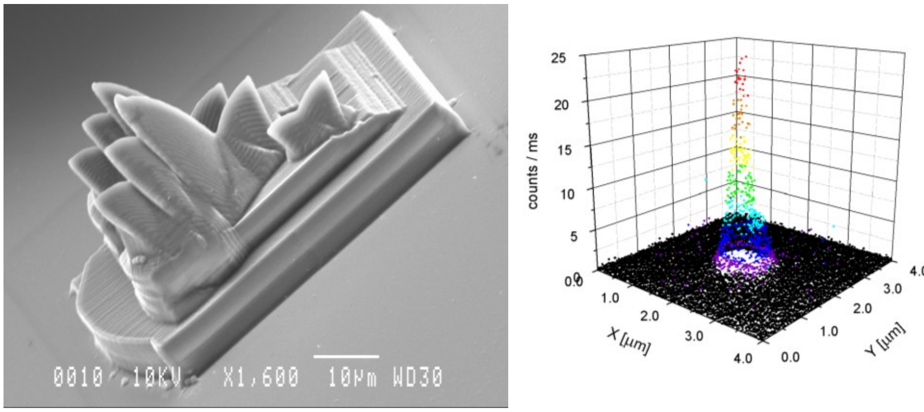
Complex-shaped, 3D microstructures have recently received a significant amount of attention within, as well as beyond, the scientific community because of the promise they hold for exciting new applications in a variety of areas.

These structures may serve as mechanical or optical microdevices in micro environments or even nano environments. For instance, diagnosis or surgery inside the human body may become more efficient because of micromovers and pumps that can interact on the cellular level.

In addition to mechanical characteristics, these structures can be fabricated to have interesting optical properties and can be used as photonic devices in such applications as telecommunications and optical information processing.

We fabricate these structures by scanning a liquid of monomers and oligomers through a high-intensity laser focus, where the polymerization reaction solidifies the material, building a solid polymer structure along a preprogrammed pathway.

Observing the fluorescence of a sample in 3D at high resolution permits researchers to obtain information in many experiments, from biology to physics. Low-light-level applications – for example, observing processes in living cells – are particularly challenging. We used National Instruments hardware and software to fabricate these photopolymer microstructures.



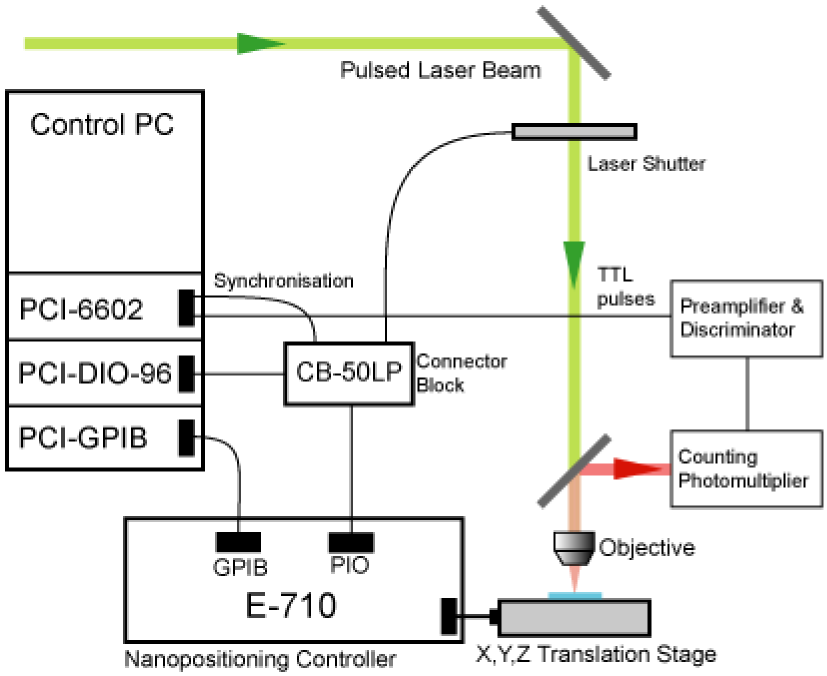
Micromodel of the Sydney Opera House viewed with an electron microscope at 1600 times magnification, fabricated using LabVIEW (left). Fluorescence from a CdSe nanocrystal moving through a cross section of the focal spot of a tightly focussed 560 nm-laser light (right).

Our solution uses a photomultiplier tube to collect the light and generates pulses upon photon-capture events. We use a National Instruments PCI-6602 counter/timer, which has a sufficiently high count rate, to count pulses. We then use NI LabVIEW to process count rates to generate images of the object under scrutiny.

We use an NI PCI-DIO-96 digital I/O board to communicate positioning data to the stage controller and provide trigger signals for the laser shutter, and we use an NI PCI-GPIB board to transfer command strings. With the PCI-6602 counter/timer, we can count pulses from a photon-counting photomultiplier simultaneously with the translation stage movement.

Digitally Controlled Nanopositioning Using the PCI-DIO-96

Custom-built LabVIEW software running on the control PC communicates with a Physik Instrumente E710 digital translation stage controller and a mechanical laser shutter. This involves both ASCII and binary data, which is sent via the PCI-GPIB and the PCI-DIO-96 boards, respectively. We use the ASCII commands to initialize the controller and set experimental parameters such as the scanning velocity. The positional information is sent as 16-bit digital data, along with three address lines and three control lines, which communicate to the controller via the PCI-DIO-96.



Set-up for LabVIEW controlled microstructure fabrication and photon counting imaging in three dimensions. Note the three National Instruments PCI boards and their connections to the nanopositioning controller, the shutter, and the photon detection equipment.

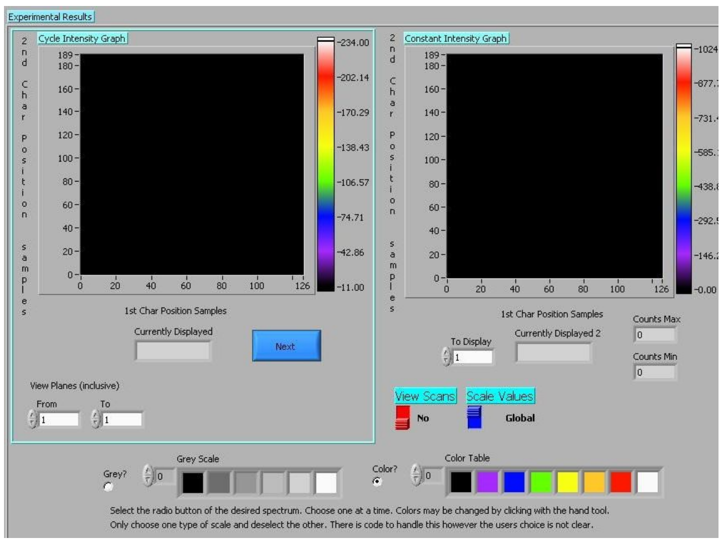
We configure the board ports as input/output as necessary during the beginning of the program. These settings remain unchanged for most experiments. To issue a movement command, we change the signal levels on the control lines according to specific timing diagrams to latch the address of the axes and the coordinates. The PCI-DIO-96 board also controls the laser shutter, which opens or closes given a TTL input, controlling exposure of the sample to the laser light irradiation. This process must be regular and reliable or microstructures strongly degrade.

3D Imaging at Low-Light Levels Using the PCI-6602 Counter/Timer

A more sophisticated version of our nanopositioning program combines 3D movement capability with synchronized acquisition of fluorescence photon count rates measured at each point, or pixel, for a predetermined dwell time. We use the first three of eight counter channels on the PCI-6602 to count photon-capture TTL pulses, provide an accurate pulse train, and monitor movement latching. This hardware gating pulse train with a period of the pixel dwell time gives consistent dwell time quoted with accuracy to the nearest microsecond. This provides an external source to trigger movement, eliminating software delays. The PCI-DIO-96 polls an optimized integer number of the gating periods, depending on the pixel size, to provide a precise delay to complete the movement.

Because scans often involve many thousands of points, minimizing the processing time for each point becomes essential, so we employ the PCI-6602 internal buffers. Both buffers operate in a cumulative manner and need to be processed at each scan completion. The first of these buffers stores the fluorescence count rates, while the other verifies that movement occurred during the correct gating period, ensuring the observed count rates correspond to correct translation stage positions.

We implement three scanning techniques – count rate acquisition in a line trace, raster planar scanning, and a volume scan. We display results on a scatter plot or color intensity chart as well as write them to data files for later manipulation.



Section of the control panel of the imaging software. Some of the numerical controls can be seen to the bottom part of the image. The two large panels allow for a comparison of two-dimensional scans in different planes.

In an ever-changing experimental physics environment, National Instruments hardware and the LabVIEW graphical programming language helped us conveniently develop control systems for microfabrication and imaging. We easily modified interfaces and programs, which we developed much quicker than some earlier work in the line-by-line code C.

For more information, please, contact:

Prof. Min Gu
Centre for Micro-Photonics
Faculty of Engineering and Industrial Sciences, Mail 38
Swinburne University of Technology, PO Box 218
Hawthorn, Victoria 3122
Australia
Tel: +61-3-9214 8776
Fax: +61-3-9214 5435
E-Mail: mgu@swin.edu.au