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# X Ray Microimaging by Diffractive Techniques

## Progress Report

The first year of the research program resulted in significant progress on several fronts. We had a rapid start, because the soft x-ray undulator beamline, X1A, at the National Synchrotron Light Source became operational shortly before the start of the grant period.

In **microimaging by diffraction**, Dr. David Sayre was successful in recording moderately large angle diffraction patterns from single diatom specimens. The patterns (Fig. 1) correspond to information down to the 70 Angstrom level, and are by far the best achieved to date. To obtain these, a new diffraction camera was constructed and commissioned. It features a multiple pinhole collimator to define a 10 micron diameter beam, and an alignment system to position the 2 micron specimen within it.

The diffraction patterns were presented by Dr. Sayre at the annual meeting of the American Crystallographic Association during his talk as recipient of the Association's Fankuchen Award. Dr. Sayre has also been invited to discuss recent progress on the project during the upcoming ACA annual meeting in New Orleans.

Recent efforts have been aimed at two aspects of the diffractive imaging problem: One of these is an effort to improve the signal/background ratio in the recorded pattern. Background

is partly due to fog on the film, and is more serious on the soft x-ray film we must use, because the lack of protective coating results in some grains being activated by mere handling in the packaging process. To reduce its effect, the specimen-film distance has been reduced, and a program has been started to reduce or eliminate fog from the film. The other study is to isolate radiation damage effects. Vycor glass is a spongy material with structure on any length scale desired. It will serve as a radiation resistant control against which to measure the deterioration of high resolution data of biological materials. Micron size particles of vycor have been obtained from Merrill Shafer at IBM, and their diffraction patterns are about to be recorded. Both of these efforts point in the direction of the ultimate goal, which is a reconstructed image at or as close as possible to the theoretical limit of half a wavelength.

In **Fourier transform holography**, graduate student Ian McNulty constructed and commissioned a cooled CCD camera. The optics and camera design, and the first patterns to be recorded with the apparatus were the subject of a paper, presented at the National Conference on Synchrotron Radiation Instrumentation in Berkeley last August (see Appendix). This paper will be published in Nuclear Instruments and Methods. Since that time the CCD detector has been improved considerably, going from thermoelectric to liquid nitrogen cooling, and from in-house to professional deposition of the phosphor coating. Present efforts concentrate on improving stability against thermal drift in order to obtain the highest quality holograms. The latest holograms

(Figure 2) show the expected rich fringe pattern over most of the detector area, and hold considerable promise for reconstruction. In this work the reference wave is generated by a Fresnel zone plate, fabricated by Dr. Erik Anderson of the Center for X-ray Optics, Lawrence Berkeley Lab, working with Dr. Dieter Kern at IBM.

Dr. Shawn Williams joined our work in September as postdoctoral associate. He did his graduate work on chromatin, and since his arrival has been working on the development of chromosome preparations as specimens for high resolution imaging.

Under his subcontract, Dr. Malcolm Howells has been carrying out studies on the possibilities of ultrahigh resolution recording media and has identified some realistic candidate materials on the basis of reported electron beam experiments (in the 1 - 5 nm range) and theoretical considerations. We are preparing to test these at the X1 beamline. Dr. Keith Nugent spent 3 month at LBL on leave from the University of Melbourne with support from the grant. He stimulated significant improvements in the holographic reconstruction procedure used by Howells and Dr. Chris Jacobsen from Stony Brook, particularly with regard to suppressing twin-image noise in in-line holograms.

Our program for the second and third years of the grant are unchanged from the original proposal. We propose to continue to work on the development of high resolution diffraction and Fourier transform holography. During the second year we should be able to reconstruct as well as record holograms of test objects, and to extend the diffraction data set. High resolution detectors will also be tested.

The enclosed **budget** is consistent with the original plan. In the equipment category we propose to spend $23,000 to replace the plane mirror present in the beamline by a cylindrical one. The cost is dictated by the need for water cooling, and the tight figure and surface tolerance. The replacement will provide us with a fivefold improvement in useable coherent beam. In addition we need to upgrade our optical table with vibration isolation consistent with the high resolution we are planning to achieve.

In the travel category we request funds to permit Dr. Williams to attend the International Symposium in X-ray Microscopy, to be held in London in September. Dr. Williams will present a paper on X-ray imaging of chromosomes.

The subcontract to the Lawrence Berkeley Laboratory will continue to support the work directed by Dr. Howells according to the original plans. Expenses grouped under the "other" category include shop charges at Stony Brook, and service account for work done in support of the project at the NSLS.

At the end of the current grant period we anticipate that no funds will remain uncommitted.

Figure 1.

Portion of diffraction pattern from a single diatom. The region shown is at an angle corresponding to 120 Angstrom resolution. The blotchy appearance is similar to our expectations based on calculations for a model specimen.

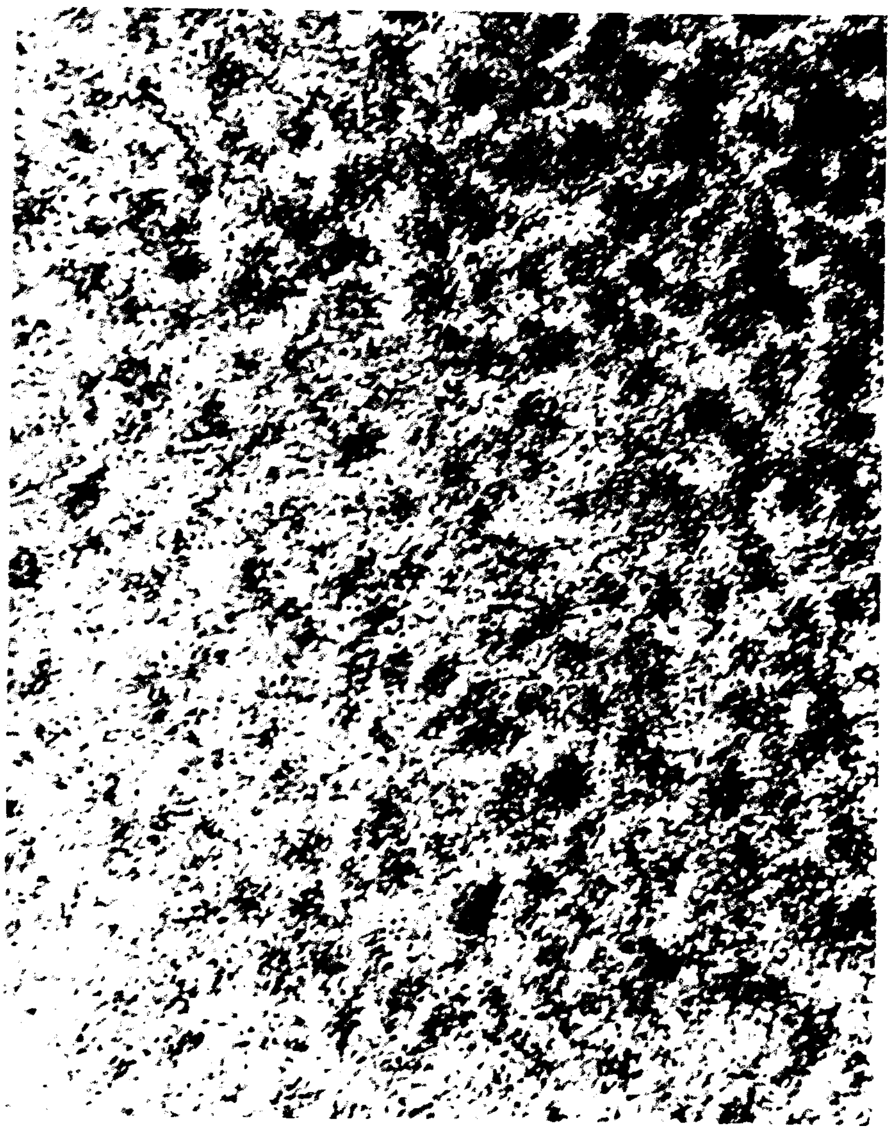
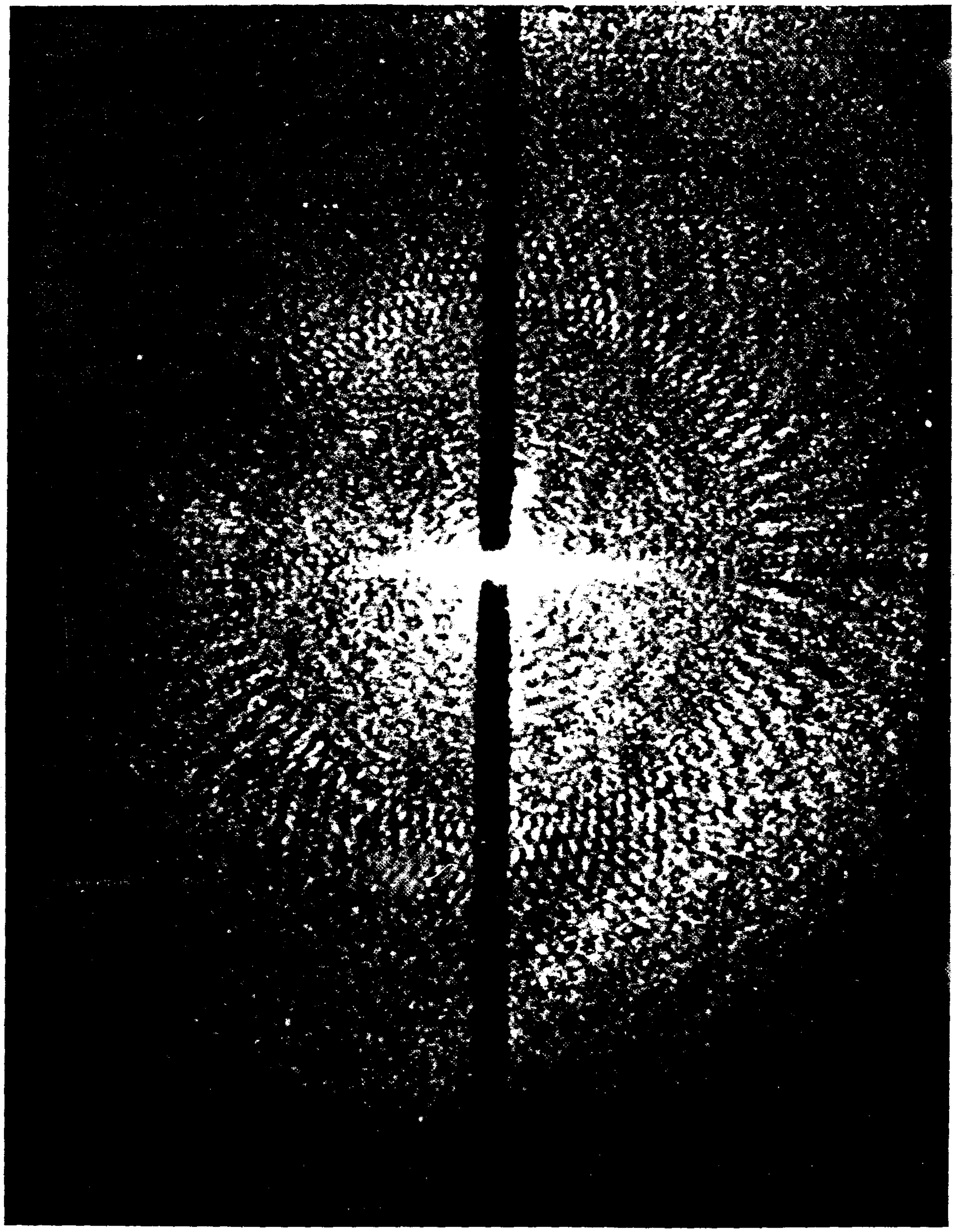


Figure 2.

Fourier transform hologram of a test pattern, recorded with our CCD camera. The dark vertical column is the beam stop.



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