a given threshold, but to apply no smoothing in regions where significant values are found. When all three steps have been followed, one is left with an image showing small-scale structures that exceed a given threshold compared with the local mean. (See the cover of this issue.)

The STScI group was able to see the microcalcifications previously seen by Freedman and, in the two blind analyses, to identify microcalcifications that were hard to find in the unprocessed data.

This year the team members want to determine the limiting size of detectable microcalcifications and the limiting signal-to-noise ratios that lead to reliable identifications.

Steven Salzberg (Hopkins), the principal investigator on the NSF grant, has been working on automatic detection schemes using neural networks. The collaboration hopes later to be able to automate the classification of suspicious microcalcifications.

Still later on, Freedman told us, the collaboration may also try image restoration (deconvolution) to increase the dynamic range and to improve the resolution of the shape of the microcalcifications. Freedman believes that the results of the collaboration with the astronomical imaging experts will be applicable to digital mammography in general.

Another technique being used to improve digital mammography also grew out of work on the Hubble Space Telescope. Last year NASA announced that an extrasensitive charge-coupled device developed for Hubble is being used in a digital camera system for spot mammograms. The CCD camera system enables doctors to replace surgical biopsy in some cases with stereotactic large-core needle biopsy.

Susan Blumenthal, deputy assistant secretary for health in the US Department of Health and Human Services, has been trying to help the medical community take advantage of the imaging technologies developed by the defense, space and computer graphics industries to improve breast cancer detection. She is setting up a panel on dual-use technologies. For example, John Wood, lead optics engineer for the Hubble, told us that CIA-developed neural network software that searches for groups of tanks in a forest is being adapted for use in mammography. The software looks for changes in a complex scene.

At a recent press conference Senators Arlen Spector and Bob Kerrey, who head the Senate Intelligence Committee, urged the CIA and other intelligence agencies to release their advanced imaging techniques for medical applications. Georgetown's Freedman believes that mammography may very well benefit from some of these techniques.

GLORIA B. LUBKIN

X Rays Illuminate Dynamics On Near-Atomic Length Scales

Eighty years after x rays were first used to determine the structures of well-ordered crystals, coherent x-ray beams are beginning to probe the atomic-scale dynamics of random distributions of matter.

When a beam from a laser or some other coherent light source scatters off a random distribution of matter, it produces an interference pattern of light and dark "speckles" that is uniquely determined by the instantaneous matter distribution at the scale of the light's wavelength. And if changes occur in the sample as a function of time, the speckle pattern evolves to reflect those changes. Physicists exploit this phenomenon when they investigate the diffusion of micron-sized particles in liquids, for example, with techniques like photon-correlation spectroscopy and dynamical light scattering.

In principle, it should be straightforward to extend such techniques to shorter and shorter wavelengths until one can measure the dynamic fluctuations of matter at the atomic scale. However, it is less than five years since researchers demonstrated that synchrotron storage rings could produce coherent x-ray beams of sufficient intensity to generate a speckle pattern,[1] let alone reveal the dynamics of the system off which the beam scattered. Even with the most intense beams now available, one must take care in selecting the system to be investigated and designing the experiment so that x-ray photon counting statistics are high enough to provide an adequate signal-to-noise ratio. Physicists working at the European Synchrotron Radiation Facility[2] in Grenoble and at Brookhaven National Laboratory's National Synchrotron Light Source[3] have apparently found two winning combinations for using coherent-x-ray speckle to elucidate the short-length-scale dynamics of relatively slow processes in disordered materials.

Because no sufficiently intense x-ray laser has yet been developed (see PHYSICS TODAY, October 1994, page 19), researchers prepare coherent x-ray beams by first filtering out all but the desired wavelength with a monochromator—a crystal of material oriented so that it diffracts only x rays of that wavelength—and then collimating the beam by passing it through a pinhole in a metal foil. The resulting coherent beam then scatters off the sample. Researchers measure the speckle pattern by scanning it with a single-point detector or by imaging the complete pattern with an area detector.

The group working at ESRF, which consisted of Stephan Brauer and Brian Stephenson of IBM; Mark Sutton, Ralf Brüning and Eric Dufresne of McGill University; Simon Mochrie of MIT and Gerhard Grübel, Jens Als-Nielsen and Douglas Abernathy of ESRF, examined the speckle pattern of x rays diffracted from the binary alloy Fe_3Al near the critical temperature T_c for an order–disorder transition. In this system the order and disorder express themselves only at the atomic level. Below T_c the alloy's ordered phase, in which Fe and Al atoms occupy alternating lattice positions in the crystal, is favored because of its lower energy. This leads to a fairly static long-range order with a periodicity of 2 atomic spacings, or about 3 Å, in the crystal's structure and a correspondingly static speckle pattern. Above T_c the long-range ordering of Fe and Al atoms is lost, and time-dependent critical fluctuations of short-range order appear, causing the speckle pattern to fluctuate as well. Despite less-than-optimum detector resolution and limited signal, the researchers did observe an abrupt transition between the characteristic static and fluctuating speckle patterns as they raised the temperature through T_c in small increments.

The group working at NSLS, Steven Dierker of the University of Michigan, Ronald Pindak and Robert Fleming of AT&T Bell Labs, Ian Robinson of the University of Illinois and Lonny Berman of Brookhaven, looked at the x rays scattered at small angles to the incident beam by an opaque colloid of gold nanoparticles with an average diameter of about 300 Å suspended in glycerol. Coherent interference of scattered x rays from individual gold nanoparticles produced a speckle pattern that fluctuated as the particles underwent Brownian motion. By recording a movie of the fluctuating speckle pattern with a CCD area detector and analyzing the time evolution of the pattern from frame to frame, the group measured the time scale associated with the particles' random motion.

One of the most important factors in the success of the measurements at NSLS was the delicate balance achieved between beam coherence and beam flux. The researchers were careful to match the x-ray beam's coherence length, a measure of its degree of coherence, to the length scale of the Brownian-motion fluctuations. Measurements performed on the colloid with a more coherent, less intense beam were found to have a much poorer signal-to-noise ratio than those reported in the paper.

The main limitations of the studies at ESRF and NSLS resulted from the limited coherent-x-ray fluxes currently available there. New high-brilliance x-ray sources, such as the Advanced Photon Source at Argonne National Lab, scheduled to begin operation this summer (see PHYSICS TODAY, May, page 59) and the SPring-8 facility, under construction in Japan, along with improvements in x-ray optics, will certainly help this problem. With more brilliant and coherent x-ray beams, researchers hope to examine somewhat faster processes, such as polymer dynamics, near-atomic-scale hydrodynamics, the dynamics of glasses, other phase transitions and sliding charge-density waves. Higher fluxes of usable coherent x rays could also allow researchers to simultaneously examine dynamics on a wider range of length scales by looking at x rays scattered in different directions (corresponding to different momentum changes of the incident x ray).

The authors of these studies stress that they are just beginning to learn how to use these techniques to map the dynamics of matter at near-atomic scales. If progress continues at the rapid pace of the last few years, physicists may have a new technique whose future is limited only by the brilliance of coherent x-ray sources.

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