Spotlight

New technologies and research at Los Alamos

Acoustic Flow Cytometry

Have you heard? A Laboratory-developed innovation is using sound waves to make cells or particles line up for accurate, fast analysis. The new technology—acoustic flow cytometry—may bring much-needed medical diagnostics to many parts of the Third World.

Flow cytometry is particularly useful to the medical profession, which uses flow cytometers for producing blood counts and monitoring the progress of HIV/AIDS patients. The standard instrument uses a hydrodynamics (fluidics) system to transport cells, one by one, through a horizontally focused laser beam.The cells are suspended in saline solution that flows at the center of, and in the same direction as, a larger and faster-moving stream (a "fluid sheath"). This configuration forces the cells into single file for their trip through the laser beam, so the light they scatter or emit can be readily detected and analyzed by a data system.

But the bulk, expense, and fragility of the hydrodynamics system have long confined cytometers to the most-sophisticated laboratories and clinics.

The new technology, licensed by the Laboratory to Acoustic Cytometry Systems (ACS), a Los Alamos company, eliminates the fluid sheath. Instead, it sends the suspended cells through a glass capillary that has a "piezoceramic" acoustic source bonded to its outer wall. The source converts an electric charge into an ultrasonic field that drives the cells to the center of the capillary.

The new design makes cytometers smaller, lighter, less complicated, and also less expensive. Compared with the fluid sheath, the ultrasonic field produces a slower transit of cells through the laser. Because each cell gets interrogated longer, scattering and emitting more light, a smaller, less-expensive laser and less-demanding optics can be used.

All these advantages—including eliminating the sheath's purified water, which may be rare in Third-World countries— may free flow cytometry for wider use. Indeed, acoustic cytometry is about to go global. ACS has been by purchased by California's Invitrogen Corporation, which provides life-science products and services around the world. So a Laboratory-developed technology will soon be helping many more people.

Quantum Slip

Air-bag actuators, handhelds such as iPhones, and video-game controllers all get motion or orientation information from tiny motion sensors whose even-tinier parts rotate or bend freely when the device is spun or accelerated.

As Diego Dalvit of T-Division knows, an arcane quantum-mechanical force—the "Casimir" force—can stop those parts from rotating or bending at all. But he and his Los Alamos team appear to have found a way to keep things moving.

Each motion sensor is usually fabricated on a chip called a microelectromechanical system, or MEMS. As MEMS are made smaller, several forces arise that can cause the sensor's moveable parts to stick to nearby surfaces. For nanoscale MEMS—devices a thousand times smaller than the width of a human hair—the Casimir force dominates. In fact, unless it can be neutralized, the Casimir force threatens to halt the progress of the incredible shrinking MEMS.

The Casimir force is subtle. Quantum physics predicts that photons can suddenly appear and disappear from the vacuum in a very short time. During their fleeting existence, these "virtual" photons exert a "radiation" pressure on surfaces, in the same way that sunlight pushes on comet tails. For example, between two thin parallel conducting plates, the only wavelengths of light that can exist are those that exactly match the distance between the opposing surfaces of the plates. Outside the plates, the light has no such constraints. As a

result, the radiation pressure of the virtual photons outside the plates is greater than it is between them, so the plates are pushed together.
Previous theoretical studies of the Casimir force considered only conducting or semiconducting surfaces, for which the force is always attractive. However, Dalvit's team found that special magnetic metamaterials—materials whose properties derive from tiny structures patterned onto their surface—can neutralize the attraction and even make the Casimir force repulsive! Team members are planning an experiment to test the theory. If it's right, then nanoscale MEMS with nonstick, metamaterial parts could make for some very freewheeling devices.

High-Performance Fabric

A microelectonics revolution arose from the use of plasma for manufacturing computer chips. Now plasma, an ionized gas consisting of electrons, ions, and chemically active neutral fragments, is revolutionizing the clothes we wear.
Former Los Alamos staff member Gary Selwyn recognized that plasma used in a vacuum (as it is for computer chips) might also be used at atmospheric pressure, under the right conditions. Pursuing that idea, he developed a technique in which a jet of plasma was used to decontaminate vehicles and equipment. It was, in effect, one of the Laboratory's first homeland security projects. To commercialize the plasma jet, Selwyn founded APJeT, a Santa Fe company, and licensed the technology from the Laboratory.
The high cost of vacuum plasma had kept plasma treatment from being used for commodity items, but the new atmospheric plasma-jet opened the door. APJeT targeted fabric treatment for the high-performance outdoor clothing market.
Using helium for the plasma gas was one key to success, allowing APJeT to develop a high-density (for treatment speed) atmospheric plasma that was also "nonthermal"—cool enough for use with fabric. Helium has a high thermal conductivity that allows any heat generated to be easily removed. In addition, helium is unique in that it prevents arcing (sparking), a common problem with atmospheric plasmas. Suddenly, the complicated, vacuum-based plasma that was used before could be created at atmospheric pressure and room temperature.
As a result, APJeT's methods can take a commodity textile product—woven or knitted polyester—and turn it at low cost into a product rivaling DuPont and Gore-Tex products. In addition, because APJeT's fabric finishing is plasma-based and so done in the gas phase (unlike traditional "wet" methods), fabrics can be given sequential single-side treatments to produce a product that repels water and stains on the outside and absorbs moisture on the inside.
 APJeT's plasma machine is manufactured under license by Morrison Plasma Systems. Installed at the College of Textiles at North Carolina State University, it is currently being demonstrated for customers.

HIV's Evolving Evolution

The human immunodeficiency virus (HIV)—the virus that causes AIDS—is such a tenacious pathogen because its genetic material readily mutates when the virus reproduces. Once inside the body, the HIV population quickly evolves and diversifies into thousands of different viruses, so-called quasi-species, making it nearly certain that some viruses will evade the body's immune system and resist antiviral drugs.
Curiously, during the later stages of HIV infection, the quasi-species begin to accumulate fewer new genetic differences from the original viral strain (the divergence of genetic sequences begins to saturate), and the number of different viruses (the viral diversity) begins to decline. These changes always precede the progression of the disease to AIDS, although the time for AIDS to develop varies greatly from patient to patient.
Understanding the dynamics of these changes could help scientists develop new ways to stop the virus. That was why Los Alamos researchers Ha Youn Lee, Alan S. Perelson, and Thomas Leitner, all of the Theoretical Biology and Biophysics group, and collaborator Su-Chan Park from Cologne University, Germany, developed a simple model of HIV sequence evolution. The model had two main components: (1) fitness, the number of offspring produced, and (2) the proportion of offspring that are mutants. They tested the model using data from the Los Alamos HIV Sequence Database, which holds more than 250,000 genetic sequences of HIV from patients around the globe.
The results were surprising. In short, fitting the model to data showed that after evolving at a

constant rate, the quasi-species' rate of evolution slowed down.

HIV infects cells of the immune system, reproduces within them, and then kills the cells, a course of action that suggests several possible reasons for the slowdown. One possibility is that because there are fewer immune cells in the later stages of the infection, the reproduction rate decreases. Another is that the weakened immune system is no longer able to apply "selective pressure" to drive the evolution. In any case, the work has already reconciled previously conflicting observations of the relationships between the rate of HIV evolution and disease progression.

The work is reported in a recent paper, "Dynamic Correlation between Intrahost HIV-1 Quasispecies Evolution and Disease Progression," PLoS Computational Biology 4 (12), e1000240 (2008).