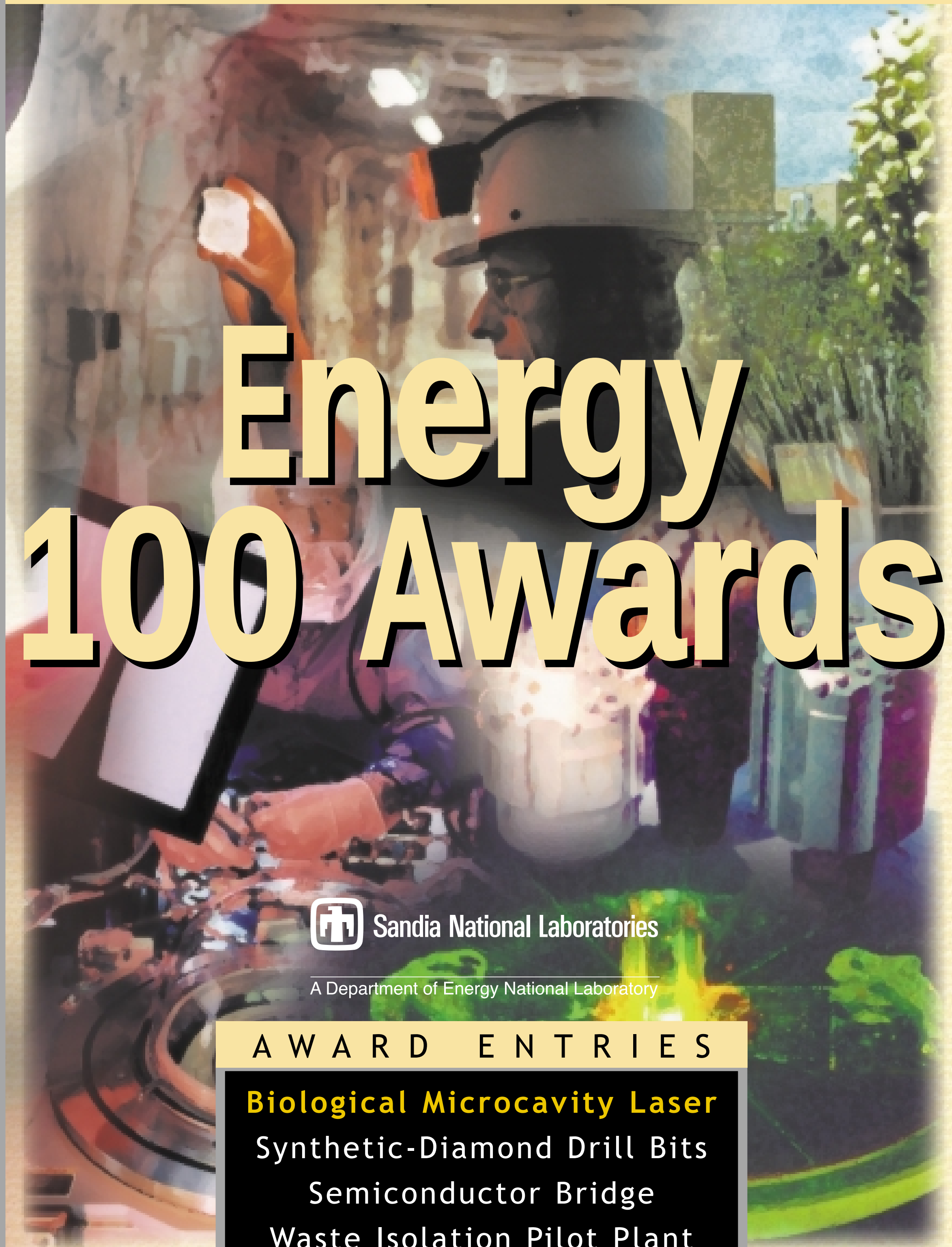
SANDIA NATIONAL LABORATORIES

Energy 100 Awards



Sandia National Laboratories

A Department of Energy National Laboratory

AWARD ENTRIES

Biological Microcavity Laser

Synthetic-Diamond Drill Bits

Semiconductor Bridge

Waste Isolation Pilot Plant

Energy Storage System

Strained-Layer Semiconductor

Biological Microcavity Laser

Energy 100 Award Nomination
Technology: Humanitarian
Title: Biological Microcavity Laser

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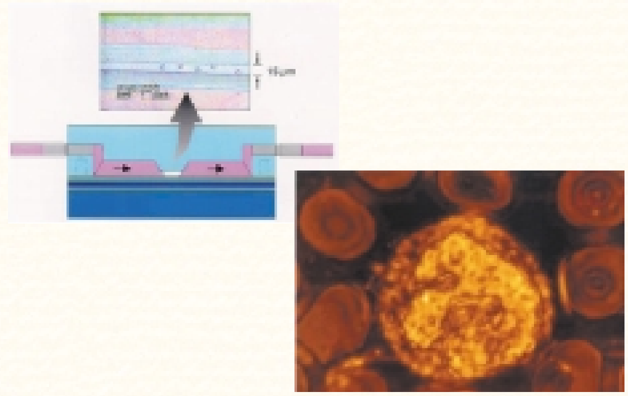

Above: Red blood cells flow through the microcavity laser.
Lower right: Red blood cells surrounding a white blood cell.

ABSTRACT

Sandia National Laboratories has created a biological microcavity (biocavity) laser, a micro-electromechanical systems (MEMS) device, using a radical approach to analyze cell structures, such as blood, cells, or tissue. Offering low manufacturing costs, the biocavity laser has advantages over existing technologies (i.e., miniaturization, cost containment, faster results, better point-of-care delivery, and increased diagnostic yield). It can analyze living and fixed cells from humans, animals, and plants (without chemical staining) in a doctor's office, natural-disaster areas, or under-developed countries. Using a native biological cell as an internal-optical guide in a semiconductor microcavity, the laser offers profound applications within a simple design.

1. Program Description

The biocavity laser operates at resonant frequencies established by the dielectric properties of the cells. Samples may be whole blood, cells from a culture, or tissue from a biopsy or scraping. The cell acts as an intrinsic component of the laser and superimposes information about its biochemical composition and structural form onto the emitted laser beam. The beam, in turn, can be fed directly into a fiber optic for rapid transmission to a high-speed computer for analysis.

Using a high-resolution spectrometer, these lasing frequencies can be resolved into narrow spectral peaks. Thus, the spacing and intensity distribution between peaks provides a unique spectral signature for each different cell—enabling, for instance, rapid detection of sickled blood cells from normal ones. This rapid and accurate detection in cell structure and composition can help doctors identify cancer and other diseases in earlier stages to begin patient treatment.

Compact spectrometer reads microlaser output.

Without the biocavity laser, pathologists currently rely on microscopic examination of cell morphology using century-old staining methods that are labor-intensive, time-consuming, and frequently in error. New micro-analytical methods for automated, real-time screenings without chemical modification are in critical need to advance pathology and improve diagnoses.

Already, the biocavity laser has won such prestigious awards as a 1997 "R&D100" award, a 1998 Department of Energy Materials Science Award, and was 1999 national winner of a DOE Basic Energy Sciences Bullet Competition. In addition, a team of scientists and medical doctors used the biocavity-laser concept to create a "nanolaser biochip" that evaluates tumor cells by quantifying their total protein content. Initial results with normal and cancerous human brain cells show that only a few hundred cells—equal to a billionth of a liter—are required to detect abnormal growth. The ability to detect cancer in such a minute tissue sample is crucial for resecting a tumor margin or grading highly localized tumor malignancy.

2. Improving Quality of Life

Potential applications for the biological microcavity laser include pharmaceutical development by real-time drug testing of living cells, ultrasensitive sensing of harmful micro-organisms, and high-speed detection and/or eradication of rare cells in large populations. Thus, the laser goes beyond simple cell counting and detection to become a cell laboratory-on-a-chip.

Also, higher cell identification rates can be achieved. In preliminary experiments, the biocavity laser has shown the capability to probe the human immune system, characterize genetic disorders, and distinguish cancerous and normal cells from tumors. It is anticipated that the biocavity laser will eliminate timely and costly processing. Furthermore, it uses smaller sample volumes (less invasive for patients). For instance, a finger puncture can provide similar information as compared to venipuncture. Given the laser's speed and efficiency, it can be used in cellular analysis to find rare events, such as detecting malignant, dying or infected cells. Applications may include examining tissue cells to find precancerous cells or sampling blood specimens for blood cancer. The biocavity laser is able to revolutionize stem-cell transplantation (used in treating blood cancers and other serious disease). Because the biocavity laser finds rare cells rapidly and efficiently, a patient can avoid making unexpected trips to a doctor's office to provide blood or urine samples. And, the biocavity laser offers near instantaneous results from the place (i.e., clinic, or doctor's office) where the samples were obtained—without having samples sent to a large reference laboratory for analysis days later. Testing at a doctor's office can relieve patient anxiety and provide important data at the same time. For example, patients can have biopsy test results within minutes from providing a sample—compared to waiting days with traditional methods.

3. Cost Savings

Due to considerable technical advantages inherent in the microcavity-laser design, it offers many cost advantages compared to existing technologies. With chips ranging in price from $500–$2,000, the microcavity laser can be mass-produced 10-to-100 times less expensively than current devices. A complete analysis system is notebook-size, portable, and has the potential to provide real-time analysis of up to 100,000 cells/sec (a rate 5 times higher than other methods), exceeding the capabilities of expensive, conventional cell-analysis methods, such as the bench-top cell counter or flow cytometer, whose operation requires a small room, highly trained operators, and a large frame laser.

4. Other Noteworthy Benefits

The biocavity laser offers other important benefits. Its technique has been used to size polystyrene spheres, micromanipulate cells by the laser-tweezer effect, perform microsurgery on cells, destroy selected cells, and measure refractive index values of cell constituents. In addition, its has been used to quantify properties of fluids injected into the microcavity. This later configuration may be useful in understanding cellular and molecular events occurring in blood-cell production. Such technology also may aid the histopathologic examination of tumors, such as in cervical cancer. (Conventional methods of sectioning, staining, and microscopic examination of abnormal cells rely on qualitative human vision and interpretation of color images—which are operator dependent and subject to frequent misidentification.) Focusing on being applied to healthcare delivery to provide accurate information in a timely fashion using minimally invasive procedures to the human body while controlling cost, the biocavity laser is on the forefront of providing needed advances in medicine.

SUPPORTING MATERIALS

The microcavity laser has received the following awards:

1997 R&D100 award
1998 Department of Energy Materials Science Award
1999 national winner DOE Basic Energy Sciences Bullet Competition

Copies of the following materials are contained for your reference.

"Laser Cavity Incorporates Flowing Blood," Photonics Spectra, June 1998.

"Blood Disorders Analyzed in Minutes," Electronics Now, March 1998.

"Biocavity Laser Can Analyse Blood Samples in Minutes," Clinica, Sept. 1, 1997.

"Patented Laser Device Detects Blood Disorders Near-Instantly," Sandia National Laboratories, News Release, Aug. 15, 1997.

Laser Focus World, April 1997.

"Sandia's 8 'R&D 100' Awards Are Its Best Effort," Sandia National Laboratories, News Release, June 30, 1997.