Silicon chip beams light through a liquid-core waveguide to detect one particle at a time

By guiding light through liquid-filled channels smaller than a human hair, researchers at the University of California, Santa Cruz, and Brigham Young University have succeeded in building a silicon chip that can detect tiny particles one at a time. The research, published online this week in the journal *Lab on a Chip*, could revolutionize the fields of medical and environmental sampling by making analyses sensitive, portable, and fast.

"We've laid the groundwork in the past and shown it's possible to guide light through liquid channels," said Holger Schmidt, associate professor of electrical engineering at UCSC. "But this is the first analytical device where both the liquids and the light are guided on the chip and single-molecule resolution is achieved."

Chips like the one Schmidt and his collaborators developed could one day be used in handheld sensors that detect viruses or pollutants. This would enable analyses that are currently restricted to laboratories to be conducted nearly anywhere. The chip's ability to detect single particles would make detecting certain biohazards--a flu virus, for example--a much faster procedure.

"We're really pushing the design down to very high sensitivity without the need for expensive microscopy setups," Schmidt said. "We can detect one particle per 100 femtoliters, so ultimately, we hope to be able to take samples from people, analyze them on the chip, and detect virus levels." (A femtoliter is one millionth of a billionth of a liter.)

Schmidt collaborated with the microelectronics group led by coauthor Aaron Hawkins of Brigham Young University to build the precision device. David Deamer, research professor of biomolecular engineering at UCSC, provided the tiny biological particles used as targets in tests of the new chip. The paper's first author is Dongliang Yin, who performed the study as a graduate student in Schmidt's lab.

The system achieves its sensitivity using so-called liquid-core waveguides, which ensure that even the faintest traces of light from a target particle can be detected. Researchers inject a liquid sample into the waveguide core and illuminate it with a laser, causing target particles bearing a fluorescent tag to emit light.

The waveguide walls, made of silicon materials layered in precise thicknesses, keep the light on course much the way fiberoptic cables guide light signals that transfer data between computers. Without the waveguides, Schmidt says, physical properties of the liquid would scatter the light almost immediately, rendering it useless.

In addition to its sensitivity, the new design is far more compact and portable than previous approaches to optical analysis. In the past several years, advances in microfluidics have enabled researchers to route tiny volumes of liquid around a chip. Detecting an optical signal, however, has always required looking down at the chip with a microscope or camera. This new waveguide design frees the chip from the microscope. It can be built from ounces of silicon, instead of pounds of metal and glass, which will keep costs down.

The new chip design measures 1.2 x 0.8 centimeters (0.5 by 0.3 inch). Two tiny brass reservoirs hold up to 10 microliters of fluid each and are connected by a waveguide channel 5 microns deep and 12 microns wide. (A micron is one-millionth of a meter, or about 0.00004 inch. The thinnest of human hairs are about

17 microns wide.)

To analyze a sample, researchers flood the channel between the two chambers. At a carefully designed intersection, the laser illuminates a tiny amount of fluid--85 femtoliters. If that sample contains a tagged particle, it lights up, and the light is guided down a separate waveguide channel to a light detector.

The addition of fluid reservoirs provided control over the sample fluids, eliminating the shortcomings of earlier waveguides and resulting in a functional device, Schmidt said. Future research will focus on incorporating even more laboratory elements onto the chip. On the to-do list are integrating the light source and detector, performing sample preparation steps on the chip, and incorporating the circuitry to make the chip programmable. Schmidt said the first commercial chips could appear within the next two to five years.

Source: University of California, Santa Cruz