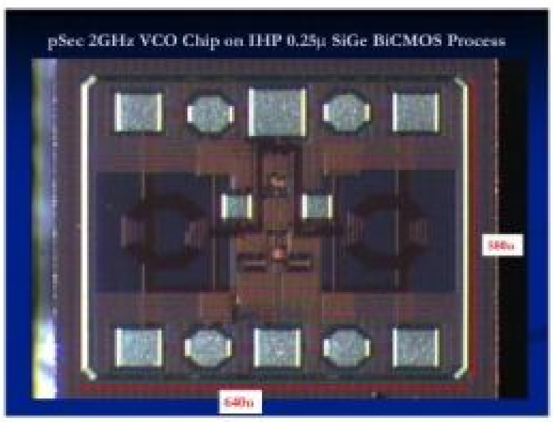
Medical, high-energy physicists collaborate to improve PET scans

May 23 2007



Photograph taken through a microscope of a microchip measuring 650 microns across. Such chips are designed by engineers and students working in the University of Chicago's Electronics Design Group using sophisticated software tools. Credit: Image courtesy of the Electronics Design Group, University of Chicago

Physicists are developing new electronics for identifying subatomic particles in high-energy accelerators that may also enable radiologists to detect cancer at an earlier, more curable stage.

"The electronics needs in medical imaging look very closely related to the needs we have in high-energy physics," said Henry Frisch, Professor in Physics at the University of Chicago. "Physics tends to advance by new capabilities in measurement, the same in radiology."

Radiologists, medical physicists and high-energy physicists share a desire to more precisely measure the velocity and location of subatomic particles, Frisch explained. A significant improvement in Positron Emission Tomography technology could mean the difference between life and death for some patients, said Chin-Tu Chen, Associate Professor in Radiology at the University of Chicago. Being able to detect a tumor measuring a quarter of an inch in diameter rather than half an inch would mean initiating treatment when the disease mass is eight times smaller by volume.

Frisch, Chen and physicist Karen Byrum of Argonne National Laboratory are pursuing the joint effort with initial funding provided by the U.S. Department of Energy, Argonne and the University of Chicago Cancer Research Center. Their work is part of an international scientific trend to apply high-energy physics technology to biomedical imaging techniques.

While medical physicists look for disease, high-energy physicists seek to identify what types of subatomic particles they produce in collider experiments. The identity of many such particles remains a mystery, and thus a barrier to some potentially dramatic new insights into the operation of the universe at the smallest of scales.

Today's high-energy physics experiments typically measure particle velocities to within an accuracy of 100 picoseconds (a trillionth of a second). A photon of light can travel approximately one inch in 100 picoseconds. Frisch would like to increase the resolution to one picosecond.

"We are not as ambitious as Henry," Chen said. "We are aiming more toward 30 picoseconds."

In the PET world, more accurate particle velocity measurements would translate into improved image quality and thus more accurate diagnoses, Chen said. Doing so would require an emerging technique called "time-of-flight PET," which provides a positional measurement that conventional PET technology lacks.

Only last December did the first commercial time-of-flight PET scanners become available. These scanners provide a time-of-flight resolution of 750 picoseconds, which corresponds to a resolution of a couple inches. "That's really not useful for improving the spatial resolution of PET," said Chien-Min Kao, Assistant Professor in Radiology.

But when used in connection with conventional PET, time-of-flight measurements do help improve image quality by sorting out useful signals from confusing static, Kao said. Physicists can help here, because they have solved some data-acquisition problems that still plague biomedical imaging.

In conventional PET scans, patients receive a dose of short-lived radioactive material that emits positrons. The PET scanner then detects the photons released when the positrons collide with neighboring electrons. This approach generates millions of signals, including countless spurious signals that require intense computational analysis to filter out. Furthermore, the locations of the signals can only be determined along the direction of the detector face.

But collection of new time-of-flight data permits determination of signal locations in a direction at a right angle to the detector face as well. "If time-of-flight measurements can be assessed with an accuracy less than 30 picoseconds, better resolution in both directions can be achieved, essentially eliminating the need for complex and costly image reconstruction," Chen said.

The medical imaging community first showed interest in time-of-flight PET in the early 1980s. Chen, then a Ph.D. student, devoted his dissertation to the topic. But the limited precision available from the detector crystals of the day prevented the concept from moving beyond the prototype stage. "I shelved my dissertation after I graduated, and for 15 years or so, no one talked about time-of-flight PET," he said.

In recent years, the development of faster crystals has renewed biomedical interest in the technique, as Frisch learned when he and Argonne's Karen Byrum organized a November 2005 workshop of picosecond particle measurements. The workshop brought them together with Chen and Patrick Le Dû of the French atomic energy commission.

Le Dû and Frisch had worked together almost 20 years ago to develop an instrument for the ill-fated Superconducting Supercollider. Nevertheless, "It was a complete surprise to find out that we were thinking along absolutely parallel lines," Frisch said of the ideas that Le Dû presented in his talk.

Scientists all over Europe, in fact, now work in concert to develop time-of-flight PET technology. Frisch, Chen, Kao and Byrum, meanwhile, have formed their own biomedical imaging effort that includes the Electronics Design Group at the University of Chicago's Enrico Fermi Institute.

Frisch recalled what happened when he first shared his idea for improving subatomic particle measurements with Harold Sanders, who heads the Electronics Group. "That was on a Friday afternoon, and Harold said, 'you're out of your mind.'" But the following Monday, Sanders said, "You know, maybe it's not completely crazy."

That was before they began working with Chen more than a year ago. "It still looks good, and we think it's far from crazy," Frisch said. "In fact, it may be possible."

Source: University of Chicago