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Helping to shrink digital cameras wins a big prize for Dartmouth professor

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When you're talking to a guy who won what is sometimes called the Nobel Prize of engineering for helping make smartphone cameras possible, you want to hear a good "Eureka!" story.

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The first (and still the best) of such stories, of course, came when Archimedes leapt from his bath and ran down the street in naked excitement after discovering displacement. But science is full of them – my favorite being William Hamilton using his pocketknife to carve quaternion equations on a bridge abutment after inspiration hit when he had no paper or pencil.

So when I called Eric Fossum at Dartmouth to talk about receiving the Queen Elizabeth Prize for Engineering, I immediately asked for his Eureka story.

Alas, no bathtubs and no pocketknives.

"Unfortunately, it wasn't like a giant light bulb went off in my head. Sorry," Fossum said.

> "I have had other ideas that were 'aha' moments," he added helpfully. "But unfortunately the ideas turned out to not be as good. Oftentimes you think you've got a great idea, only to discover that you're not the first person to have the idea. That has happened to me many times."

Darn you, reality – always getting in the way of a good article.

Fossum is a professor at Thayer School of Engineering and director of its Ph.D. innovation program. He recently received the Queen Elizabeth Prize for his role in helping create the "camera on a chip" that shrunk imaging systems enough to put in smartphones.

He'll share the million-pound ($1.25 million) prize with three other researchers, including one who has already won a Nobel Prize. He said he'll use much of his prize to boost Camp Invention, a program for STEM education in elementary schools.

What did Fossum do to be part of the trio of these biennial prizes from the British government? He helped figure out how to replace CCD with CMOS.

That didn't mean much to me, either, until Fossum explained.

CCD, which stands for charged couple device, was the obvious technology to replace film as photography went digital. Obvious but not terribly efficient, which is why early digital cameras were big, expensive and consumed batteries like nobody's business.

Fossum and many others realized that CMOS, as in complementary metal-oxide semiconductor, "the recipe that almost all modern electronics are made out of," would be more efficient and lead the way to smaller, less power-hungry cameras.

How so? Fossum gave a technical analogy in a 2015 story in *Dartmouth Engineer Magazin*e.

Imagine that the pixels in a digital camera are thousands of 5-gallon buckets covering a football field, he said. The pixels measure light at each point, and the buckets collect rain at each point.

To empty a bucket in CCD, which is the analogy for getting information out of a pixel, "you have to transfer the charge packet that represents the accumulated photoelectrons step by step across the chip without losing many electrons," he told the magazine. Doing that quickly requires a lot of power and is relatively hard to miniaturize.

With CMOS, however, each bucket can be emptied directly, rather than step by step via its neighbors. That is quicker and easier, by far.

This was obvious to everybody, said Fossum, but CMOS was too "noisy" – resulted in too many false signals – to create good photos, so it wasn't used.

At the time in the 1990s Fossum worked at the Jet Propulsion Laboratory, where engineers really wanted lighter cameras for weight-conscious space flight. He figured out a way to reduce the CMOS noise through a process called intrapixel charge transfer, which measures the charge before and after a pixel is hit by photoelectrons.

This is where the "Eureka" moment should have occurred, but he says the answer was actually developed over time. Part of the delay was due to an odd-sounding obstacle: His insight seemed too obvious.

"It wasn't that difficult, but what was really difficult was to answer the question: This is so straightforward, surely other people have thought of this and it didn't work," he said.

But they hadn't thought of it and it did work. End of story?

Far from it.

“It was a good five years of government research and development, then trying to transfer that technology to U.S. industry. We traveled to many U.S. companies to convince them they should commercialize this but nothing came of it,” said Fossum. “There was a feeling like we’re going to miss this window of opportunity if we don’t do something ourselves, and that really motivated the spinout of Photobit.”

Started by himself and his wife, Sarah Kemeny, Photobit eventually grew to 125 employees before they sold it in 2001. The field really took off when mobile phones provided a vast new market for small digital cameras.

The usefulness – ubiquity, really – of this technology undoubtedly contributed to the prize, which has previously gone to the inventors of the internet and the World Wide Web, and to an MIT chemist whose work controlling the delivery of drugs with large molecular weights has been cited for saving up to 2 billion lives. The Queen Elizabeth Prize values impact at least as much as originality.

Fossum admits that luck is a big part of such impact.

“CMOS happened just at the right stage of advancement at the time of the need for cameras in smartphones emerged. That was a very happy coincidence,” he said. “But it’s very rewarding to see people use your technology. The highlight of any engineer’s career is seeing your technology in the hands of a happy user.”

Fossum, 59, came to Dartmouth in 2010 after getting restless with semi-retirement in New Hampshire.

“One of my jobs here is to help promote entrepreneurship among faculty, try to spin out companies,” he said. I think the younger faculty at Dartmouth are very interested in entrepreneurship opportunities.

“Some of the more senior faculty sometimes have the feeling that it’s not pure if you’re doing something that has applications, but even among them that attitude is shifting. It will be pretty much be dissipated in the not-so-distant future.”

I hope he reminds them to say “Eureka” at least once. It makes the elevator pitch a lot easier.

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