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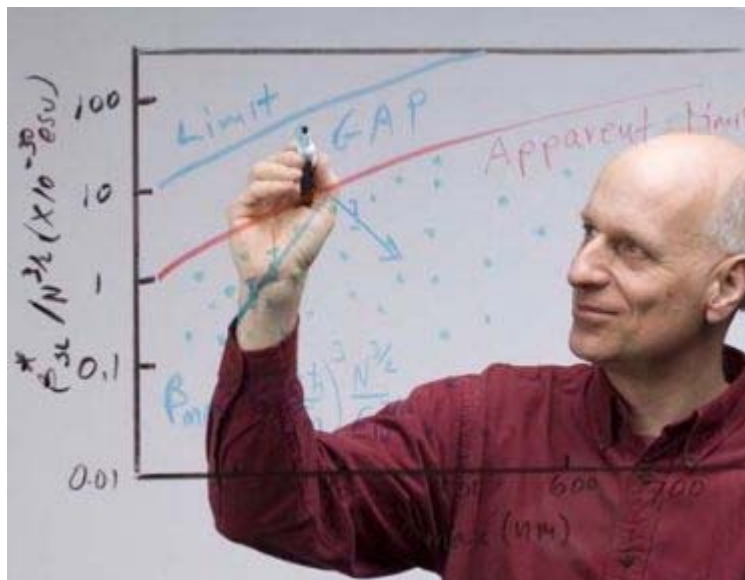
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Taking it to the limit

by Cherie Winner



"Because it's so simple, it had to be fundamental. There's some beauty in the equations."

Physicist Mark Kuzyk. Photo by Robert Hubner.

When it comes to scientific immortality, not much beats having a fundamental physical relationship named after you. Ask Washington State University physicist Mark Kuzyk, who in 2000 discovered what has become known as the Kuzyk Limit.

"It's actually kind of embarrassing to call it that," says Kuzyk. He attributes the term to a group at the University of Toronto who used the limit as the basis of their own research. "Their press people came up with this. They coined the term, and it stuck."

Kuzyk prefers the term "fundamental limit." The limit isn't a single number; it's a curve on a graph that shows how strongly any given kind of matter can interact with light. The notion that light and matter "interact" might sound odd to a layman. To a physicist, it opens a whole spectrum of possibilities.

Matter can affect light, as when a crystal converts a beam composed of many wavelengths into a higher-energy beam of a single wavelength—a laser. Likewise, light can affect matter. Molecules that absorb light efficiently can gain enough energy to cause their electrons to behave in new ways.

"It turns out there is a fundamental limit to how much an individual molecule can absorb," says Kuzyk. "Whatever process you can think of that has light interacting with matter will have to obey that limit"—and that has implications for a wide variety of applications, from optical switches in computers to advances in medicine.

Kuzyk describes a cancer therapy in which a dye is injected into the bloodstream and becomes attached to tumor cells.

"Then you shine bright light through the skin," he says. "It turns out that some colors of light will go right through your flesh. The idea is that these [dye] molecules strongly interact with the light, and it burns the tumor." His limit tells doctors how efficient the cancer therapy can be.

One of the biggest mysteries about the limit is why none of the thousands of molecules

tested so far come anywhere near it. A curve showing actual performance parallels the limit curve but is about 30 times lower. The discrepancy between what's theoretically possible and what has actually been achieved in the lab is so consistent that it has also been given an unofficial but widely accepted name: the Kuzyk Quantum Gap.

Figuring out how to make chemicals that are efficient enough to get into the gap—and closer to the fundamental limit—is “the million-dollar question,” says Kuzyk.

He recently teamed with WSU mathematician David Watkins to do numerical simulations to understand how the shape of a molecule affects the strength of its interaction with light.

“We’ve suggested shapes of molecules that would be worthwhile to try,” he says, “but the chemists tell me when they look at those shapes, they’re not sure if they can make those kinds of molecules.”

Kuzyk says he first thought about trying to find the limit more than 20 years ago, when he was a graduate student, but he never had time to pursue his ideas until a brief sabbatical in 1999.

“In that two-month period, I was just kind of sitting around doodling and thinking about it,” he says. “And very quickly, I tried several calculations and I hit upon the right one.”

He knew he was on the right track when the complicated equations he started with—“a real big mess,” he says—reduced to a simple algebraic equation.

“So then I knew it had to be something correct,” he says. “Because it’s so simple, it had to be fundamental. There’s some beauty in the equations.”

He recalls that his breakthrough didn’t win applause at first. “The funny thing is, when I was a graduate student, I thought to myself, boy, if anyone could calculate this, it would be so fantastic,” he says. “And then when I first published it, it was a very quiet response. I think people didn’t notice it for about a year.”

Then, some scientists who did notice Kuzyk’s work weren’t happy with it.

“Those are people who get lots of funding to make better molecules. So if they’re saying they’re making improvements, and I show this plot that shows they’re *not* making improvements, it doesn’t go over well.”

Kuzyk got a more enthusiastic response from graduate student Xavier Perez-Moreno. “He caught on very quickly,” recalls Kuzyk. “He fell in love with this work. He said, ‘I can imagine doing this for a lifetime and never running out of interesting ideas.’”

After completing his master’s degree in physics at WSU, Perez-Moreno, a native of Spain, went to Belgium’s University of Leuven to pursue doctoral studies in the same field. Kuzyk will join him this summer for further work on the theoretical aspects of the limit and gap that, despite his embarrassment, now bear his name.

“I have more colleagues that are starting to get interested in it,” says Kuzyk, who also now has National Science Foundation funding for the work. “The horizons are expanding. It really has been fun, because I feel like there’s something really interesting buried in there. I don’t think we’ve gotten to the most interesting stuff. It’s about to come.”

—*Cherie Winner*

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