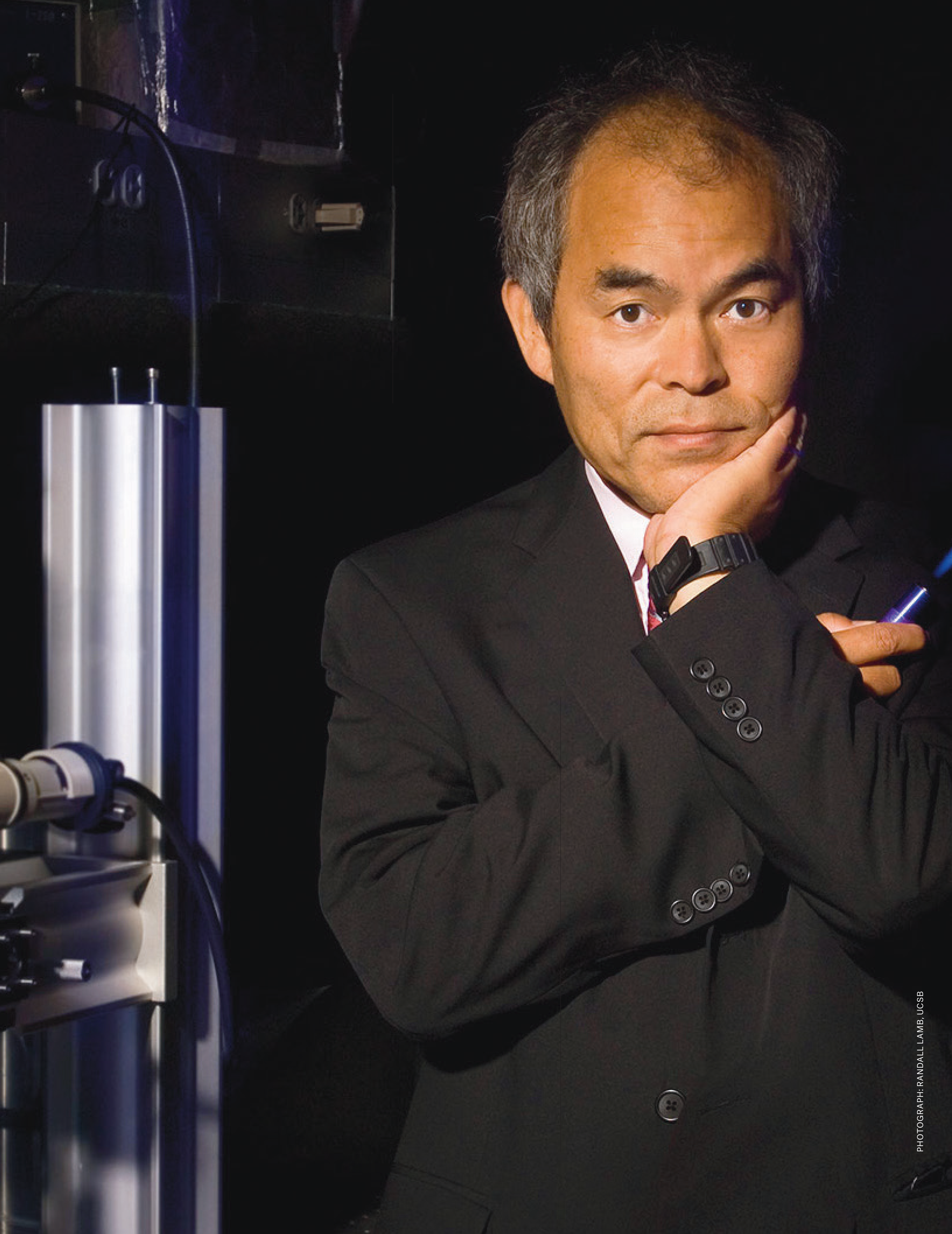

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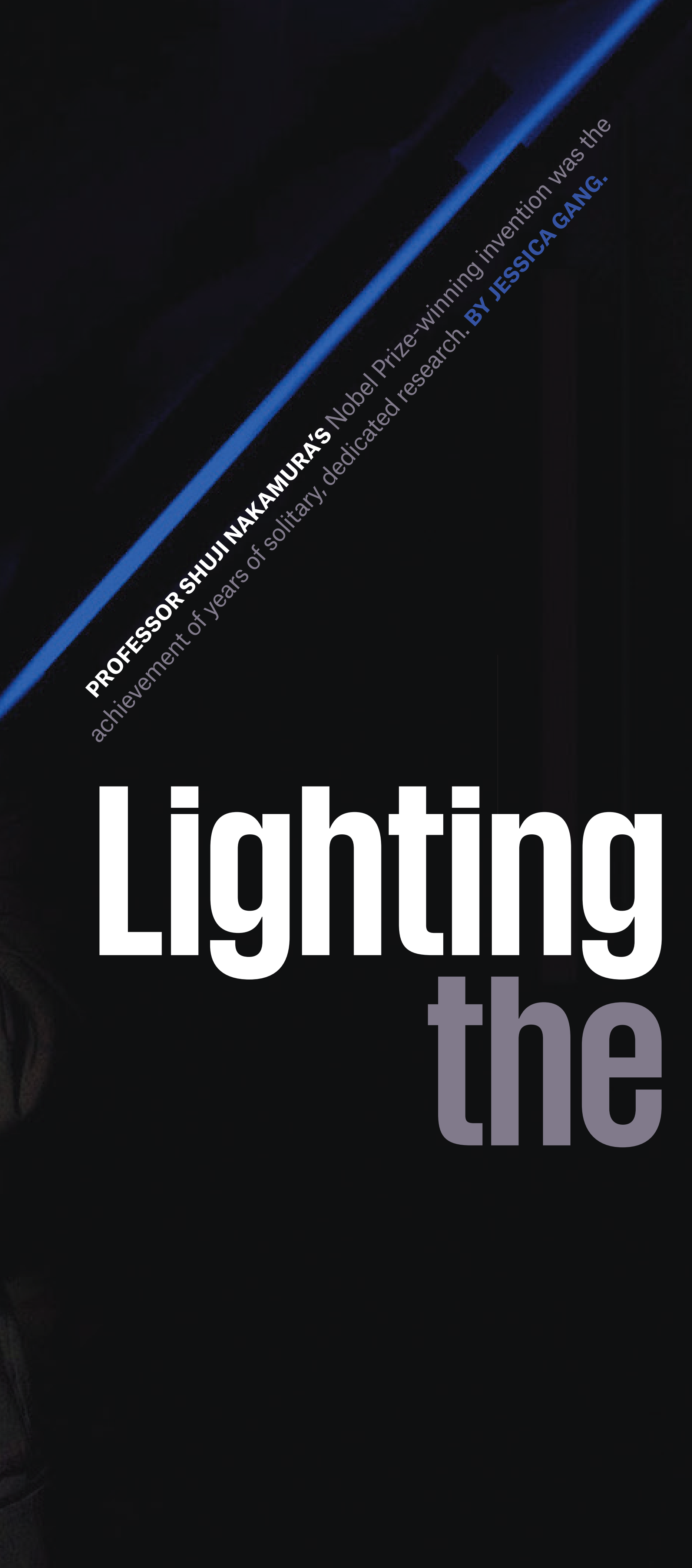

Lighting the Future

PROFESSOR SHUJI NAKAMURA'S Nobel Prize-winning invention was the achievement of years of solitary, dedicated research. **BY JESSICA GANG.**

THE INVENTION OF THE INCANDESCENT lightbulb by Thomas A. Edison in 1879 was a watershed moment in the history of electricity. Gone were the days of weak and irregular gas-powered lamps, with their risk of fire, suffocation and devastating gas leak explosions.

The lightbulb and the electric light infrastructure that Edison created transformed the landscape of social and economic life; for the first time, industrial workers could hold night jobs in factories and plants without risking safety violations, and electricity could be widely distributed using a single power source.

In the 21st century, however, electric lightbulbs have begun to be replaced by something even more innovative—LED lights. These light-emitting diodes are now commonly found in streetlights, phone and tablet screens, and laptop displays. They are used to light sidewalks, driveways, offices and even billboards in Times Square, and their bright light, versatility and sustainability make them a more popular lighting choice than lightbulbs for both billboards and desk lamps.

If you've basked in the warm glow of a streetlight lately, adjusted the brightness on your tablet or phone screen, or stood in awe of the bright lights of a billboard, chances are that you owe part of your good fortune to a discreet manufacturing company located on Japan's smallest island, Shikoku. It was there that one man's tenacity, over many years, would help make a discovery that sparked a lighting revolution.

Shuji Nakamura was born in a small fishing village off the coast of Shikoku, the son of a maintenance man for Shikoku Electric Power. In 1973, he entered Tokushima University, a small state school in Shikoku, to study electrical engineering. At that university, he first developed an interest in the physics of solid-state materials, which would eventually propel him to colossal heights.

After graduating from Tokushima, Professor Nakamura began working at Nichia Chemical Industries, a little-known company on Shikoku that was primarily known for its development of fluorescent lamps and phosphors for color television. When Professor Nakamura joined the company in 1979, however, Nichia had hit a dead end. If they wanted to continue growing, they needed to move beyond the crowded Japanese market for fluorescents and create something more innovative. They envisioned using colored LEDs to create a more vibrant future, and this is where Professor Nakamura came in.

For two decades, Professor Nakamura worked tirelessly on LED light production for Nichia. His original task was to create gallium phosphate, an efficient LED light base. Professor Nakamura's own inexperience with LED lights and the fact that Nichia had no budget for equipment, meant that he had to conduct dangerous chemical experiments using a makeshift reactor, cobbled together from discarded lab materials. The phosphorus explosions from Professor Nakamura's afternoon and evening experiments became so commonplace that, eventually, his coworkers stopped coming to see if he was all right.

Professor Nakamura spent countless hours in the lab, first working to create LED light bases, and then LED lights themselves. These inventions were not enough to raise significant revenue for the company or raise his profile in the world of research, so he eventually went to Nichia's CEO with a daring proposition—he wanted to create the world's first bright blue LED light from scratch. Red and green LEDs had been on the market for some time, but the semiconductor technology that enabled their creation could not be manipulated to create blue light. The combination of red, green and blue was necessary to create white light. Therefore the creation of the blue LED light was essential. It could replace lightbulbs with white LED light fixtures on a massive scale.

So began what Professor Nakamura would later call his "climb to the top of Mount Fuji." From 1988 to 1993, he worked in the lab from 7am to 7 pm, only taking New Year's Day off. His work was largely solitary, as few of his colleagues at Nichia could understand the depth of his research. Two notable exceptions to this were Isamu Akasaki and Hiroshi Amano from the University of Nagoya, whose LED breakthroughs Professor Nakamura watched closely, and with whom he would eventually share the Nobel Prize.

After years of Professor Nakamura's hard work, in 1993 Nichia announced that it had patented its first blue LED light. From that moment on, Nakamura dedicated the rest of his career at Nichia to furthering and perfecting his discoveries, encouraging Nichia to develop white LED lights and himself inventing the blue laser diode, previously considered almost impossible.

"FROM CHILDHOOD, I LOVED TO THINK DEEPLY ... RESEARCH WAS INTERESTING FOR ME BECAUSE I DID MY RESEARCH MYSELF AND I GOT SOME DATA. I HAD TO THINK DEEPLY. I LOVED TO WORK TO SOLVE WHY I GOT THIS DATA."

In 2000, Professor Nakamura left Nichia to accept a faculty position in the US at the University of California Santa Barbara, where he serves as Research Director of the Solid State Lighting & Energy Electronics Center and the Cree Chair in Solid State Lighting & Displays, and continues to supervise research.

On October 7, 2014, Professors Nakamura, Akasaki and Amano were awarded the Nobel Prize in Physics for the invention of the blue light-emitting diode. UCSB Chancellor Henry Yang called it "a most exciting and joyful day of celebration" for the campus community, adding that since his arrival at UCSB, Professor Nakamura had "been a pioneer of not only a new field of research, but of a scientific revolution."

While many others in his shoes might see the Nobel Prize as the pinnacle of their career, Professor Nakamura shows no signs of slowing down. He has been the recipient of the 2015 Global Energy Prize, the 2018 Zayed Future Energy Prize, the 2020 National Academy of Science (NAS) Award for the Industrial Application of Science, and the 2021 Queen Elizabeth Prize for Engineering, among many others. He holds more than 200 US patents and over 175 Japanese patents, and has published over 730 papers in his field.

In an interview with Brunswick's Jessica Gang, a recent UCSB alumnus, Professor Nakamura reflects on the period that led to his industry-changing breakthrough, He also sheds light on how his time at UCSB has helped shape his post-Nobel career, what circumstances separate his experience in the US from his past in Japan, and how the COVID-19 pandemic has affected his relationship with his students in unexpected but not altogether unwelcome ways.

Are there any qualities that you believe it is essential for inventors to have?

There are so many inventors. In my case, I think about one thing very deeply. I don't have common sense [laughter]. I know small things, narrow things. I easily forget people's names. I easily forget the location of places. I can't remember those things because always I think about one thing—my research.

Just my research, always. Even within my research—just one thing. I have to solve this one thing. For 24 hours, I am always thinking about this problem deeply, until I can solve it. That is my style. But you know, other inventors have different styles.

For many years, you worked alone to create the blue LED, spending seven days a week, day and night at work. How did you remain committed? What gave you the strength to continue dedicating so much time to a project with no guarantee of success?

From childhood, I loved to think deeply. For example, I was born near the ocean. So I always went to the beach when I was a small child. And I watched the sea and the ships going past. So I'm thinking about where the ship is going and how the ship is moving. I was just alone, always thinking about those things deeply.

Since childhood, if I found one curious thing, I always thought about it. When I joined the University of Tokushima, for the first three years, at the university, class was so boring. Just taking classes and going back. You know, it's so boring. But in the third year, I started research at the university.

Research was interesting for me because I did my research myself and I got some data. I had to think deeply. I loved to work to solve why I got this data. I loved to work on experiments. I started being curious about research myself and continue to be curious today, too.

Right now, I work together with students. Students get strange research data, and always, I think about that curious, strange data with them. "Why did we get this result?" I want to solve this problem.

So that's the reason. I continuously worked on the LED. Just researching to invent the blue LED, getting all kinds of data and experiment results. I loved working for those results. Because that was most interesting to me.

After you win an award as prestigious as the Nobel Prize, what are some factors that motivate you to continue pursuing your research?

The Nobel Prize is the most prestigious award among scientists. So after receiving the Nobel Prize, I lost some incentive to work very hard [laughter]. But right now, my motivation is as a professor, I have to work with students. I always have about 10 graduate students. All the students have to graduate in five years. They have to get great research results; they have to publish papers and patents. They need at least a couple of papers.

So right now, my highest incentive to work very hard is my students. It's very important to me. Students are very young, so they have a lot of new and crazy ideas.

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Following along this Nobel Prize theme, do you remember what you were doing when you first received the news that you had won the Nobel Prize?

Basically, I was sleeping. Because I live in California, in Santa Barbara. The phone call was in the early morning—around 1am or something like that. And they said, "Oh, congratulations" [laughter].

How was the rest of your day? I imagine it was probably full of fun—phone calls and congratulatory messages.

Yes, you're right. The Japanese mass media surrounded my house here early in the morning. And my colleague Steve DenBaars lives just next to my house. He came to my house and he said, "Oh, you cannot interview here because our neighbors are mad," [laughter]. So we went to the university to conduct all kinds of interviews.

In your Nobel Prize biography, you said that breakthroughs are born out of unusual circumstances. What are some of the unusual circumstances that have led to your greatest breakthroughs?

In my case, when I was working for my company, in the first and second year when I started new research, I had no results. I was so depressed [laughter]. It was no result, no result. I became very lonely and so dispirited. It's almost like going to the bottom of hell [laughter]. Having no results made me so depressed. So, I tried to go to the bottom of my research.

To get to the bottom of my research, I concentrated. Almost 24 hours a day, I thought about why I could not get a great result. "Why? Why is something wrong?" I thought about it deeply every day.

After the bottom, I could find some new idea or new discovery and in the third year, I could make a breakthrough or some new finding. And in the fourth year and fifth year, I could make a great product. That is my style of research.

At the university recently the same thing happened, because due to coronavirus, I cannot do business trips. Before, I had to do a lot of business trips for the university, basically for fundraising and also conferences. But due to the coronavirus, I had to stay at the university. I could work together with students very closely. Some students, in their fifth year, could not graduate because their research subject results were not good. They are very good students; they're very smart. But if their research subjects are bad, they cannot publish papers. So that is my problem. I had to find new research for them.

One student worked for six months with no results. So I had to find a new research project for him. That is a professor's duty. I was always in my office thinking "What is best for him?" And finally, I got to the bottom of the research, and I had a great idea. I asked him "So how about this research project? Why don't you try this one?" And in a couple of days, he got great results. Oh my gosh, it was an amazing result. And I hope this will be more innovative than the blue LED.

So I am always thinking deeply alone. Due to coronavirus, there were no students and no faculty around. I was alone in my office, and I could concentrate on my students deeply.

A Scientific American interviewer in 2000 asked you about what you hoped to achieve in America. And you said, "I want to achieve the American dream. I couldn't achieve the American dream in Japan." Why could you not achieve the American dream in Japan, and do you think that you now have achieved it?

When I was in Japan, I was working for a small company and I invented the blue LED, and green LEDs, but there was basically no change in my salary. A little change. But in Japan, people who work for a company are called "salarymen" because their salary is always the same. In Japan, all employees are the same. Same position, with no change even if they did a great, great job for a company. In the United States, doing great work means you can become the Bezos of Amazon, or Elon Musk.

In Japan, that never happens because people are all equal. It's bad. That is the reason I wanted to do something like try the American dream. In Japan, there is no American dream. Also, at the same time, I started a company with my colleague. I co-founded three companies. Two companies are successful. So I'm so happy. In Japan, that never happens. Because in Japan it's very difficult to start a company.

Are there differences in Japan and the United States in terms of research culture and perhaps research funding?

In Japan, funding comes only from the Japanese government. It's difficult to get funding from industries. In the United States, you can get funding from the US government, also many industries all over the world. In Japan, even if you get the funding from the Japanese government, it's small money, tiny money. That's a big difference.

But if you get the funding from the US government, it's still very difficult. We have to work very hard. So that's the reason, you know, before coronavirus I had to travel a lot all over the world.

> "ALL KINDS OF LIGHTING CAN BE REPLACED BY LED OR LASER LIGHTING, THERE ARE MANY APPLICATIONS, I CAN SAY. ONE PHYSICS PROFESSOR AT UCSB HAD A GREAT IDEA. HE WANTS TO USE LASER LIGHT TO ACCELERATE A SATELLITE."

Do you follow a daily routine during the days that you teach or when working on a research project?

Before receiving the Nobel Prize, I had to teach and research with students. But after I received the Nobel Prize, I had no obligation to teach anymore so I could concentrate on research. Because of the coronavirus, I cannot meet with students in person. Basically, I use my cell phone almost as an office. I'm always calling each student. Zoom is not so convenient. Cell phone and email are much easier. But before coronavirus, I talked with students face to face. Each student's personality is different. So face-to-face meetings are most important.

Do you enjoy working with students or do you prefer to research alone?

I enjoy working with students. I'm getting older, I can't do research myself. I give them research direction. That's all. And some ideas about the project. And research itself should be done by students, you know? I'm too old. Education is also most important. So, they have to publish papers. They have to write a patent themselves.

In your view, what is the most promising future usage of the blue LED light?

I am not sure. All kinds of lighting can be replaced by LED or laser lighting, there are many applications, I can say. One physics professor at UCSB had a great idea. He wants to use laser light to accelerate a satellite. The speed of light is the fastest that anything can travel. So, a satellite's speed can be pushed faster, using a laser. Using his idea, to go to Mars, it might only take one week. Right now, going to Mars takes us six months. It takes a long time. So a blue light laser could be used to accelerate the satellite. That is one idea. The applications in that respect are unlimited because the speed of light is the fastest speed we know of at this moment. But I don't know what other kinds of applications are coming.

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