Metamaterials Research Earns Teen IEEE Presidents' Scholarship

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By JOHN R. PLATT 7 July 2009

IEEE members, meet budding metamaterials researcher Rahul Kumar, a 17-year-old from Rochester Hills, Mich., who is the latest recipient of the **IEEE Presidents' Scholarship**.

Kumar, who just completed his senior year at Stoney Creek High School, received the US $10 000 scholarship for his project, "A Microwave Metamaterial Lens With Negative Index of Refraction." The scholarship was presented in May at the 60th annual **Intel International Science and Engineering Fair**, in Reno, Nev.

Administered by **IEEE Educational Activities**, the scholarship from the **IEEE Foundation** is awarded annually to a high school student who creates a project that demonstrates an understanding of electrical or electronics engineering, computer science, or other IEEE area of interest. The amount is payable over four years of undergraduate study. The prize includes a complimentary IEEE student membership and student society memberships during Kumar's four years of college. He also received a framed certificate and engraved plaque.

"While many students were anxious about speaking to judges, I felt the fair was a great opportunity to share my passion for research with so many smart people," Kumar says. "And I definitely learned about effective communication. I have a much better understanding of how to send a meaningful message to an intended audience in a limited time."

FOCUS ON METAMATERIALS Kumar's research led him to put forward a new theory regarding the behavior of exotic metamaterials, which are manmade composites that display electromagnetic properties beyond those available in nature. His two-year project proved that precise control can be exerted over the focusing characteristics of negative index materials (NIMs), types of metamaterials that show a reversal of Snell's Law (also known as the law of refraction) and refract an electromagnetic beam at negative, rather than positive, angles. In theory, Kumar says, metamaterials could bend light waves around a region and emerge on the other side as though the waves went through empty space, in effect cloaking an object to make it invisible.

Kumar built a three-dimensional lens array with a negative index of refraction, transmitted microwave signals through it, and tested their behavior in terms of how the lens affected the propagation of electromagnetic (EM) waves.

"In a normal material such as glass or plastic, any transmitted EM wave would simply diverge after exiting the lens," Kumar says. "However, in an object with a negative index of refraction, a wave would be refracted on the same side of the normal to the interface. Thus, in a metamaterial, we should expect to see a convergence point [also called a focusing point] of the waves on the exiting side of the lens."

With an EM wave, the convergence point is indicated by an area of magnitude increase, which Kumar measured with a network analyzer. By laying down a grid on a field map beyond the lens and measuring the magnitude of the exiting electromagnetic wave at each point in the grid, Kumar showed that a negative index of refraction resulted in a proper focusing point.

“A focusing point would only exist if a wave bent ‘backward,’ indicating that the wave bent with a negative index of refraction, so it is bent opposite of conventional material properties,” Kumar says.

The project was not without its challenges. “I didn't initially realize how sensitive a network analyzer was,” Kumar says. “I had to discard my initial results and remeasure after removing all metal objects from the room where I was conducting the tests.” Other challenges included building the lens and “the tedium of collecting the data, with over 100 data points for each frequency I tested,” he says.

PROMISING FUTURE There is much interest in metamaterial research these days because of its tremendous potential for novel applications. In cellular communications, for example, filters, antennas, and other electromagnetic devices can be modified with negative refraction. One application involves so-called perfect lenses, which are not subject to the “diffraction limit,” a fundamental upper limit to the resolution of a focusing device such as a microscope or telescope. The limit exists due to diffraction, which is the bending of waves around obstacles. Using metamaterials, a “superlens” can be created for subwavelength focusing.

Another area of interest lies in cloaking mechanisms, which would refract EM waves and could theoretically render an object invisible.

Kumar got the idea for his award-winning project from an article he read describing research that could make the invisibility cloak featured in the Harry Potter books a reality by using negative refraction. Wanting to participate, Kumar contacted local researchers and became involved in his project through Gopalan Srinivasan, a physics professor at Oakland University, in Rochester, Mich., who is working on projects dealing with negative refraction.

Kumar says he first became interested in science at the age of 5, when his father, Ajay, a senior project engineer at General Motors, would ask him questions such as “Why do you think the sky is blue?” and then discuss the answers.

In the fall Kumar plans to attend Stanford University and study theoretical physics or electrical engineering.

“The generous support of the donors and the IEEE Foundation means a great deal to me,” he says. "Knowing I have such support makes me realize how privileged I am in pursuing the many opportunities at Stanford.”