Photonic Materials
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Paving a New Road as both a Researcher and the Director of the Research Center for Advanced Science and Technology

Interviewer: Tohru Ifukube, professor

Light and material: an exploration of unresolved domains

—— I imagine you must be busy with your double role as both a researcher and as the center's director so I appreciate your taking time today to tell us about your research and the motivation behind that research. First, could you please explain in basic terms what kind of research you are currently undertaking?

In the larger framework, my research belongs to the experimental fields of the material sciences and solid-state physics. Of the fields concerned with materials (i.e. their physical properties), there is both science and engineering. Though there is not much of a divide between the two, the sciences examine the principles behind why things happen the way they do, and engineering considers their applications.

To give one example, the late John Bardeen was awarded two Nobel Prizes in physics. The first prize was for his practical contribution of inventing the transistor, and his second prize was for his theoretical research on superconductivity. In this way, there is a considerable relationship between whether something is useful and whether a material is interesting, so the boundary between utility and theory is not all that distinct.

Currently, one of the research trends in the material sciences are the phenomena expressed by the term 'strongly correlated.' All material is completely determined by the state of its electrons so when the degree of mutual correlation between one electron and another is strong it is said to be strongly correlated. The reverse case is when there is no such correlation. To put it differently, this is the condition when the electrons within a material behave as if they were isolated particles.

Presently, it is explained that most electronics do not need this correlation and that it need not be considered for them to be used. However, on the other hand, if the correlation is strong, for instance, a material becomes an insulator or metal when struck by light. While this is not a regular phenomenon, surprisingly it is also not very distinctive. It is, rather, something that until now has not been well understood and therefore has not been researched, but research and experimental methods have been expanded and theoretical frameworks have broadened. As a result of both of these developments, this area has become the object of scientific inquiry.

Though magnetism is the oldest known phenomenon of electronic correlation, in the past this was not recognized with the word "electronic correlation." That is, what has generally been called magnetism until now is actually nothing other than a strong correlation and is perhaps correctly thought of as a new way of recognizing an old phenomenon.

The biggest breakthrough was twenty-one years ago with the discovery of high-temperature superconductivity. At that time, physics was absolutely incapable of understanding this discovery, but from there experimental methods and theoretical frameworks have advanced and we are now extending its implications.

—— Turning metal into a nonconductive substance or turning a nonconductor into metal is, for instance, the same as water (a fluid) becoming steam (a gas) or ice (a solid), isn't it? Is it that this phenomenon occurs because water has strong correlation?

Water becomes ice when fellow molecules recognize their neighboring molecules and form a solid. However, water remains a fluid even if there is no such recognition. With electrons it is the same. There are two possible conditions: it is either important that there is another electron nearby or it does not matter at all. Usually, electrons in a metal are in a free state where, if a switch is not thrown, the state does not stop (i.e. it doesn't become insulated). However, supposing there is a condition where fellow electrons could inform each other to stop on a dime, it would be possible then, because of the electrons themselves, for them to become either a metal or an insulator.

This topic is currently a strong research trend within the material sciences and we would like to gain insight on these phenomena, but, since the high-temperature superconductivity that was the start of this research, not much has been learned and as ever little is understood. Ordinary superconductivity until now conformed to a formula and is understood through explanations based on quantum mechanics. However, high-temperature superconductivity cannot be understood with that thinking and it turns out to be a very complex system. With various factors mixing and interacting together, this phenomenon does not occur without these factors understanding all of these interactions. Therefore, it is a fundamentally complex system. At this point, we don't even know how to write a formula for these phenomena. But, of course, there are some rules that apply.

—— If in the future it becomes possible to use light to control a phase transition caused by this strong correlation, what kinds of applications do you see for this research?

Within this strong correlation, there is the phenomenon where by sending a current in one direction it becomes metal, and when sending it the opposite direction it becomes an insulator. This kind of thing can act as a very simple kind of memory. In other words, a memory can be made by just connecting an electrode, but, when compared with the memory of today's semiconductors that write and delete at a rate of one-million cycles per second, this won't compete. For that reason, while this is an interesting phenomenon, economically it is not likely to be feasible. And, in this sense, I do not know where this research can be applied.

In pursuit of an inner world order: the road from aspiring novelist to physics engineering

—— When looking at your research, there is that aspect where I am somewhat envious that in your field you can clear things through proof, but didn't you also aspire to become a novelist? It seems, though, that your current research and the novel's complete disconnect from scientific proof are in opposite worlds...

Basically, it's that I like being alone. And, it's that, if I had the ability, I wanted to become a mathematician. I simply thought that the mathematician's work dealt with the perfect world within oneself. This shares some similarity with the novelist in that they construct this kind of world all by themselves. But, at some point, I thought again that it's quite hard to earn a living as a novelist. Another reason for abandoning my desire to be a novelist was that in reading chronologically through the history of Japanese literature, at about the period of Katai Tayama's and Hakucho Masamune's naturalism, I got fed up with it all...I mean what's so interesting about self-confession? At that point, I thought there is no way I'd become a novelist. But, I still had the desire to make a living by writing so I thought about becoming a literary critic, but during high school I read the essay "Multiple Designs" (*Samazama na ishо*) by Hideo Kobayashi and really felt that with my limited smarts I could never become a literary critic. For me it would be impossible.

Also, since I was young I'd liked science. Now when I think about it the experiment was quite dangerous, but when I was in the fourth grade of elementary school I used lye to make soap. I was also interested in science since you can find a certain kind of world and have fun with that world on your own. So, thinking I could at least become a science reporter for a newspaper, I enrolled in a freshman science class, but one thing led to another, and here I am today.

—— By the way, you went abroad immediately after graduating in engineering physics, right? What was the motive behind that?

Just at that time, there was the so-called campus unrest, and I really felt something was lacking with the irresolute stance of professors in Japan. So, I told a professor that I was thinking about looking for a job after graduation. "You're not suited for company life," he replied and instead suggested I go to America. Of course, there was research that I wanted to do, but at the time, had he not said anything, I think I would have gotten a job at a company.

—— How do you feel about the differences between Japan and overseas?

In terms of academia, there is almost no difference. Whether a person from a foreign country comes to Japan or a Japanese person goes to a foreign country, I don't think there is any feeling of discomfort.

Speaking of the good and the bad, the good part of Japan is that it is not an overly competitive society. When I was in America, I had constant stomach pain, but upon returning to Japan this completely disappeared. There was no one thing in particular. It was just that there was always pressure.

In any society, there is always the chance of losing your job. When I was at the Argonne National Laboratory in the United States, a post-doc researcher could be fired if the group leader said "you are finished." You need a laboratory director to fire an assistant professor and, though with an associate professor or above it is of course more difficult, you can always terminate someone. You see, to make a person work, it is best to have them think that they can be fired at any time. That's why American researchers work really hard, but whether that makes for good research or not is another issue. In that sense, I think it was good that I returned to Japan.

Conversely, in Japan, nothing is said even when a person is

imposing an obvious drawback to an organization. That's not good. It creates a very difficult situation for an organization, and in America those kinds of people definitely would not be able to make it.

—— Japan also is trying to adopt America's competitive system, but how were evaluations done?

Argonne National Laboratory is a large research center with four to five thousand employees, but it is the directors of research divisions that decide everything. Level of administrative contribution, number of published papers, and number of invited lectures were used as criterion, and the salaries were also assessed using these criteria.

Establishing a system with a high degree of freedom and reviewing the educational curriculum: What is the systematic reform for the Research Center for Advanced Science and Technology?

—— Even for the Center, systemic reform is one of its missions. As its director, what is your thinking about this?

I think the ideal form for an organization is the situation where one does not feel constrained and can do their job at their full strength. A degree of freedom is real important. Because people demonstrate their abilities when they are doing what they want to be doing, it's not effective to have a management approach where people feel they must do certain things. While I won't go against the way things are done now, you could say that, at least within acceptable limits, my manifesto is "to make a system with the highest degree of freedom."

As a specific policy, the management of effort percentages allows, for instance, a way of working where one puts 50% of their effort toward their professorial work at the Center and 50% elsewhere. I believe it will not be long before this policy will be realized. However, the problem is that when this becomes disconnected from personnel expenses including retirement benefits, there is considerable resistance against the policy. As someone who experienced the period of campus unrest, I don't think that the world is always stable. Rather than drive on a road that is already paved, it is better to pave the road yourself. It is my philosophy that it is better to think about planning for the future. But you can't force people too much...

——Well, the Center is a place where people research with others in different fields, but actually I get the feeling that when one gets too removed from one's specialization it is difficult to harmonize with other fields. The same is true with education. While in America and elsewhere students are educated to look at things broadly, in Japan they suddenly jump into a specialization. What are your thoughts on education at the Center?

First, I actually don't really understand what is referred to by the merger of the humanities and sciences. If there are problems due to the division between the humanities and sciences, it is alright to fix those, but I absolutely don't believe there is an unspoken agreement that the humanities and sciences must do things together. Then again, for instance, at the Center we are hosting the Intellectual Cafe. The other day, the topic was about the discharge of carbon dioxide gas, but with that topic there are important crossover questions such as the technological factor of where to put the discharged carbon dioxide gas, the economic factor of achieving the target figures for reduced discharge, and the diplomatic factor of how to take the initiative on international negotiations. Perhaps, it is only at the Center where these questions can be discussed at the same place and from multiple perspectives.

Elsewhere, regarding education, we have curriculum discussions. On the education side, systematic reform is necessary, including whether it is good or not to have classes that are in the interdisciplinary omnibus-manner that is said to be becoming of the Center. The biggest difficulty is that students' interests are narrow. Even with talk that is unrelated to their field, I think somehow they have to interact. It's not whether you know or don't know something; it's a part of one's intellect. Training people to be able to properly communicate, I think, is an important role for the Center.

——Lastly, how are you doing in your double role as both a researcher and the director?

Presently, it is kind of hard to say whether or not I'm doing double duty, but at least it is not as bad as thought it might be. The reason for that is clearly the quality of the staff. When there is an unresolved issue, it is sent to the person in charge and some proposal emerges. At those times, there are two important things. The first are those things internal to the Center that have to be understood and written about. The other thing is the understanding of the background of a problem. In order to keep continuous track of a problem, energy has to be focused on it, but not having to do that makes it very easy. This is not only the case for me; I think it is true for the entire Center. I want everyone to realize that our staff reduces the workload of the Center's faculty members. It really is a reduction in work for us.

—— I was worried about the stress of your taking on the position of director, but now I'm somewhat relieved. I certainly hope that you will not only continue your work as director, but also in research, as you also mentioned there is still so much that is not understood. So, please devote some of your energy to your research and also continue provide us with your leadership. Thank you.

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Links

Miyano Lab
http://www.myn.rcast.u-tokyo.ac.jp/index.html.en