Messages from Modern Inventors to the Next Generation

1. *Electron Microscope to Look at the Microscopic World* - Dr. Akira Tonomura, Hitachi, Ltd.

Electron microscopes are, as the name indicates, scientific instruments for observing very small objects using a beam of electrons to illuminate the specimen and create magnified images of it. Since an electron microscope can magnify a marble to the size of the earth, it is an indispensable tool in medical research, for example observing viruses and microorganisms, which normally cannot be seen with the naked eye.

Dr. Tonomura has been studying electron waves at Hitachi, Ltd. and developed a holography electron microscope to observe quantum mechanical phenomena. Among his world-class achievements is the experimental verification of the existence of the Aharonov-Bohm effect. Because of these achievements he has received many awards including the Benjamin Franklin medal in physics in 1999.

What inspired you to become an inventor/researcher?

When I was a child, I enjoyed collecting plants and observing insects in the fields. Even now, I enjoy watching a butterfly on a flower extending its proboscis to sip nectar. In my childhood days, I was frequently ill, and while being bedridden, I used to look up the beautiful wood grain on the ceiling imagining its three-dimensional structures. On a rainy day, I used to gaze at ripples spreading on a rain puddle. Upon entering junior high school, I joined the physics club and reported at the meeting why the recently launched satellite “Sputnik” was able to go around the earth without dropping down to the earth. This episode was mentioned by my former classmate at a class reunion many years later. I guess in this way I naturally took the road to study physics.

Upon entering the University of Tokyo, I was intrigued by the “quantum mechanics,” which

describes laws of the microscopic world. Since then I had the strong desire to directly observe the quantum world and became an electron microscope researcher. I have not achieved the stature of Antonie van Leeuwenhoek (1632-1723: Dutch biologist and inventor of the world's first microscope) who built 500 handmade optical microscopes to see microbes. Nevertheless, I have been developing new types of electron microscopes to see what nobody else has ever seen.

What specific ideas and difficulties have you faced as an inventor/researcher?

You have to develop new equipment when you attack a new problem. In addition you must have "new ideas" and "persistence" to attain your goal.

When I joined Hitachi, Ltd. in 1965, development of higher resolution electron microscopes was stalled because of the problems of aberration. To overcome these difficulties and improve the performance of the electron microscope, I began to develop a new microscope using "electron holography" with an aim of directly observing electron waves. For a successful use of wave properties, the electron beams must have high coherency just like a laser. For 40 years, I have been developing the technique called field emission by which electrons are extracted from the needle tip using only an electric field based on the principle of lightning rod. Electron beams coming out of the needle tip are so weak that they become easily disturbed even if there is small vibration of the source needle. In addition, we need an ultrahigh vacuum for electron beams not to collide with remaining particles in the air. After various efforts to achieve these conditions, we finally succeeded in observing "electronic ripples" which had never been seen.

What gives you joy as an inventor/researcher?

Electron beams emitted from the needle tip, moving in parallel, are very delicate, and a small amount of disturbances can deteriorate the performance of electron microscope.

We tried every means we could think of to find the cause of disturbances. One episode is still vivid in my mind.

We wondered whether the disturbance might possibly be caused by trains passing near our laboratory. One of us went up to the tower on the 12th floor of the Central Research Laboratory, and by phone he reported the coming-and-going of trains to the other member who was observing electron beams. Around midnight, as the number of passing trains decreased, the disturbance of the electron beam also decreased. After the last train passed by, the main disturbance vanished. The disturbance occurred when a train started at the Kokubunji station.

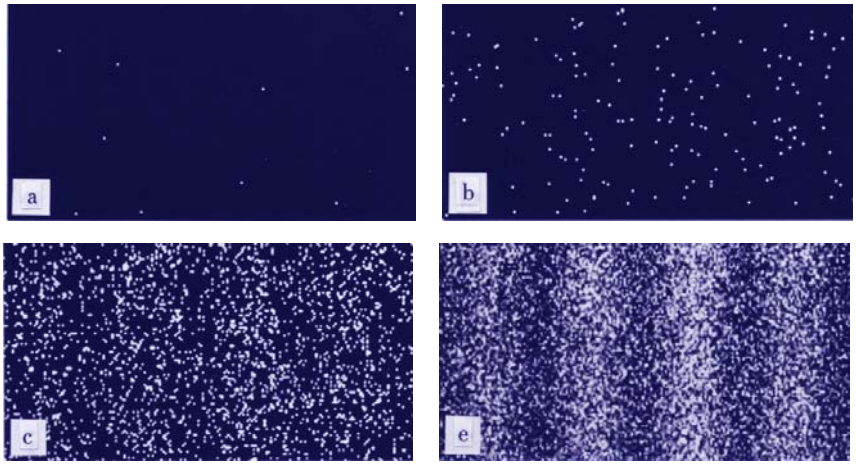
Finding a cause is the same as solving the problem. After months of persistent effort, we succeeded in having an excellent outcome with a surprising photograph. The number of fine stripes on the film called “interference fringes” exceeded 3000, indicating a dramatic improvement of equipment performance. That was the day when “electron holography” was realized.

Once you find the cause of a problem, you can achieve success through persistent effort. “Finding the cause” and “solving riddles” are indeed the real thrill of research and development.

Photo of the “One-million Volt Holography Electron Microscope” developed by Dr. Tonomura.

What message would you like to give to the next generation?

I’m sure you are very interested in various issues in the world. As you grow up, you will probably lose interest in these things around you because of an increasing amount of studies and examinations at school. However, it is very important for you to be continuously and increasingly interested in many things. Albert Einstein established the special theory of relativity while he kept asking the following question: “Light always travels at the speed of light and there exists no speed faster than the speed of light. Then, what happens when you run at a speed close to the speed of light and observe the light?” When you have a lot of curiosity, you will be able to concentrate on your research, recover from failures, and continue your efforts for a long time. Research results and inventions must be “the first in the world” and imitations have no value. The significance of your research results are not necessarily recognized immediately. For example, my double slit experiment performed in 1989 was chosen as “the most beautiful experiment in the history of physics” by the British magazine in 2002 - more than ten years after the experiment. The transmission electron microscope equipped with electron beams emitted from the needle tip, which I developed, was commercialized ten years later and has spread worldwide.



Photographs showing the double slit experiment chosen as “the most beautiful experiment in the history of physics.” The emitted electrons (white dots) create a striped pattern when the number of electrons is increased (from a to d).