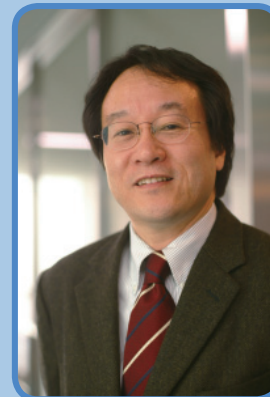


Wakōdōjin – The Harmony of Light in the Nano-World

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▶ Tokyo Tower

I would have never dreamed that I would be impressed by the use of computer graphics – not in a science fiction film about the future or space travel – but in a Japanese production entitled *Always Sunset on Third Street*, a motion picture set in Tokyo during the “good old days” of the 1950s. It was Michael J. Fox in *Back to the Future* who taught me that the place I longed to visit was not the distant future, but rather the memory-filled past; However, I believe that *Always Sunset on Third Street* managed to successfully breathe Japanese culture into the world of computer graphics. Through the sequel and other films such as *Invitation from Cinema Orion*, a new Japanese film culture is being created within the world of digital cinema. *Always Sunset on Third Street*, a film that grew out of the Japanese *manga* tradition which is now being regarded as “cool” by many young people around the world, is an embodiment of the roots of contemporary Japanese culture, from the three-wheeled Midget pickup truck – the symbol of Japan’s postwar recovery – television sets, refrigerators, and other electrical appliances, to Japanese *izakaya* bars where “salarymen” around the world now find comfort.

Another film, *Memories of Tomorrow*, taught us that immediately forgetting recent events, while at the same time recalling memories from the far-off past, is a symptom of dementia, which I found to my great regret to be true. *Always Sunset on Third Street* caused me to realize that, while I sometimes forget things that happened yesterday, I can clearly remember when I would run over to a

nearby friend’s home to watch the television when I was in elementary school, or the day when my family bought our first television set, or the time that all of us were thrilled as we watched the champion wrestler *Rikidōzan* deliver a powerful karate chop over the airwaves. Programs that I listened to on the radio like *Akadō Suzunosuke* (Redbreast Suzunosuke) and *Otōsan wa Ohitoyoshi* (Father Is Good-Natured) were adapted into television programs, and the *Astro Boy* which I enjoyed was not the cartoon but the original live-action version. It seems that I remember the period between the late 1950s and early 1960s quite well. The Tokyo Tower was built, the Kodama express train ran on the Tokaido line between Tokyo and Osaka, at home we acquired a plethora of new electrical appliances – a television, refrigerator, washing machine, and vacuum cleaner – and Japan was in the midst of a period of steep economic growth. Occasionally, when we would see large American cars cruising around town we realized that we were still a long way behind, but everyone still felt a sense of pride when “made-in-Japan” small machines like cameras and televisions were making inroads into the world.

▶ Watches and Cameras

It was out with fighter planes and battle ships, and in with watches and transistor radios – Post-war Japan made its contributions to the world through precision instruments and electronics. From the Walkman and the Nintendo DS to Choro-Q toy cars, plastic models and

compact cars, the manufacturing of small machines has remained Japan's forte to this day. Japan is a country where buses and trains run strictly according to schedule and people are known to work hard and meticulously. Perhaps it is no wonder that the Japanese are well suited to jobs that require intricacy and precision.

Making optical instruments such as cameras is also a particular specialty of the Japanese. From the age of the film-based camera on to the current age of the digital camera, the image of the camera has been closely identified with Japanese manufacturers. Technological innovation in the optical industry proceeds almost exclusively from Japan, covering everything from microscopes and integrated circuit patterning (lithography) to DVDs, camcorders, and non-camera items such as liquid crystal displays and semiconductor lasers.

In the present 21st century, small machines have evolved from the mini to the micro and now to the nano. Optics has grown from the science of optical instruments to a quantum science called photonics, which now stands

on par with that of electronics. The opening of the nano world has led to the creation of a new science, nanoscience, which is functionally and effectively different from the micro world. Likewise, photonics is now driving the industrial application of science based on the interactions of photons and matter, in a way which is essentially different from previous optical technology. The precision and optical instruments which underpinned post-war Japan are now mirrored in the nano and photon technologies which are beginning to make contributions to the entire globe.

The Future of Photonics

Unlike electrons as charged particles, which propagate through either metals, semiconductors, or vacuum cathode ray tubes, non-charged particles, photons move through water, glass, and air. Herein lies the



major difference between electronics and photonics. Wireless LANs (Local Area Networks), mobile phones, and television remote controllers all receive and transmit photons (including microwaves and near infrared light) through the air. Projectors and laser pointers also transmit visible light through the air without wires; CDs, DVDs, and Bluray Discs operate through the recording and reading of optical signals via a non-contact mechanism. The bandwidth of optical fiber is much wider than that of conventional electric cable.

The advance of photonics into the world of clinical treatment and diagnosis is also phenomenal. Light is harmless to the body; the near infrared light and microwaves are not absorbed with body. Spectroscopy is a powerful tool to identify or analyze molecules with their colour and it is used in biosensors and biochips. Laser therapy or photodynamic therapy is a promising painless therapy of the future.

The future of photonics has a vast amount of potential. The switchover from electronics to photonics is evident in the development of a range of industrial sectors and fundamental sciences. Because optics and spectroscopy provide the foundation for not only quantum science, astronomy, and other physical sciences, but all varieties of natural sciences including mathematics, chemistry, and biology as well, the importance of photonics has been often overlooked, but in the 21st century, it is indeed photonics that will be opening the way for cutting-edge scientific advances and new industries.

 **Mr. Photon's Dilemma**

There was a problem with our friend "Mr. Photon." He was a giant in the Nanotechnology generation; he was not able to pass through a nano-hole smaller than himself. Mr. Photon was worried that he would not be able to make his own contribution to the heralded age of nanotechnology. Heisenberg has stated that it would not be possible to precisely determine the momentum and the position of an electron or a photon. A photon cannot pass through a pinhole smaller than its own wavelength. The only thing able to pass through nano-hole is ex-

tremely short wave light X-ray.

Abbe stated that a photon diffracts and spreads out as wide as its wavelength. This accepted principle of classical physics was overturned by the new concept "slow light." The wavelength is a function of (proportional to) its speed. The wavelength of slow light is shorter than ordinary light; it passes through a nano-pinhole, draws and reads nano-structures.

Slow light exists on the surface of metal. It is due to the resonance mode of collective oscillation of electrons on the surface of metal, which is called as a "surface plasmon polariton." The study on this quanta is known as "Plasmonics." A light microscope to visualize nano-structures by scanning the sample surface with a metal needle is referred to as "near field scanning optical microscope (NSOM)." In these days, everyone agrees that metallic nano-probe provides nano-resolution image with near-field microscope geometry, although it was not well-accepted by people when I presented fifteen years ago. Plasmonics is another veritable Egg of Columbus.

As it turned out, Mr. Photon's dilemma was resolved by metal, especially gold and silver and other precious metals. Existing optics textbooks will be rewritten as that the diffraction limit of light could be exceeded. In addition, the statements that there is no substance with a negative refractive index and that the magnetic permeability of any substance within the range of visible light is 1(unity), will also be refuted by the recent research results in plasmonics. Textbook is not dead, but keeps updating.

Yukichi Fukuzawa, a great Japanese social theorist of the 19th century, stated that the "advance of civilization has always arisen from heretical opinion" and that "scholars should not heed the clamor of public opinion but have the courage to voice the opinions without any fear of being called wrong." (*An Outline of a Theory of Modernization*)

 **Nano-colored Dreams**

If nanostructures could be manipulated using photons, the resulting science would provide an unparalleled level of utility and also excitement. With electron microscopes,

the sample is placed in a vacuum to be irradiated with an electron beam. If nanostructures are visualized using photons, they can be observed as they are without being placed in a vacuum. An image obtained with an electron microscope is in black and white, while a light microscope provides a color image of a sample. This indicates in the future that DNA and other molecules can be seen in full color through a light microscope. Imagine what a wonderful experience it would be if we could see DNA as a color image without having to subject it to chemical processing!

One of recent public concerns in Japan is the contamination of pesticide in frozen pork dumplings made in China. Liquid chromatography and other chemical analyses are used to detect such substances. However, chemical processing does not visualize the distribution of contamination either in the vegetable or the skin or pork meat. Near field scanning fluorescence or Raman microscope would examine the sample at nano level and in color. It would tell you which part of the dumpling the chemical was present. The molecular distribution, crystallinity and defects of nanomaterials, devices and cells are now observed in color. Nanophotonics would revolutionize not only modern natural sciences but also cutting-edge industries.

Schumpeter

Joseph Schumpeter, a modern economist who introduced the concept of “innovation,” said that “innovation arises from creative destruction.” The challenge thought to be impossible, in the spirit of creative destruction, constitutes the thrill of science and also of business. An idea currently commonly accepted by people might have been an extreme opinion just until only a few years ago, and no one would have believed it to be possible. For example, it was a common sense in Japan until a few years ago that national universities should maintain the freedom of scientific against any industry or private companies, and professors who carried out the research collaboration relations was overlooked by his colleagues with jealousy. Making money was seen as an evil for

university professors. However, now noone criticizes university participation in the creation of new industries, but rather it is encouraged. Through government incentives, professors feel under pressure to promote tie-ups with industry and business startups. For big companies, the central research laboratory system is longer gone but no more contemporary. A new movement for them is afoot to make the best use of Japan’s universities. The universities and industries have begun to work together to create new sciences, industries, and human resources from the previous relationship called water and oil in Japan.

A new age demands a new scientific discipline and a new program. Osaka University has established a new center program, Photonics Advanced Research Center under the science promotion grant program of Ministry of Education, Culture, Sports, Science and Technology. This new center ties up with five Japanese enterprises including Nitto Denko to promote nanophotonics for both scientific and industrial contribution. New sciences and new industries do not arise exclusively from university or industry, but are born through innovation arising out of integration of sciences, applied research, and product planning and development, as well as customer requirements. Nanotechnology and photonics will be required particularly to act as pioneers in this process. Osaka University wishes to make a continuous contribution to the creation of new industries where nanotechnology and photonics are key elements, I believe.

The title of this article – *Wakōdōjin* (Dimmed his Light and Mingled with Dust) – is a quote from the ancient Chinese philosopher Laozi, which refers to the state of the Buddha as concealing the “glory” of his wisdom and virtue (dimming his light) and taking on a mundane form in order to better relate to dust, or earthly beings (mingling with dust). The Chinese character for “dust” also indicates a numerical unit far smaller than one 10^{th} , 100^{th} , $1,000^{\text{th}}$, or $10,000^{\text{th}}$, 10^{-9} , which is the “nano” unit. I deliberately chose this phrase for my title out of a sincere wish that the nano unit and the photon will underpin the civilizations of a new era as they mingle together and wisdom is assimilated into society.