Dr. Arpad Bergh is President of the Optoelectronics Industry Development Association (OIDA), Washington, D.C., which represents the North American optoelectronics industry. A physical chemist, Bergh spent many years at Bell Laboratories and Bellcore working on lasers, LEDs, and other photonic devices. While at Bell Labs he co-authored a book entitled Light Emitting Diodes. Published in 1976, this pioneering work is still used as a university text.

A Bright New Paradigm

What is your vision of lighting ten to twenty years from now?
Bergh: There will be a new lighting paradigm, which will constitute solid-state technology’s third major transition. The first transition came about when transistors replaced electron tubes. The next was when flat panel liquid crystal displays began replacing cathode ray tubes. The third will come when today’s lighting — incandescent and fluorescent glass vacuum tubes — will be replaced by solid state LEDs and OLEDs.

When will that transition take place?
Bergh: There are two main categories of lighting. The distinction is whether one looks at the light source, or at the reflected light. The first area involves signage, signaling, and large area outdoor displays where LEDs are currently making inroads. This is because LEDs are very efficient at producing certain colors, like the ones used in traffic lights. Lighting for illumination, however, requires white light. This is not yet efficient for reasons ranging from insufficient brightness to the different voltage requirements and aging characteristics of the various color LEDs. But LEDs are ideal for mobile platforms, cars, airplanes, ships, and trains, where they are also beginning to be used because of their long life, small size, rugged nature, and the readily available low voltage (3.5 volts) DC current at which they operate. But LEDs will not be used as reflected light sources for at least another ten to twenty years.

When do you expect OLEDs to make their commercial debut?
Bergh: OLEDs have only been around for ten years, while LEDs have been in existence for 30 years. As a result, OLEDs have not yet reached the point where practical applications can be demonstrated. To make a light source you need efficient light, long life, and color control. All of these have been demonstrated in OLEDs, but not in the same structure. OLEDs have another problem in that the material used in them is sensitive to oxygen and water vapor, so they must be sealed. If the seal breaks, they immediately degrade. Nonetheless, OLEDs are ready to enter the market in small displays, such as cell phones, where little light is needed.

Do OLEDs have any advantages over LEDs?
Bergh: Their primary advantage is low cost. Organic materials — plastics — are inexpensive, and they can be produced in large formats. You can cover walls or ceilings with OLEDs. Unlike LEDs that are made of expensive materials and provide concentrated light, OLEDs are not very bright, but they generate light over very large areas. Furthermore, they have great potential as a display medium since they are fast, capable of displaying video and, unlike today’s liquid crystal displays, have a wide viewing angle.

What forms might solid-state lighting eventually take?
Bergh: Most people imagine the new light sources as one-to-one replacements of the old ones, but that is incorrect. Sixty years ago the radio was a large box full of electron tubes. Today you can have one in your wristwatch, and it is no longer expensive. Just as transistor radios did not replace the old boxes, but rather the function, the same type of major paradigm shift is coming in lighting. We will not be replacing light bulbs, we will be replacing lighting. Today’s light bulbs require volume. There are fixtures for bulbs in ceilings, and major sections of car bodies are cut out for lamps. Solid-state light sources will be much smaller. We will move from 3-D to 2-D, and the new lights will be virtually everywhere. They will be intrinsic parts of structures, and intrinsic parts of anything inside the structures. They will be built into furniture, into walls and ceilings, and they will be permanent parts of these structures because their lifetimes will be extremely long.

What is required before LEDs can be used for general illumination?
Bergh: Efficiency is a major issue. At 20 to 30 lumens per watt LED efficiency already exceeds that of incandescent lamps, which is around 16 lumens per watt. But before LEDs can become useful for general illumination they have to beat fluorescent lamps, which offer some 85 to 100 lumens per watt. To become really attractive, LEDs will have to reach something on the order of 200 lumens per watt. The fundamental problem with LEDs is not generating light, but getting the light out of them. Light is generated inside a semiconductor material, which has a very high index of refraction. What’s important is how many photons are derived from every electron sent into that structure. That’s called the internal quantum efficiency.
which for some LEDs can be close to 100 percent. The problem comes with getting the photons out of the structure. High index refraction materials have very narrow escape cones, or angles. If a light beam hits the surface outside that escape cone, it is reflected internally. Typically, only about 20 percent of the light escapes from an LED. Structures allowing 50 percent of the light to emerge have been demonstrated, but they are elaborate and expensive.

What makes LEDs efficient for signals?
Bergh: Color. Consider a red stoplight that uses a red filter in front of an incandescent lamp that generates 16 lumens per watt. The red part of that light is only about ten percent of the total, so you end up with 1.6 lumens per watt output. With a red LED only red light is generated, making LEDs much more efficient than filtered white light.

How will LEDs change our lives?
Bergh: The lighting industry has been left out of the information age. When it does catch up, lighting will be used intermittently for illumination and information displays, and it will be intelligent. Built-in light displays will flash information virtually everywhere. And because LEDs can be easily mounted on integrated circuits, they will become smart lights that will turn on when and where they are needed, and they will give the type of lighting required. They will be able to adjust their color, brightness, and directionality.

What additional benefits do you foresee?
Bergh: A major benefit will be energy savings, which means environmental improvement. Also, with the new lighting paradigm, the type of light needed will be generated where it is needed, when it is needed. And the small size of LEDs will give designers the freedom to provide light in places we don’t think of today, such as at keyholes.

How big could energy savings be?
Bergh: It has been estimated that total U.S. lighting-related energy consumption amounts to eight quads, in other words eight quadrillion British thermal units (that’s equivalent to 288 million tons of coal or about eight percent of total U.S. energy use). If solid-state lights could squeeze 150-200 lumens out of each watt, the maximum potential savings would amount to four quads, or half the current lighting-related energy consumption of the U.S. The Department of Energy’s most optimistic replacement scenario estimates a potential cumulative saving of 16.6 Quads between 2000 and 2020 with a cumulative saving of $112.8 billion to the consumer.

Do you envision virtual environments?
Bergh: They are not going to be virtual; they are going to be ideal environments. During the day the color of light outdoors changes. It is reddish in the morning and at night, and bluish during the daytime. Experiments have shown that people respond well to these changes. Solid-state lighting provides opportunities to create indoor environments that imitate the natural outdoor environment. That’s going to have positive psychological effects on people, and improve productivity.

What does the future hold for the “old” lighting technologies?
Bergh: They will fight back, which they are already doing very successfully. Compact fluorescent lamps that reach up to 60-80 lumens per watt have been developed to replace incandescent bulbs. Because of this and existing installations, I think the old technologies will be around for a long, long time. LEDs will first be used to perform functions the old technologies cannot, and they will replace the old technologies on mobile platforms within 10 to 15 years. Those applications will have to generate large volume usage so that the price comes down, before they totally replace current lighting sources. LEDs will have to reach a price of under $3 per thousand lumens before they can successfully compete with conventional light sources for general illumination. On stationary platforms that will happen gradually, first for special applications, and in mass when today’s buildings are replaced by new ones. The primary point is, don’t have a replacement mentality because you will misjudge what is to come. Think of a new paradigm.

■ Interview by Victor Chase

Potential savings could amount to half the current lighting-related energy consumption of the United States.