A revolution in lighting

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Modern illumination is not only much more efficient, but increasingly responsive to the rhythms of human life.

Lower Manhattan at night. Reflection. (New York City, USA) Photo: Colourbox

Look at a satellite image of a city at night and one thing is clear: we produce a lot of light. Streetlights, cars, houses, offices and factories all illuminate an otherwise dark Earth. There is no doubt that our lives are far more comfortable than they were before the invention of electric lighting some 200 years ago, but all that light has its cost.

One downside is the sheer amount of energy consumed – lighting accounts for around a quarter of all electricity used globally. Another is the effect that light has on our physical and mental well being. Oliver Stefani, a designer and engineer at the Fraunhofer Institute for Industrial Engineering in Stuttgart, notes that for millions of years humans experienced nothing but darkness at night, whereas many of us are now exposed to nearly constant levels of light while awake. That is a problem, he says, because our bodily rhythms depend on a cycle of light and dark. Interrupting that cycle, studies have shown, can disturb our sleep and make us depressed.

The importance of colour

While modern technologies allow us to reduce the quantity of light that we use (or at least the amount of energy we use for lighting), they also make it possible to improve the quality of our lighting. In other words, to vary light's colour, tone and intensity. An enormous range of colours can be generated by combining the output of several blue LEDs, each with a phosphor that

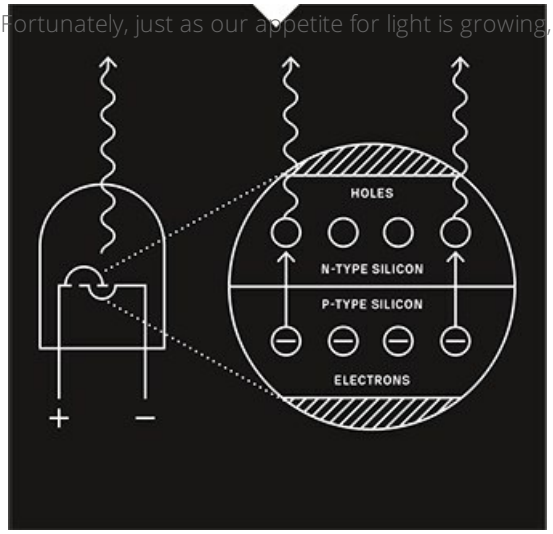

Figure 07. LEDs consist of a sandwich of semiconducting materials. When power is applied (left), photons of light are generated.

Fortunately, just as our appetite for light is growing, so too is our ability to produce and control it. In fact, says Jaime Gómez Rivas, a physicist at the Foundation for Fundamental Research on Matter in Amsterdam, we are currently going through a "revolution" in lighting. At the heart of that revolution is the light-emitting diode (LED), a tiny semiconductor device initially snubbed by consumers for its harsh white light and unreliability but which can now produce light with unprecedented efficiency and in colours that respect our body clocks.

The first LEDs, which emitted red light, were developed back in the 1950s, but it wasn't until the 1990s that three Japanese researchers invented a blue version. Earning the trio last year's Nobel prize in physics, this breakthrough was crucial for the manufacture of white-light sources, which generally employ a blue LED coated with a phosphor that gives off red and green light as well. The best commercial LEDs can now reach efficiencies – how much visible light they emit per unit input power – of about 150 lumens per watt (lm/W). That literally leaves incandescent and fluorescent bulbs in the shade, since these generate about 15 and 75 lm/W, respectively. It is still only about half of the theoretical maximum, but Hans van Sprang of Philips Research in Eindhoven argues that making up the remaining difference will make only a "marginal" contribution to overall efficiency, given the enormous improvement already achieved.

However, says van Sprang, there are still plenty of other areas where lighting can be improved. One is directionality. Standard LEDs emit light in all directions, but many devices, such as floodlights, projectors or headlights, require it to be beamed. Gómez Rivas and co-workers are developing silver and aluminium antennas just a few hundred nanometres long that are embedded in an LED's phosphor and which resonate with the light that the phosphor gives off. Arranged in arrays, these antennas create interference that reinforces emission in some directions – roughly doubling the intensity – and reduces it in others.

Another innovation is to make better use of the light that is produced. Dutch company Tvilight has developed a set of sensors that allows streetlights – whether using LEDs or more conventional techno- logy – to emit at full power only when a person or car, say, passes by. The sensors maintain output at a lower level for the rest of the time, and are able to distinguish passers-by from other sources of movement such as animals or rustling leaves. The system reduces energy consumption by up to 80%, according to Tvilight CEO Chintan Shah, and has so far been installed in a number of cities in the Netherlands, Germany, Ireland and Korea.

generates a different primary colour. So rather than giving off a fixed type of white light, LED devices can, for example, emit a warmer, yellower light in the evening and a colder, bluer light during the day. (Other technologies can do this, but they throw away much of the light in the process). What's more, it is now possible to save and then activate lighting schemes for certain rooms or times of day via a smartphone or tablet computer. Varying light so that it is more in tune with human needs is the aim of two projects underway at the Fraunhofer Institute. One involves studying the different combinations of primary colours that yield a given output colour, in order to be able to vary the amount of blue light given off by a screen without changing the screen's appearance. The other project is the "virtual sky" – tens of thousands of ceiling-mounted LEDs that simulate the varying daylight associated with passing clouds overhead, and which, according to Stefani, leaves people less tired than they would be under normal office lighting.

When it comes to mimicking the sky indoors, a new project by Italian company CoeLux is also sure to turn heads (upwards). CoeLux has created what looks like a skylight above which the Sun shines in the middle of a bright blue sky. In fact, the installation consists of an LED projector, some fancy optics and a layer of nanoparticles just a few millimetres thick. The latter act like a compressed version of the molecules in the real atmosphere – scattering the sun-like LED light so that it appears blue. Potentially a boon for windowless offices or basements, the technology currently costs a cool €60,000.

Light the world

LEDs are not the only game in town. White light can also be produced using blue laser diodes and a phosphorous plate, an approach that

German carmaker BMW is employing to generate extremely bright, focused beams for headlights. Another alternative is the organic light-emitting diode, or OLED, which emits photons from a film of organic semiconductor and which might prove useful in illuminating large areas uniformly. For Philips' van Sprang, however, the very high efficiencies already demonstrated by LEDs mean these technologies will probably occupy niche markets.

Indeed, LEDs' modest energy consumption has led to their deployment in the world's poorest regions, where there is limited access to electricity. The portable, ready-to-assemble lamps by LEDSafari, an EPFL start-up, are an inexpensive alternative to noxious kerosene lamps. It's hard to imagine anything simpler: built from plastic bottles and recycled electric wires, they use a mobile-phone battery to power an LED. More unconventionally, the British designed GravityLight relies on a slowly lowering bag of ballast to drive a small dynamo that in turn powers a set of LEDs.

As Tvilight's Shah says of street lighting in the developed world, "we have to move from dumb lighting to smart lighting". In countries where lighting can cost you your life, his statement rings even truer.

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