

Light Matters

Designing illumination systems with high-brightness LEDs

Two Latin words- *circa* (about) and *dies* (day) form the term *circadian*, as in circadian rhythm. This period, about a day in length, is one of the critical biological oscillations which govern many aspects of life on earth. For me the tie-in to light, and potentially to high-brightness LEDs, is fascinating.

Most biological rhythms have both endogenous and exogenous characteristics; they are internally driven and externally synchronized. In other words, they are similar to a phase-locked loop circuit. The internal “clock” in this case has a natural free-running period of about (*circa*) 24 hours. In the presence of certain stimuli, primarily a narrow spectrum of blue light, the oscillator’s period and phase are synchronized to the outside world. Without a source of external synchronization, the range of free-running circadian oscillators in nature generally varies between 20 and 28 hours, and is species-related.

The biological rhythms of microbes, plants, insects and animals have been studied carefully, but the last two groups of organisms are particularly interesting—they have many organs with intrinsic rhythms that are somehow synchronized to each other and they have a brain. This suggested that the brain contains a “master” exogenously entrained oscillator. The search for this mechanism began, and in the 1960s a particular area of the hypothalamus was identified. It’s known as the SCN, (suprachiasmatic nucleus) because of its location (above the optic chiasm, the spot where the left-right optic nerves cross).

As I mentioned earlier, light-dark cycles are the major synchronizer of circadian rhythms. This implies that all of these organisms must have some type of photoreceptors. Those photoreceptors are in our eyes, but for some mammals, circadian photo-entrainment occurs through the skin.

Until recently, there was another circadian mystery to unravel in humans—if circadian photo-entrainment occurs through our eyes, how is it that some people who are blind maintain circadian synchronization? The answer is that there is a different photoreceptive mechanism at work, beyond the familiar rods and cones we use for vision. In some presentations on this topic I use the term “third eye”, although the sensors don’t form images in the brain like rods

and cones do. These sensors are intrinsically photosensitive retinal ganglion cells, which unlike the other ganglion cells in the eye, are not associated with rods or cones. They’re essentially “free agents” with their own unique photosensitive protein (opsin) called melanopsin. Light of the right wavelength impinging on these cells is the primary signal used to synchronize the SCN. The action spectra is about 468 nm (blue light).

Just a few of the critical bodily functions related to circadian rhythm are alertness, appetite, hormone secretion, adrenal activity, sleep-wakefulness, electrophysiological processes associated with memory (learning) and possible dampening of behavioral disorders such as depression.

Taken together, I see the potential to beneficially influence many of our daily biological rhythms with carefully architected light. Such a light source needs to be controllable in terms of overall brightness as well as dynamic spectral content, especially selective introduction of 468 nm blue. This is an application of high-brightness LEDs (HBLED) that goes far beyond cost-savings due to improved energy efficiency. But caution is advised—yes, a properly designed HBLED source can help us overcome jet lag, but blue light should be used in moderation, with careful consideration of other “system-level” impacts. For example, there is gathering evidence that

excessive blue light at nighttime may increase the incidence of breast cancer¹. A possible cause is the fact that the SCN controls the pineal gland, which in turn excretes the hormone melatonin. Melatonin production drops when the eyes are exposed to 468 nm light. Melatonin appears to play an active role in the immune system² and functions as an antioxidant. We might want to use it to

resynchronize our clocks, but we certainly don’t want to eliminate it. Darkness is as essential to life as light.

Your comments are always welcome. This and other Light Matters articles are downloadable at www.em.avnet.com/LightSpeed

Fig 1 drawing by Yassine Mrabet, under GNU license, using data from Smolensky and Lamberg, and landscape clip inserts from Ryan, OCAL
¹ Davis, Mirick, Stevens (2001), Journal of the National Cancer Institute
² Carrillo-Vico A, Guerrero J, Lardone P, Reiter R (2005). “A review of the multiple actions of melatonin on the immune system”



Cary Eskow is Global Director of LightSpeed, the solid state lighting and LED business unit of Avnet Electronics Marketing. An ardent advocate of energy efficient LED-based illumination, he has worked closely with LED manufacturers, advanced analog IC and secondary optics vendors since his first patent using LEDs was issued two decades ago. LightSpeed works with customers through their national team of illumination-focused engineers called “Illumineers,” experienced in thermal, drive stage and optics design. Prior to LightSpeed, Cary was Avnet’s technical director and managed Avnet’s North American FAE team.

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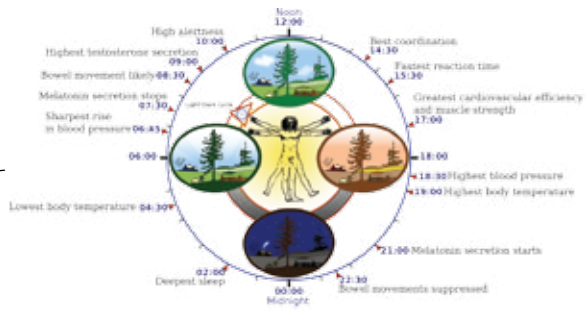


Figure 1 – One circadian revolution and a partial list of entrained functions



To learn more about designing an LED-based illumination system, go to: www.em.avnet.com/LightSpeed