High-power LEDs provide illumination and treatment in medical applications

An enormous range of medical applications, from surgical illumination to photodynamic therapy, can benefit from the advantages offered by LED light sources, according to **Gareth Jones** and **Grant Barnett** of Enfis Ltd.

The medical market has traditionally been an avid adopter of photonic technologies, from the use of laser sources for surgical and cosmetic applications to the more traditional use of specialized illumination sources for surgery or examination. The medical market places stringent requirements on the design of medical devices, with particular emphasis on the safety of the patient and operator. LED light sources are a safer and lower cost source of light and, with recent advances, LEDs are well placed to replace other high-power light sources for many medical applications.

The use of light in the treatment of medical and cosmetic conditions is a rapidly growing segment of the treatment market. Light can be used for both active treatment, with or without a drug, and also for sensing or diagnosis of medical conditions such as tumor detection. Treatments associated with the skin (dermatology) and cosmetic treatments are billion-dollar worldwide markets (see figure 1). With the advent of ultraviolet (UV) and white LED light sources, there are a growing number of opportunities in the use of LEDs for medical and dental lighting systems incorporating visible light and diagnostic elements such as UV fluorescence.

Medical applications make use of wavelengths from the UV-C band around 260 nm through to the upper end of the visible region around 750 nm, and also use white light. The needs of white lighting devices in medical applications are diverse, but in general require a stable source of high-quality (high CRI) white light that does not impart heat onto the examination area and is compact, safe and energy efficient. If designed properly, LEDs can be made to suit these requirements.

Examples of medical applications

The medical illumination, treatment and diagnosis fields encompass an enormous range of applications. Many of these utilize specialized light sources to enhance either the illumination level for the surgeon or to induce a response within the body such as fluorescence used to diagnose the presence of certain chemical or biological species. In this article we will describe some of the uses of high-power LEDs, for example:

- Medical lighting for the operating room and home environment;
- Phototherapy for dermatology and neonatal jaundice;
- Photodynamic therapy (PDT) and photodynamic disinfection (PDD);
- Deep-UV LEDs for photobiological disinfection.

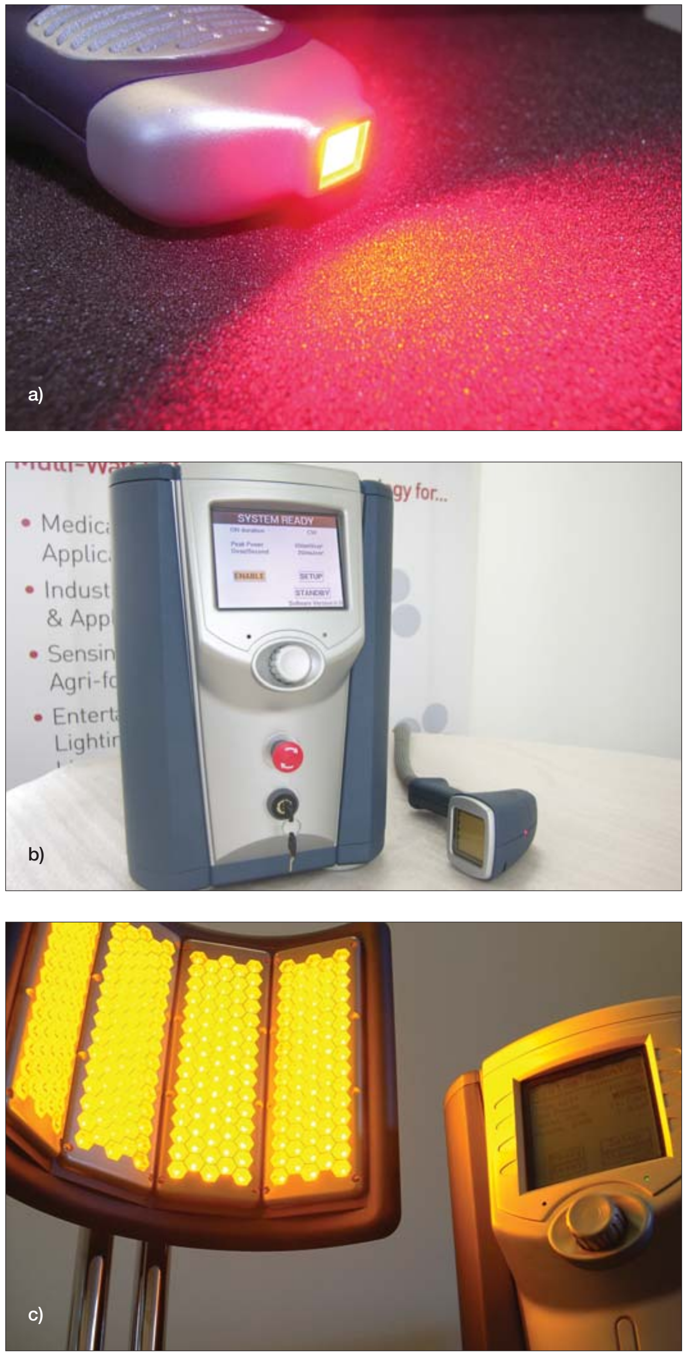

Fig. 1. LED-based systems from Enfis Ltd designed for various dermatological treatments: (a) a portable LED treatment device for use in the home; (b) a very high power-density system for use in a hospital or doctor's surgery; (c) a wide-area illumination system intended for use by doctors or in spas and health centers.

Medical lighting

High-power LEDs provide a number of unique advantages in medical illumination. They provide "cold" lighting, due to a negligible amount of infrared emission, which is a source of large amounts of heat from traditional lighting devices. LEDs also provide the ability to tune the color temperature across a wide range, and the ability to switch between colors quickly. They are generally small, compact and rugged light sources with higher efficiency and therefore lower power consumption than traditional sources, and there is a lack of mercury or glass in the lighting element. LEDs also have longer lifetimes, leading to lower cost of replacement and higher confidence in the lighting solution.

Of course, the use of LEDs in many lighting applications is still in its infancy, with issues still to be resolved, but none of these will prevent LEDs from achieving widespread adoption in the medical illumination fields.

Operating room illumination

Lighting an operating room (OR) places strong safety and reliability demands on lighting systems. LEDs have many technical and practical advantages over conventional halogen and gas discharge lamps, including extremely low radiative heat generation and high reliability, if designed properly.

With some LED fixtures, the surgeon can change the color temperature and maintain a high color rendering index to suit their own personal preferences during surgery. There is no need to filter out any UV wavelengths (since no UV is emitted).

LEDs also have an extremely long lifetime. As an example, halogen bulbs last between 200–1000 hours, while various types of LEDs claim a lifetime of between 8000–50,000 hours. As well as eliminating the need for replacement bulbs, such a long lifetime also reduces the associated down time of the OR room and maintenance costs.

LED surgical lights are already on the market (see figure 2). Systems with multiple (100–200) LEDs purport to emit 120,000–160,000 lux at 100 cm (the maximum light output permitted in many countries) with a color temperature of 3500–5000 K. Many different-colored LEDs populate the lens, enabling the surgeon to change the color temperature and color rendering index (CRI) in the 80–95 range. This is a product benefit to the surgeon when working in a location where there is a weak or heavy blood supply, as the color temperature can be altered for optimal contrast and differentiation.

As LED technology has developed, it is now possible for an OR illumination system to be built around a single multi-watt LED light engine and array. Such innovation may supersede existing "multi lens" systems with the potential for much lower costs and smaller, more maneuverable devices in the near future. The single source will operate in a similar fashion to conventional lighting-based OR systems, but will boast extremely long lifetimes, no IR or UV output, high efficiency, high CRI and the facility to change color temperature as and when required; these are safety and user features that halogen and gas exchange lights are not able to offer.

Lighting for health and well-being

One type of medical application that is gaining widespread interest, especially in Japan, is the use of light sources to provide low-level photobiological influences to people. Such effects include increasing the alertness of shift workers, reducing jet lag for long-haul passengers, and improving the symptoms of seasonally affected disorder (SAD).

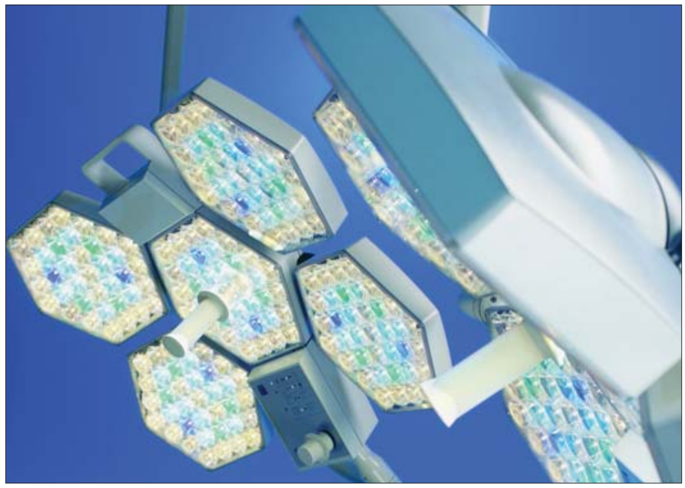

Fig. 2. Trumpf Medical Systems' iLED lighting system, a multi-LED light source for operating rooms that allows surgeons to adjust the color temperature (see www.ledsmagazine.com/articles/news/3/8/4).

Many companies are beginning to recognize the growing importance of lighting as a lifestyle entity and that the use of LEDs can dramatically enhance lifestyle effects. Lighting designers will soon be faced with a basic question. "Is the fundamental objective of lighting to provide an appropriate level of visibility without discomfort, or should we consider the photobiological effects of lighting as equally, and sometimes more, important?"

For many years scientists did not believe that such photobiological effects occurred in humans at the illuminance levels typically used indoors. Researchers thought that illuminance levels of at least 2000 lux were necessary to have any photobiological effect. Recently it has been shown that this is not true, depending upon the time of day that the light is administered, leading to a resurgence in the provision of lighting for well-being enhancement.

Shift work

In the United States and Europe, approximately 20% of the workforce is involved in shift work. Many workers can appreciate the difficulty of working what is called the graveyard shift (typically, midnight to 8:00 a.m.). Basically, you are trying to work when your body is telling you to sleep, and trying to sleep when everyone else is awake. Rapidly adjusting the sleep/wake cycle at the start and end of a series of night shifts, by using light to shift the phase of circadian rhythms, can alleviate this situation. (Circadian rhythms are a roughly 24-hour cycle in the physiological processes of living beings, and are important in determining sleep and feeding patterns.)

To make an economic case for the use of the photobiological effects of light on nightshift workers, however, tests have been performed to demonstrate that being more awake at night affects task performance. Following exposure to bright light, subjects who underwent cognitive performance tests showed improvements in complex cognitive tasks requiring logical reasoning and short-term memory.

Knowledge of these effects has led to the installation of lighting that provides high illuminance levels at times designed to shift circadian rhythms in a number of power-station and chemical-plant control rooms, where alert judgment can have major safety and economic impacts.

Fig. 3. The Litebook LED light therapy product (www.litebook.com) contains multiple white LEDs and treats jet lag, shift-work problems and the winter blues. The *elite* model launches this fall.

Jet lag

A common experience of unsynchronized circadian rhythms is jet lag, the feeling of being out of step with the pattern of life at their destination experienced by people who have traveled across several time zones. Timed light exposure is important for treating jet lag in business people, airline flight crews, and long-distance tourists. It is possible to predict the best times for light and dark exposure to rapidly shift a person's circadian rhythm and, in particular, the sleep/wake cycle.

Seasonally affected disorders

Less immediate effects of light are associated with seasonal changes, commonly manifested as SAD. This is a psychiatric condition in which people experience lethargy, depression, and food cravings during the winter, but not in the summer. SAD can often be successfully treated with exposure to light. Typically, light treatment uses two kinds of devices; the light box and the dawn simulator.

People diagnosed with SAD sit in front of the light box for a predetermined period of time; the higher the illuminance at the eye, the shorter the time of exposure. Conditions for exposure are typically 2500 lux at the eye for two to four hours or 10,000 lux for 30 minutes.

At present, many light-box products use fluorescent lamps (see for example www.lighttherapyproducts.com/products_lamps.html) to achieve the desired illumination levels and spectrum, but developments underway in LEDs sources will provide the same effects with a single source of high-intensity light with extended lifetime and compact form.

One problem with a light box is that it limits the patient's activities during the recommended exposure period, which is daily for several weeks. The dawn simulator is, as its name implies, a device that slowly increases the amount of light in a bedroom while the person sleeps to improve their mood at awakening. Both devices reduce seasonal depression for a number of the people who use them. However, the results of light exposure on seasonal depression provide no widely accepted explanation of the effect; light may be simply a very effective placebo. Although this is a possibility, scientists have demonstrated that both the light box and the dawn simulator alleviate depression more effectively than other relatively low-level lighting conditions designed to act as placebos.

Beyond vision

In the future, designing lighting solely for vision will be inadequate, but to meet this new challenge lighting designers and physiologists will have to meet additional needs. We will need a clearer understanding of the mechanisms involved, particularly for the treatment of depression and for the immediate effects of light such as the effect of lamp spectrum and its effect on the retinal photoreceptors.

It is only when we identify the spectral sensitivity of the active photoreceptors (and the requirements for vision) that we can derive the optimum lamp spectrum. This is where LED sources will become strong players since they are easily made up of many discrete wavelengths and can be added together to fine tune to achieve the best photobiological response.

This section on lighting for health and well-being has drawn upon the descriptions provided by Peter Boyce of the Human Factors Program at the Lighting Research Center in Troy, New York.

Phototherapy and dermatology

Multi-watt LED systems are starting to be used in the medical treatments sector to treat dermatological conditions such as acne, psoriasis and eczema. High power levels are a pre-requisite for efficacious treatments, but cost and safety issues have prevented the effective penetration of laser systems into the dermatology market.

LED light engine technology has been well proven to treat conditions such as mild to moderate acne. Recent trials used an Enfis high-intensity LED source, employing a narrowband yellow LED at 570–600 nm. This is similar to laser-based systems that claim to provide a fast and effective acne treatment. Figure 1 shows examples of LED-based systems developed by Enfis, which are being trialed for various dermatological treatments.

Well-proven clinical results and the safety of LED products means that the use of LED technology in the home environment without expert supervision is a viable prospect within a short timescale. The devices can be battery powered, are eye and skin safe, and are low cost. For many patients they provide a suitable efficacious alternative to conventional pharmaceutical compounds, which might not suit their lifestyle.

There is great interest from dermatologists who see the potential for high-power LED devices being used to treat their patients using UV, visible and infrared wavelengths. To enhance usability, it is now possible to incorporate, monitor and control multiple wavelengths on a single array, thus offering products that are truly differentiated from those available until now to the consumer, beauty therapist or dermatologist.

Treatments associated with the skin are billion-dollar worldwide markets. It is estimated that by 2009 the number of worldwide consumers utilizing light-based devices will increase to more than 12 million, with consumer sales rising to an estimated $1.4 billion. ●

Medical applications, part 2

In the next issue of *LEDs Magazine Review*, the authors will look at more medical applications for LEDs, including neonatal phototherapy, photodynamic therapy (PDT), photodynamic disinfection (PDD) and the use of deep-UV LEDs for disinfection.

About the authors

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