TECHNOLOGY

The art of illumination

In November 2006, the Yamaguchi Prefectural Art Museum in southern Japan held an exhibition entitled 'The Trip to Sesshu'. It commemorated the 500th anniversary of the death of the Zen Buddhist monk and painter Sesshu Toyo, whose delicate *suibokuga* ink paintings have been designated 'National Treasures' by the Japanese government.

So that visitors could appreciate Sesshu's scrolls as closely as possible to the way original admirers did — under candlelight or torchlight — some of the paintings were illuminated by a specially designed light-emitting diode (LED) system. Tsunemasa Taguchi and Michitaka Kono now provide the technical details of that system (T. Taguchi and M. Kono *J. Light Visual Environ.* **31,** 149–151; 2007).

LEDs are solid-state light emitters known for their energy efficiency, flexibility of design and robustness. For a long time, they were made to emit light only in a particular part of the visible-wavelength spectrum. But in the mid-1990s a new generation emerged, based on blue LEDs covered with a yellow phosphorescent layer, which emitted bright, white light.

Taguchi and Kono's lighting system used special LEDs that contained three different phosphors, each emitting at different frequencies. This meant that the white light emitted had a particularly high colour quality, as quantified on a scale known as the colour-rendering index. To optimize viewers' appreciation, the authors tailored the LEDs to render the earthy red colours characteristic of the antique scrolls especially well.

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The individual lights were positioned so as to distribute light evenly on the artwork (first two paintings pictured), rather than scattering it around them as fluorescent lamps would do (paintings in background). The output of the LEDs was stable and did not cause heating, thus assisting preservation of the precious scripts.

White LEDs are becoming ever brighter, more efficient and less expensive. As a result, traditional light bulbs are increasingly on the way out. Large-scale applications, such as car lights, traffic signals and Christmas decorations, are where the economic benefits of LED use are being felt. But the illumination of antique Japanese art must surely rank as one of the diodes' most aesthetically pleasing applications.

Liesbeth Venema

the spatial clustering of synapses with similar firing patterns. Thus, for some forms of activity-dependent plasticity in the hippocampus, the fundamental unit of regulation might be larger than an individual synapse[9], and rather a physically clustered cohort of synapses with similar firing patterns, whose spatial arrangement on dendrites arises naturally following mutually reinforcing interactions between synapses.

It is neuroscientists' goal to understand the plastic features of the brain that make storing memories and learning new behaviours possible. In trying to achieve this formidable goal, many neuroscientists hope that, by uncovering the mechanisms behind the regulation of individual synapses, they will reveal the rules that govern the wiring of the brain. Harvey and Svoboda's results introduce a new level of complexity. They demonstrate that these rules vary across distances as short as a few micrometres, and are themselves altered on a minute-by-minute time frame. ■

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METROLOGY

New generation of combs

Steven T. Cundiff

To measure an optical frequency, you are best off using an optical frequency comb. A radical approach shakes up how these combs are produced, and will permit their closer integration into optical-fibre technology.

Increasing the range over which frequencies can be accurately measured is an exertion driven both by applications (making sure that a mobile phone uses the right channel, for instance) and by fundamental physics: time and frequency are the most accurately measured physical quantities, and thus are often used in tests of theories such as relativity and quantum mechanics. Optical frequency combs[1,2] — arrays of regularly spaced, well-defined reference frequencies — have revolutionized these endeavours[3,4]. Optical atomic clocks using this form of benchmarking can be more precise[5] than the very best clocks referenced to the current caesium atomic time standard, and combs are increasingly being used for sensitive and rapid detection of molecular processes[6]. The growing importance of the technique was recognized by its appearance in the citation for the 2005 Nobel Prize in Physics[7].

On page 1214 of this issue, Del'Haye *et al.*[8] describe the creation of an optical frequency comb using a toroidal glass microresonator. The very strong light fields produced drive the optical response of the glass into the nonlinear regime, where the principle of wave superposition no longer applies and waves can mix with one another to create new frequencies. The flexibility and small size of this apparatus give it huge potential for use in diverse areas, from telecommunications to astrophysics.

Frequency combs provide a way of accurately measuring frequencies that are too high to be measured directly. At radio frequencies, combs are produced by driving an electrical element, typically a step-recovery diode, with a simple, sinusoidal input signal. Once this sine wave exceeds a threshold, the diode converts it into a square wave, which contains new frequencies. The highest frequency is determined by the switching time, and is around 100 picoseconds for the best diodes. The standardized comb frequencies thus generated are integer multiples (harmonics) of the well-known input-wave frequency.

Generating a comb with a useful frequency spacing at optical frequencies requires a different approach. Until a few years ago, this meant injecting light from a continuous-wave laser into an optical cavity containing an electro-optic modulator driven by a radio-frequency signal[9]. The result was a cascade of evenly spaced frequency lines above and below the laser's optical frequency, corresponding to adding or subtracting integer multiples of the radio-frequency modulator signal, with each line generating the next. Combs generated in this way generally spanned a frequency range of several terahertz.