Tunable lenses offer compact solution to combine floodlights and spotlights in one product

A luminaire's beam angle can be flexibly adjusted using a tunable-lens technology in which the shape of the lens can be adjusted, as **JOERG WERTLI** and **MICHAEL BUEELER** explain.

When designing an LED spotlight, components are available that enable many different beam angles. However, because each component usually provides a fixed beam angle, the customer has to decide in the design phase which beam angle (or angles) to use for an installation.

Sometimes it's possible to exchange optics to produce different beam angles. However, this is time consuming and cumbersome, especially as lamps are often hard to access after the installation is completed.

Other solutions are available that enable a variation in the beam angle without exchanging components, but they are inefficient and can be complex. In some cases it's possible to shift the lens away from the LED to focus the beam (up to a certain point). However, rings and shadows typically appear in the spot, and a lot of light is lost as the distance from the LED increases.

On the other hand, large show-lights or even some museum lights are equipped with a zoom lens for spot-size adjustment. As well as requiring lots of space and being inefficient, such zoom lenses are expensive in development and manufacturing, making them unsuitable for mass lighting applications.

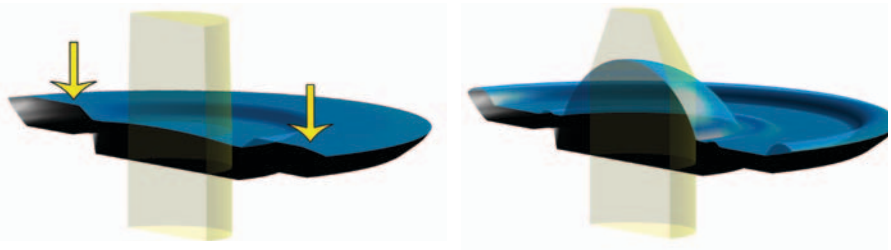

FIG. 1. Working principle of the tunable lens. Twisting the lens-shaper ring (left) applies pressure to the liquid-filled central container, causing a spherical lens to form (right), which reduces the beam angle.

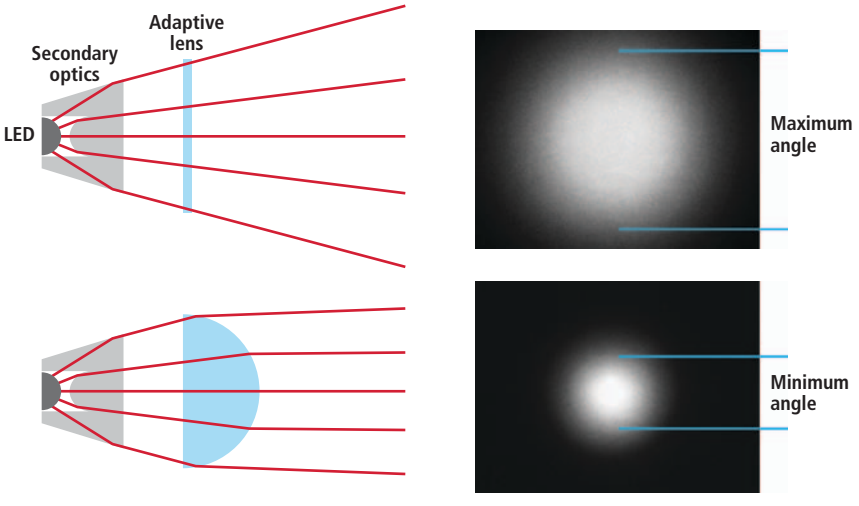

FIG. 2. Optical design using a tunable lens. (top) The maximum tuning angle corresponds to the beam-angle from the secondary lens. (bottom) The minimum beam angle/spot size results when the adaptive lens is fully tuned.

Tunable lenses

The tunable-lens technology developed by Optotune allows the beam angle to be set on site and to be adjusted whenever necessary. There is even the possibility of motorizing the tuning process for remote-controlled adjustments.

As well as reducing complexity costs by having just one product that can produce a range of outputs, from flood to spot, the tunable lens also offers new opportunities to change the beam angle for different settings, for example in a museum with chang-

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ing exhibitions.

The principle of the tunable-lens technology is outlined in Fig. 1. A ring, or so-called lens shaper, is pressed into a polycarbonate container filled with an optical liquid and sealed with a thin polymer membrane. This causes a spherical lens to form. The focal length of the lens changes in proportion to the liquid pressure. The clear aperture remains constant throughout the whole tuning range.

While being very efficient and compact, this technology allows a flexible adjustment of the beam angle when implemented in a spotlight. Turning a ring controls the movement of the lens shaper into the liquid-filled container and therefore the shape of the lens. A cogwheel in the housing offers the possibility of motorizing this process, enabling remote control of the beam angle.

FIG. 3. ML-25-50 Lumilens tunable lens from Optotune, which has an aperture of 25 mm and an overall outer diameter of 50 mm.

Optical design

Fig. 3 shows a spotlight design using Optotune's ML-25-50 Lumilens, illustrating the compact design possibilities for a spotlight. The optical design of a spotlight with a tunable lens is outlined in Fig. 2. The LED and the secondary optics define the maximum beam angle. It's important to use secondary optics with an even light distribution for a good tuning result. The tunable lens is then used to focus the beam from the wide flood angle to a narrow spot beam. For the spotlight design presented here, the beam-angle range goes from 40° down to 10°, but this range varies according to the design and optical components used.

Although a very new technology, tunable lenses have been extensively tested in various environments. Based on these results, the expected lifetime of the tunable lens is over 10 years within the operating temperature range of -20°C to 85°C. The lenses are built in a dust-free environment (clean room) and have a protective housing to keep them clean. However, the current products do not have waterproof housings, and are only suitable for indoor use.

The lens in Fig. 3 is one of Optotune's standard products, which has a clear aperture of 25 mm with an outer diameter of 50 mm. The largest lens currently available has a clear aperture of 55 mm, designed for large LED spotlights with lighting power of 2000-4000 lm. Prices for these standard lenses start at around EUR 20-30 depending on the volume and lens size. Technologically, it would be possible to build even larger lenses, or lenses as small as a 2-mm aperture.