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Recycling Light

Rotating a hemispherical mirror increases the intensity of a xenon lamp.

Hank Hogan

What do you do when you don't have enough light? Recycle what you have. That is the verdict of researchers from Ben-Gurion University of the Negev in Midreshet Ben-Gurion, Israel. They examined the effectiveness of recycling light in ultrabright short-discharge plasma lamps, revealing that light returned to a lamp's radiant zone can heighten the brightness by up to 70 percent.

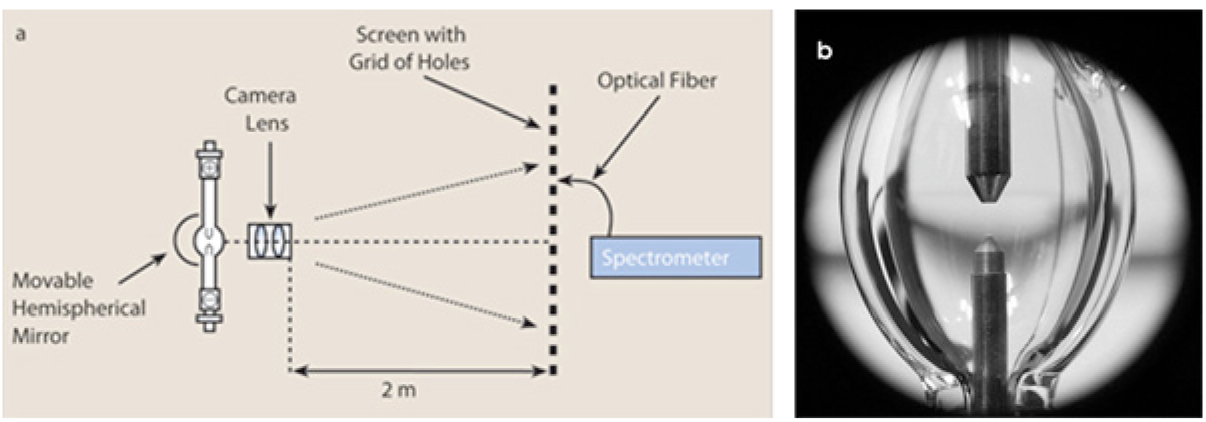

Figure 1. *A schematic shows an experimental setup for measuring the effectiveness of recycled light as a way to boost radiance. A hemispherical mirror reflects arc lamp emissions back through the lamp and onto a screen where the magnified plasma arc was mapped and its spectral content assessed with a spectrometer. The mirror can be moved so that parts of the plasma are imaged onto another for recycling (a). An image depicts a xenon lamp's bulb and 2-mm interelectrode region prior to ignition (b). Figures reprinted with permission of Optics Express.*

In conventional projection applications, it produces more and brighter flux on the screen. In other applications, light recycling could play a necessary role, said Jeffrey Gordon, a professor of solar energy and environmental physics at the university.

“In some chemical reactors and photopic surgical procedures, until a certain minimum power density is achieved at the target, the desired effect is not generated. By increasing the effective radiance — the brightness — of the lamp output, light recycling can achieve this,” he said.

The researchers used Hamamatsu 150-W xenon lamps for their experiments. Discharge lamps are bright and have a broadband emission, which could be useful in producing the near-infrared light needed for deep tissue penetration. They used a specular hemispherical mirror with a 35-mm radius and a reflectivity of about 90 percent. They placed the mirror so that it imaged plasma arc emissions back onto the lamp’s radiant zone.

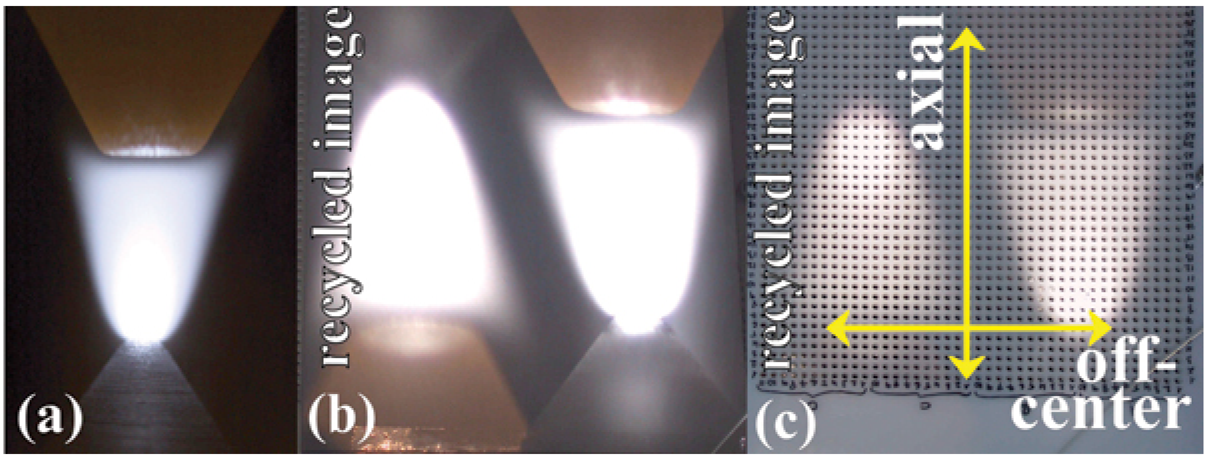

Figure 2. *A magnified image of a plasma arc with no light recycling (a) contrasts with an image of recycled light traversing the cooler outer plasma region (b). Adjacent images are shown projected onto a perforated screen (c). The center-to-center hole distance is 5 mm.*

They moved the mirror parallel to the lamp’s interelectrode axis, maximizing the light reflected into the plasma arc, a condition called full-gap recycling. They also overlapped the brightest regions of the actual and recycled arcs, a technique known as small-gap recycling.

Using a standard 50_ camera lens, they projected the image onto a screen perforated by a grid of holes and used a fiber probe to send the light from one hole at a time to a spectrophotometer made by Analytic Spectral Devices of Boulder, Colo. In this way, they mapped the spectral and spatial performance of the various light-recycling configurations that arose from different mirror positions.

Measurements showed a maximum radiance increase of 70 percent, but this increase was not over the entire discharge arc region or over the entire spectrum. Instead, the efficiency was 1.38 for full-gap and 1.23 for small-gap recycling, much less than the 1.7 maximum that the measurements indicated was possible.

Geometry, the researchers concluded, explained the shortfall. For full-gap recycling, they reported that the maximum was limited because the brightest regions of the recycled image traversed the more emissive zones of the plasma. Small-gap recycling, they noted, maximized local radiance within part of the arc, but overall collection efficiency was reduced because recycled light was projected beyond the plasma arc onto the cathode.

One solution, according to Gordon, might be to change the optics so that they do not image the cathode onto the anode or vice versa. “One could develop an optic that does not invert the image, or that double-inverts the image, such that the cathode is imaged near or onto itself.”

He added that such an adjustment should improve the global recycling efficiency noticeably. The group plans to follow up on this and other possible solutions. A drawback to light recycling could be a shortening of lamp life. Commercial vendors reportedly also are investigating this effect.

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