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Naomi J. Miller and Michael Grather

Another Sky-Glow Culprit The trouble with tilted outdoor lighting

With parking-lot lighting, it's so tempting to skip the calculation step in the design and simply specify the pole-top luminaire with a knuckle mount, so that it can be tilted if the throw of light doesn't reach all the way across the parking lot. It's a U0 fixture, and tilting it won't change the amount of glare or uplight...or will it?

You bet your socks it will. Tilting increases glare for many drivers and pedestrians, and alters the luminaire's backlight-uplight-glare (BUG) ratings. Many of us are weary of seeing tilted luminaires installed not just in parking lots, but also in warehouses, on buildings and along roadways. **Figure 1** shows a few all-too-familiar examples.

Luminaires, when shipped to a laboratory for photometry, are carefully mounted and leveled according to the manufacturers' intended installation orientation, and that's generally with the aperture facing downward (**Figure 2**). It's in this orientation that the intensity distribution is measured, reported in an .ies file, and the data evaluated for the BUG classification. The BUG system assigns a value of U0 through U5, depending on how many lumens are emitted upward, and IES guidelines and recommended practices use these classifications for different lighting zones. For example, in Zones 0 and 1 (the most environmentally sensitive zones), most utilitarian lights should be fully shielded, emitting light only downward and earning a U0 classification. Luminaires with a U0 classification minimize the scattering of light that is compounded into sky glow or that affects birds, insects and other wildlife looking for a tasty snack or a new date. Glare impact for drivers and vehicles is built into the BUG system, too. When you tilt a luminaire near a roadway, the luminous intensity could be increased in the direction of the driver's view. This can increase discomfort and veiling luminance that interfere with the driver's ability to see details on the roadway (such as that critter chasing a snack).

Sky glow, the glowing haze above most cities at night, is most affected by uplight, which is why tilting is such a concern. Calculating sky glow is complex, but the U.S. Department of Energy (DOE) Lighting R&D Program has developed a simple spreadsheet calculator (at *https://www.energy.gov/eere/ssl/potential-impacts-led-street-lighting-sky-glow*) to help estimate sky glow from different atmospheric conditions as well as from different luminaire optical choices, light output and spectral power distributions (SPDs). (The IES has a committee working on a Technical Memorandum on the calculation and prediction of sky glow caused by human-made lighting, so stay tuned.)

> "Tilting luminaires drastically affects their light-distribution traits, and not for the better

The calculations you see in **Tables 1 through 3** used that DOE tool to estimate the relative sky-glow contributions from different angles of tilting (a special shoutout to our Pacific Northwest National Laboratory colleague Jessica Collier for running the AGi32 simulations; calculations of tilted luminaire values were performed using Lighting Analysts' Photometric Toolbox). It's important to note here that all outdoor luminaires contribute to sky glow unless they're switched off. Even luminaires that direct all light downward will contribute to sky glow indirectly, since some percentage of the light is reflected from the ground and surrounding structures. But direct *uplight* is not mitigated through reflection and can be compounded by multiple bounces ("scattering") among the particulates and aerosols in the atmosphere. Consequently, a 10% increase in uplight can cause *much more* than a 10% increase in sky glow. In these tables, the baseline sky-glow contribution from the non-tilted luminaire is assigned a value of 100%, so that you can see the relative sky glow produced by the tilting.

Tilting the luminaire improves the pavement illuminances and

Photos: Courtesy of Michael Grather

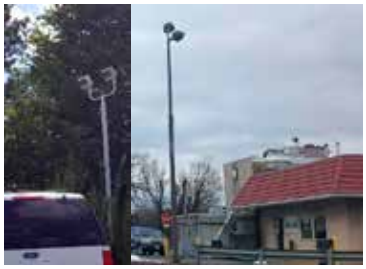


Figure 1. Two examples showing tilted luminaires in action.

Photo: Courtesy of LightLab International

Figure 2. Luminaire mounted for photometry in a laboratory; note the orientation.

the uniformity farther from the pole, so it's a natural assumption that this is a "harmless enough" practice. **Figure 3** shows a simple warehouse parking-lot calculation example, with two luminaires mounted 25-ft high and spaced 100 ft on center. The luminaire, when mounted horizontally or tilted, is oriented to the left. In the lower left of the calculation grid, at 100-ft horizontal distance you'll see the plan-view of a car driving toward the top of the grid. That driver is there so that we can calculate the intensity of the luminaire toward his or her eye, since intensity is proportional to veiling luminance, which can impair visibility and visual performance. (For the nerds in the audience, the candela value from the

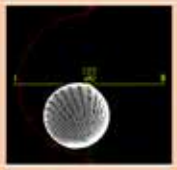
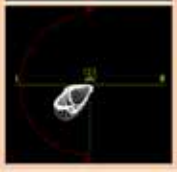
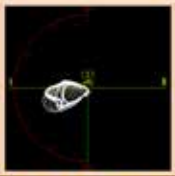
Cosine Distribution Luminaire Polar plot	Tilt	Lumens Downward	Pavement Illuminance at 75' from Pole (lx)	% Uplight	Relative Skyglow	BUG Ratings	Intensity Toward Driver's Eye (cd)
	0°	20,000	0.0 - 0.1	0.0%	100.0%	B4-U0-G2	258
	20°	19,680	0.2	1.6%	~120%	B3-U3-G5	2200
	45°	17319	0.3	13.4%	>220%	B3-U5-G5	4200
Type II Short Luminaire Polar plot	**Tilt**	**Lumens downward**	**Pavement Illuminance at 75' from Pole (lx)**	**% Uplight**	**Relative skyglow**	**BUG Ratings**	**Intensity toward eye (cd)***
	0°	20,000	0.0 - 0.1	0.0%	100%	B3-U0-G3	4000
	20°	19,782	0.3 - 0.4	1.1%	~112%	B2-U3-G5	5000
	45°	15,704	0.4	21.5%	~270%	B1-U5-G5	7600
Type IV Medium Luminaire Polar plot	**Tilt**	**Lumens downward**	**Pavement Illuminance at 75' from Pole (lx)**	**% Uplight**	**Relative skyglow**	**BUG Ratings**	**Intensity toward eye (cd)***
	0°	20,000	0.1 - 0.4	0%	100%	B3-U0-G3	132

Table 1. Values that result from aiming the cosine luminaire straight downward, at a 20-deg upward angle and a 45-deg upward angle. Note how tilting increases the illuminance at the 75-ft line from the luminaires, but also increases the percent uplight, the relative sky glow, the uplight and glare BUG ratings, and the luminous intensity toward the driver. Note that it also reduces the downward lumens.

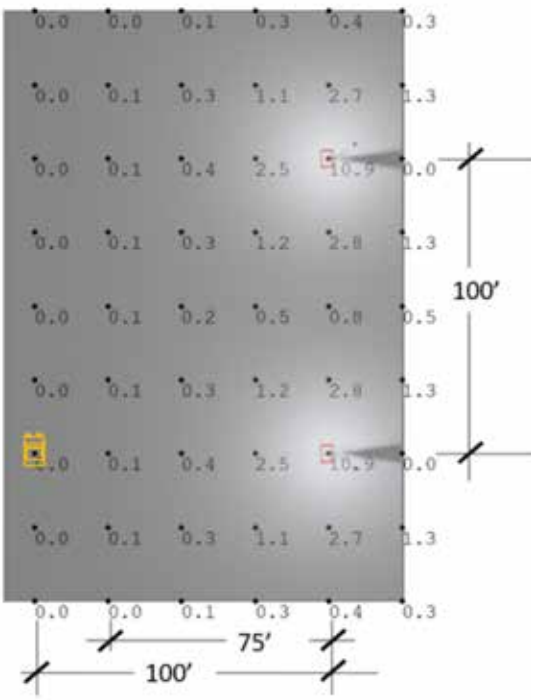


Figure 3. Calculation grid of a parking lot with two luminaires (shown by the red squares), each on a 25-ft pole, with the poles spaced 100 ft apart. The ground illuminances are in lux, for a cosine distribution luminaire at 0-deg tilt.

non-tilted luminaire toward the driver is from a 45-deg azimuth, 82-deg elevation angle.)

We have selected three simple shoebox-type, U0 fixtures of 20,000 lumens, roughly equivalent to a 150-W LED luminaire, all with the same SPD and all drawing equal watts. The first luminaire has a simple cosine (or "blob") distribution, which is common for parking-lot lights. The second is an IES Type II Short distribution, and the third is an IES Type IV Medium optical system that produces a distinctly asymmetrical pattern of light. We will call these luminaires "cosine," "Type II" and "Type IV." **Figure 3** shows the horizontal-illuminance grid from the lighting layout, using the cosine luminaire aimed at 0 deg from nadir (i.e., straight down). The fourth columns of Tables 1 through 3 show the horizontal illuminance at a line 75 ft from the line of the luminaires, due to tilting, and you can see that tilting increases the illuminance for the cosine luminaire from a range of 0.0-0.1 lux to 0.3 lux, and increases the illuminance for the Type II luminaires from a range of 0.0-0.1 lux up to 0.4 lux at that 75-ft line. Compare that to the Type IV luminaire listed at the bottom of the table. That luminaire is designed to move lumens asymmetrically even when not tilted, and performs almost as well as the luminaires tilted at 45 deg.

So far, so good—it looks like tilting is doing the job of increasing the pavement illuminance. "But how much does tilting affect the luminaire's performance in terms of uplight, skyglow, BUG values and glare?" you might ask. "Depends on which optical package you're specifying, and the angle of the tilt," we reply. **Table 1** shows a graphic and numeric comparison of what happens when that simple cosine luminaire is tilted upward at 0, 20 or 45 deg. Although tilting the luminaire does increase the uniformity of the light on the pavement, note how the tilting increases the % uplight and the relative sky glow, and increases both the U-value and G-value of the BUG ratings.

Table 2 shows the same shoebox luminaire as in Table 1, but with the Type II distribution instead. It is fully shielded when aimed downward (U0), but tilting to 45 deg increases the amount of uplight from 0 to 21%, multiplies the amount of sky glow by 2.7, and doubles the intensity in candelas toward the eye of the observer.

So how do we get the light to the edge of the parking lot without tilting? We use a luminaire with optics designed for this type of area lighting application. In this case, an asymmetrical-distribution luminaire will give us the candela distribution we need, without sacrificing uplight, sky glow or glare (see **Table 3**).

In conclusion, spread the word that tilting luminaires drastically affects their light-distribution characteristics, and not for the better:

- Tilting increases the potential for causing uplight, sky glow and glare.
- Specifying "U0" products is not sufficient to eliminate uplight, if luminaires can be tilted on-site. Avoid specifying knuckle-mounts, to reduce the chances of the luminaire being installed inappropriately.
- Use a luminaire in the orientation for which it was designed and in which it was photometered.
- If you need to move light asymmetrically, specify asymmetrical optical systems in lieu of tilting.

Tilting might be cheap and easy, and it lets you skip on some calculations—*but* it's irresponsible from an environmental and safety standpoint. In the interest of responsible design, this information needs to get to designers, specifiers, facility managers, and installers to ensure that outdoor lighting is delivered as effectively as possible, with the minimum of sky glow, disability glare and discomfort.

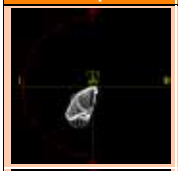
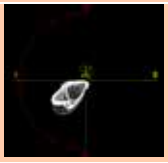
Type II Short Luminaire Polar plot	Tilt	Lumens Downward	Pavement Illuminance at 75 from Pole (lx)	% Uplight	Relative Skyglow	BUG Ratings	Intensity Toward Driver's Eye (cd)
	0°	20,000	0.0 - 0.1	0.0%	100%	B3-U0-G3	4000
	20°	19,782	0.3 - 0.4	1.1%	~112%	B2-U3-G5	5000
	45°	15,704	0.4	21.5%	~270%	B1-U5-G5	7600

Table 2. Values that result from aiming the Type II luminaire straight downward, at a 20-deg upward angle and a 45-deg upward angle.

Type IV Medium Luminaire Polar plot	Tilt	Lumens Downward	Pavement Illuminance at 75' from Pole (lx)	% Uplight	Relative Skyglow	BUG Ratings	Intensity Toward Driver s Eye (cd)
	0°	20,000	0.1 - 0.4	0%	100%	B3-U0-G3	132

Table 3. Values that result from aiming the Type IV luminaire straight downward. These illustrate how to get the light to the edge of the parking area without causing more uplight, sky glow and glare: Use a non-tilted, asymmetrical, fully shielded luminaire.

Naomi J. Miller is a designer and scientist working at Pacific Northwest National Laboratory to improve lighting quality using LED light sources. Her pet peeves include flicker and glare.

Michael Grather is the CTO of LightLab International and the current chair of the IES Science Advisory Panel. His goal is to increase the quality of lighting through scientific practices.