On the Use of Clusters of Light Emitting Diodes (LEDs) in Transportation Signaling lights

Carl K. Andersen
U.S. Federal Highway Administration
6300 Georgetown Pike, McLean, VA 22102-2296

Transportation signaling includes myriad applications and aspects. Signals may be visual or audible in nature, and can provide guidance, right-of-way indications and warnings. Signals may be internal or external to a vehicle. This paper will focus on external light signals used to provide right-of-way information at roadway intersections, commonly known as traffic lights. While traffic lights are presented at supratheshold levels, much of this discussion is pertinent to other forms of transportation signaling, including lights that produce a far lower illuminance at the eye of the observer. The statements made in this paper are those of the author, and do not necessarily reflect the position of the U.S. Federal Highway Administration.

Over the past decade, development of new types of light emitting diodes has yielded substantial improvements in luminous efficacy and color range. Significant achievements in this area include development of AlInGaP (aluminum indium gallium phosphide) and InGaN (indium gallium nitride) LEDs. The performance provided by these new LEDs has resulted in an historic opportunity to dramatically improve visual signaling technology.

High-output LEDs provide several advantages over filtered incandescent lamps for providing critical transportation signals. These advantages include; substantial energy savings, extended service life, potential for low-voltage operation and/or integration of uninterrupted power supplies (UPSs), increased reliability due to multiple emitters within a signal light and extended maintenance intervals.

As with any major technological change, however, there are challenges to successful implementation. Careful consideration of the impacts of this new technology on signaling theory and existing infrastructure and establishment of performance criteria based on human factors testing, are key to insuring that these challenges do not become significant drawbacks.

Evaluations and trials of LED traffic signals were begun in the early-1990s using AlGaAs (aluminum gallium arsenide) LEDs. While the power consumption of these modules compared very favorably with filtered incandescent lamps, there was significant degradation of light output over a relatively short time period, as much as 30% after 12 to 18 months of operation. This has been attributed to oxidation of the top layer of aluminum under exposure to moisture. In addition to this long-term, irreversible degradation, the first LED traffic signals also experienced temporary reductions in luminous intensity when operated at elevated temperatures. Reliability data for AlInGaP LEDs, including results from Wet High Temperature Operating Life (WHTOL) tests, indicate that this new technology should not suffer from these limitations. Development of InGaN LEDs have also allowed for cost-effective replacement of green incandescent traffic signals with LEDs.

A second hurdle for LED traffic signals is successful integration into the existing signal-control infrastructure. Installed traffic signal controllers include mechanical relays and solid-state switches. Some of these systems are designed to sense lamp failure, and to switch the signals to a flashing mode as a precaution. The low current demands for an LED module, however, have resulted in some failures in these systems. Initial models of power supplies for LED traffic signals have also experienced failures due to fluctuations in line voltage, and susceptibility to EMI.

An area still under investigation is the actual performance requirements for an LED traffic signal. Traffic signals must provide a conspicuous signal to a wide variety of drivers over a broad range of environmental and geometric conditions. The incandescent traffic signal, developed from existing maritime and railroad signaling systems, was a compromise between luminous efficiency and color saturation. While higher color saturation might result in an improved recognition level, it also resulted in a lower intensity which decreased the detection and recognition distances. The use of direct-emitting sources may allow for rejection of such compromises.

Without final resolution of performance requirements of traffic signals based on human factors research, there exists the problem of differing specifications, and questions as to the validity of any established requirements. There are at least three specifications for LED traffic signals; a draft European specification, an interim U.S. equipment standard, and a Japanese standard. These documents have significant differences in luminous intensity and color requirements. In addition, CIE recommendations have not been updated to account for new LED technologies and capabilities.

Even though LED technologies continue to evolve, the time appears right for adoption of LED sources in transportation signaling. The technology and understanding of potential problems have reached a level of maturity that allows for earlier promises to be achieved. In the U.S. alone, there are an estimated 300,000 signalized intersections, outfitted with approximately 7 million individual signal lights. Using filtered incandescent lamps, this system consumes 2.3 billion kWh per year. Total conversion to LED signals would result in an 80% reduction in power consumption, with an annual savings of over $200 million. In addition to direct cost savings, there is also a benefit to easing the demands on the power grid and reduced emissions due to the power savings.