ANNUAL AVIATION LIGHTING CONFERENCE

October 22, 2014
Orlando, FL

ILLUMINATING ENGINEERING SOCIETY
AVIATION LIGHTING COMMITTEE

LED Approach Sequenced Strobe Lights

Improved Usability by Taking Advantage of LED Characteristics

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LED Flashing Lights

Content

- Introduction
- Electrical Design and Maintenance Issues
- Effective Intensity and Methods to Increase Flash Light Perception
- Conclusion and Comparison of Operational Aspects

Introduction

LED Flashing Lights

- First LED Approach Flasher has been operating in Kassel, Germany since April 2013.
- Further installations are in
  - Muenster (Germany)
  - Nordholz (mil) (Germany)
  - Frankfurt (Germany)
  - Geilenkirchen (mil) (Germany)
  - Finkenwerder (Germany)
  - Dubai (UAE)
  - Iasi (Romania)
  - Innsbruck (Austria)
  - Warsaw (Poland)

- Many more are due to be in operation soon.

LED Flashing Lights

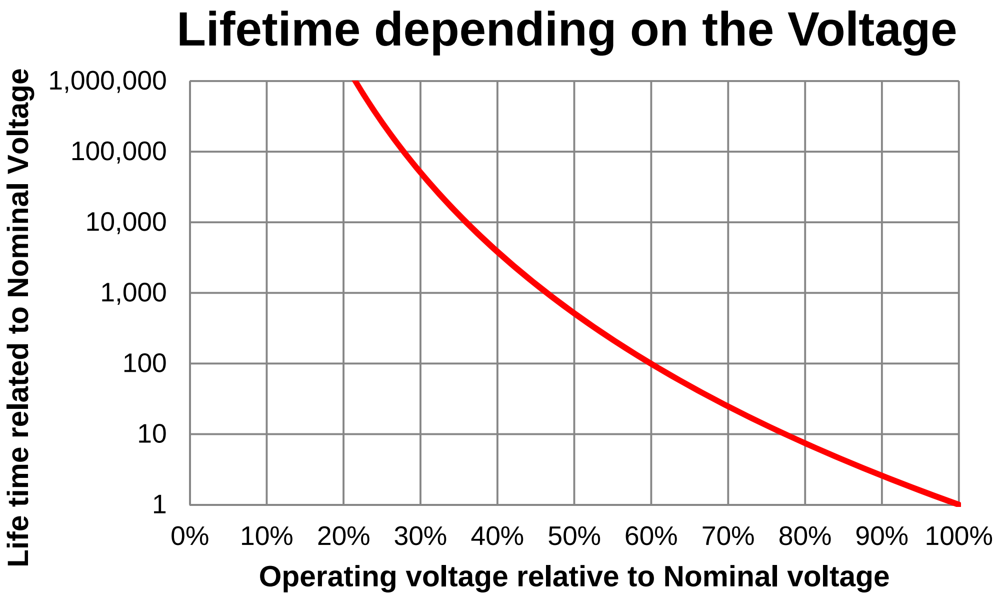
- Deployment of these sequenced flashers have brought about many questions.
- These questions are:
  - How can we eliminate the high voltage problems of Xenon flashers?
  - Can high intensity flashers realized economically with LED?
  - What should the LED light signal shape be to provide best perception?
- This paper aims to answer those questions.

Electrical Design and Maintenance Issues

What is the effect of high voltage on lifetime?

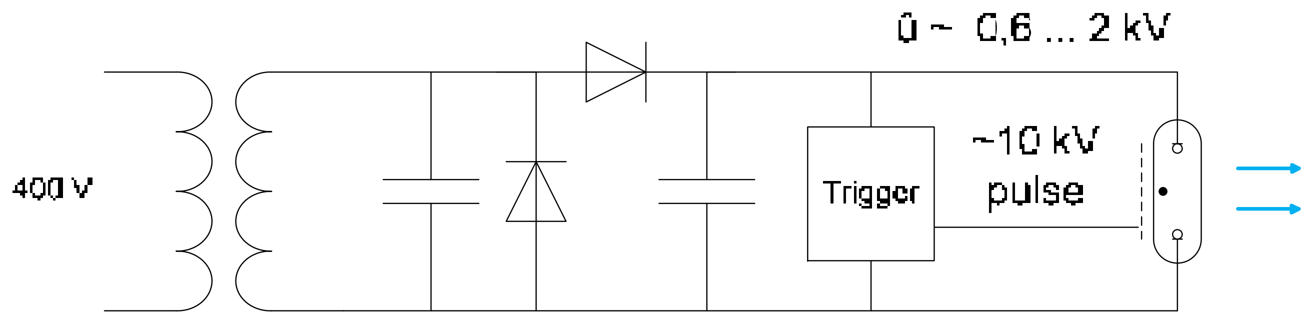
- Voltage present results in an electrical field that stresses particularly in areas with a high electrical field concentration
- Material aging results from a “treeing” with micro discharges
- The literature gives an empirical lifetime law

Life time ~ $1/U^{10}$



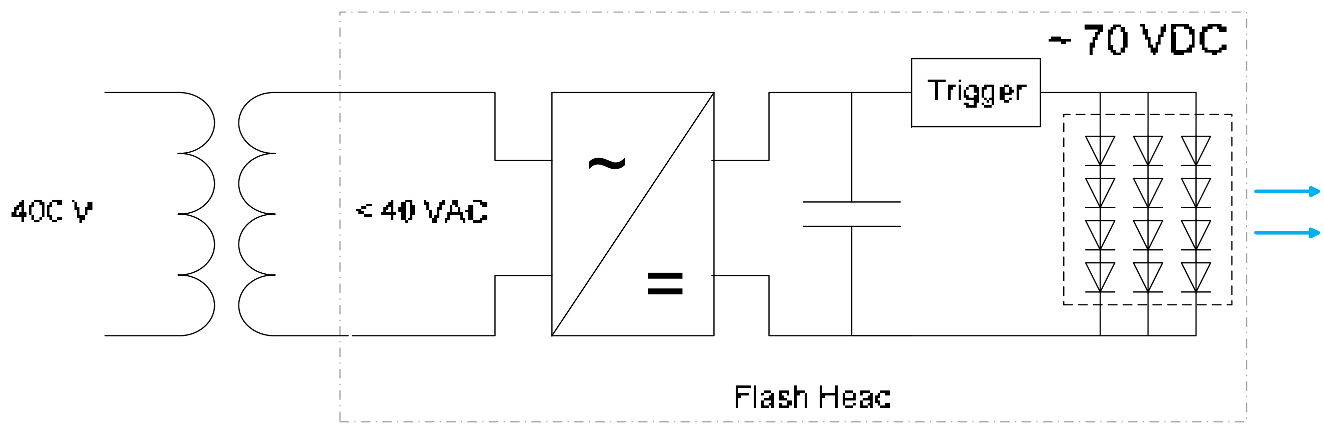
Flasher Schematics

- Xenon



High intensity Xenon flashing light requires internal high voltage up to 8 - 15 kV

- LED



LED flashing light operates with Safety Extra Low Voltage (SELV) with max. 70 VDC

Differences in electrical characteristics

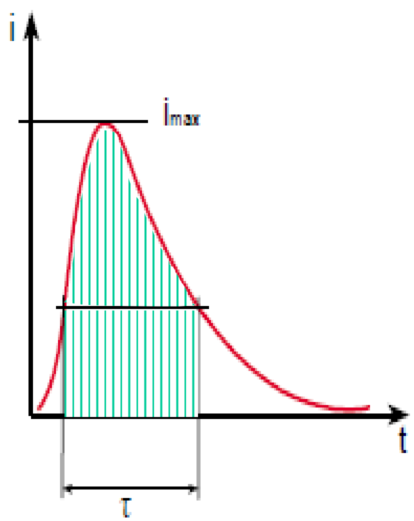
Characteristics	Xenon	LED
Sensitivity to moisture	Protections required	Very robust
Work safety	High voltage issues (max. 15,000 V)	Absolutely safe (max. 70 VDC)
Lifetime	~ 500 to 10,000 hours. High voltage circuitry requires maintenance attention.	> 25,000 hours
Light head dimensions	Small (with separate Individual Control Cabinet)	Requires larger optical output
Inset lights available	Very limited. Inset light conditions (moisture, condensation, vibration) not beneficial for high voltage Xenon.	Yes, no restrictions. Max. intensity may be limited by the available optical aperture. Can be solved by twin light combination.

Effective Intensity
and
Methods to Increase Flash Light Perception

Light output from Xenon and LED

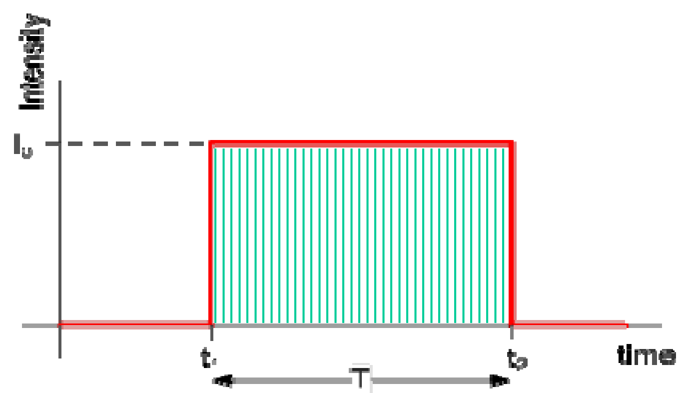
Xenon

- Flash is extremely short with a high intensity peak (t < 10 µs [micro seconds])
- According to the Blondel & Rey calculation, parts of the rising and falling edges do not contribute to the effective intensity (optical losses)



LED

- Flash intensity shape is close to a rectangular flat light signal (t ~ 50 ms [milli-secs])
- According to the Blondel & Rey calculation, the total light output contributes to the effective intensity



Flash Light Intensity Definition and Calculation

- Design Manual Part 4 chapter 18.3 based on the Blondel & Rey equation:

$$I_e = \frac{\int_{t_1}^{t_2} I \, dt}{a+(t_2-t_1)} \quad for \begin{cases} a = 0{,}2\,s \\ (t_2 - t_1) = T < 0{,}2s \\ I(t_1) = I(t_1) = I_e \end{cases}$$

- Simplified for rectangle flash intensity:

$$I_e = I_o * \frac{T}{a+T} \quad where \begin{cases} a = 0{,}2\,s \\ T < 0{,}2\,s \end{cases}$$

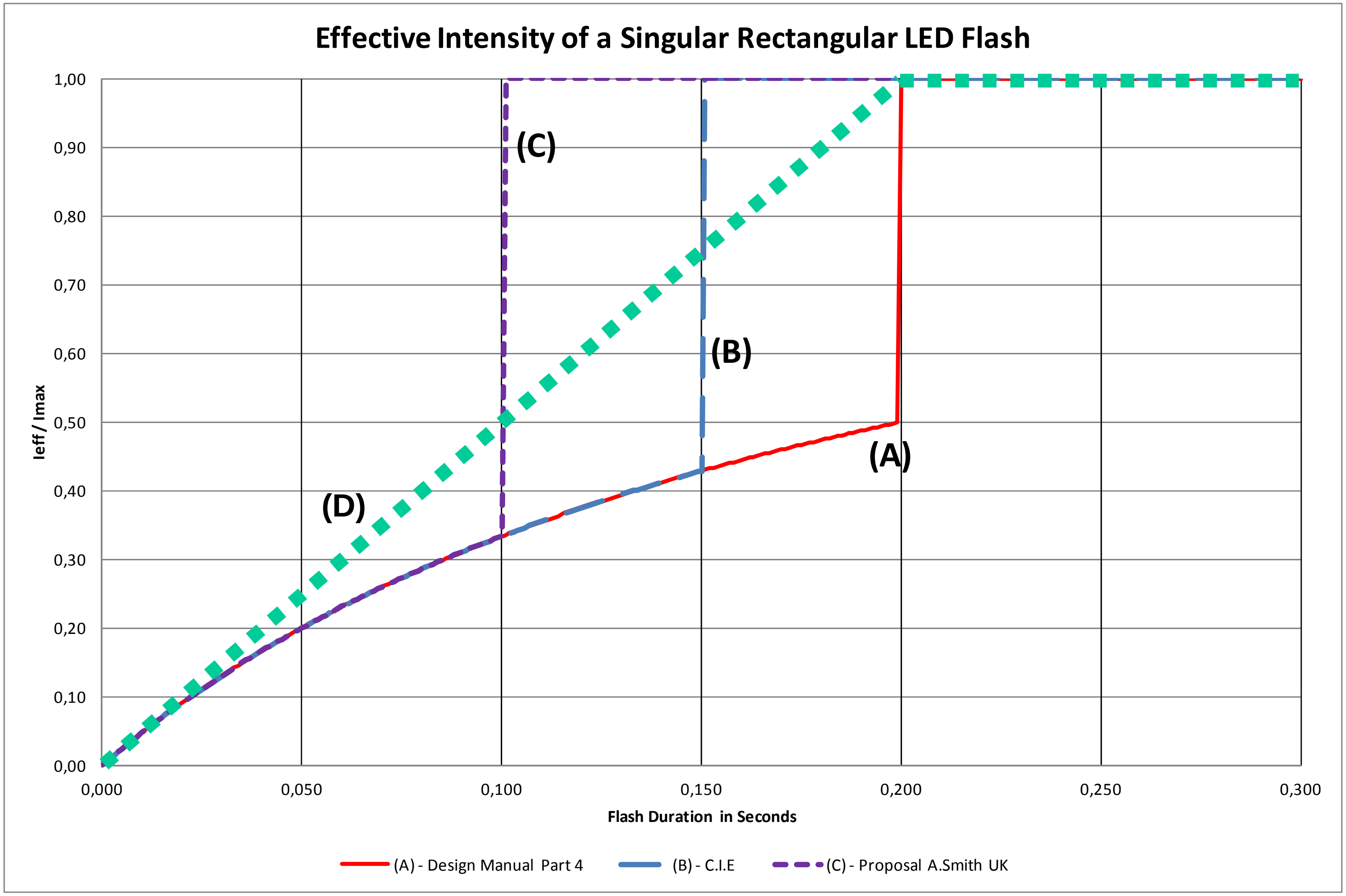
$$I_e = I_o \qquad where\ T \geq 0{,}2\,s$$

- Proposed change for the Design Manual for better linear approximation of 50 to 199 ms durations (considering several studies about blinking LED light intensities)

$$I_e = I_o * \frac{T}{C} \quad where \begin{cases} C = 0{,}2\,s \\ T < 0{,}2\,s \end{cases}$$

$$I_e = I_o \qquad where\ T \geq 0{,}2\,s$$

Flash Light Intensity Definition and Calculation



- Several studies (B) (C) mentioned that blinking / flashing lights seems much brighter than calculated Blondel & Rey effective intensity (A) expects. (D) shows the proposed linear approximation.

What flash duration should be used?

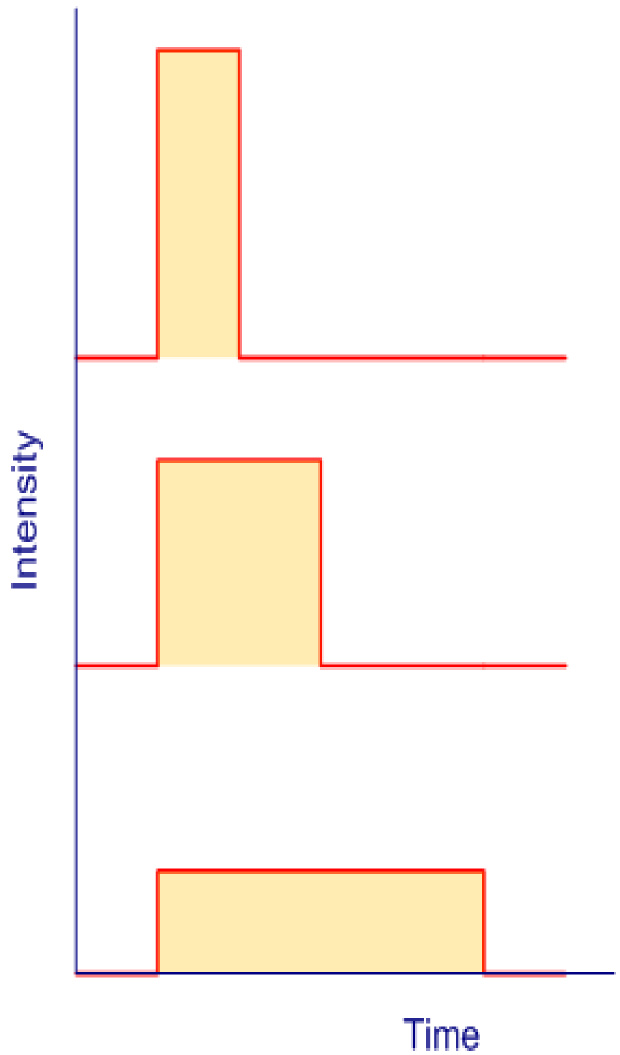
- With LED, the flash duration and the maximum peak intensity can be chosen in a certain range.

$$I_{eff} \propto T * I_0$$

- The 3 rectangle flash shapes on the right provide the same calculated effective intensity.

- Extremely short durations requires a high intensity peak with high current peaks and thermal peak stress.

- The length of the duration is limited by the flash frequency and the flash characteristic of a short blink.



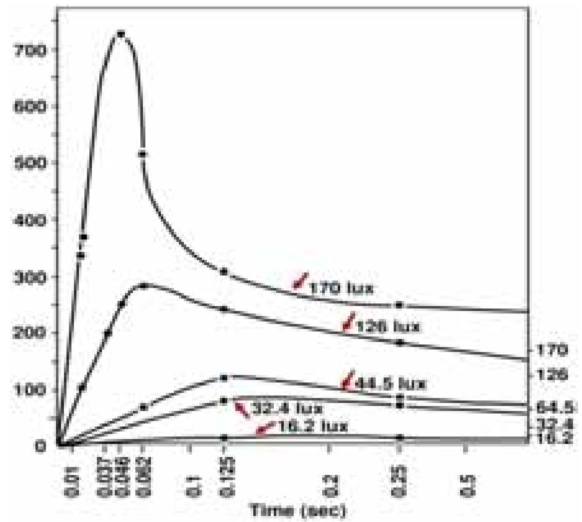
Let's remember the Broca–Sulzer-Effect

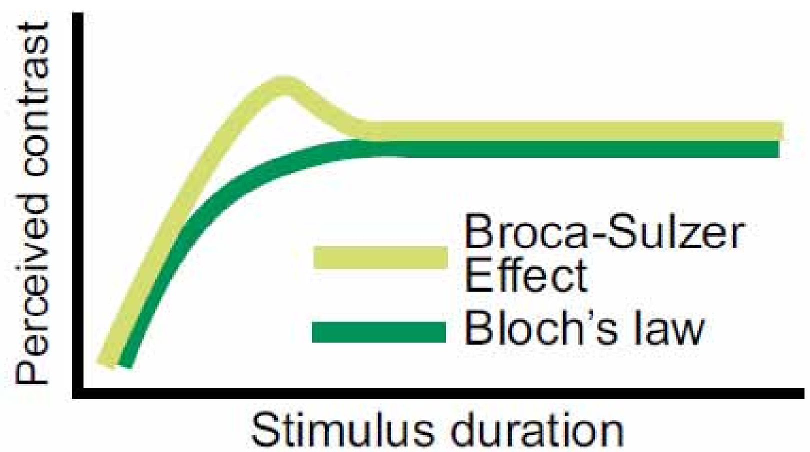
Broca and Sulzer published in ~ **1902** that short pulses of definitely visible light of a certain duration will appear brighter than if the pulses lasted longer in time.

It seems that the effect is a result of the visual signal evaluation in the human optic nerve and/or brain (till now no valid explanation available).

The "Broca-Sulzer-Effect" has been confirmed by several scientific studies.

<u>The effect does not increase the physical amount of light but improves the perception!</u>

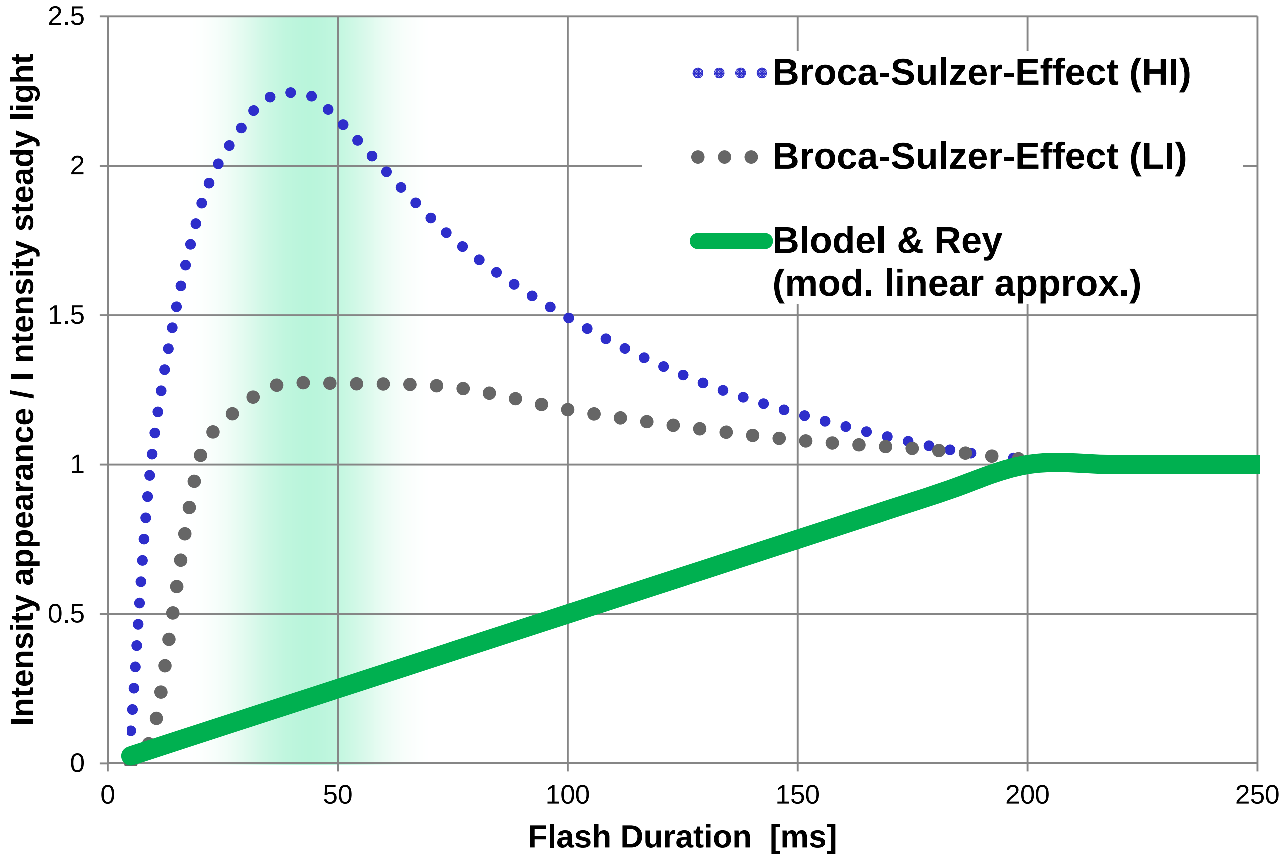




Broca-Sulzer brightness enhancement occurs at stimulus onset for high intensity incremental targets. Here flash brightness is plotted as a function of duration for flashes of different luminances. Data from Hart (1987) et al.

What will be the optimized flash duration?

According the Broca-Sulzer-Effect a flash with a duration of 40 – 70 ms should appear VERY much higher than a longer or shorter flash.

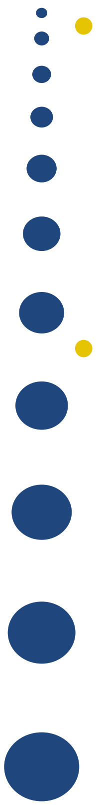


Selection of the Flash Duration

- The best solution is a 50 ms flash
- It provides the best perception according the Broca-Sulzer-Effect.
- The LED current / thermal peak and the thermal dissipation can be handled.
- The required capacity voltage to provide the flash energy in the 50 ms time can be kept in the SELV range.

What is the benefit of overlapping light pulses?

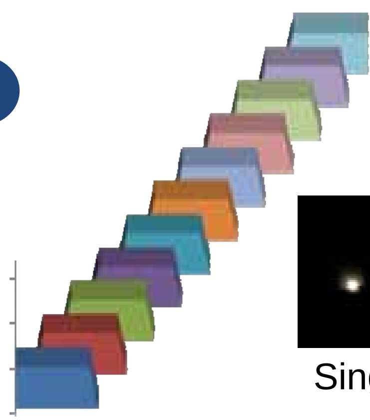
Short distance view



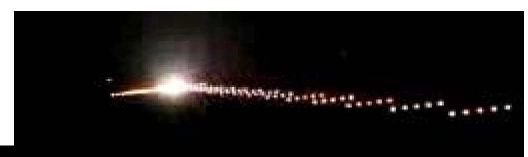
- The eye resolution can separate all sequenced flashing lights
- Recognized is the intensity of an individual light e.g. 15,000 cd

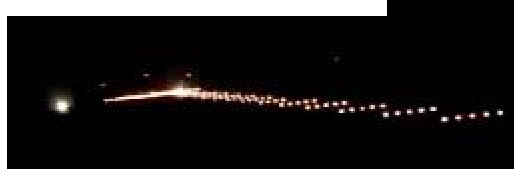
Long Distance view

- The eye resolution cannot separate individual lights
- Recognized is a virtual light with an intensity formed by all lights covering the smallest viewing angle. (e.g. with 3 adjacent lights = 45,000cd)

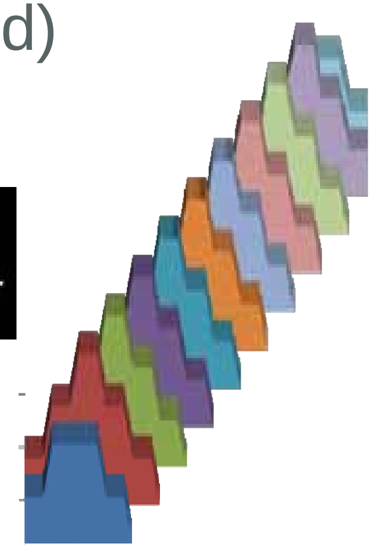


Flash Cluster in the Row





Single Flash at the Threshold



Conclusion
and
Comparison of Operational Aspects

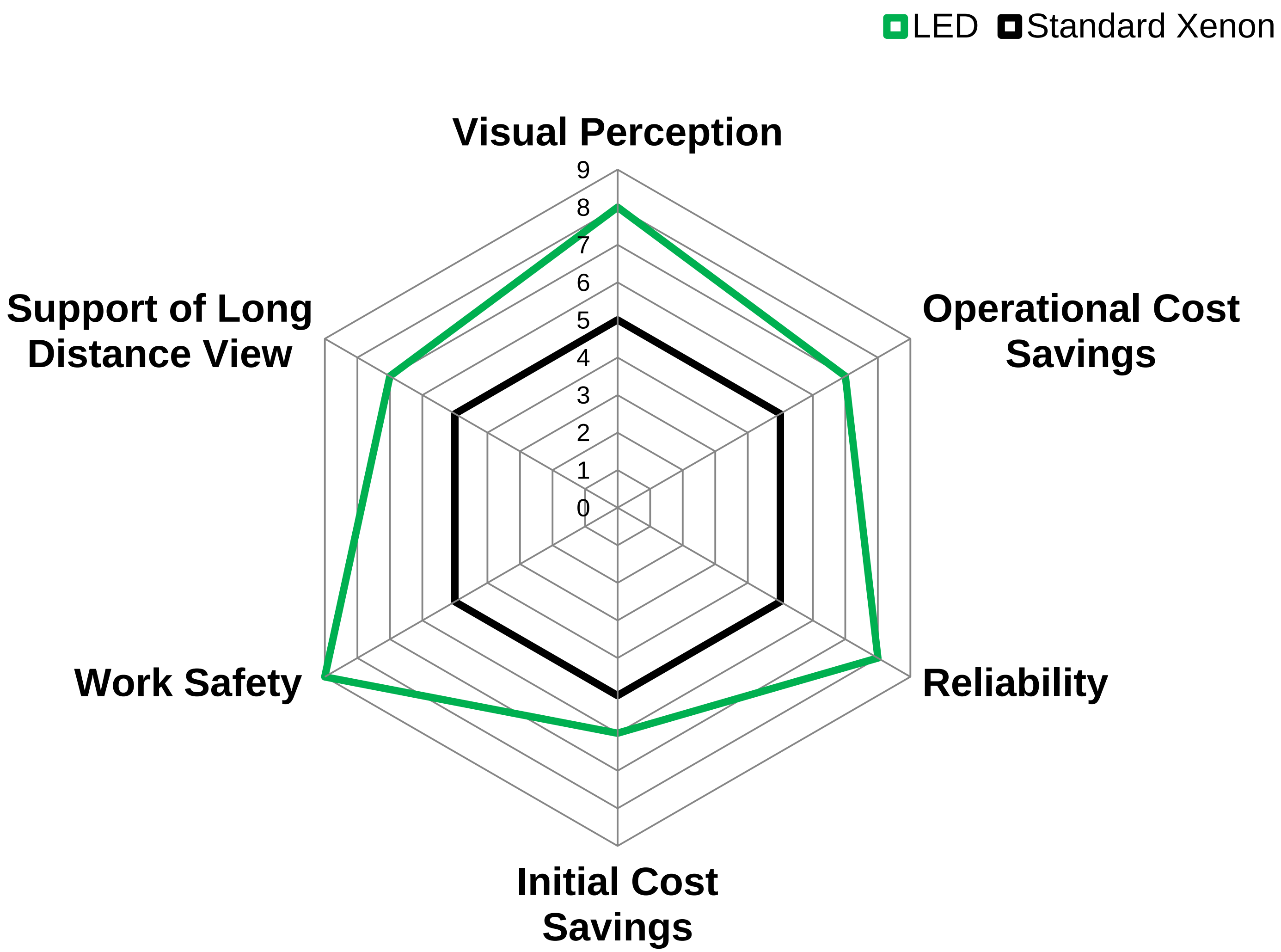
Operational aspects of LED flashers

By taking advantage of the LED characteristics we reached:

- Highly reliable component and high grade of work safety due to extra low voltage level (SELV).
- Increased perception by using the advantages of the Broca-Sulzer-Effect.
- Best long distance recognition by using the advantage of light accumulation of adjacent lights.

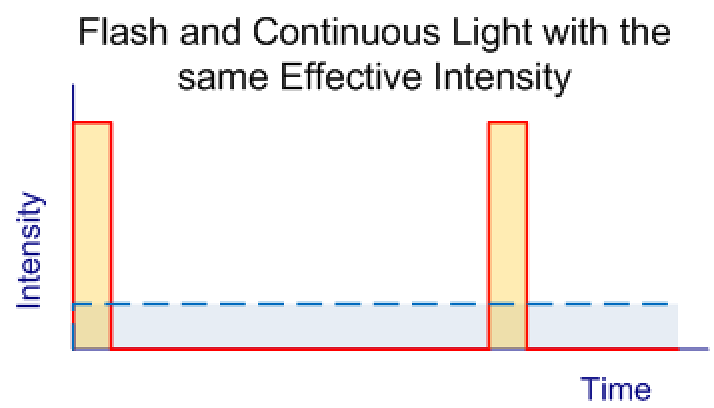
Operational aspects of LED flashers

LED Flashes compared to Standard Xenon Flashes



How to migrate from a flasher to an approach light?

- The difference between a LED flashing light and a white approach high intensity light is just the pulse length and peak intensity.



- LED settings (e.g.):
  - Flash: Light pulse to reach 100,000 cd_{peak} → 20,000 cd_{eff}
  - Steady Burning Light: Lower continuous light with 20,000 cd_{eff}

- A steady burning LED light needs ~ 2 to 3 times more power, and requires much more efficient cooling.

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Thank you for your attention!

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Questions?