DARMSTADT
UNIVERSITY OF
TECHNOLOGY

2001 PAL®

PROGRESS IN AUTOMOBILE LIGHTING

Laboratory of Lighting Technology
September 25-26, 2001

ANIMAL FOUNTAIN BY ANTON LUSSMANN, DARMSTADT

PCNA Ex. 1029
U.S. Patent No. 9,955,551

2001 PAL®

Progress in **A**utomobile **L**ighting

Proceedings of the Symposium

Darmstadt University of Technology
Laboratory of Lighting Technology

Published by

Prof. Dr.-Ing. H.-J. Schmidt-Clausen

in the Series

Darmstädter Lichttechnik

Herbert Utz Verlag Wissenschaft

München

ISBN 3-89675-971-X

PAL '01: 2 Volumes, Vol. 8 & Vol. 9; not to be sold separately

Die Deutsche Bibliothek – CIP-Einheitsaufnahme
Ein Titeldatensatz für diese Publikation ist
bei Der Deutschen Bibliothek erhältlich

ISBN 3-89675-971-X

Das Werk ist urheberrechtlich geschützt. Die dadurch begründeten Rechte, insbesondere die der Übersetzung, des Nachdrucks, der Entnahme von Abbildungen, der Funksendung, der Wiedergabe auf photomechanischem oder ähnlichem Wege und der Speicherung in Datenverarbeitungsanlagen bleiben, auch bei nur auszugsweiser Verwertung, vorbehalten.

Die Wiedergabe von Gebrauchsnamen, Handelsnamen, Warenbezeichnungen usw. in diesem Werk berechtigt auch ohne besondere Kennzeichnung nicht zu der Annahme, daß solche Namen in Sinne der Warenzeichen- und Markenschutz-Gesetzgebung als frei zu betrachten wären und daher von jedermann benutzt werden dürften.

Copyright © 2001 Herbert Utz Verlag GmbH

Herbert Utz Verlag GmbH, München
Tel.: 089-277791-00
Fax: 089-277791-01
utz@utzverlag.de
www.utzverlag.de

Content page

Werner Adrian: University of Waterloo, Canada
Visual Acuity and its Dependency on Observation Time and Contrast 1

Yukio Akashi: Lighting Research Center, USA
The effect of oncoming headlight glare on peripheral detection under a mesopic light level 9

Daniel Armbruster: F. Porsche AG, Germany
Motor vehicle signal lamps in a fog environment 23

Gerd Bahnmüller: Automotive Lighting Reutlingen GmbH, Germany
Headlamp Development - Reduced Time to Market 28

Gerhard Bierleutgeb: Hella KG Hueck & Co., Germany
Interior Lighting Control (ILC) System Aspects for a New Approach 35

Werner D. Bockelmann: Ophthalmologist, Germany
Coloured head-down displays (HDD) from the point of view of information transfer 43

Doris Boebel, Automotive Lighting, Germany
Signal Image in PES Systems 49

Christian Boehlau: Hella KG Hueck & Co., Germany
Optical Sensors for AFS – Supplement and Alternative to GPS 56

Gary Brown: Mira, UK
Integrating Pedestrian Impact Protection into Future Headlight Design 61

Berthold Büdel: Audi AG, Germany
Clear lenses for lighting components – The actual trend and its problems 74

John D. Bullough: Rensselaer Polytechnic Institute, USA
Forward Vehicular Lighting and Inclement Weather Conditions 79

Michael Burg: Hella KG Hueck & Co, Germany
Infrared Headlamps for Active Night-Vision Systems 90

Tso-Wei Chang: Lunghwa Institute of Technology, Taiwan
Driving Performance Analysis on Interactions among Factors of Center High Mounted Stop Lamp and Road Environment 99

Christophe Chenevier: Valeo Lighting Systems, France
Thermal Simulation in Lighting Systems – 5 Days / 5 Degrees 109

Andreas Chudaska: Hella KG Hueck & Co., Germany
Headlamp Cleaning Systems – Trends of Development and Future Demands 119

Sharon Cook: Loughborough University, UK
Warning beacon intensity 127

Content page

Francesco Cortese: St Filippo Neri's Hospital, Italy
Biological and Statistical Profile of Road Accidents Victims in an Urban Area
A One-Year Experience in a Major Hospital 138

Thomas Dahlem: Volkswagen AG, Germany
Physiological Investigation of the Proportioning of Headlamp Illumination 155

Maria Teresa Dalmasso: Automotive Lighting, Italy
Signal LAMPs with hidden light sources 164

Joachim Damasky: Hella KG Hueck & Co., Germany
Trends in Auxiliary Car Lighting and the Influence on OE Development 173

Ad de Visser: Philips Lighting B.V., The Netherlands
Activities of CIE relevant to automotive lighting 186

Detlef Decker: Hella KG Hueck & Co., Germany
Aspects of dynamic light control in automotive applications 196

Christophe Dubosc: Valeo Lighting Systems, France
Lighting Systems and Show Cars 206

Alexis Dubrovin: Valeo Lighting Systems, France
Optimised Lighting Systems Architecture 224

Martin Enders: BMW Group, Germany
Pixel Light 234

Jürgen Ewald: Nippon Carbide Industries B. V., The Netherlands
Visual Performance of Fluorescent Retroreflective Sheeting 240

Frank Ewerhart: Robert Bosch GmbH, Germany
Video Based Curve Light System – Sensor, System and Results 252

Matthias Fiegler: OSRAM GmbH, Germany
PLANON, a mercury-free flat panel light source, with high potential
for automotive applications 266

Michael J. Flannagan: The University of Michigan, USA
Feasibility of Developing a Headlighting Rating System 275

Helmut Frank: Mechatronic, Germany
New Aspects for the Photometric Characterisation
of Microprismatic Retroreflective Sheeting 283

Gianpiero Fusco: Automotive Lighting, Italy
Headlamps Beam Patterns Evaluation by CCD Camera 309

Takashi Futami: Stanley Electric Co.,Ltd., Japan
Development of the "Gatling Beam" Headlamps 316

Content page

Reiner Gödecker: Hella KG Hueck & Co, Germany
Hella introduces MOLIS® - the world's first ,free design' modular lighting system 330

Martin Grimm: Hella KG Hueck & Co., Germany
Improved Nighttime Visibility for Drivers through Dynamic Bend Lighting 339

Martin Grimm: Hella KG Hueck & Co., Germany
ECE Headlamp Performance Status and Potential for Improvement 348

Helmut Haf: IHH Ingenieurdienstleistungen, Germany
SensorLEDIHH – Dual Operational Systemblock to Measure Perceived Brightness and to Simultaneous Adaptive Signal Image Display 355

Michael Hamm: Automotive Lighting, Germany
System Strategies for Adaptive Lighting Systems 368

Michael Hamm: Automotive Lighting, Germany
Headlamp Performance Specification: A Summary of New and Comprehensive Evaluation Methods 381

Takahiro Hara: University Yoto, Japan
Evaluation of AFS from driver's point of view 397

Wolfgang Hendrischk: Hella KG Hueck & Co, Germany
From Xenon, BiXenon to Vario Xenon 403

Henning Hogrefe: Automotive Lighting Reutlingen GmbH, Germany
Headlamp Design with New Double Filament Bulbs 414

Shao Hong: Fudan University, China
The Investigation on Chinese Visual Perception 422

Rainer Huber: OSRAM Opto Seminconductors, Germany
Flexible SMT LED Submodules 441

George Iatan: DBM Reflex Entreprises Inc., Canada
Simulation software for complex reflectors 447

S.E. Jenkins, Optical and Photometric Technology Pty Ltd, Australia
Use and Measurement of LED Clusters for Signals 454

Norbert L. Johnson: 3M Company, U.S.A.
A comparison of Retroreflective Sign Performance in Europe and the United States based on Market Weighted Headlight Data 461

Josef Kalze: Hella KG Hueck & Co., Germany
Situation Adapted Light Distributions for AFS-Headlamps 474

Hiroyuki Kanai: Shinshu University, Japan
Proposition of Road Visual Environment Simulator for Evaluation Visibility of Driver 485

Content page

Takeshi Kimura: Koito Manufacturing Co. Ltd, Japan
Japan's Plan for Introducing ECE Regulations Into Japanese Safety Regulations 503

Nils Knollmann: Audi AG, Germany
Interior lighting concept on the basis of psychological and physiological influences on night-time driving 508

Thomas Knoop: LichtVision GmbH, Germany
Digital Light Measurement for Automobile Applications 520

Shoji Kobayashi: Koito Manufacturing Co. Ltd., Japan
Next Generation Lane Indication/Recognition System, Study of Phase II 522

Toshiyuki Kondo: Stanley Electric Co. Ltd., Japan
Developing Highly Efficient LED Combination Rear Lamps 546

Prasad Koppolu: Visteon Corporation, U.S.A.
Knowledge-Based Engineering Application for Lighting Design and Development – KBE-SmartLite 560

Harald Küster: Alanod Aluminium-Veredlung GmbH & Co. KG, Germany
Large Area Coating of Aluminium Coils for Automotive Applications 577

Peter Lehnert: BMW Technik GmbH, Germany
Disability and Discomfort Glare under dynamic Conditions – The Effect of Glare Stimuli on the Human Vision 582

Yandan Lin: Fudan University, China
Visual Performance at Mesopic Light Levels 593

Thomas Luce: Philips Automotive Lighting, Germany
Optimized Light Source for High Incoupling Efficiencies in Distributive Lighting Systems (DLS) 599

Peter Ludwig, Delphi Automotive Systems, Germany
Wiring Integrated Illumination 612

Karl Manz: Lichttechnisches Institut der Universität Karlsruhe, Germany
The Influence by Size of Headlamp on Discomfort Glare 618

Karl Manz: Lichttechnisches Institut der Universität Karlsruhe, Germany
Tolerances of Cut-Off-Measurements 635

Janusz Mazur: Warsaw University of Technology, Poland
Computer Visualisation into Effect of Lighting Road by Car Projector with Using Programs from Group CAD 646

Stefan Milch: smart microwave sensors GmbH, Germany
Pedestrian Detection with Radar and Computer Vision 657

Content page

Wolfgang Möhl: SCHOTT Glas, Germany
Coating Technology and Materials for Lighting Applications 665

Ulrich Möller: Difa Diemer & Fastenrath GmbH, Germany
Non Dazzling Reading Lamp 679

Kazumoto Morita: National Traffic Safety and Environment Laboratory, Japan
Theoretical Analysis of Effect of Daytime Running Lamps on the Visibility of Automobiles 682

Martin Mühlenberg: Hella KG Hueck & Co., Germany
Vision Sensors and Image Processing – a Contribution to Intelligent Light Function Control 695

Julius Muschaweck: Optics & Energy Concepts, Germany
Constructive design of free-form optical components for illumination 703

Kohei Narisada: Chukyo University, Japan
Role of Adaptation in Perception under Traffic Lighting Conditions 712

Rainer Neumann: Visteon Corp. Europe, Germany
Future Rear Lighting Trends – Safety and Styling Aspects 723

Bernhard Newe: Hella KG Hueck & Co., Germany
Improved Signal Lighting 733

Hiroo Oyama: Stanley Electric Co. Ltd., Japan
The Development of the "Vertical Shape Line-Beam Headlamp" 738

Salvatore Pierro: Automotive Lighting S.p.A., Italy
Plastic Transparent Reflectors for Clear Lens Signal Functions 751

Wilfried Pohl, Bartenbach LichtLabor, Austria
Enhancing Visibility by reducing Glare of Street Luminaires and Headllamps 759

Thomas Reiners: OSRAM GmbH, Germany
Introduction of Optical Features into Light Sources 769

Justin Rennilson: RCS rennilson consulting service, U.S.A.
International Cooperation in Establishing Requirements for Traffic Control Devices 776

Lawrence M. Rice: Guide Corporation, U.S.A.
Predictive Tools for Automotive Lighting 785

Birgit Richter: Reitter & Schefenacker GmbH & Co.KG, Germany
Innovative Tail Lamp Concept Enhances Perceptibility Under Bad Weather Conditions 793

Hartwig Riehl: OSRAM GmbH, Germany
Interference Coatings in Signal Lighting 804

Content **page**

Joachim Ripperger: BMW AG, Germany
Luminance: the Future Photometric for Rear- and Brake-lights 810

Ernst-Olaf Rosenhahn: Automotive Lighting, Germany
Adaptive Headlamp Systems concerning Adverse Weather: Fog 817

Kåre Rumar: The University of Michigan, U.S.A.
Intensity of High-Beam Headlights 829

Kåre Rumar: VTI Dev, Sweden
Night traffic and the zero vision 849

Arnulf Rupp: Osram GmbH, Germany
Discharge Lamps in Automotive Lighting 859

Torsten Ruths: Hella KG Hueck & Co., Germany
Vehicle signature 871

Luca Sardi: Automotive Lighting, Italy
Light Guides for new Lighting Systems 878

Takashi Sato: Stanley Electric Co. LTD., Japan
The Smart Headlamp System with Variable Low-Beam Pattern 883

Thomas Schnell: The University of Iowa, U.S.A.
The Development of a Nighttime Driver Visibility Model
for ultra-violet activated Pavement Markings 890

Gabriel Schwab: Volkswagen AG, Germany
GEOSim – a Tool for the Development of Adaptive Frontlighting System Control 904

Touichirou Shiozawa: Koito Manufacturing Co. Ltd., Japan
Thermal Air Flow Analysis of an Automotive Headlamp 915

Michael Sivak: The University of Michigan, U.S.A.
Quantitative Comparisons of the Benefits of Applying Adaptive Headlighting
to the Current U.S. and European - Low-Beam Patterns 942

Tomasz Targosinski: Motor Transport Institute, Poland
Analysis of the Properties of the ECE Requirements Concerning Headlights 958

Qifei Tu: The Institute of light sources, Fudan University, China
Perspectives of LED Automotive Signal Lights in China 969

Wout van Bommel: Philips Lighting, The Netherlands
Road Lighting Research: yesterday, today and tomorrow 974

Mark van den Berg: LumiLeds Lighting, The Netherlands
Development of High Brightness LED's for Automotive Applications 987

John van Derlofske: Rensselaer Polytechnic Institute, U.S.A.
Evaluation of High Intensity Discharge Automotive Forward Lighting 994

Content page

Stephan Völker: Hella KG, Germany
Investigation of the visible range of different types of headlamps 1009

Alexander von Hoffmann: Volkswagen AG, Germany
Analysis of Adaptive Light Distributions with AFSim 1018

Pieter L. Walraven: Em TNO Human Factors, The Netherlands
Required changes in $V_M(\lambda)$ 1030

Herbert Wambsganß: Hella Innenleuchten Systeme GmbH, Germany
Innovations in Lighting Technology in Vehicle Interiors 1035

Takao Watanabe: Koito Manufacturing Co. LTD., Japan
The Research on the Effectiveness of AFS Bending Lamp in Japanese Road Environment 1042

Christine Weber: Reitter & Schefenacker, Germany
Micro controlled LED rear combination lamp with innovative signal configurations 1054

Thomas Weber: Hella KG Hueck & Co., Germany
Virtual Night Drive 1062

Peter Weissleder: Audi AG, Germany
The Demand for Attraction – Styling meets Design 1070

Gösta Werner: Swedish National Testing and Research Institute, Sweden
Conspicuouity of road workers at night and day, experiences of two Swedish studies 1078

Wei Xu: Institute of Electric Light Sources, Fudan University, China
The Measurement of Photometric Parameters of Lamps 1083

Wojciech Żagan: Warsaw University of Technology, Poland
Chosen luminance measurement results of the cars' signal lamps 1088

Jiyong Zhang: Fudan University of Shanghai, China
Computer Simulation of Headlamp Beam Pattern and Its Potential Utilization 1096

Li Zhou: Institute of Light Sources, Fudan University, China
The Monte Carlo Method in Design of Automobile Lighting 1104

Wei Zhou: Fudan University, China
Measurement of the Temperature Distribution on the Filaments of the Automotive Lamps Using the Spectroscopic Method 1110

Development of High Brightness LED's for Automotive Applications:

Mark van den Berg , LumiLeds Lighting Netherlands

1. Introduction

In recent years the efficiency of Light Emitting Diode (LED) technology has increased dramatically making it the preferred light source in many different applications. Typical examples of applications utilizing the improvements of the LED developments are full color video signs, information signs, traffic signals and flashers.

In the automotive market LED's are the preferred solution for High Mounted Stop Lamps. Several Rear combination Lamps are using high brightness LED's, and in the United States the first Emergency Vehicles are using Light-bars on top of the car using LED's.

The reason for this large scale conversion is the fact that high brightness LED's are offering a unique set of benefits such as lower power consumption, Long operating life, compact size, increased reliability and very low maintenance requirements depending on the application.

2. History of LED Technology

The first LED's appeared during the late 1960s with typical efficiencies (Luminous watt output per electrical watt input) of 0.05 Lumens/Watt (lm/W).

It wasn't until the late 1980s with the introduction of Aluminium Gallium Arsenide (AlGaAs) technology did LED's really begin to come close to incandescent bulbs in terms of efficiency at 7Lm/W in Red.

AlGaAs technology remained the standard "High Brightness" material until the introduction of Aluminium Indium Gallium Phosphide (AlInGaP) and Indium Gallium Nitride (InGaN) in the mid 1990s with dramatically increased performance in Lumens/Watt making LED's more efficient than filtered incandescent and later even Tungsten Halogen

The AlInGaP material produces colours ranging from Amber 588 nM through to Red 630nM.

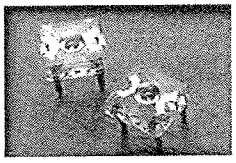
InGaN material produces colours from Blue 470nM through to Green 530nM. The InGaN material is also used for producing White LED's by taking a Blue chip and including a phosphor layer in the LED.

3. Different types of LED's

There are several types of LED's available in the market. The conventional 3mm or 5mm through hole LED's, the Surface Mount LED's (SMD) which are being produced by the billions every year.

SMD LED's are very popular for dashboard backlighting. In the late 1990s the Super Flux LED's have been introduced (Picture 1). This LED became a standard in the Automotive industry for High Mount Stop Lamps. Whereas most conventional LED's are limited in light-output , this Super Flux LED's had the capability to maintain reliable at higher currents due to improved heat management.

The Super Flux LED can be driven at 70mA. Utilizing the best available TS (Transparent Substrate) AlInGaP material this LED has set new records in light output per LED opening up a range of new application. This LED was initially available in Red and Amber but will in 2001 also become available in Blue,Green,Cyan and White



Picture 1: Super Flux LED's

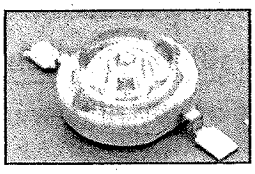
The next step towards higher performance LED's was the SnapLED™ LED introduced by LumiLeds Lighting in the late 1990s. This LED could be used at current of 150mA while maintaining reliability and efficiency. This LED also enabled the reduction of the number of LED's used in specific applications which helped to reduce the overall system costs, as well as had the possibility to do stylish 3-dimensional array designs.

The trend was clearly set. In order to enable more applications inside and outside automotive a few things need to happen.

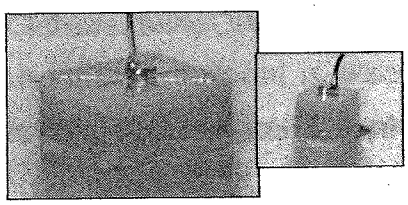
© PAL 2001 Symposium; Darmstadt University of Technology

1. continue to improve the efficiency of the AlInGaP and InGaN material to enable higher Lumens/Watt values
2. Improve packaging of the chip to get the light in the correct direction as efficient as possible
3. Find a way to drive the chips harder while keeping the same reliability , same forward Voltage and same efficiency to enable higher Light-output.
4. Further reduce the number of LED's used, and reduce the overall system cost per application.

LumiLeds Lighting introduced in 1998 a high flux emitter (Luxeon ™) (Picture 1) with even higher current capabilities. The main characteristics of the LED are the large LED Chip (Picture 3), excellent thermal characteristics and an optimized light extraction making it possible to drive the AlInGaP LED's at 250mA and the InGaN LED's at 350mA.
The LED's show a dramatic increase in light output per device and per unit area when compared to other LED's. There is no sacrifice in reliability caused by the increase in total device current since the current per unit area in unchanged. (Larger Chip). The LED chip itself is mounted on a slug that serves as a heatsink to dissipate the heat from the chip and to transfer this heat to a secondary heat sink . The slug is fixed in a body that support the cathode- and anode lead. On the topside a plastic lens covers the LED chip. The body and the plastic lens can accommodate a high expansion and shrinkage due to the temperature differences, and the chip is surrounded by a low stress opto-coupling gel. Both lens and gel are highly resistant to UV radiation (from outside) to ensure high lumen maintenance.



Picture 2: Luxeon ™ High Flux Emitter



Picture 3: Large AlInGaP Chip vs. small chip

The Luxeon LED is available in 2 different radiation pattern. A Batwing radiation pattern with a peak intensity near 40 degrees with a steep drop-off of intensity outside this angles. This pattern has been designed to provide uniform incidence to a planar secondary optic.
The second radiation pattern is a Lambertian "point source" pattern.

Good thermal system design is critical to achieve the best efficiency and reliability of the Luxeon™ LED's. AlInGaP LED's (Red and Amber) experience a temporary loss in light output as the temperature increases. The lower the die or the junction temperature is kept, the better the luminoue efficiency of the product.

In 2001 LumiLeds released the Lambertian LED in Red, Red-Orange and Amber with capabilities to use at current of 385mA, achieving records in light output performance of typical 44 lumens per LED in Red. The Lambertian LED is using a new type of special shaped chip which maximized the light output efficiencies.
Also the Batwing Luxeon™ has been qualified at 350mA for all colors.

Table of Power development:

Type of LED	SMD	5mm	Super Flux	SnapLED	Luxeon Batwing	Luxeon Lambertian
DC Forward current	20mA	20mA	70mA	150mA	350mA	385mA
Typical light output (red)	0.5 lm	1 lm	3 lm	6 lm	25 lm	44 lm

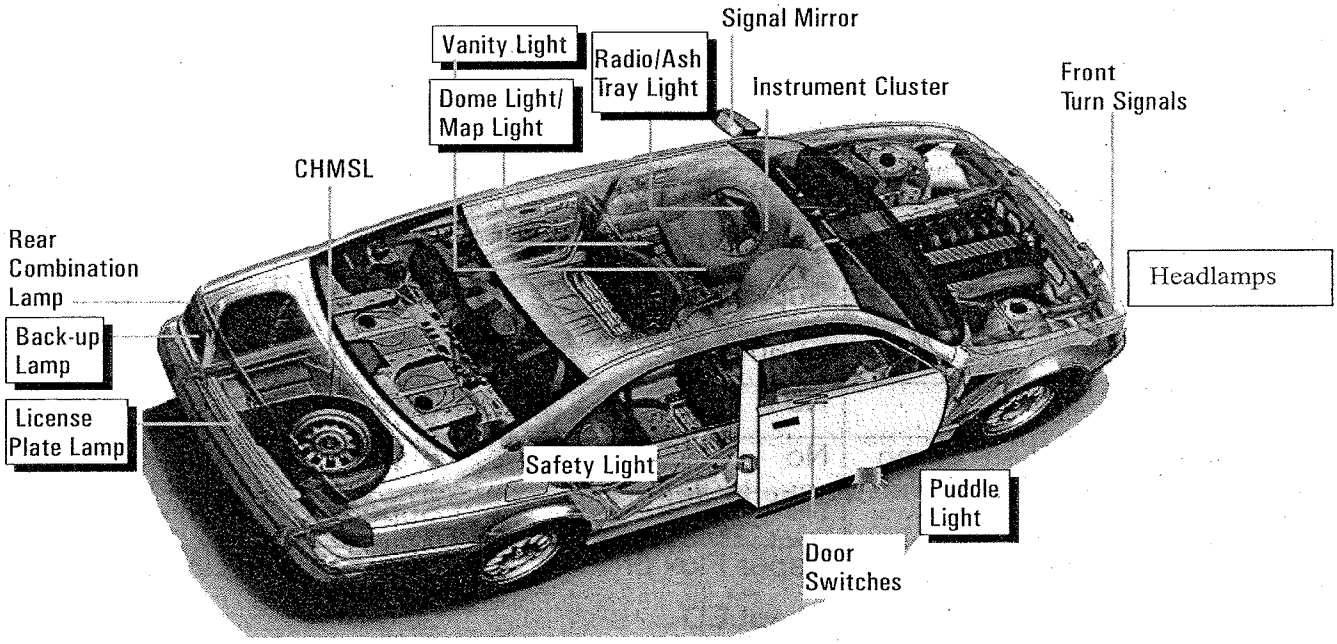
© PAL 2001 Symposium; Darmstadt University of Technology

4. Potential Applications for LED's in Automotive

As stated earlier, several applications are today using LED technology as the preferred solution. Main applications on the road today are dashboard backlighting, indicators, Air-conditioning – and Radio backlighting as well as High Mount Stop Lamps and Rear Combination Lamps in Automotive exterior.

As the LED's are getting brighter and brighter more applications in Automotive can start to make use of the benefits of LED's.

In the next year we will see the first cars on the road using Amber LED's for Turn Signals. White LED's for puddle lamps or position lamps , as well as Red,Green,Blue LED's for Navigation systems.



Inside the car High Flux LED's are being considered for mood-lighting, ambient lighting and reading lamps.

In addition to all these potentials, the probably biggest potential for LED's in Automotive is in Headlamps. As LED's are achieving a brightness of 150 – 200 Lumen in White it will be possible to achieve the needed brightness levels.

Application	LED used today	LED for the future
Interior :		
Dashboard-backlighting	SMD	SMD or Luxeon (Edge-lighting)
Buttons	SMD	SMD
AC / Radio	SMD	SMD or Luxeon
Navigationsystem	No	Luxeon
Mood Lighting	No	Luxeon
Ambient Lighting	No	Luxeon
Reading Lamps	No	Luxeon
Exterior :		
Rear Combination Lamp	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
High Mount Stop Lamp	Super Flux or SnapLED	Super Flux or SnapLED
Front Trun Signal	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Back-up Lamp	No	Luxeon
License Plate Lamp	No	Super Flux or Luxeon
Puddle Light	No	Super Flux or Luxeon
Signal Mirror	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Side Repeater	Super Flux or SnapLED	Super Flux, SnapLED or Luxeon
Position Lamps	No	Luxeon
Headlamps	No	Luxeon

Table of LED / Application

© PAL 2001 Symposium; Darmstadt University of Technology

5. Summary and Outlook

High Flux LED's will play a big role in the future of Lighting. More and more applications in general illumination will start to use LED's. In the Automotive market there is a big potential to use the High flux LED's in a lot of different applications , giving both the end-user as well as the car-maker benefits.

The Luxeon™ LED's will allow further reduction in LED's and in specific applications reduce the overall system costs.

Important is to use the LED's in the right way in order to achieve the maximum result and benefits.

The future of the LED is bright. Enclosed a flux per LED roadmap for the next years for the main colors in Automotive Red,Amber and White

Colour	2001	2002	mid 2003	mid 2004
Red	12	44*	48	50
Amber	12	36*	40	44
White	18	40	75	120

Typical performance of LED in Lumens/LED. Chip size or current density might change

* new special shaped chip @385mA

All values are subject to change, and are best on expectations.