Ultra Small OLED Pico Projector

Ground-breaking, active illumination-free concept enables new projection applications

An ultra compact projection system based on a high brightness OLED micro display is developed. System design and realization of a prototype are presented. This OLED pico projector with a volume of about 10 cm³ can be integrated into portable systems like mobile phones or PDAs. The Fraunhofer IPMS developed the high brightness monochrome OLED micro display. The Fraunhofer IOF designed the specific projection lens [1] and integrated the OLED and the projection optic to a full functional pico projection system. This article provides a closer look on the technology and its possibilities.

One of the strongest growing industries of the last two decades is mobile communication; their applications are dramatically changing the way we live our lives. Actually the communication is limited to speech and low bandwidth image or data transmission. The key driver for the future of mobile communications will be mobile multimedia. Actually there is only one way for visual image transmission: the mobile display itself. In contrast, the presented pico projection system modifies the image and data presentation drastically and submits any information onto a screen. Thus, images and data can be presented to a group of people. This opens a wide range of different kind of applications beyond multimedia.

Actual projection systems work with an active illumination of a micro display. In the majority of cases reflective micro display like LCoS (Liquid Crystal on Silicon) or DMDs (Digital Micromirror Device) are used. In the pico projection system an OLED (Organic Light emitting Diode) micro display (Fig. 1) is the image device which emitted light by itself. Consequently an external illumination system is not necessary and the whole optical projection system can be minimized.

The image of an OLED micro display will be projected onto a planar screen [2]. This easy way to project information, images or movies enhances the range of applications. The challenge is the realization of a high

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Constanze Großmann studied physical engineering and information processing at the University of Applied Sciences of Merseburg, Germany, and wrote her diploma thesis about construction and characterization of dome projection systems in 2006. In 2006–2008 she studied Laser- and Optotechnologies at the University of Applied Sciences of Jena, Germany, and wrote her master thesis about the optical design of a high resolution optical system. In 2008 she started to work in the Optics System Development Group at the Fraunhofer IOF in Jena, Germany.

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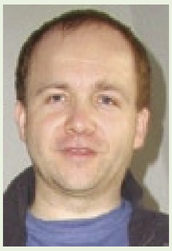

UWE VOGEL

Uwe Vogel became skilled worker in semiconductor microelectronics (Funkwerk Erfurt) in 1983, received diploma in information technology (TU Chemnitz) in 1991, doctoral degree in biomedical engineering in 1999 (TU Dresden). After visiting Center for Applied Optics Studies at Rose-Hulman Institute of Technology (Terre Haute/Indiana, 1992) and a position in hearing research at Dresden University hospital (1995-1998) he has joined Fraunhofer Institute for Photonic Microsystems (IPMS) in Dresden/Germany since 1998. Now he is managing the Analog/Mixed-Signal IC design activities inside the business field Sensor & Actuator Systems, being closely related to IPMS' OLED efforts, mainly focusing on the design of OLED-on-CMOS devices and applications, OLED displays and driver IC.

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Fraunhofer IPMS carries out developments in the fields of microelectronics, micro-systems technology and organic materials and systems. App. 210 employees work with the latest equipment to solve customer specific problems in the areas of light-modulating micro-systems, organic materials and systems, sensors, actuators, as well as digital and analogue circuit design. Particularly developments based on highly efficient OLEDs in combination with the flexible fabrication technology and new integration principles have led to recent advances in OLED-on-CMOS and microdisplay technology. Its OLED fabrication technology offers the opportunity to integrate highly efficient OLED light sources into silicon wafers to establish a new class of OLED-on-CMOS micro-systems. Integration is focused onto both microdisplay and opto-sensor applications. Including the CMOS driving circuitry design and integration technology the Fraunhofer IPMS offers product developments starting with the system concept till fabrication.

FIGURE 1: **Realized high brightness OLED micro display for micro-projection applications.**

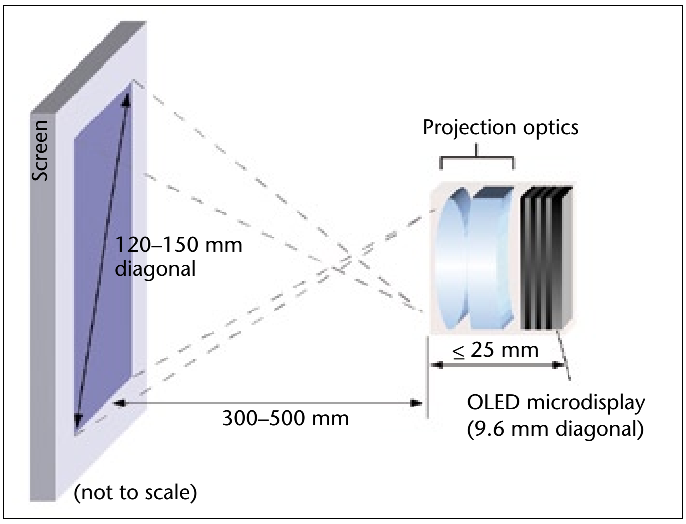

FIGURE 2: **Principle system design of the ultra compact projection system with the OLED projection engine (right).**

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The Fraunhofer IOF was founded 1992 and has app. 140 employees. The central components of IOF expertise are optics and mechanics design. The Fraunhofer IOF is a competent partner to the industry and is also supplier to the public sector. Research and development at Fraunhofer IOF focuses on optical systems technology with a view to continually improving the control of light from generation via guiding and manipulation up to its application. Our core competences include opto-mechanical design and simulation, multifunctional optical coatings, manufacturing and integration techniques of optical components and systems, opto-mechanical precision systems, measurement systems and sensors. We escort our clients all the way from the idea to prototype.

brightness OLED micro display and an ultra compact projection system which can be integrated into wearable systems like a mobile phone or PDA.

One of the few disadvantages of actual OLED micro displays is the low luminance [3, 4]. Nowadays high brightness OLED micro displays with very low energy consumption are developed. Nevertheless an adapted optical system with a specific optic design is absolute essential to combine excellent coupling efficiency, geometrical conditions, transmission, and also the traditional features for projection lenses like distortion and field curvature.

OLED micro display

Regarding OLED integration small-molecule and polymer technology can be used to achieve optimal performance. Both approaches target different applications. For micro projection applications, high brightness (at least 10,000 nits) is one of the most important target parameters. Here highly efficient SM-pin-OLED structures are used. For easy integration of the micro display into full-featured multimedia systems, a standardized high-speed serial video interface will be added in order to reduce system-level complexity. To realize highly efficient green (~ 530 ± 30 nm) top emitting OLED for micro-projection a p-i-n-type OLED stack with a double-emission layer will be evaporated on the CMOS backplane. A bottom emitting OLED with such a stack operates at low voltages of 2.85 V and efficiencies of 51 cd/A at a luminance of 1000 cd/m² and 3.4 V/51 cd/A at a luminance of 10,000 cd/m² [5]. For a good interaction with the ultra compact projection optics the top layers are optimized to obtain high luminance at small viewing angles.

System Design and Realization

A pico projection system for mobile application based on OLED technology is developed. This system will project images or any other multimedia-, business-, and automotive information.

According to the dimension of the OLED micro display (Ø 10–15 mm) the system is optimized to a small volume of the optical system. The whole compact projection unit

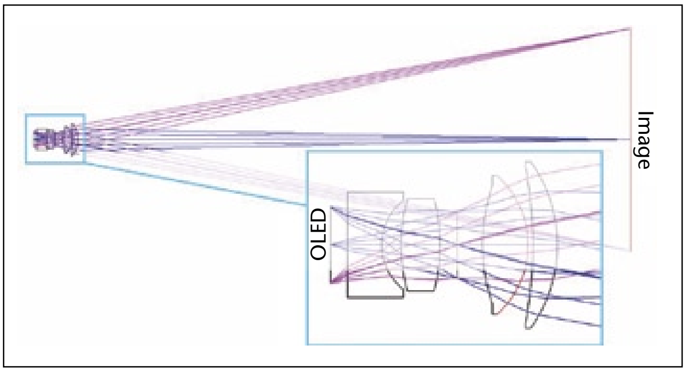

FIGURE 3: **Current optic design of the ultra compact projection system.**

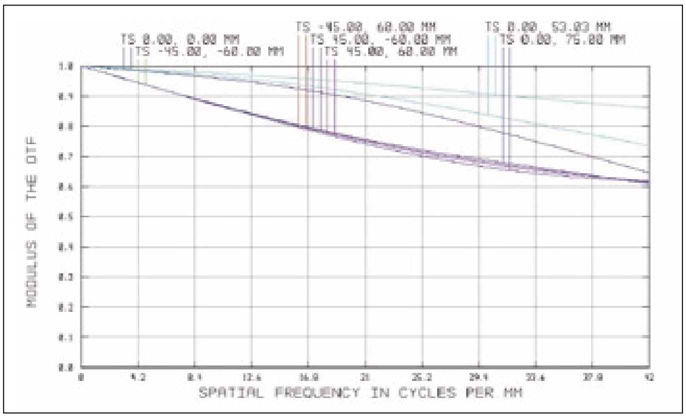

FIGURE 4: **MTF (calculated) of the current optic design of the ultra compact projection unit.**

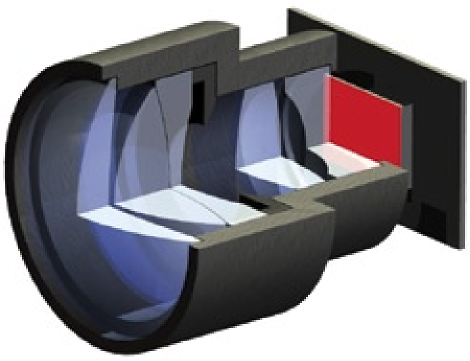

FIGURE 5: **Design and layout of the prototype of the pico projection system.**

has to fit into a mobile device; thus the installation length should be smaller than 25 mm. The principle design of the ultra compact projection system is shown in Fig. 2. On the right hand side the projection lens (IOF) and the OLED micro display (IPMS) are placed. The working distance is around 300–500 mm. The optical magnification of the projection is between the factors 12 and 15. Other critical points are the working distance and further optical features of the pico projection system which influence the luminance and the contrast of the image. For this reason a specific optic simulation and calculation has been performed.

An optimized projection lens has been developed by taking into account these optical and geometrical conditions. The optical design consists of five elements (lenses) with a maximum lens diameter of 17 mm and an installation length (incl. OLED cover glass) of 24 mm. The lens design of the pico projection system is shown in Fig. 3. On the left hand side the projection lens and the OLED micro display are placed and on the right hand side the projection screen is positioned.

In the following overview the system parameters of the pico projection system are collected:

NA image space (OLED)	0.3
NA display space	0.02
Magnification	15x
Object space	8 x 6 mm²
Resolution OLED	VGA (640 x 480 pixel)
Pixel size	12 µm
Pixel pitch	12,5 µm
Image space	120 x 90 mm²
Working Distance	300 mm
Wavelength	530 ± 30 nm
Distortion	4 %
Length (lens + OLED)	24 mm
Diameter (lens + OLED)	17 mm
Mechanical dimension (lens + OLED)	~10 cm³

There are a lot of difference evaluation criterions for conventional projection lenses. In the Fig. 4 the MTF (Modulation Transfer Function) is presented. The lower boundary of the MTF for projection lenses should be above 50 %. The calculated MTF for each field coordinate (0 ± 75 mm) of the projection lens design reaches values above 60 % at a spatial frequency of 42 cycles per mm (pixel size 12 µm). That means over the full image screen a good contrast of the image is achieved.

The full functional optic and constructive design is shown in Fig 5.

Impact

An OLED based pico projection system for mobile applications is developed on the basis of a specific optical design of the projection lens. Signal element of the system is the high brightness OLED micro display for image generation. This system is realized as a compact unit within approx. 10 cm³. The system will be presented at the LASER World of PHOTONICS 2009 in Munich, Both # B2.421.

Acknowledgement

This work was (in parts) funded by the European Commission within the HYPOLED project (High-Performance OLED-Microdisplays for Mobile Multimedia HMD and Projection Applications, ICT-2007.3.2-217067).

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