Optics Communications 315 (2014) 258–264

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Masking LED hot spots in a thin direct lit backlight unit using semitransparent and perforated masks

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ARTICLE INFO

Article history:
Received 30 September 2013
Received in revised form
31 October 2013
Accepted 3 November 2013
Available online 25 November 2013

Keywords:
Backlight
Direct-Lit
Illumination design
BSDF, BRDF, and BTDF

ABSTRACT

As the demand for thin displays with more features accelerates, the need for backlight systems to become thinner and capable of multiple features increases. Direct lit concepts supporting 2-D dimming provide higher contrast ratios. However masking led hot spots with thinner backlight thicknesses is yet a significant design challenge. Efficient light coupling and recycling mechanisms in combination with relatively high optical efficiencies are key parameters in overall system design. We demonstrate an optimal masking design of the led hot spot for a thin light guide plate in the direct lit architecture. The overall concept system is simulated and prototyped. The resultant performance is discussed.

1. Introduction

Advances in the liquid crystal (LC) panel technology helped in greatly improving the image quality in several areas such as resolution, contrast, viewing angle, moving objects and sharpness (due to fast LC effects). In the backlight area the implementation of technologies such as scanning backlight or 2D dimming brought additional improvements not only for motion portrayal and contrast but also resulted in more energy efficient systems [1]. This configuration also allows the possibility of 2D dimming feature which have higher contrast than displays with a continuous backlight. In area lit backlights, a matrix of LEDs is placed in the backplane of the backlight to get homogeneous light output [2]. These above mentioned improvements refer to the key important characteristic of the display i.e. image quality. While this will remain one of the key aspects for the consumers, market studies and industry benchmarking reports suggest that the design factors of the display is becoming a key appreciated feature among consumers. These factors refer for example to a reduced thickness or a small screen bezel [3]. In a typical LCD display, the backlight module occupies a large portion of the overall volume. Current area lit displays utilize air as a mixing medium to achieve efficient light mixing and to deliver good luminance modulation. Introducing light guide plates reduces this thickness significantly.

In conventional direct lit backlight configurations with LEDs as light source, the 'hot spot' is a major design challenge due to the shorter path of light trajectories [4,5]. Typical hot spot reduction is achieved by using multiple diffuser sheets in combination with a significant large air gap along with an optical stack of prism sheets foils. Several novel architectures have been explored on LED backlights with various elements in the design process and with varying luminance modulation performances [6,7]. This paper delineates and explores the design possibility within a direct lit backlight configuration with the emphasis on reducing the overall backlight thickness while maintaining the local dimming feature, aimed at the LCD Television industry particularly.

The direct lit display for a Philips 3000 or 4000 series 2013 range have a thickness of 65–80 mm (including mechanical cover and bezel dimensions) indicating considerable backlight thicknesses from 45 to 55 mm [8]. Edge backlight designs are generally thinner than direct lit designs and their thicknesses are round 10 mm [9]. Our aim was to build a slim direct lit backlight unit in the region of 5–6 mm, and to make a demonstrator based on high power LEDs. In typical direct lit backlight designs, a certain LED count is considered for a given display surface area which then defines the necessary thickness of the total display [10]. This seemingly intrinsic relation between thickness and led numbers (or pitch) is decoupled in our approach. Given the cost drive in the display industry, the design considerations are driven on the basis of available industrialized technologies.

2. Ultrathin backlight

2.1. Backlight layout

The light guide is made out of a 2 mm thick light guide plate (LGP) made of PMMA with white paint dots printed on one side (adjacent to

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http://dx.doi.org/10.1016/j.optcom.2013.11.004

the reflector sheet) as out-coupling structure. They are cut with a laser from larger sheets without burr and low surface roughness [11] as required for an optical quality surface that can support total internal reflection (TIR) transport of light. The designed mask is prototyped based on the radiation pattern of the thin diffusor made of Toray E6SR [12] material and a thin specular metal sheet, (Miro [13]) with laser ablated perforations designed to let the right amount of flux through it. The radii and the geometries of these perforations are determined via simulations. The light grey part depicts the aluminum back plate. The two main functions of the aluminum plate are spreading the heat generated by the LED (keep their operating temperature low) and provide the mechanical stiffness for the display in general. LEDs are mounted on FR4 boards (depicted in green in Fig. 1) which are then fixed and thermally anchored to the back plate.

A white diffuse reflector is used to reflect the light out-coupled towards the back of the light guide (depicted in yellow in Fig. 1a). The MCPET has a thickness of 0.7 mm, comparable to the one of the LED sub mount. The estimated total backlight module thickness is < 6.5 mm and is given in Table 1.

The zoomed inset in Fig. 1b shows the three main ray trajectories prevalent in this design. Ray path (i) refers to the ray path corresponding to the TIR light bouncing across the PMMA

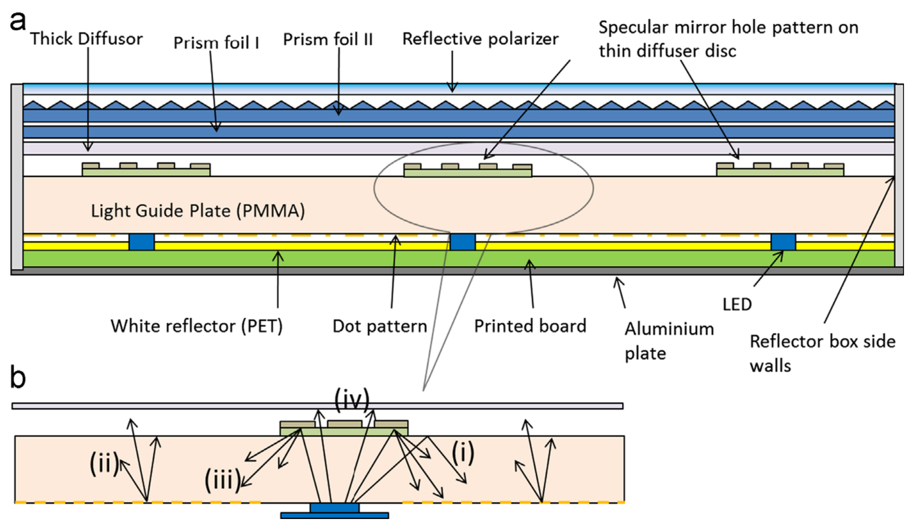

Fig. 1. (Color online) (a) Schematic of the direct lit backlight configuration. Note that there are no design-in air gaps intended in the actual sample. (b) Inset of the ray trajectories in the design.

Table 1
Design parameters for the thin backlight prototype.

Layer thickness	Thickness [mm]
Reflective polarizer, 2 × prism foils	1.0
Diffusor plate	1.2
Mask	0.15
LightGuide (PMMA)	2
LED	0.5
Reflector sheet	0.32
Flex board	0.2
LED support	0.5
Nominal LED support—back cover	0.5
Estimated thickness	6.3

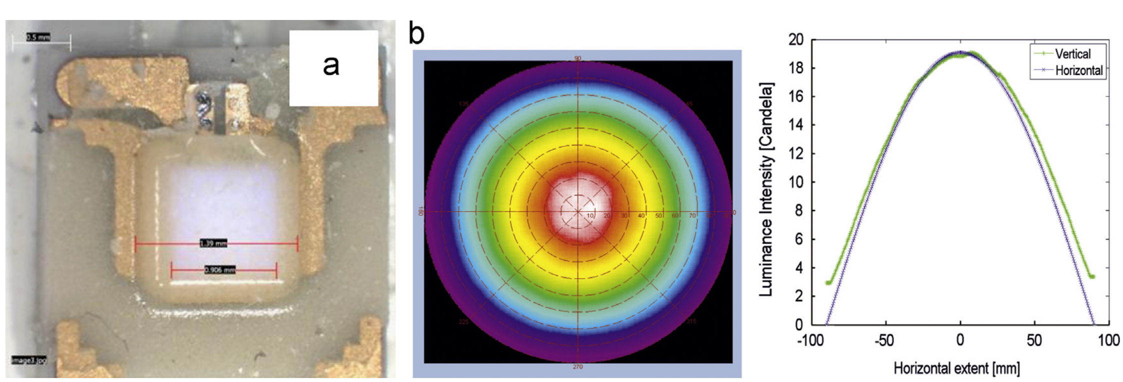

Fig. 2. (Color online) (a) The LED surface area without the dome when lighted up and (b) the corresponding luminous intensity measured on the goniophotometer indicating the lambertian emission profile of the LED.