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Light guide with internal mirror array for LCD backlight

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Requirements

- Wider viewing angle
- Higher contrast ratio
- Improved conversion efficiency of light generated by the backlight to light emitted from the front of the display towards the viewer
- Ideally no polarisers or colour filters which absorb a lot of light
- Lower electrical power consumption
Requirements

- Thin, flat, lightweight and small size light source, e.g. LED and backlight
- Good uniformity and high brightness
- Better colour gamut on CIE diagram by adopting three wavelength light sources
- Easy to fabricate
Introduction

- Research builds on earlier experimental work
- Foresight Challenge Displays Technology Alliance EPSRC/DTI LINK project: Novel Optics
- Participants included: EPIGEM, Philips, Hewlett Packard, CRL, Merck, British Aerospace, Screen Technology Ltd, Cambridge University, Heriot Watt University.
- UCL experimental work thanks to Tim York, Lawrence Commander, Veronika Tsatsourian.
- Polymer replication of components thanks to Tim Ryan, Tom Harvey of EPIGEM
Overview

- Ray tracing models a total-internal-reflection (TIR) lightguide structure to optimise its performance.
- Light entering the multimode lightguide emerges at periodic "windows" but some is reflected out of the opposite side of the guide.
- An array of micro-mirrors set within the guide reflects these rays back out of the windows.
- Modelling measures the distance of the mirrors from the windows, the mirror size and guide dimensions to optimise the optical uniformity and efficiency.
- Other micro-optical polymer components are used to direct the light for optimum contrast
LCD Backlight Structure

- Polariser
- Color-filter & glass
- Nematic Liquid Crystal
- TFT & glass polariser
- Backlight
Light guide with cylindrical lens structure

LED

Lightguide 990 \( \mu \text{m} \)

Air

Lenses 284 \( \mu \text{m} \)

Liquid Crystal Display

\( n = 1.52 \)

\( n = 1.50 \)
Lightguide with grating window

- Lens
- Air (30 µm)
- Photoresist Layer
- Grating (140 µm)
- Lightguide
Backlight illumination system

- LCD pixels
- Lens
- Grating
- Lightguide
- Reflected 0th order
- Reflected 1st order
- 1st order
Illumination system without mirror (ASAP)
Light can leave from opposite side of light guide (ASAP)
Light guide with embedded mirror structure

Lightguide 990 µm

Lenses 284 µm

Mirrors

LED

Air

Liquid Crystal Display
Lightguide with embedded mirrors

- Lightguide
- Grating 140 µm
- Mirror $w$ µm
- Photoresist Layer
- Lens
- Air 30 µm
- Photoresist Layer
- Lightguide
- Mirror $d$ µm

Dimensions:
- Lightguide width
- Grating width 140 µm
- Photoresist layer thickness
- Mirror width $w$ µm
- Mirror and lightguide depth $d$ µm
Illumination system with embedded mirrors (ASAP)

Mirror position, $d$: 10 $\mu$m to lightguide upper surface
Mirror Width, $w$: 160 $\mu$m
Light leaving from grating windows (ASAP)
Measurement of depth of mirror

Grating window
140 µm

331 µm

Mirrors

Light guide

Air

$d$ µm

$w$ µm
Rays leaving outside of grating versus depth of mirrors

- Depth of mirrors, $d$ (µm)
- Number of rays leaving outside of grating "windows"

Mirror position: Variable
Mirror Width: 331 µm

Lightguide lower surface
Rays leaving outside of grating versus depth of mirrors

No rays leaving outside of grating windows
Rays leaving through grating versus depth of mirrors

Mirror position, $d$: Variable
Mirror Width, $w$: 331 $\mu$m

Lightguide lower surface
Rays leaving through grating versus depth of mirrors

No rays leaving outside of grating windows
How to establish optimum depth of mirror

- Mirrors must keep all reflected rays within the grating “windows”
- When mirror depth is shallower than 10 µm, there were no rays leaving from outside of the grating
- Mirrors too close to the upper lightguide surface can block the light from reaching the grating “windows” so the output is reduced.
- In the range of mirror depths, $d = 0$ to 10 µm, the maximum output occurs at 10 µm
Optimum depth of mirror

Optimum mirror depth

No rays leaving outside of grating "windows"

Number of rays leaving from grating

log (depth of mirrors, $d$) (µm)
Conclusions

- A thin backlight illumination system was made without colour filters.
- A mirror array layer inside the multimode lightguide can stop the light loss from the opposite side of lightguide and improve efficiency by up to 38.2%.
- Replicated cylindrical micro-lens components are used to direct the light for optimum contrast and viewing angle.
Future Plan

- Change position of light source, vary size of grating windows
- Use improved LED model.
- Improve design of micro-mirror within lightguide to obtain better uniformity
- Design new structure of lightguide to reduce the total light loss
- Experimentally investigate transmissive colour LCDs