高性能LED背光模組與照明應用之光學設計

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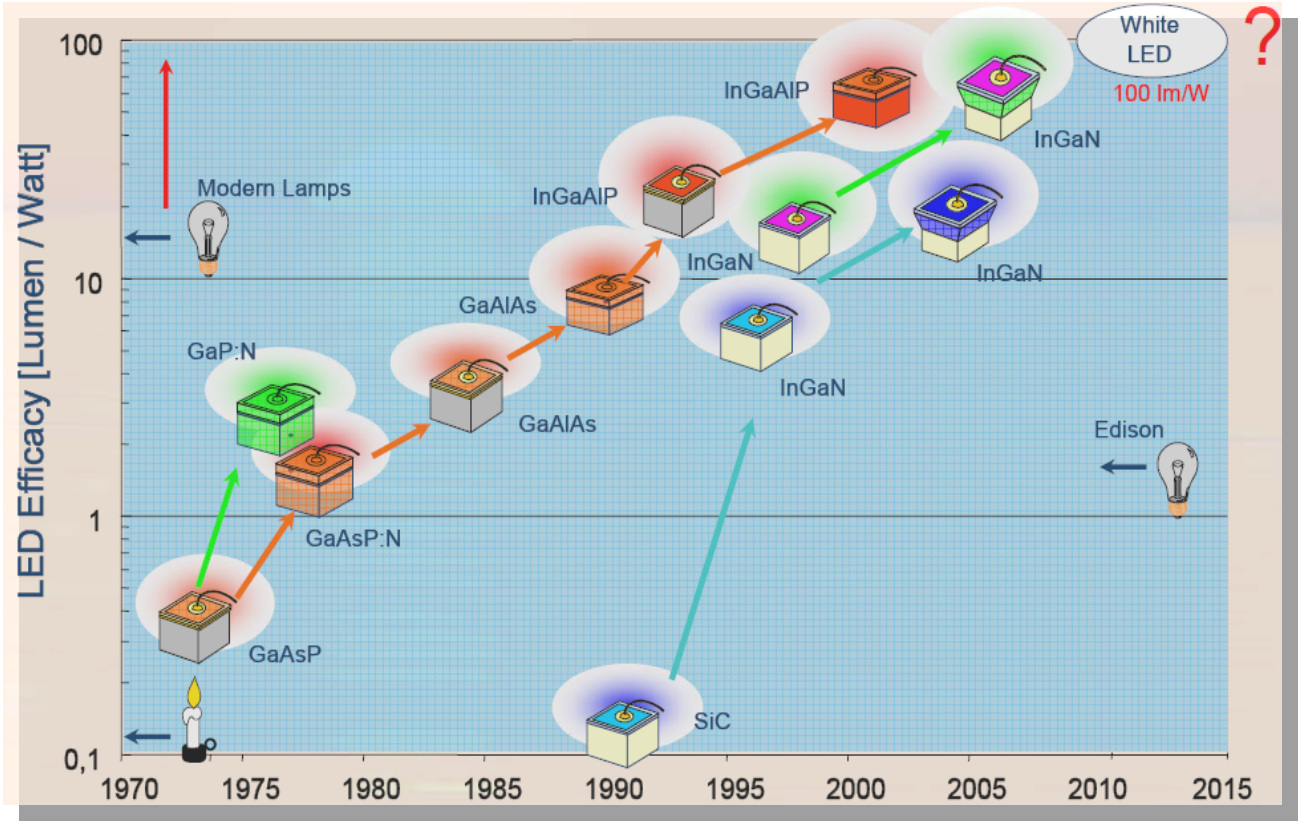
Outline

- Introduction
- Some aspects for optical design and simulation
- Some examples
- Conclusions

Introduction

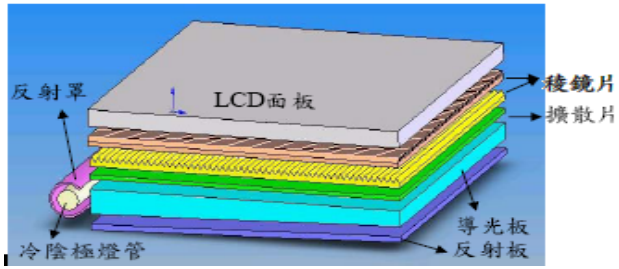


LED will keep playing an important role in backlight and lighting as its performance keeps improving.

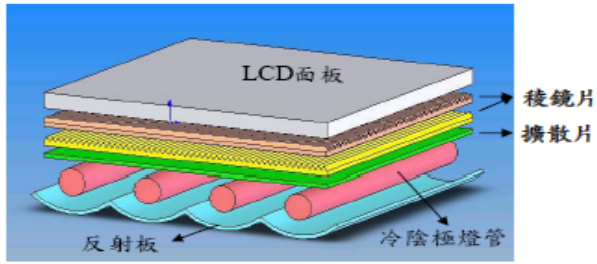
背光模組結構分類

- 側光式(Edge Lighting)結構：發光源為擺在側邊之光源，導光板採射出成型無印刷式設計，一般常用於18"以下中小尺寸的背光模組，側邊入射的光源設計擁有輕量、薄型、窄框化、低耗電的特色。
- 直下式(Bottom Lighting)結構：其光源放置在液晶面板下方，使光線以直接穿透或間接反射的方式，提供液晶面板亮度，一般常用於大尺寸之平面顯示器，其光源使用效率較佳。

側光式導光板

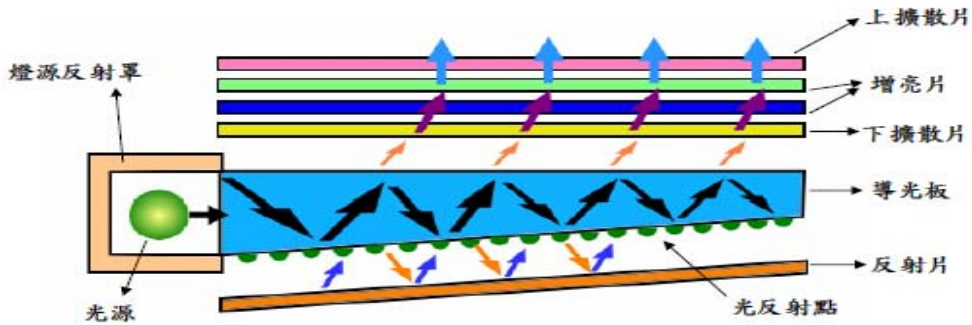


直下式導光板

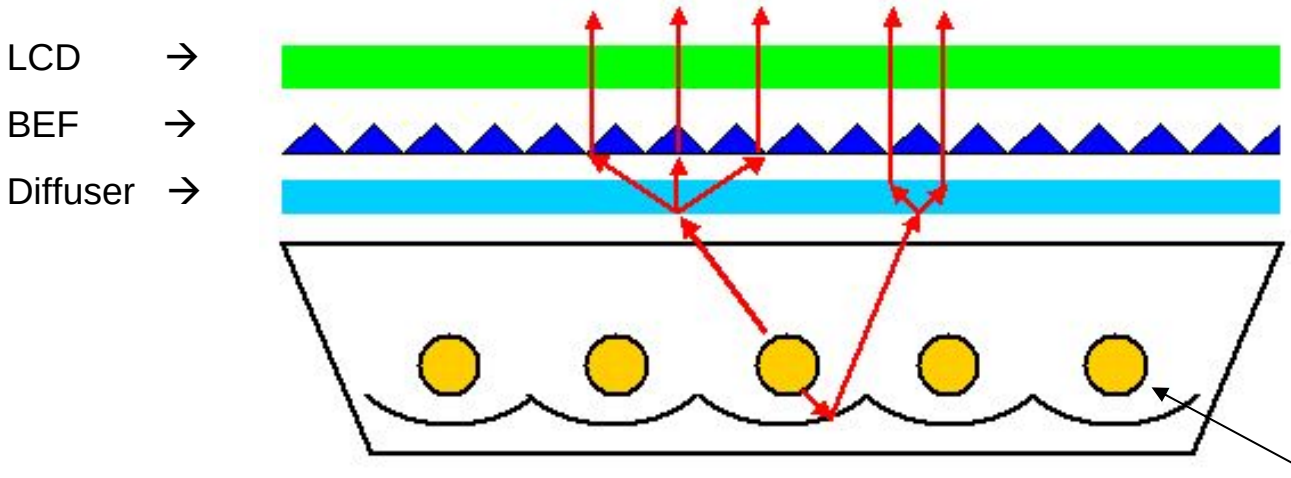


背光模組的組成

- 導光板—用來引導光線方向，提高面板輝度且控制均勻度
- 擴散板—將來自導光板的光線擴散出去
- 增亮片—將擴散後的光線加以折射入面板，提升背光板亮度
- 光源— LED及CCFL皆可做為光源



Bottom Lighting Backlight

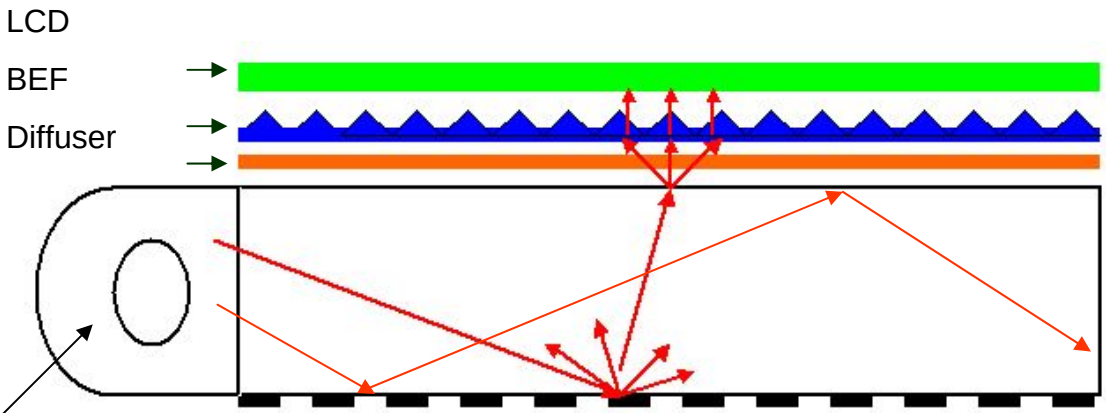


Light source:

Special Designed LED (or CCFL)

Applications: Large size LCD TV or monitor

Edge lighting Backlight



Light guide plate

Light source: LED
(or CCFL)

Scattering dots
or pattern

Application: small or medium or Large size LCD display

such as cellular phone, PDA or PC monitors.

Features of good LED backlight

- High luminance

Higher efficiency LED light source

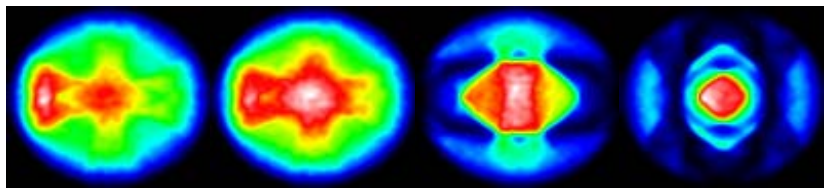
Less loss in light coupling and light extraction

- Good uniformity

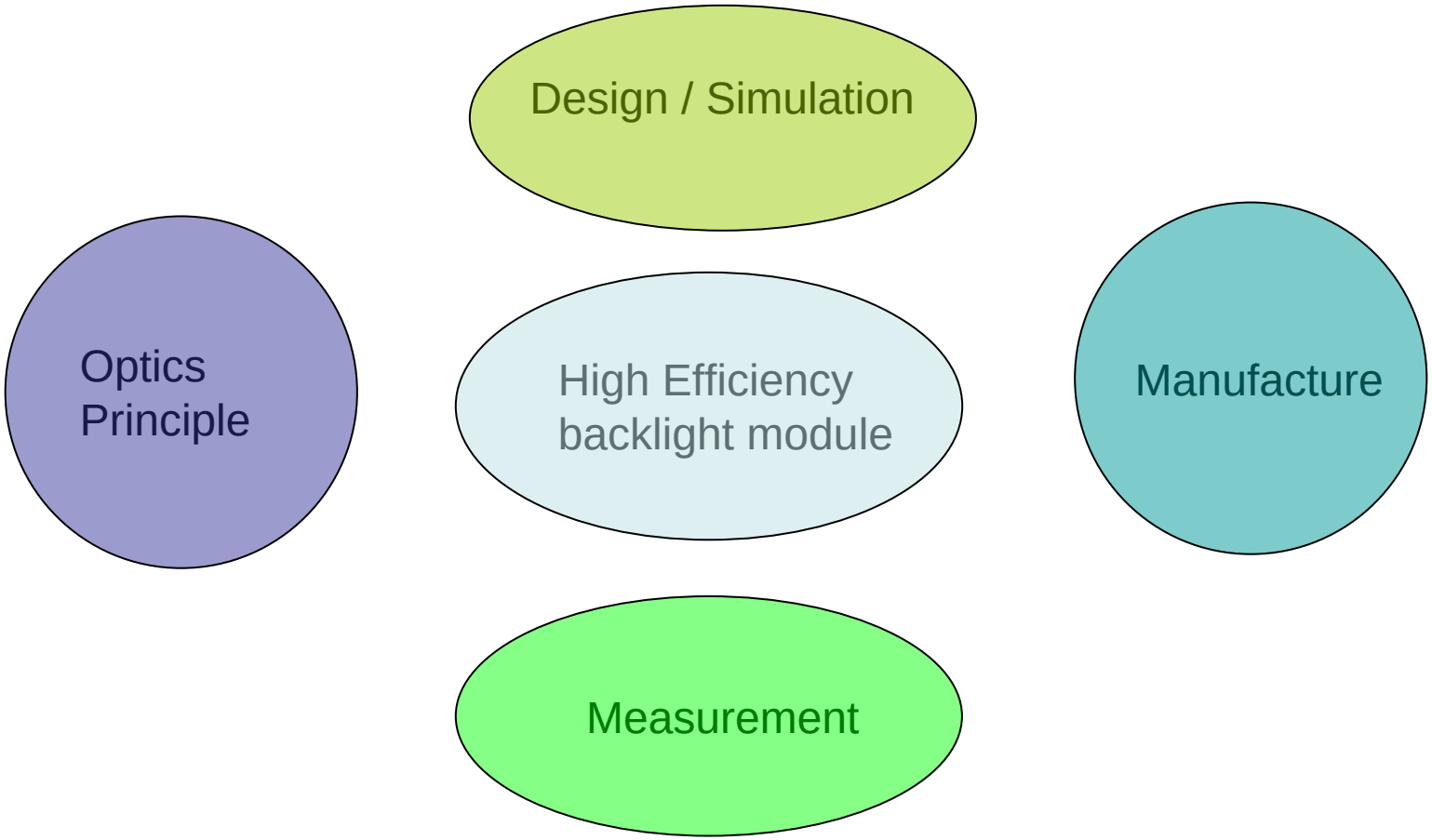
LED is a small light source, some special structures are needed to solve the problem caused by using it. (example: v – cut). A/P ration problem.

Uniformity can be improved by suitable arranging the distribution of scattering pattern.

- Needed Angular Distribution (Beam Pattern)



Some aspects for optical design and simulation



Personal view points

- Use your simulation tool carefully, it is better to have some optical principle or reasons which support your design.
- Do not try to simulate a structure which is too complicate, or it is not easy to obtain useful information due to the tool's limitations. (There are some sources of variations or uncertainties from manufacturing or measurement.)
- Specify your target or problem you want to solve, and keep your simulation connected with experiments or measurement, even if it is only qualitatively not quantitatively.

Some issues

- Non-uniformity

A. Hot-Spot problem

Possible solutions:

A1. Light guiding trench

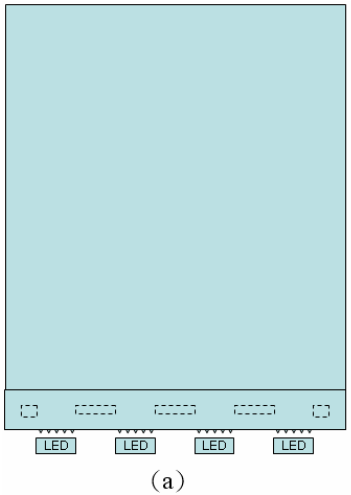
A2. Connectable LGP

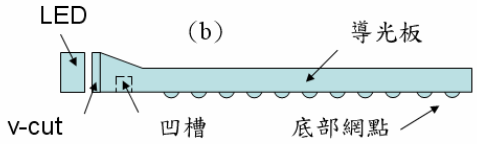
B. AA problem

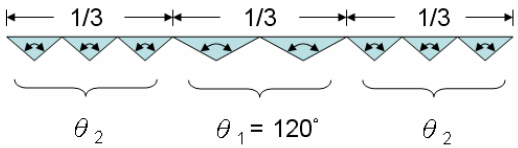
B1. Light coupling structure

B2. Dots pattern distribution.

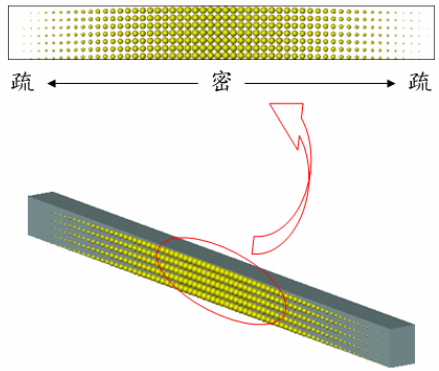
A1. Light guiding trench



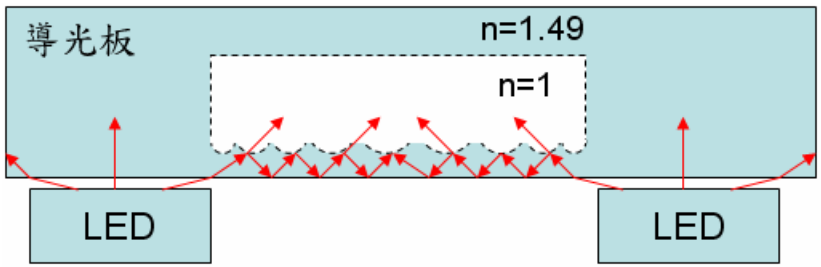


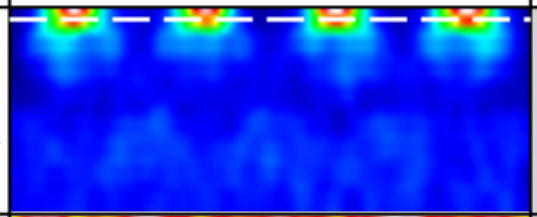
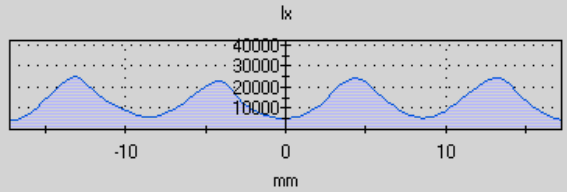
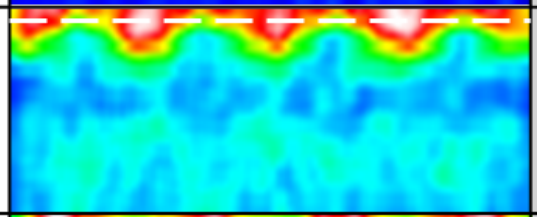
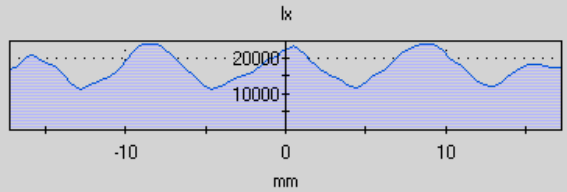
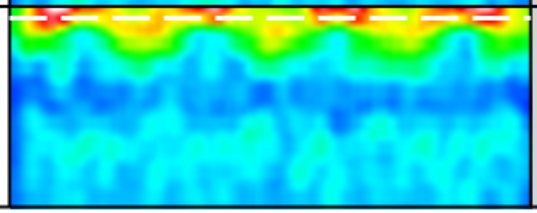
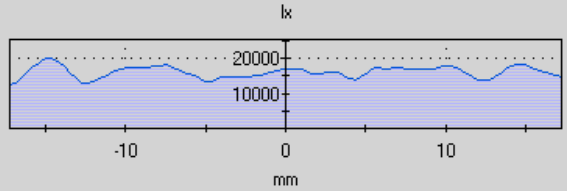


(c)

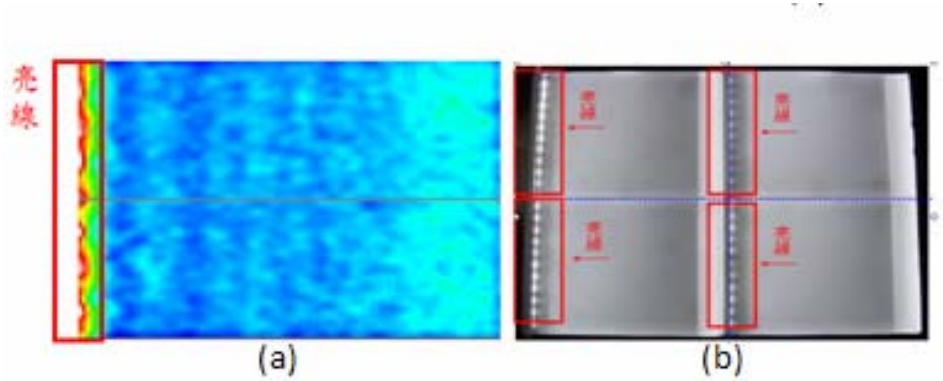


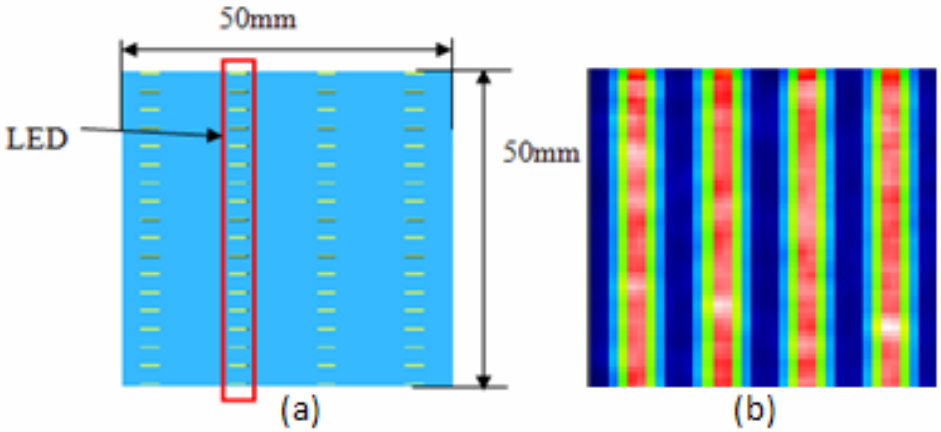
(d)



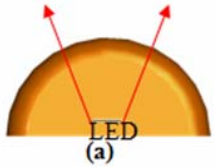
	入光處照度圖	橫剖線截面	通量(lm)	均勻度(%)
未加 入光結構			13.11	16
120° v-cut			13.48	47
凹槽 + 複合角度			13.27	62

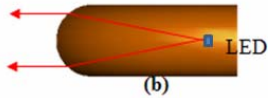
A2. Connectable LGP

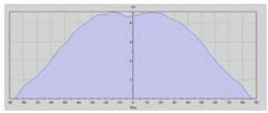


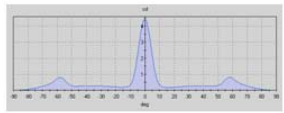


LED Package

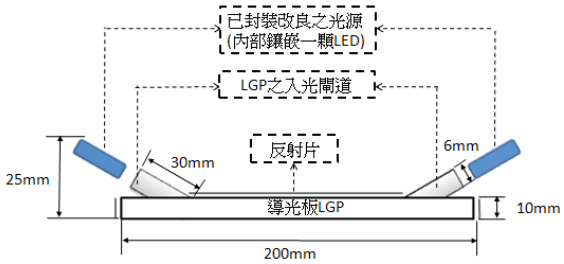


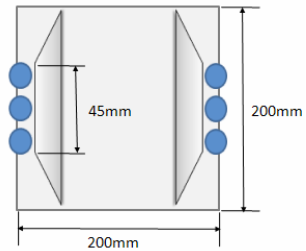



(a)

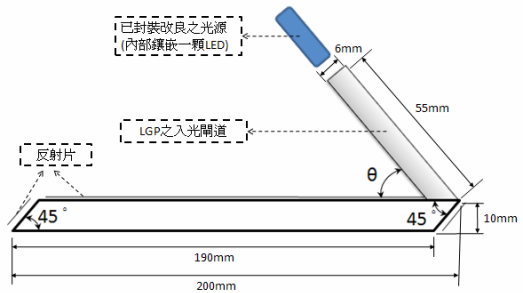

(b)

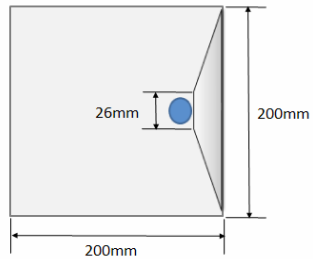
Type A

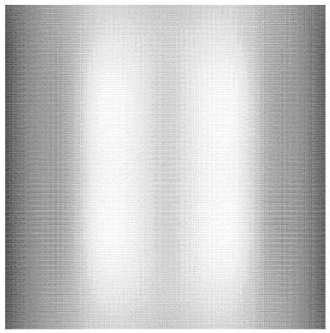




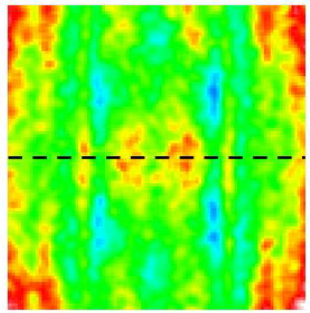
Type B



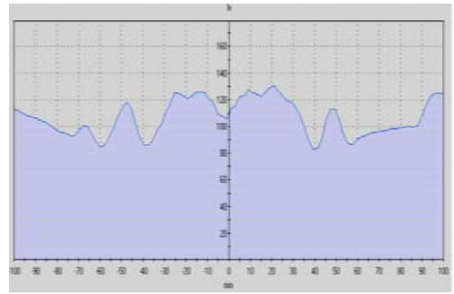




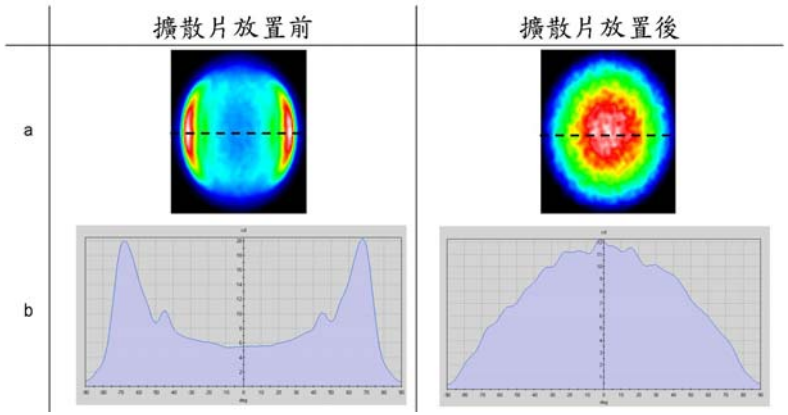
(a) 網點分佈圖



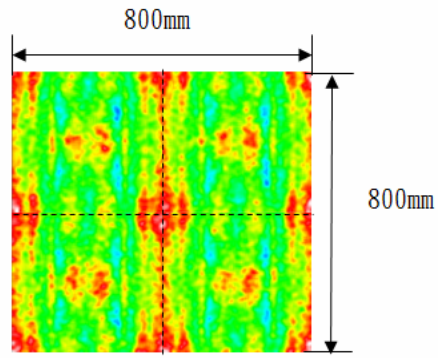
(b)導光板照度圖



(c) 照度橫向剖線圖



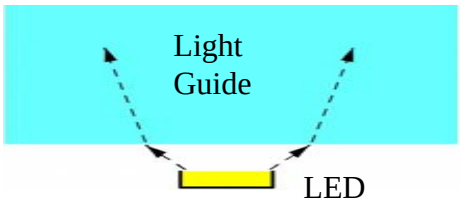
(a) 導光板角度圖 (b)橫向角度剖線圖

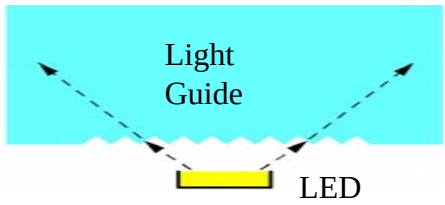


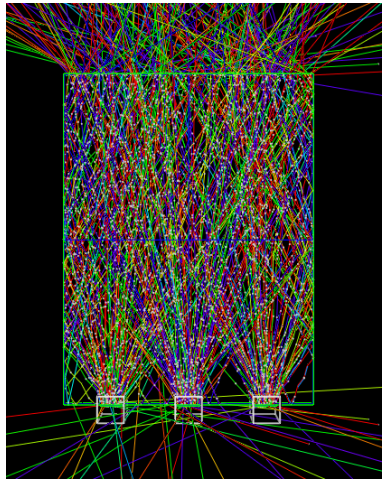
四塊拼接照度圖

V - cut structure for wider angle distribution of LED

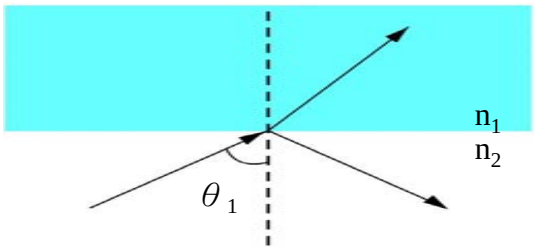
Light coupling structure

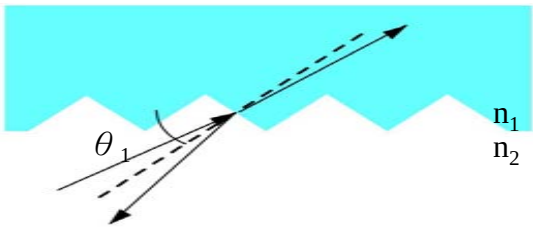


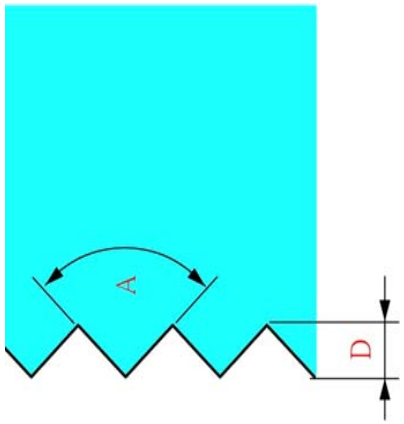


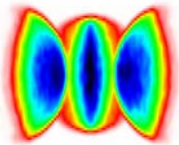


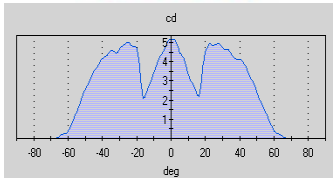
No V-cut



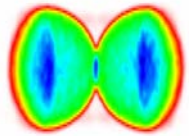


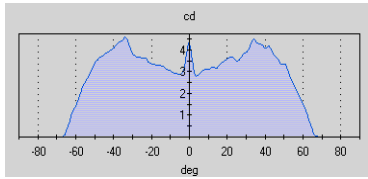






A = 60°





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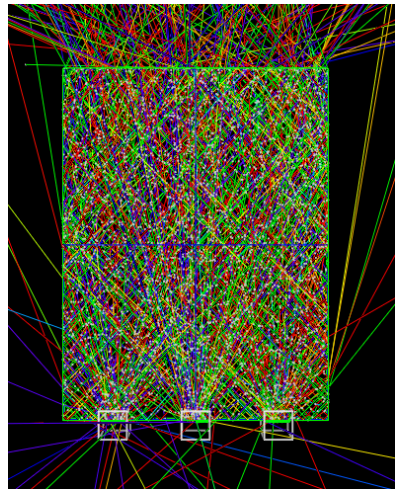
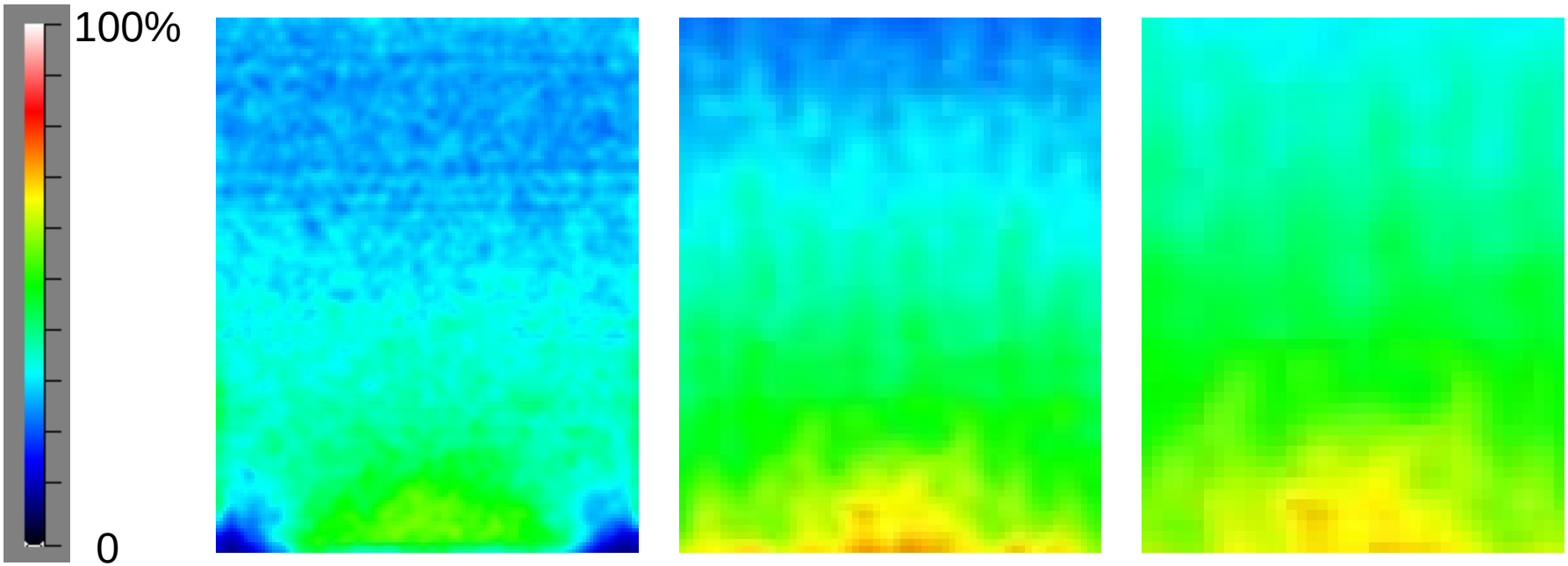


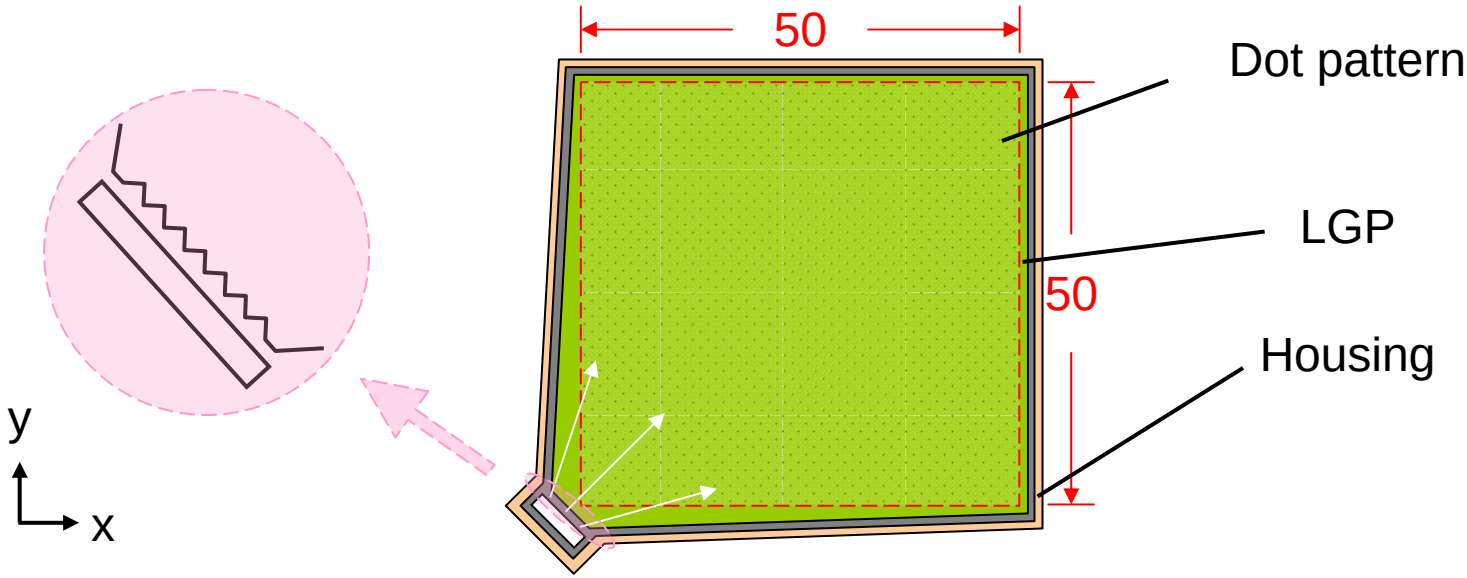
With V-cut

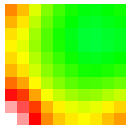
Dots pattern distribution strategy



(a) Original structure (b) Dark region correction (c) Better uniformity

Corner Emitting





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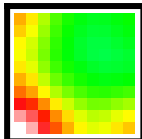	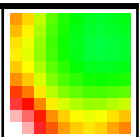	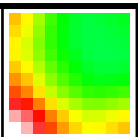	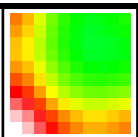	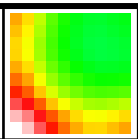	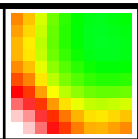	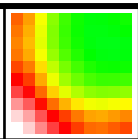	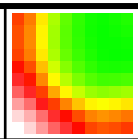	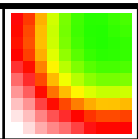	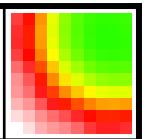
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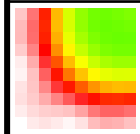	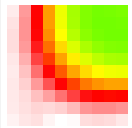	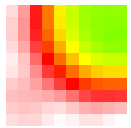	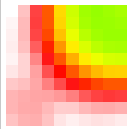	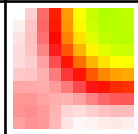	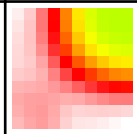	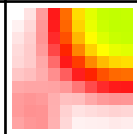	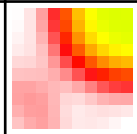	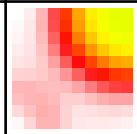	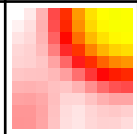
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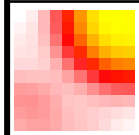	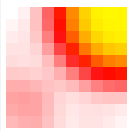			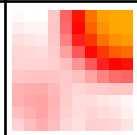	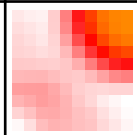	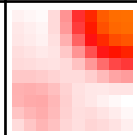	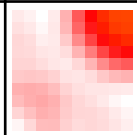	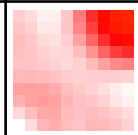	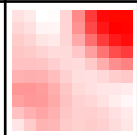
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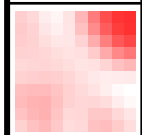	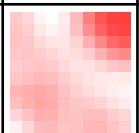	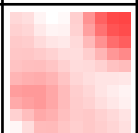	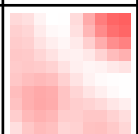	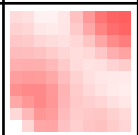	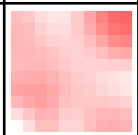		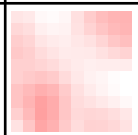		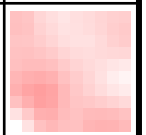
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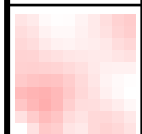
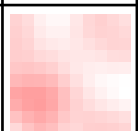
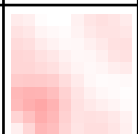
									
041	042	043	044	045	046				

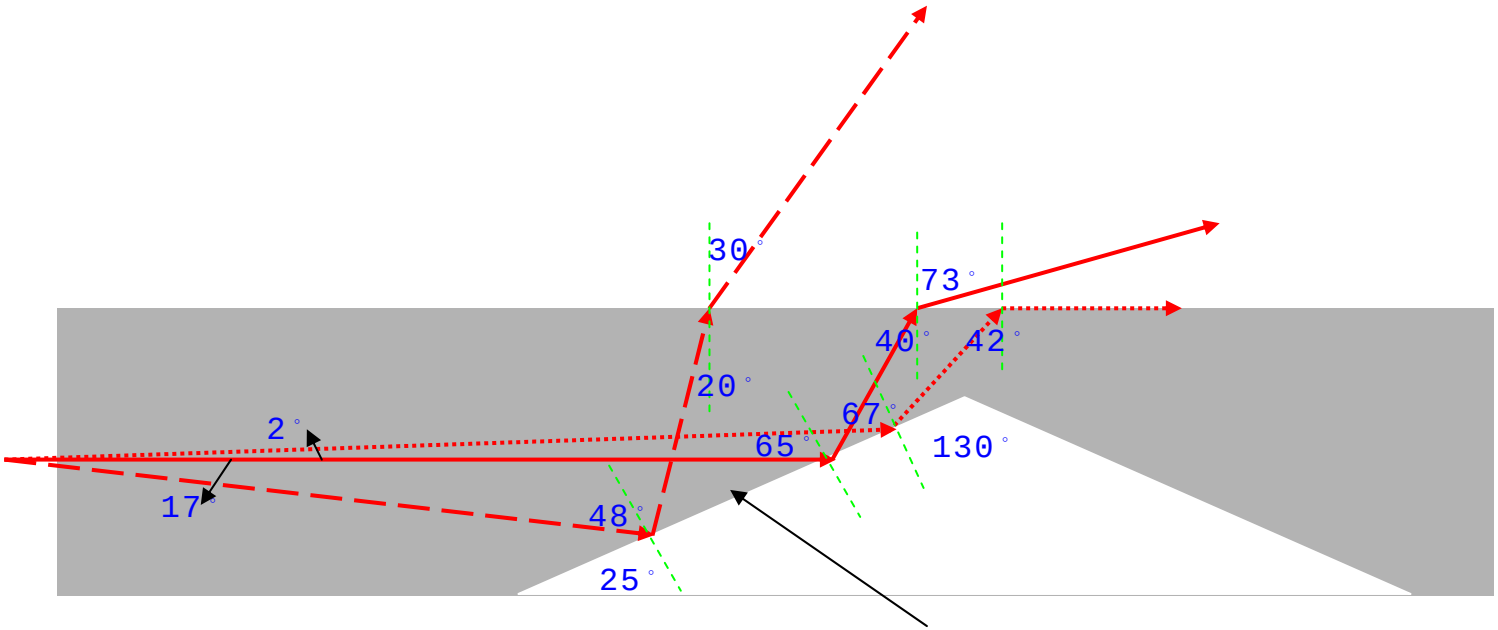
High luminance

Surface roughness of scattering dots on the lightguide plate

It is found that smooth (polished) surface can direct light out of the lightguide more efficiently by total internal reflection (TIR) than rough surface by scattering. It is worth to make the surface as smooth as possible.

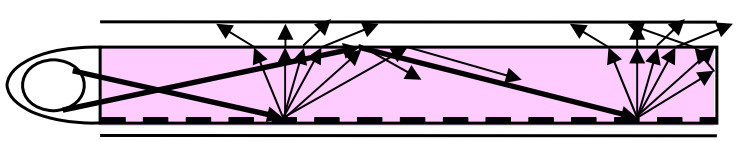
- Rough surface: printing, etching, sand blasting, etc.
- Smooth surface : Photolithographic+ thermal reflow, micromaching, Lasers, LIGA, etc.

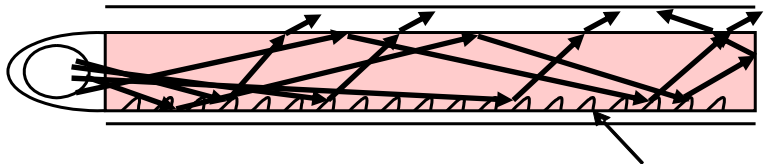
Slope analysis

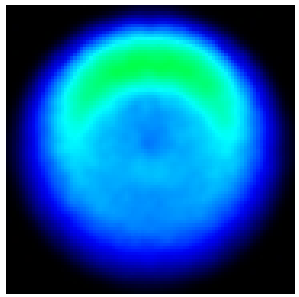


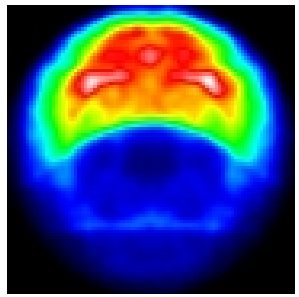
Concave spectacular surface

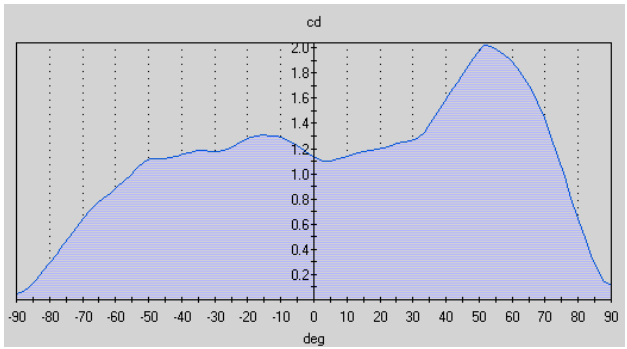
Rough Surfaces vs. Smooth Surfaces

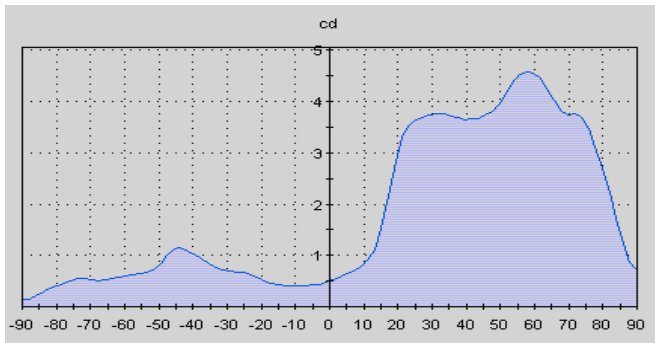






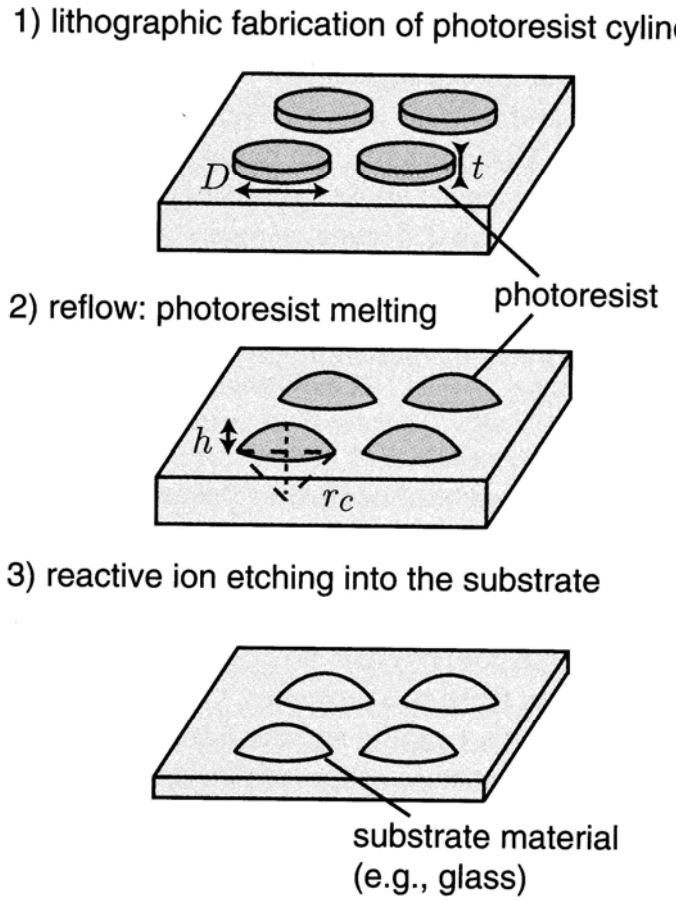






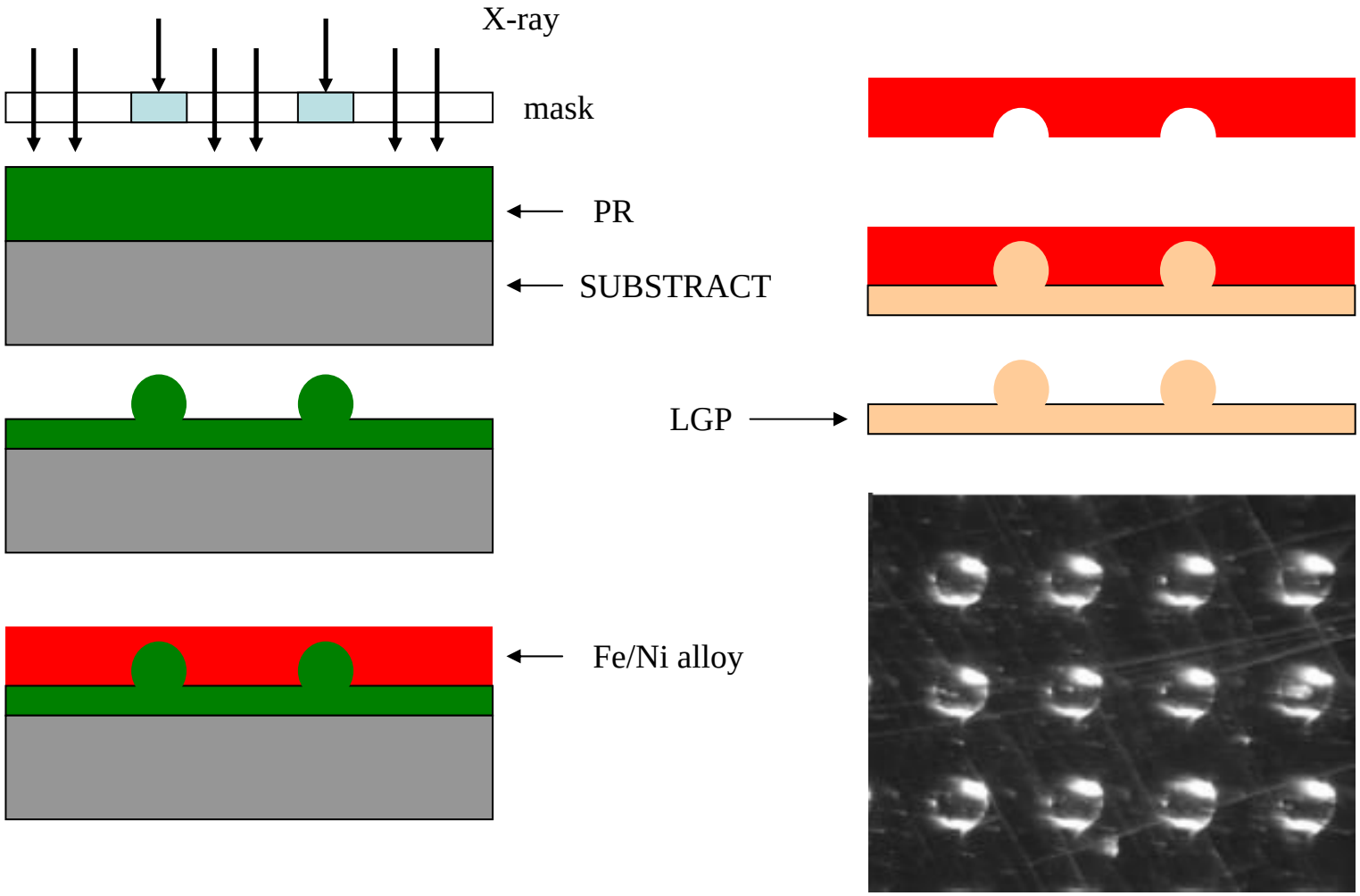
Higher Efficiency!!

Manufacturing the smooth surfaces

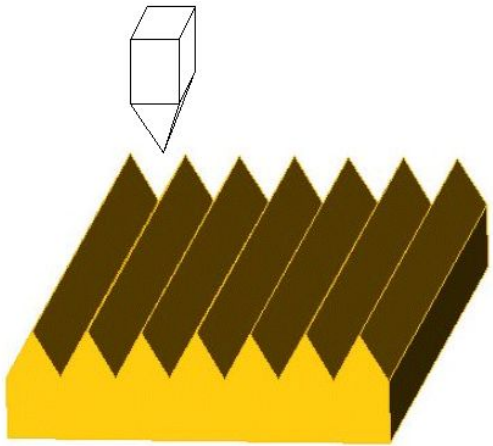


Stefan Sinzinger, Jurgen Jahns,
"Microoptics", Wiley, Germany, 2004

Electro-forming

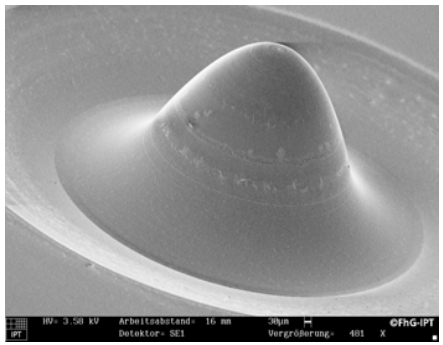


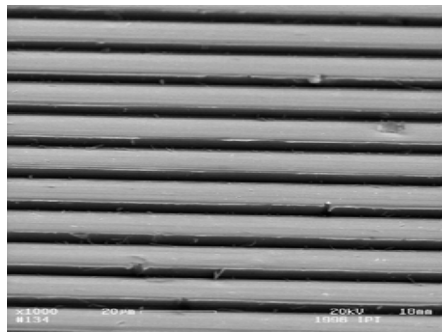
Micro Machining

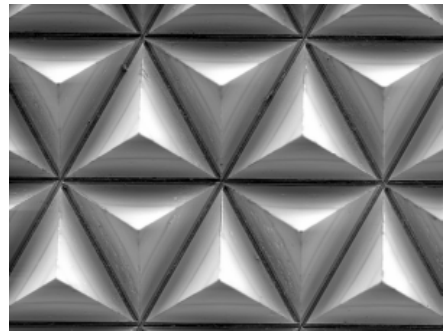


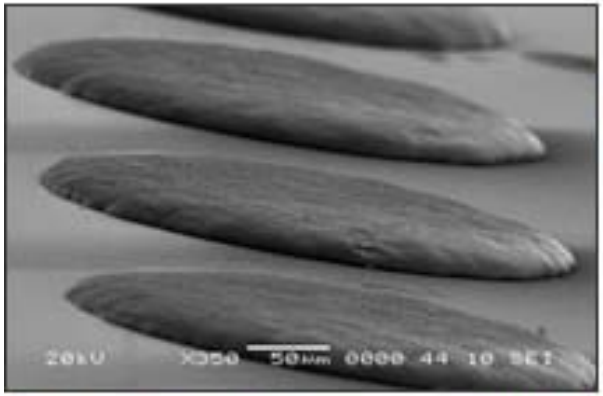
Turning
Milling
Fly-Cutting
Drilling
Grinding

Sources: Fraunhofer IPT









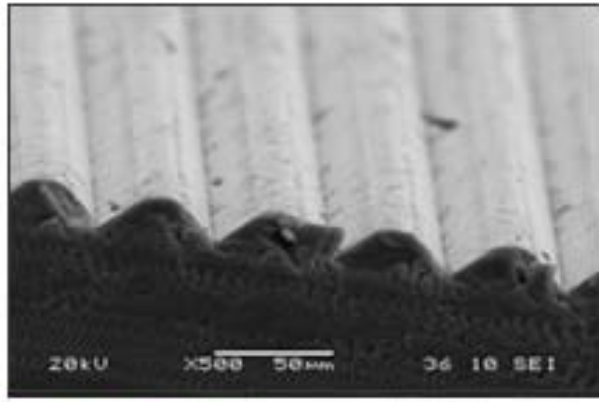
蝕　刻
(Etching)

最小點直徑
100 um

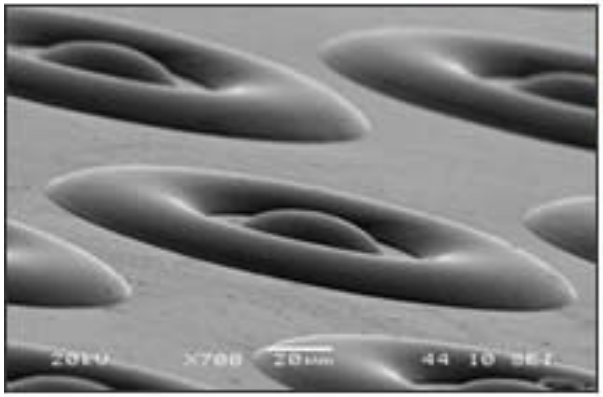
蝕刻製程改良,增加Pattern出光效率

微溝切削
(V—Cut)

最小pitch 5 um
最小深度　1 um



提升光學效率



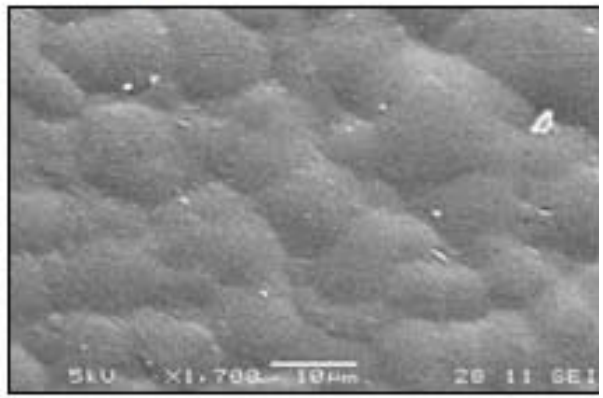
電　鑄
(Stamper)

最小點直徑
10 um

光學圖樣(Pattern)型態最佳化,
增加出光效率

噴　砂
(Sand-brust)

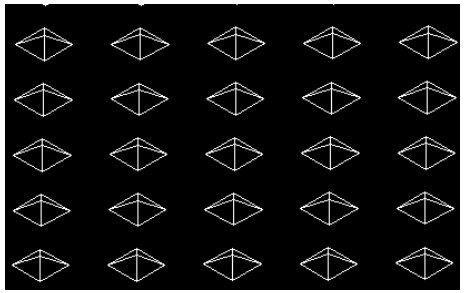
最小點直徑
100 um



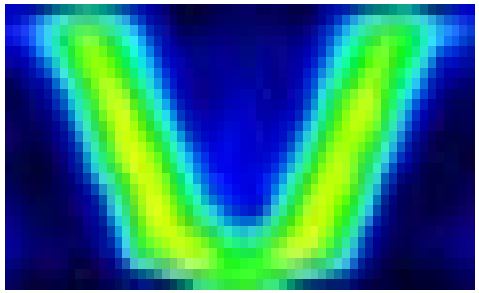
提升能量利用率

比較項目	蝕刻技術	電鑄技術	噴砂技術	V-CUT
加工深度	500μm	100μm	10~20μm	1~30μm
加工面限制	受限於板材壓延方向	佳	佳	須注意板材壓延方向
材料限制	蝕刻級金屬	金屬	金屬	模具鋼
製作成本	中等	高	低	很高
技術成熟度	高	中等	中等	發展中
生產效率	佳	差	佳	差
光學表現		輝度提升3~5%均勻性佳	減少下擴	輝度提升10~15%均勻性較差視角差

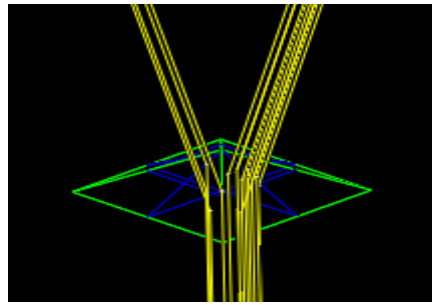
New problems from smooth surfaces



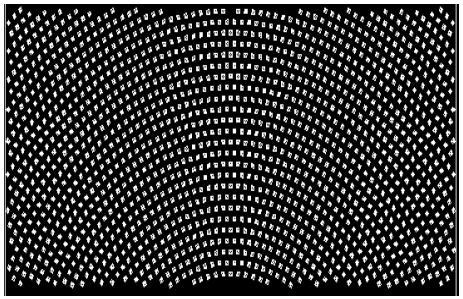
(a) small pyramid structure



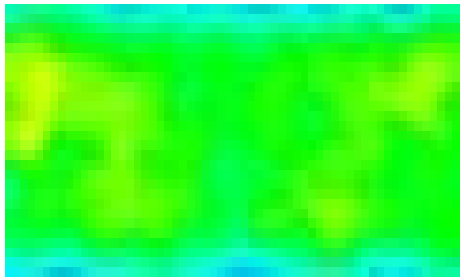
(b) unexpected stripes



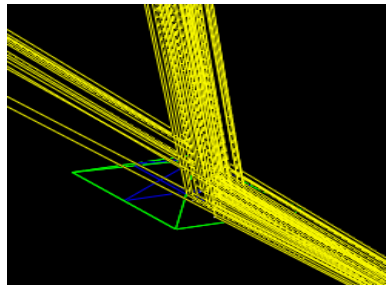
(c) Simulation



(d) Different shapes or orientations



(d) Better situation

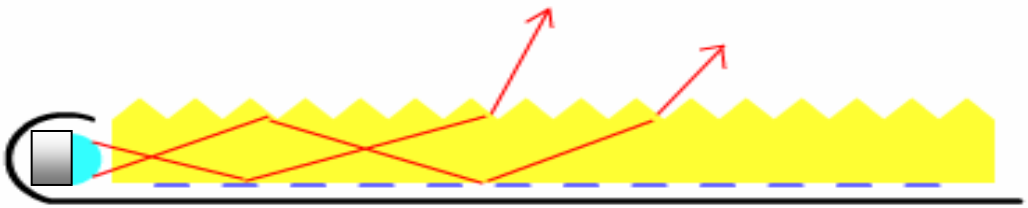


(e) Simulation

Proceeding in OPT 2005 PG-SA1-23

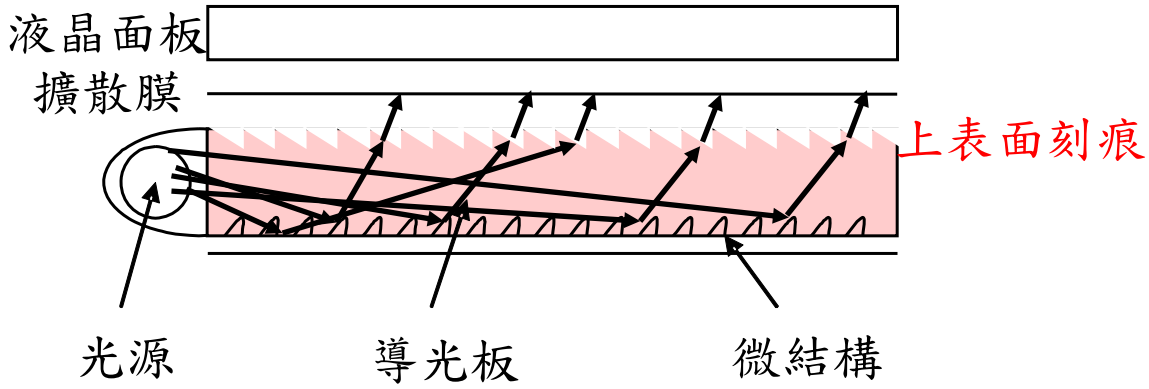
Needed Angular Distribution

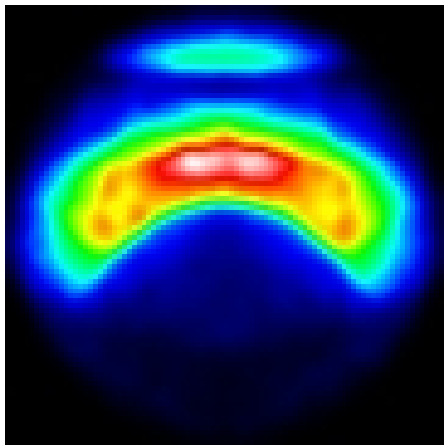
V-cut一體複合式導光板
:利用上表面

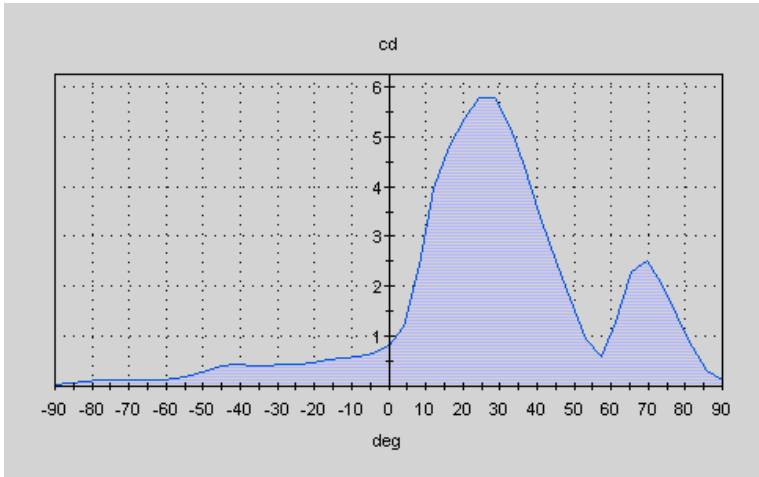


- 未來趨勢：減少光學膜片或LED使用數量。

Advantages: Better Directivity and Efficiency.







Idea 2

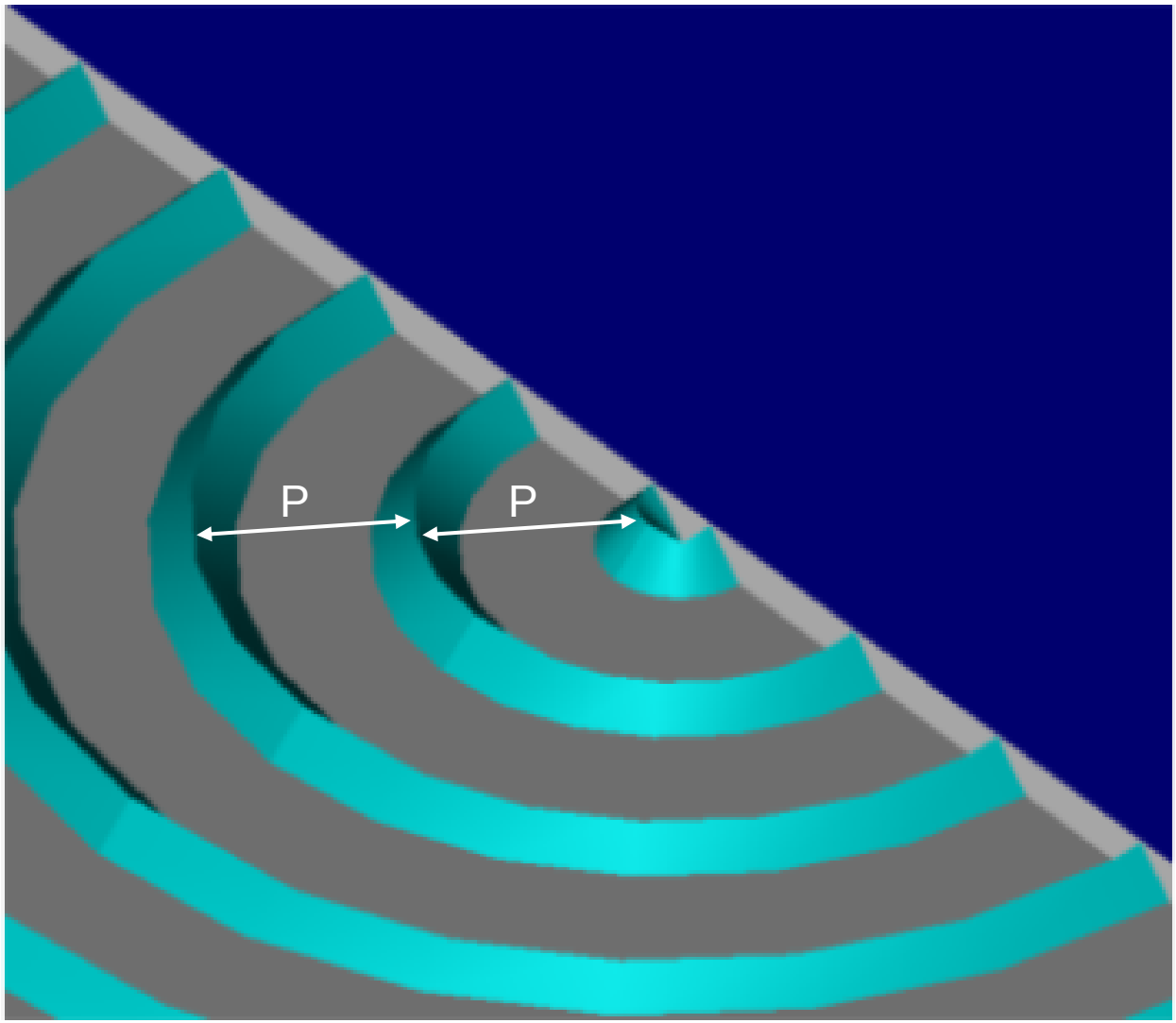
環型V-CUT分區變化結構導光板設計

創新性說明:

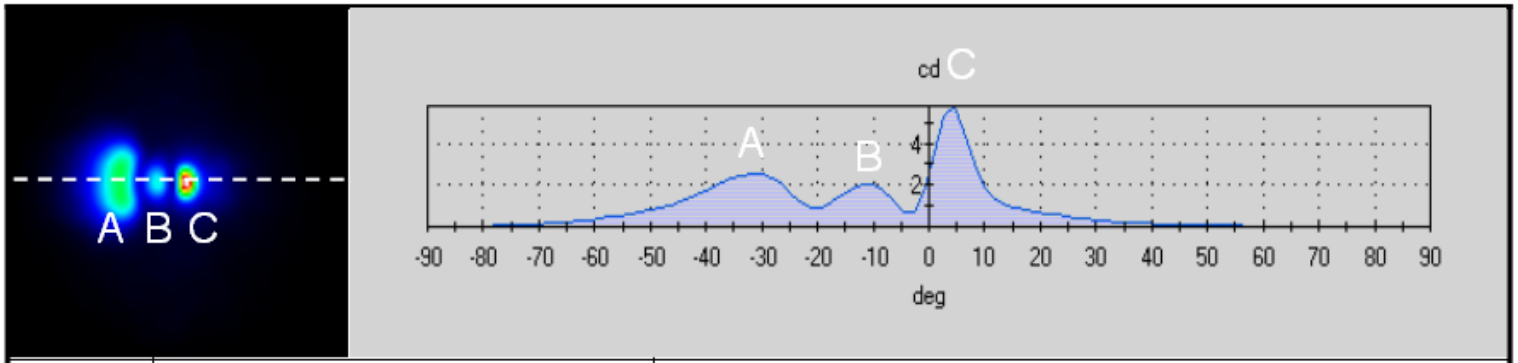
不同區域做不同的微結構

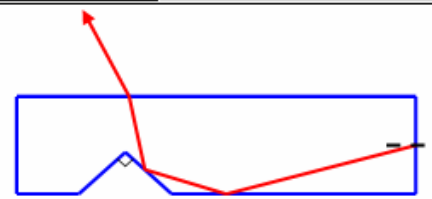
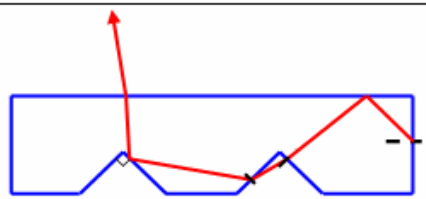
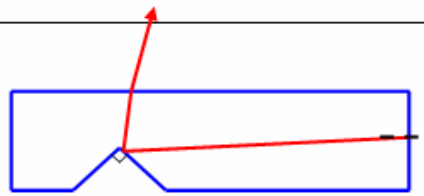
或漸變微結構

導光板底部環型結構設計示意圖

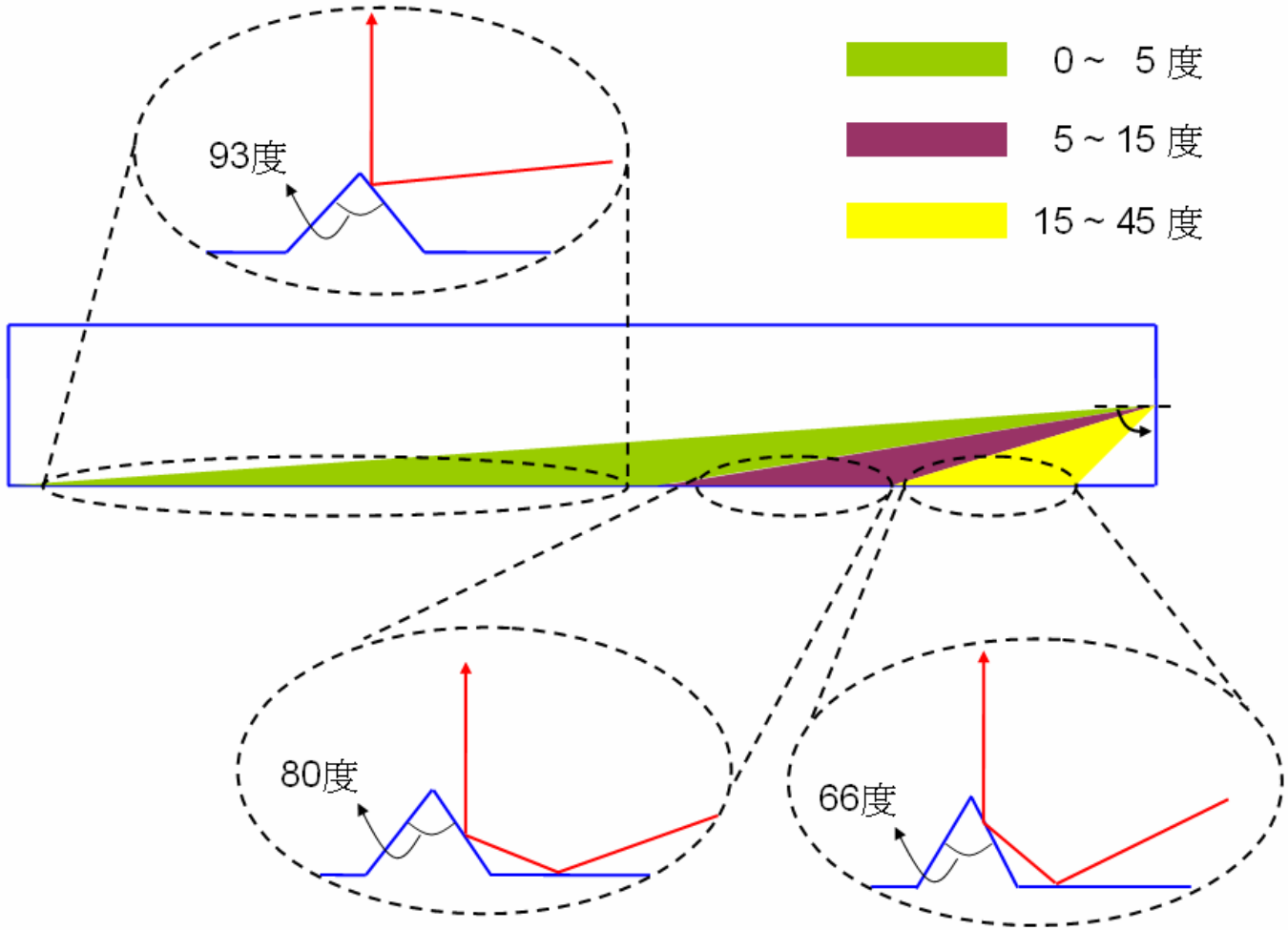


光在導光板中的三種行為:
幾何光學搭配光學模擬

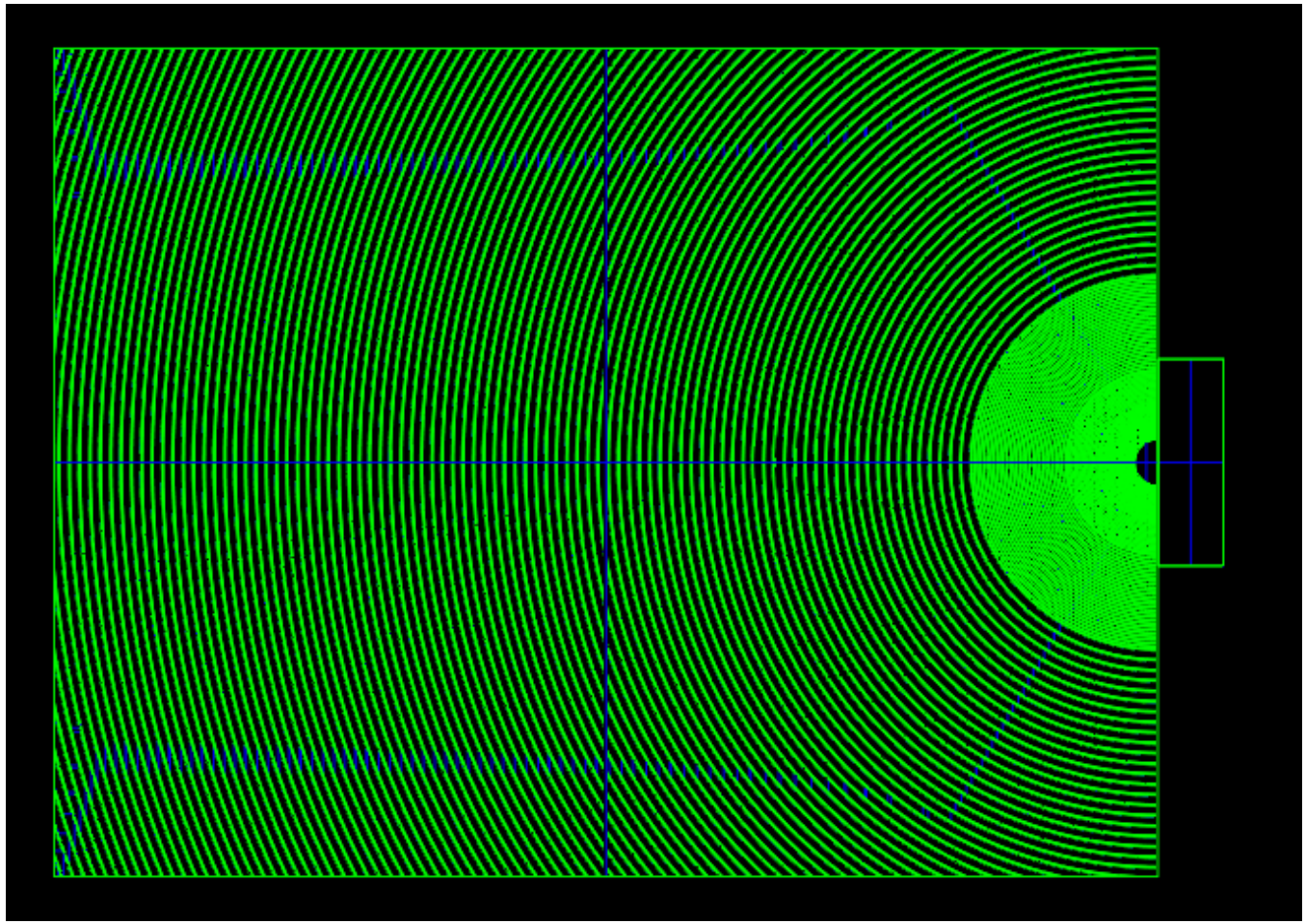


A		較低角度的光先在導光板底面做一次全反射，然後在環型結構上做另一次全反射，最後經由折射在－30°處出光。
B		較高角度的光先在導光板頂面做一次全反射，然後在環型結構上做兩次偏折，再由後面的環型結構全反射至－12°處出光。
C		平角度的光直接在環型結構上做一次全反射，最後經由折射在 5° 處出光。

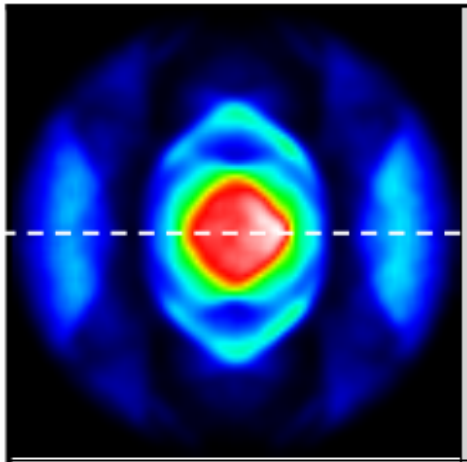
不同區域做不同角度的微結構

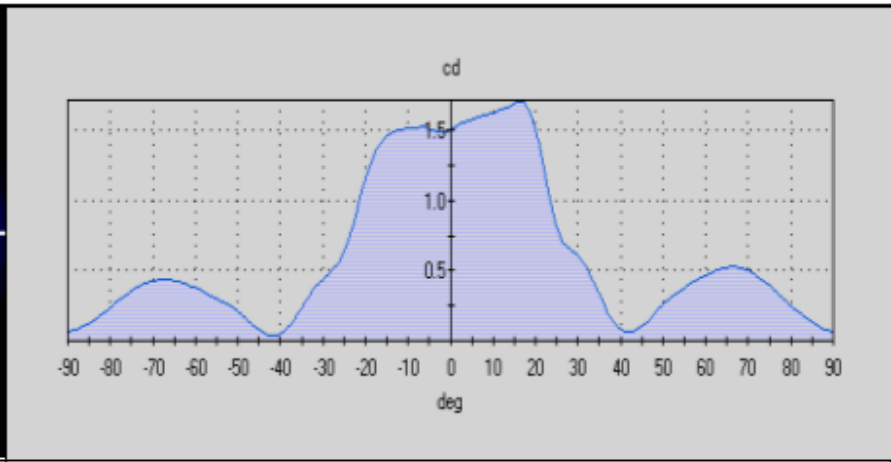


分3區設計結構

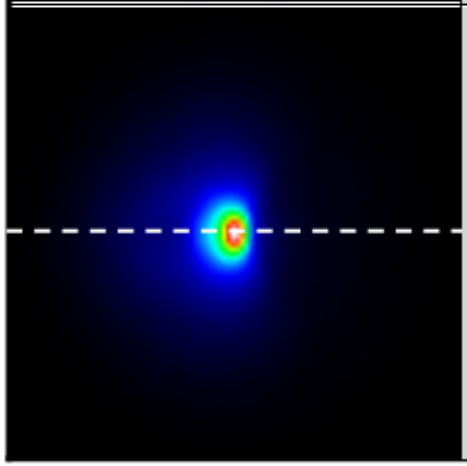


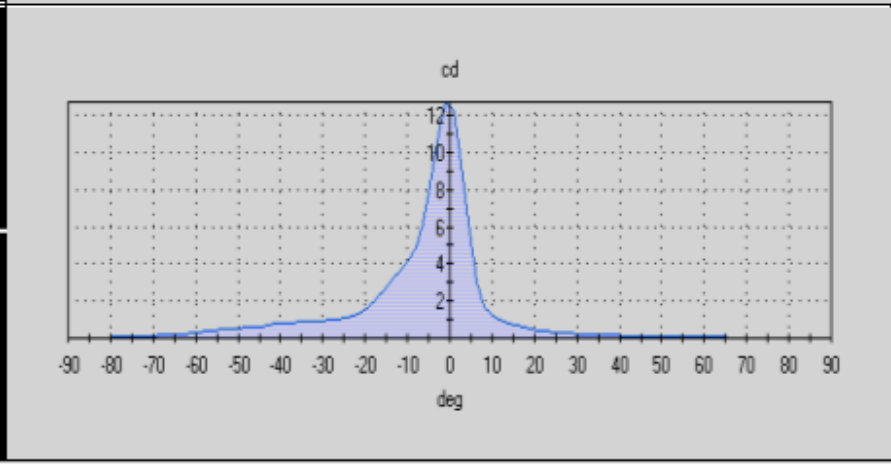
模擬結果說明





傳統的背光模組經由許多光學膜片的搭配下，由角度的剖面圖可以知道半功率全角約50度。





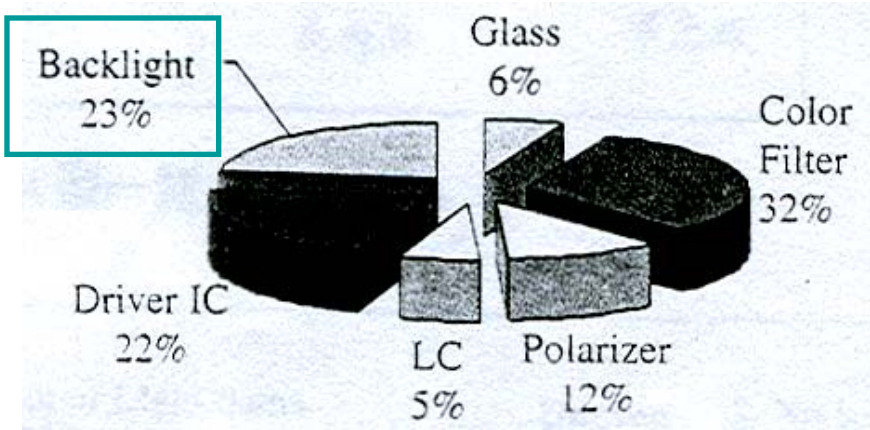
環型梯度變化結構導光板在沒有光學膜片的搭配下半功率全角爲15度。

優　勢

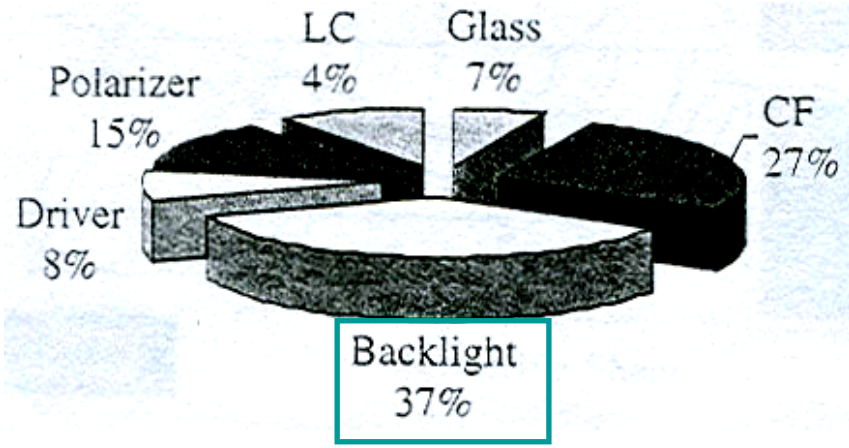
- 較傳統的背光模組於正視角中有更小的半功率全角
- 減少稜鏡片的使用
- 光強度爲傳統背光模組的數倍
- 個人的使用上具有較佳的保密性

Conclusions

- There are many possibilities and chances to improve the LED backlight's and Lighting performance.
- It is worth to make it cheaper and better for the brighter future of TFT-LCD and LED Lighting.



15" LCD cost structure



30" LCD cost structure

Others issues and open questions

- Any other cheap or quick ways to fabricate microstructures with smooth surface?
- How thin can a lightguide be?
- Double sides structures for lightguide plate?
- Other shapes or distributions for scattering dots to improve the performances?
- Special design or package for LED lamp to replace CCFL in edge or bottom emitting backlight?
- Diffractive Optics instead of Geometric Optics?

Thanks for your attention!

Any difficult problems about optical designs and measurement (BLM, LED Lighting, Headlights etc.) are welcome.