Abstract: A back light unit (110) for a liquid crystal display is provided. The unit comprises a light guide plate (102), a reflecting surface (101) arranged parallel and adjacent to the back surface of the light guide plate. Further, the light guide plate (102) comprises an interfacing surface (104) between a first material and a second material, which interfacing surface comprises microstructures (105) which are arranged such that light is outcoupled from said light guide plate (102) towards said reflecting surface (101). By using a backlight unit of the invention, the need for diffusers between the backlight unit and the liquid crystal cell of an LCD is reduced.
Back light unit

The present invention relates to a back light unit for a liquid crystal display, comprising a light guide plate having a front side adapted to face a liquid crystal cell and an opposing back side, at least one light source arranged to provide light to said light guide plate, and a reflecting surface arranged parallel and adjacent to said back surface of said light guide plate, wherein said light guide plate comprises an interfacing surface between a first material and a second material, which interfacing surface comprises microstructures. The present invention also relates to display devices comprising such back light units.

Liquid crystal displays (LCDs) are commonly used display devices in computer systems, television systems and other electronic devices, such as in handheld devices for example mobile phones, etc.

The LCD is effectively a light valve, which allows the transmission of light in one state and blocks the transmission in another state. Thus, an LCD requires a light source for operation. Back light systems, where the light is provided from behind the liquid crystal cell, are commonly used as the light source for LCDs because of the high contrast ratio and brightness obtainable.

Typical back light systems comprise a light source, which couples light into a light guide, which is a plate essentially coplanar with the liquid crystal cell. The light guide is arranged to extract the light essentially homogenously to the whole liquid crystal cell. Numerous designs are available for the light guides. For example, US patent No. 6,788,358 to Kim et al, discloses a backlight comprising a light source and an optically clear plate, which comprises a repeating micro-groove pattern in the backside. The sides of the grooves form reflective surfaces, which reflect light from the light source towards the liquid crystal cell.

However, one problem when using a backlight comprising a periodic array of micro-optical grooves to extract light from a light guide, optical interference with other periodical patterns in the LCD-array can and will occur, as the extracted light is not completely homogenous, but exhibits a periodical intensity variation corresponding to the
grooves in the light guide. Examples of such other periodical patterns are color filters, liquid crystal pixel patterns, electrode patterns and active LCD-matrix. This optical interference typically manifests itself as dark and light bands in a supposedly uniform image, and is commonly known as a Moire-effect.

In US 6,788,358, one solution to reduce this Moire effect is to arrange a diffuser in between the periodic structure of the backlight and the periodic structure of the LCD.

However, by using a diffuser, the light efficiency will decrease because more light will be reflected back into the backlight.

Thus, there exists a need for a LCD display device where the Moire effect can be reduced without using diffusers between the light guide and the liquid crystal cell.

It is thus an object of the present invention to overcome this problem, and to provide a solution for a back light unit for a liquid crystal display device in which the Moire effect is reduced or avoided, which solution obviates, or at least reduces, the need for diffusers between the back light unit and the liquid crystal cell.

The need for diffusers are especially undesired in display devices using a back light system providing polarized light, such as for example described in the published patent application US 2003/0058383 A1 to Jagt et al, as the diffusers partially destroy the polarization.

The inventors have found that the main cause of the Moire pattern is that the light is unevenly distributed over the area of the device due to the short distance between the periodical light extracting patterns and other periodical patterns.

Due to the short distance between the periodical light extracting patterns and other periodical patterns, such as color filters and the LCD pixel patterns, the light emanating from the back light system is periodical in intensity, with a periodicity corresponding to the periodicity of the light extracting patterns.

By increasing the distance between the light extracting patterns and the other periodical patterns, this periodicity in intensity would become less apparent.

However, increasing the distance between the light extracting patterns and the other periodical patterns would lead to an unacceptable increase of the thickness of the display device.
The present invention obviates or at least reduces the need for by providing a back light unit comprising a light guide plate located on the back side of the liquid crystal cell, through which the light propagates by means of total internal reflection (TIR). The light can be extracted from the plate, predominantly towards the back side of the display device, i.e. away from the liquid crystal cell. Here, a reflecting surface reflects the light towards the liquid crystal cell. By this solution, the optical distance from the light extracting periodical pattern to the other periodical patterns in the display device is increased without essentially increasing the thickness of the display device.

The increased optical distance allows for a light bundle reflected by an individual microstructure to be more wide spread when it encounters any periodical structures in an LCD display, such as a color filter or LCD-matrix.

Thus, in a first aspect, the present invention provides a back light unit for an liquid crystal display, comprising a light guide plate having a front side arranged to face a liquid crystal cell and an opposing back side, at least one light source arranged to provide light to said light guide plate, and a reflecting surface arranged parallel and adjacent to said back surface of said light guide plate. The light guide plate comprises an interfacing surface between a first material and a second material, which interfacing surface comprises microstructures, wherein the microstructures are arranged such that light is extracted from said light guide plate towards said reflecting surface.

In some embodiments of the present invention, the microstructured interfacing surface may be in the interface between the light guide plate and the atmosphere.

In some embodiments of the present invention, the light guide plate may comprise a first optically clear, isotropic, layer, which receives light from the light source, and a second layer and a third layer, wherein the microstructured interfacing surface is in the interface any two of said layers. The third layer may be arranged between said first layer and said second layer, and alternatively, the second layer may be arranged between said first layer and said third layer.

By utilizing a microstructured layer, which is separate from the optically clear first layer, the manufacturing of the back light unit may be simplified as the need for machining the optically clear layer is obviated. Instead, the second and/or the third layer, which for example may be a polymeric film, is microstructured.

In some embodiments of the present invention, the second layer may be a birefringent layer.
A birefringent second layer may be used to provide polarized extracted light, thus reducing the need for polarizers between the back light unit and the liquid crystal cell. In embodiments of the present invention, the microstructure may comprise ridges and/or grooves extending into or out of the microstructured surface. The individual microstructures may be symmetric or non-symmetric with respect to a direction perpendicular to the direction of extension. For example, the cross-section of the extended individual microstructure may in the shape of a triangle or a truncated triangle.

The angle between the normal to the interfacing surface and the normal to a side of an individual microstructure may for example be in the range of from about 55 to about 67.5 degrees, such as from about 57.5 to about 65 degrees. However also other angle ranges may be used, depending on the differences in refractive index over the microstructured interface. The angle range should in any case be selected so as to promote total internal reflection of waveguided light towards the reflective surface.

In some embodiments of the present invention, the reflecting surface arranged on the backside of the light guide plate may a corrugated surface.

With the use of a corrugated reflecting surface, the light may be more evenly distributed when encountering other periodical elements of the device except for the light guide, thus further reducing the Moiré-effect and/or the need for diffusers between the back light unit and the liquid crystal cell.

In some embodiments of the present invention, the ratio between light extracted by said light guide plate towards said reflector and light extracted by said light guide plate towards said liquid crystal cell is higher than about 2:1 such as for example up to about 5:1 or 10:1.

In a second aspect, the present invention relates to a liquid crystal display comprising a back light unit of the present invention and a liquid crystal cell having a front side adapted to face a user and an opposing back side, wherein said back light unit is arranged on said back side of said liquid crystal cell. In such a liquid crystal display, the Moiré-effect is reduced in comparison with display devices of the prior art without significantly increasing the thickness of the device. Furthermore, the need for diffusers between the back light unit and the liquid crystal cell is reduced in comparison with display devices of the prior art without significantly increasing the thickness of the device.

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing a currently preferred embodiment of the invention.
Figure 1 illustrates in cross sectional view, a first embodiment of the present invention.

Figure 2 illustrates, in cross sectional view, a second embodiment of the present invention.

Figure 3 illustrates, in cross sectional view, a third embodiment of the present invention.

As mentioned above, the present invention relates in one aspect to a back light unit for an liquid crystal display, comprising a light guide plate having a front side arranged to face a liquid crystal cell and an opposing back side, at least one light source arranged to provide light to said light guide plate, and a reflecting surface arranged parallel and adjacent to said back surface of said light guide plate, said light guide plate comprising an interfacing surface between a first material and a second material, which interfacing surface comprises microstructures, wherein said microstructures are arranged such that light is outcoupled from said light guide plate towards said reflecting surface.

In a second aspect, the present invention relates to a liquid crystal display (LCD) device comprising such a backlight unit arranged in the back of the liquid crystal cell of the display device.

As used herein, "Total internal reflection", herein also abbreviated "TIR", refers to the phenomenon where a light beam is totally reflected in the interface between two medias, e.g. that no light passes the interface. The passage of a light beam through a surface is bound to Snell's law:

$$\sin(\theta_i) = n_2 \sin(\theta_2).$$

In this formula $n_1$ is the refractive index in the first media and $\theta_1$ is the angle of incidence on the interface in the first media, and $n_2$ is the refractive index in the second media and $\theta_2$ is the angle of incidence on the interface in the second media. If $n_1 > n_2$, there does not exist any solution to Snell's law in case $\theta_1$ is large. Above a critical angle $\theta_c$ (where $\theta_c = \arcsin(n_2/n_1)$), this means that a light beam encountering the interface from the first medium, is fully reflected, without any light passing the surface.

This yields a critical angle for TIR at the microstructured interfacing surface, i.e. light incident at the interface at angles larger than the critical angle are totally internally
reflected. By combining a sufficiently large critical angle with a sufficient tilt angle of the
interface, i.e. top angle of the micro-structure, the angular region which is totally internally
reflected can be controlled to be within the waveguided angular range and the corresponding
angular direction after total internal reflection to be resulting in an emission from the light
guide. With a proper optimization, a waveguided angular region can be selected to be totally
internally reflected at the microstructured interface and directed towards angles resulting in a
polarized emission close to the normal direction of the light guide. However, a certain portion
of light in the light-guide plate will be incident on the microstructured interfacing surface at
angles smaller than the critical angle, where part of the light will be reflected back into and
part of the light will be refracted out from the light guide plate. Thus, not all of the light
provided by the light source may be reflected by means of TIR towards the reflecting surface,
but again, by proper design of the light guide plate and the microstructured interfacing
surface, a high ratio between reflected and refracted light can be obtained.

In a first embodiment of the present invention, as illustrated in Fig. 1, a liquid
crystal display device of the present invention typically comprises a back light unit 110, a
liquid crystal cell assembly 120 and optionally a diffuser 130 arranged between the backlight
unit 110 and the liquid crystal cell assembly 120. Optionally, also other components may be
comprised in a display device of the present invention, as will be realized by those skilled in
the art.

The backlight unit 110 comprises a reflective surface 101, an optically clear
(i.e. essentially isotropic) light guide plate 102 arranged on the reflective surface 101 and a
light source assembly 103 arranged to provide light and couple this light into the light guide
plate 102.

The front side 104 of the light guide plate 102 is provided with a series of
microgrooves 105 in the interface between the light guide plate and the surrounding
atmosphere. The refractive index \( n_i \) of the plate is higher than the refractive index \( n_o \) of the
surrounding atmosphere. The microgrooves 105 has the cross-section shape of a triangle.

The liquid crystal cell assembly 120 is arranged in front of the light guide
plate.

A side reflector 107 may be arranged on the side of the light guide for
recycling the preferentially trapped light within the light guide.

According to Snell's law, light incident on surfaces in an interface from a high
refractive index medium to a low refractive index medium, at an angle of incidence higher
than the critical angle, is subject to Total Internal Reflection (TIR).
Thus, in the interface between the microstructured surface and the surrounding atmosphere (typically air or partial vacuum) a certain part of the incident light will be reflected in the microstructured surface at an angle close to the normal of the surface, in a direction towards the reflecting surface.

Light thus reflected by means of TIR from each microgroove is within a wavelength interval, forming a diverging light bundle.

The path of this light bundle comprises: total internal reflection in the microstructured interface, traveling through the light guide plate, reflection in the reflecting surface, and again traveling through the light guide plate, before being extracted towards the liquid crystal cell assembly. Thus, the diverging light bundle emanating from a single microgroove is distributed over a larger area, compared to if the light had been extracted by means of the micro grooves directly from the light guide in the general direction of the liquid crystal cell assembly.

Thus, the overall effect from a back light plate of this embodiment is a more evenly distributed extracted light.

The liquid crystal cell assembly 120 may comprise the conventional components of such an assembly, such as the liquid crystal cell and electrodes for switching the liquid crystals, and optionally a polarizer and color filters. In particular, a color filter has a periodical pattern, typically with a periodicity in the same order as the microstructures in the light guide plate.

Due to the fact that the predominant part of light being extracted from the light guide plate has been reflected in the reflective surface 101 before encountering the liquid crystal cell assembly 120, the light is rather evenly distributed over the enlightened area. Thus, the Moire-effect typically seen when prior art backlights are used without diffuser layers is significantly reduced due to the longer light pathway. If a Moire-effect still is seen, this may be further reduced by using a diffuser layer 130, but here it is possible to use a much weaker diffuser, as compared to the diffusers required to reduce the Moire-effect in the prior art displays.

Before commencing with the description of the following embodiments, it is opportune to recall some properties of the phenomenon of polarization, which will be relied upon in the description of the embodiments to follow. Due to linear polarization, an unpolarized beam falls apart in two mutually perpendicularly polarized beam components. Such a polarization separation may be obtained, for example, by causing an unpolarized beam to be incident on an interface between an area with an isotropic material having
refractive index $n_{10}$ and an area with an anisotropic material having refractive indices $n_o$ and $n_e$, in which one of the two indices $n_o$ or $n_e$ is equal or substantially equal to $n_{10}$.

When an unpolarized beam is incident on such an interface, the beam component that does not detect any difference in refractive index at the interface between isotropic and anisotropic material will be passed unrefracted, whereas the other component will be refracted. If $n_{10}$ is equal or substantially equal to $n_o$ then the ordinary beam is passed unrefracted by an interface between isotropic and anisotropic material; if $n_{10}$ is equal or substantially equal to $n_e$, then an extraordinary beam passes such an interface unrefracted.

In a second embodiment of the present invention, as illustrated in Fig. 2, a back light unit 210 comprises a light guide plate comprising three separate layers 201, 202, 203. The first layer 201 is an optically clear layer, the second layer 202 is a birefringent layer and the third layer 203 is a coating layer on top of the birefringent layer 202. The second and third layers are arranged on the front side of the first layer 201.

A back light unit 210 may for example be used in a liquid crystal display device as in the first embodiment above.

In this second embodiment, the optically clear layer 201 has an essentially flat surface, whereas the birefringent layer 202 has a microstructured interface 204 towards the coating layer 203. The microstructure is in the form of elongated grooves 205 in the birefringent layer. Further, the reflecting surface 206 is a polarization conserving reflecting surface.

The first optically clear material of layer 201 has a refractive index $n_1$, the second, birefringent, material of layer 202 has a refractive index for the ordinary component $n_{20}$ and a refractive index for the extraordinary component $n_{2e}$, and the third, coating, material of layer 203 has a refractive index $n_3$. The indices are arranged such that:

$$n_1 < n_{20} < n_{2e};$$ and

$$n_{13} \approx n_{20}.$$ 

The effect of this arrangement is that in the interface between the optically clear layer 201 and the birefringent layer 202, none of the ordinary and the extraordinary components of the light will be subject to TIR, due to the transition from low to high refractive index. However, there will be a separation in angle between the ordinary and the extraordinary component, due to the birefringence. Thus, the extraordinary component of
light will enter the birefringent layer 202 at a smaller angle as compared to the ordinary component.

In the microstructured interface 204 between the birefringent layer 202 and the coating layer 203, there will be even more separation between the components. In this interface 204 the extraordinary component (shown as "e-comp" in the figures) experiences a transition from high to low refractive index and is thus subject to total internal reflection, whereas the ordinary component (shown as "o-comp" in the figures) does not experience any difference in refractive index.

Thus, there will be a separation of the components in this interface 204, as the ordinary component is "trapped" in the light guide, i.e. does not encounter any extracting structures, whereas the extraordinary beam will be extracted towards the reflecting surface.

As in the first embodiment described above, the path of this light bundle comprises traveling through the light guide plate, reflection in the reflecting surface, and again traveling through the light guide plate before being extracted towards the liquid crystal cell. Thus, the light bundle emanating from a single microgroove is distributed over a larger area, compared to if the light had been extracted by means of the micro grooves directly from the light guide in the general direction of the liquid crystal cell.

Thus, the overall effect from a back light plate of this embodiment is a more homogenously distributed extracted light.

However, in this embodiment, polarized light is provided, and thus, the need for polarizers on the backside of the liquid crystal cell is obviated, or at least reduced.

Also in this embodiment, the need for diffusers between the back light system and a liquid crystal cell assembly is obviated or reduced (i.e. it is possible to use weaker diffusers), which is much desired when utilizing a backlight unit providing polarized light.

In a third embodiment of the present invention, as illustrated in Fig. 3, the light guide plate of the backlight unit 310 comprises three separate layers 301, 302, 303, where the layers 301 and 303 are optically clear layers, and the layer 302 is a birefringent layer.

A back light unit 310 of this third embodiment may also be used in a liquid crystal display device as the back light units 110 and 210 of the above embodiments.

The layers 302 and 303 are arranged on the backside of the layer 301, i.e. facing the reflecting surface 306, which in this embodiment is a polarization conserving reflecting surface. The layer 303 acts in this embodiment as a binder material for binding the birefringent layer 302 to the optically clear layer 301.
In this third embodiment, the optically clear layer 301 has an essentially flat surface, whereas the layer 303 has a microstructured interface 304 towards the birefringent layer 302. The microstructure is in the form of ridges 305 out from the binder layer 303.

The first optically clear material of layer 301 has a refractive index \( n_1 \), the second, birefringent, material of layer 302 has a refractive index for the ordinary component \( n_{2o} \) and a refractive index for the extraordinary component \( n_{2e} \), and the third, coating, material of layer 303 has a refractive index \( n_3 \). The indices are arranged such that:

\[
\begin{align*}
\text{n}_1 &< \text{n}_{2o} < \text{n}_{2e}; \\
\text{n}_3 &\approx \text{n}_{2o}
\end{align*}
\]

In the interface from the optically clear layer 301 and binder layer 303, the light is not subject to TIR, due to the transition from low to high refractive index, and the light is thus outcoupled into the binder layer.

In the microstructured interface from the binder layer 303 to the birefringent layer 302, the light is not subject to TIR, due to the transition from low to high refractive index. However, a separation of components is present due to the transition from isotropic to birefringent material.

The extraordinary component ("e-comp") of light outcoupled into the birefringent layer 302 will, upon encountering the microstructured interface 304 from the birefringent layer 302 to the binder layer 303, be subject to TIR in this interface, and will thus be reflected by the microstructures towards the reflecting surface in at an angle close to the normal of the surface of the light guide.

The ordinary component ("o-comp") of light outcoupled into the birefringent layer 302 will, however not be subject to TIR in this interface, as this component does not encounter any change in refractive index. Thus, the ordinary component is "trapped" in the light guide.

Here again, the light path for the light bundle is longer in a back light unit of the present invention, where the light is reflected against a reflecting surface at the back side of the unit before reaching the liquid crystal cell, as compared to the prior art back light unit, where light is outcoupled directly in the direction of the liquid crystal cell.

Thus, the light bundle will be distributed over a larger area, and the overall effect from a back light plate of this embodiment is a more evenly distributed outcoupled light.
Further, polarized light is provided, and thus the need for polarizers on the backside of the liquid crystal cell is obviated, or at least reduced.

Also in this embodiment, the need for diffusers between the back light system and a liquid crystal cell assembly is obviated or reduced (i.e. it is possible to use weaker diffusers), which is much desired when utilizing a backlight unit providing polarized light.

The material used as optically clear layer 102, 201, 301 may comprise, but are not limited to materials selected from the group of transparent polymers, such as PolyMethylMethacrylate (PMMA), PolyCarbonate (PC) or PolyStyrene (PS), glasses and transparent ceramics.

The birefringent layer 202, 302 typically consists, for instance, of an oriented (e.g. stretched) polymeric layer, such as oriented PolyEthyleneTerephthalate (PET), PolyButyleneTerephthalate (PBT), PolyEthyleneNaphthalate (PEN) or of a Liquid Crystalline layer, such as a cured uniaxially oriented Liquid Crystalline layer or a cross-linked Liquid Crystal network. However, also other birefringent materials are suitable, as will be apparent to those skilled in the art.

One advantage of using a microstructured separate layer that is easier and more efficient to pattern such a separate layer than the main light guide plate, i.e. the optically clear first layer.

Thus, in alternative embodiments, the layers 202 and/or 302 in the assemblies of the above mentioned multi layer embodiments may also be isotropic layers, with that difference that such a light guide does not provide polarized light.

The coating layer 203 and/or binder layer 303 typically consists of, but are not limited to transparent polymeric materials, such as polymerized acrylics (e.g. cured Bisphenol A ethoxylated diacrylate, cured hexanediol diacrylate (HDDA), cured phenoxyethylacrylate (POEA), cured epoxy resins, mixtures of such materials or of an oriented Liquid Crystalline layer.

Furthermore, in alternative embodiments, the binder layer 303 and the first layer 301 may refer to one and the same layer.

Furthermore, in alternative embodiments, the coating/binder layer may be of birefringent material in order to enhance the selectivity of the polarization components.

The reflecting surface arranged on the backside of the light guide plate may be any reflecting surface, such as a metallic surface.

In embodiments of the present invention, the reflecting surface may be a corrugated surface in order to provide a homogenous light field.
Typically, the microstructures are in the form of grooves or ridges in the material. Typically, the width of each separate groove/ridge is essentially smaller than the microstructure period, e.g. the structures are separated by portions that are essentially coplanar with the surface of the light guide plate, or that has only a small angle with the surface, for instance 0.5 to 5 degrees.

The grooves/ridges in a light guide plate of the present invention provide facets that extend in a direction down towards the reflecting surface arranged at the back of the light guide plate, where the material on the upper side of the interfacing microstructured surface has a lower refractive index than the material on the lower side of the interfacing microstructured surface. This allows for total internal reflection in the direction of the reflecting surface arranged at the back of the light guide plate.

The microstructure period, the width of the individual grooves/ridges and the angle of the walls of the grooves/ridges are dependant on the refractive indexes of the materials used in the light guide plate of the present invention, and/or on the period of other periodical patterns of components in the display device for which the back light unit is intended.

The microstructure period is typically in the range of from 25 to 1000 µm, such as from 50 to 500 µm, for example 100 to 300 µm. The width of the individual grooves/ridges are thus in the range of 5 to 900 µm, such as 10 to 200 µm, for example 25 to 100 µm.

The angle between the normal of the light guide plate and the normal of the walls (facets) of the grooves/ridges is typically in the range of 55 to 67.5°, such as from 57.5 to 65°.

By choosing the design of the microstructured interface, i.e. the width and depth/height of the grooves/ridges, the distance between adjacent grooves/ridges, and the shape of the grooves, it is possible to achieve a high ratio between light being extracted downwards towards the mirror, and light being extracted upwards, towards the liquid crystal cell.

Here, this ratio is measured in the absence of the reflecting surface on the backside of the light guide plate, and refers only to directly extracted light. Ratios of above about 2:1, such as from about 3:1 up to about 5:1, or even higher, such as up to about 10:1 (down:up) and even higher are possible to achieve with a light guide of the present invention.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments and experiments described herein. On the contrary,
many modifications and variations are possible within the scope of the appended claims. For example, although the cross-section of the microstructures illustrated in Figs. 1 to 3 is of triangular shape having a symmetrical cross-section, also asymmetrical microstructures can be applied.

Furthermore, other modifications of the microstructures may be applied, such as deviations from the triangular shape and/or deviations from the groove or ridge-like extension in the plane of the figures, such as hole or hump-like geometries. The grooves or ridges may comprise a repetition of small grooves/ridges extending into the surface, or comprise pits or humps, and instead of being symmetrically or asymmetrically triangular also comprise concave, convex or a multitude of straight side faces. For example, the grooves/ridges may be in the form of trapezoids, or truncated triangles.

Thus, to summarize, a back light unit for a liquid crystal display is provided. The unit comprises a light guide plate, a reflecting surface arranged parallel and adjacent to the back surface of the light guide plate. Further, the light guide plate comprises an interfacing surface between a first material and a second material, which interfacing surface comprises microstructures which are arranged such that light is extracted from said light guide plate towards said reflecting surface. By using a backlight unit of the invention, the need for diffusers between the backlight unit and the liquid crystal cell of an LCD is reduced.

Experiments: Comparisons between light guide plate shining down and light guide plate shining up

Experiment 1: 200 µm light guide pitch

In order to investigate the effect of backlight units of the present invention, the performance of a light guide plate according to present invention (i.e. shining down towards a mirror) was compared to a light guide plate of the prior art (i.e. shining directly upwards).

The light guide in the inventive backlight unit comprised a optically clear plate of PMMA with index of refraction 1.49 with a microstructured layer of a stretched PEN film with indices of refraction $n_o=1.58$ and $n_e=1.78$ arranged on the backside of the clear plate.

The microstructures consisted of triangular grooves in the film, (as shown in Fig. 3) having a depth of 50 µm and an apex angle of 50 degrees (i.e. an angle of 65° between the normal of the surface of the light guide and the normal of the side of the microstructure) and a periodicity of 200 µm.
The comparative back light unit comprised a light guide having the same properties as in the inventive back light unit, however, in this unit, the light guide was flipped over, such that the microstructured layer was located on the front side of the clear plate, thus shining upwards.

The two backlight units were tested in a QVGA LCD display without polarizers, with a color filter having a pixel size of 100 x 300 µm.

The Moire-effect was assessed with and without a diffuser as well as with the grooves arranged parallel and perpendicular to the color filter stripes. The results from this experiment are shown in table 1.

### Table 1

<table>
<thead>
<tr>
<th>Moire</th>
<th>Color filter stripes parallel to light guide grooves (100 µm CF-pitch)</th>
<th>Color filter stripes perpendicular to light guide grooves (300 µm CF-pitch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light guide shining up</td>
<td>No diffuser</td>
<td>Very strong</td>
</tr>
<tr>
<td>Light guide shining down</td>
<td>With diffuser</td>
<td>Weak</td>
</tr>
</tbody>
</table>

### Experiment 2: 100 µm light guide pitch

In this experiment, the same materials were used as in experiment 1, with the provision that the microgroove pitch in the light guide was 100 µm and the depth was 25 µm.

The results from this experiment are shown in table 2.

### Table 2

<table>
<thead>
<tr>
<th>Moire</th>
<th>Color filter stripes parallel to light guide grooves (100 µm CF-pitch)</th>
<th>Color filter stripes perpendicular to light guide grooves (300 µm CF-pitch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light guide shining up</td>
<td>No diffuser</td>
<td>Strong</td>
</tr>
<tr>
<td>Light guide shining down</td>
<td>With diffuser</td>
<td>Weak</td>
</tr>
</tbody>
</table>

| Light guide shining down   | No diffuser                | Strong                        | Very weak                   |
| Light guide shining down   | With diffuser              | Absent                        | Absent                      |
From the results of the above experiments 1 and 2, it is clear that the Moire-effect can be reduced or avoided by using a backlight unit of the present invention.

Further it is clear that the need for diffusers between the light guide and the color filter is reduced, and that weaker diffusers may be used to obtain the desired elimination of the Moire-effect.
CLAIMS:

1. A back light unit (110) for a liquid crystal display, comprising a light guide plate (102) having a front side (104) arranged to face a liquid crystal cell (120) and an opposing back side,

   at least one light source (103) arranged to provide light to said light guide plate (102),

   a reflecting surface (101) arranged essentially parallel to said back surface of the light guide plate,

   said light guide plate (102) comprising an interfacing surface between a first material and a second material, which interfacing surface comprises microstructures (105) arranged for extracting light from said light guide plate (102) towards said reflecting surface (101).

2. A back light unit (110) according to claim 1, wherein said microstructured interfacing surface is in the interface (104) between the light guide plate (102) and the atmosphere.

3. A back light unit (210; 310) according to claim 1, wherein said light guide plate comprises a first layer (201; 301), a second layer (202; 302) and a third layer (203; 303), wherein said microstructured interfacing surface is in the interface between any two of said layers.

4. A back light unit (210; 310) according to claim 3, wherein said first layer (201; 301) is optically isotropic and said second layer (202; 302) is birefringent.

5. A back light unit (110; 210; 310) according to any of the preceding claims, wherein a cross-section of the extended individual microstructure (105; 205; 305) is symmetric with respect to a direction perpendicular to the direction of extension.
6. A back light unit according to any of the preceding claims, wherein a cross-section of the extended individual microstructure (105; 205; 305) is in the shape of a triangle or a truncated triangle.

7. A back light unit according to any of the preceding claims, wherein the angle between the normal to the interfacing surface and the normal to a side of an individual microstructure is in the range of from about 55 to about 67.5 degrees.

8. A back light unit according to claim 7, wherein said angle is in the range of from about 57.5 to about 65 degrees.

9. A back light unit according to any of the preceding claims, wherein said reflecting surface (101; 206; 306) is a corrugated surface.

10. A back light unit (110; 210; 310) according to any of the preceding claims, wherein the ratio between light extracted by said light guide plate towards said reflecting surface (101, 206; 306) and light extracted by said light guide plate towards said liquid crystal cell (120) is higher than about 2:1.

11. A liquid crystal display comprising a back light unit (110) according to any of the preceding claims and a liquid crystal cell (120) having a front side arranged to face a user and an opposing back side, wherein said back light unit (110) is arranged on said back side of said liquid crystal cell (120).