



# White Paper

## **In Plane Switching–Pro technology for medical imaging**

### **What's inside?**

- An introduction to LCD technologies
- A primer on IPS-Pro
- Why is IPS-Pro LCD technology important for medical imaging?
- What are the advantages of IPS-Pro over competing technologies?
- What are the clinical benefits of a more versatile diagnostic IPS-Pro display?

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## ABSTRACT

Thanks to the continuous progress in LCD technology, it has been adopted for diagnostic viewing of medical images. In most cases the LCD technology used is still monochrome because monochrome displays have a native brightness on average three times higher than that of equivalent color displays. In addition, most color displays offer a lower contrast compared to monochrome displays. This is due to the technological limitations of the state-of-the-art color filters used.

With the advent of new imaging technologies, there has been a vast increase in the use of color images for diagnostic work. This trend is driven by the successive generations of acquisition devices delivering images with a substantially higher spatial resolution and with an increased number of slices. This has led to an explosive growth in image data sets.

For radiologists, it becomes virtually impossible to view these thousands of images. This has resulted in advanced viewing software with 3D image handling concepts, enabling radiologists to look at the images in a more intuitive three-dimensional way. The use of color to segment different parts of the body became standard in these new viewing concepts.

Moreover, radiology is continuously seeking to improve diagnostic reading. Therefore, new medical imaging techniques such as image fusion are being introduced. These new techniques require the use of advanced color displays to properly view the images.

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## 1. AN INTRODUCTION TO LCD TECHNOLOGY

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### 1.1 Liquid crystals

What are liquid crystals? When we think of a crystal we think of a well ordered regular and solid structure. A good example is a diamond, where the carbon atoms that make up the diamond are organized in a well ordered structure with respect to each other. The atoms cannot change their position relative to each other. In fact the carbon atoms are in such a rigid structure that it is hard to move one of the atoms. The net result is that diamond is one of the hardest crystal structures known to man.

A liquid, on the other hand, is just the opposite. There is no order at all and the atoms or molecules can change their respective position and orientation randomly.

A liquid crystal is a very special material that can act as something in between. The molecules in the liquid crystal are somewhat organized relative to each other but they can still change their position and orientation just like the molecules in a liquid. Because of this particular behavior, liquid crystals are very useful for display applications.

Liquid crystal molecules are relatively long. One could imagine them as tiny long rods. However, they also possess the properties of a liquid. We all know that if we put a drop of oil in water, the oil will spread out as a small layer on top of the water surface. The same would happen if you would put a drop of the liquid crystal on a surface. It would spread out and form a layer of tiny rods. It has been observed that if you make long small grooves on a surface and then add a drop of liquid, the rod shaped molecules arrange themselves with their long axis in the direction of the grooves. In the LCD process, this grooved surface is called the alignment or orientation film.

In reality, an LCD is not made of a single layer of rod shaped liquid crystal molecules. In practice, a small container (with a typical height of 4-8 micrometers) is constructed. When this container is filled, several layers of liquid crystal rods are placed on top of each other. An interesting phenomenon occurs when you close the container with a glass plate that has an orientation film with grooves that are perpendicular to the grooves in the bottom alignment film: the long axis of the liquid crystals in the top layer will align itself with the grooves in the top layer. All layers in between will gradually rotate, creating a smooth spiral from the top of the container to the bottom (see figure 1).

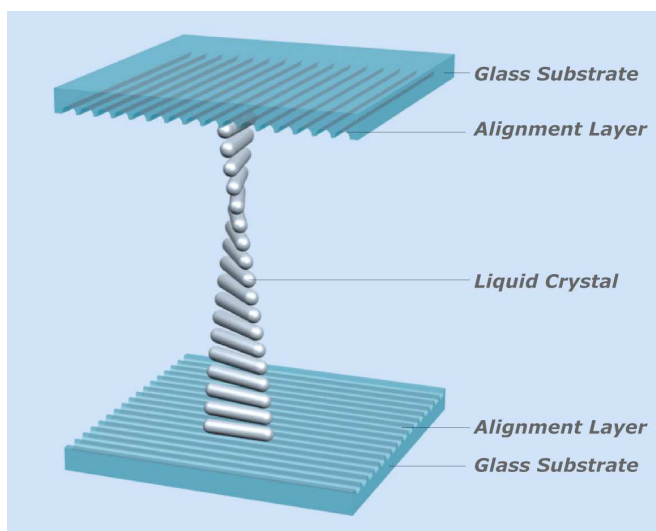


Fig. 1: alignment of liquid crystal molecules

## 1.2 Polarized light

Light is a collection of electromagnetic waves that normally vibrate in all directions. When this light is sent through a polarizing filter, only the light that vibrates in one direction will pass through the polarizing filter and all the light that vibrates in other directions will be blocked. Polarized light has some unique characteristics that, combined with the properties of liquid crystals, form the basis of every LCD display used today (see figure 2).

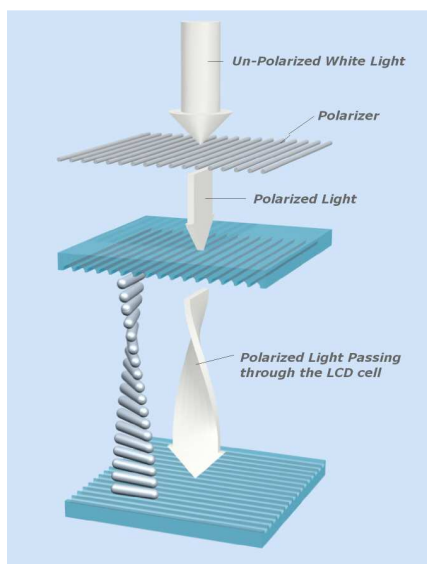


Fig. 2: polarized light

### 1.3 Basic operation of a liquid crystal cell

When we put a polarizing filter with the same polarizing orientation as the LCD crystals on top of the glass plate, the polarized light will be bent by the liquid crystals and passed through the cell. Behind the bottom plate, another polarizer is aligned with the direction of the bottom rods. The net result is that the light passes the crystal and leaves the cell at the opposite side. The liquid crystal looks bright. This is the "ON" position of the LCD cell (see figure 3).

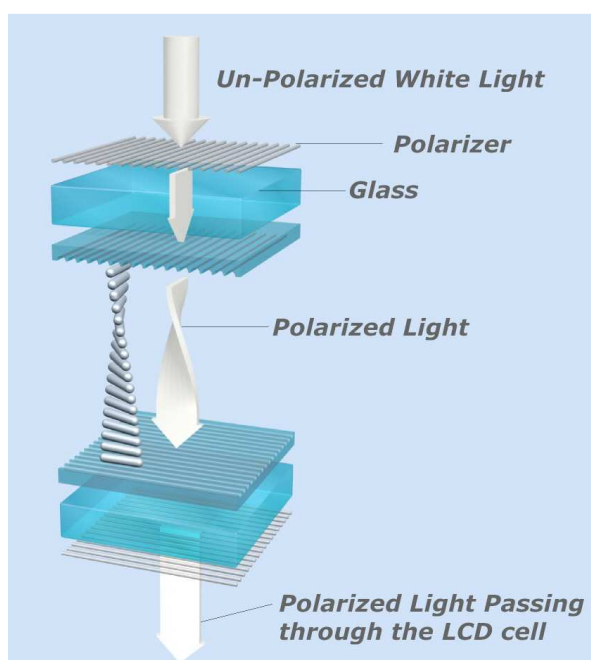


Fig. 3: polarized light passing through LCD

As described, liquid crystals have some unique physical properties. One of them is that the rods can change their position and orientation when an electromagnetic field is applied (similar to a needle that can be lifted with a magnet).

In the case of the liquid crystal molecules, the little rods can take a vertical position as a result of an externally applied electrical field.

In this case, the polarized light is no longer gently rotated by the liquid crystal and falls straight through on the back polarizer. But, as the light now has the wrong vibrating direction, it cannot pass through the second polarizer. The crystal will look dark. This is the "OFF" position of the LCD cell (see figure 4).

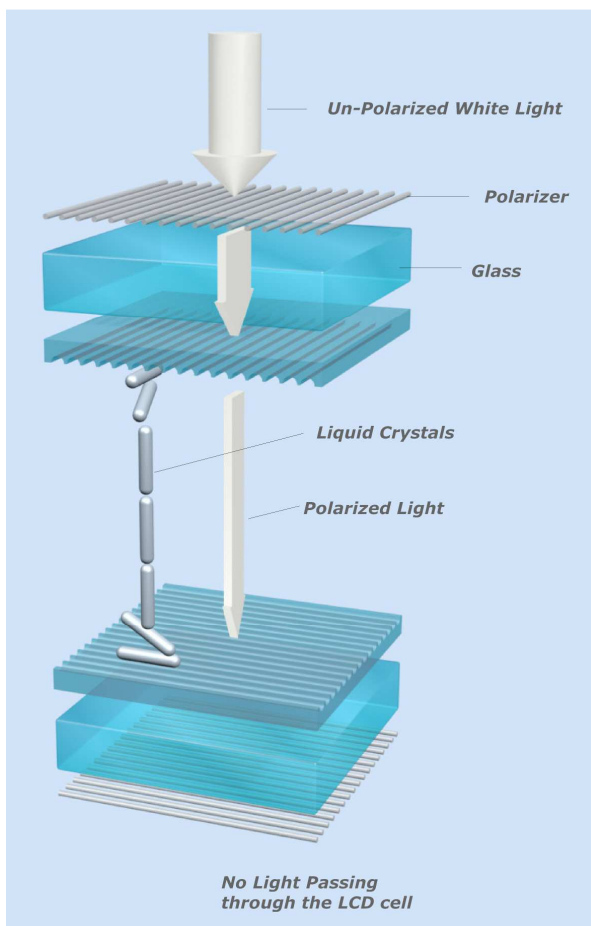


Fig. 4

### 1.4 Twisted Nematic LCD technologies

The technology explained above is called Twisted Nematic LCD technology (TN). TN is the oldest and still most widely used LCD technology. Thanks to its rather simple structure and ease of manufacturing, it is the cheapest LCD technology available today and is widely used for home and office computer applications.

Another interesting characteristic of a TN cell is its ability to quickly switch from dark to bright and vice versa. Fast switching times are required for fast moving images such as video or gaming applications. If the switching of the crystal is too slow, ghosted images become visible when an object moves over the screen.

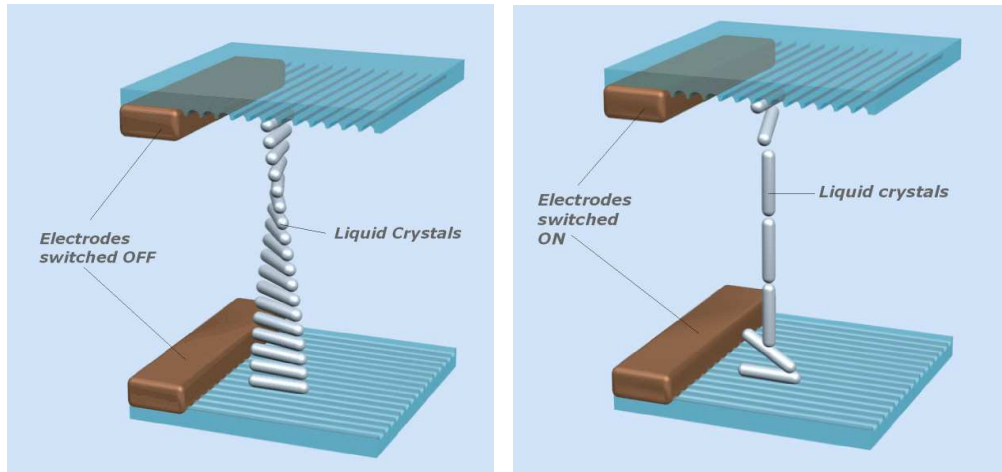


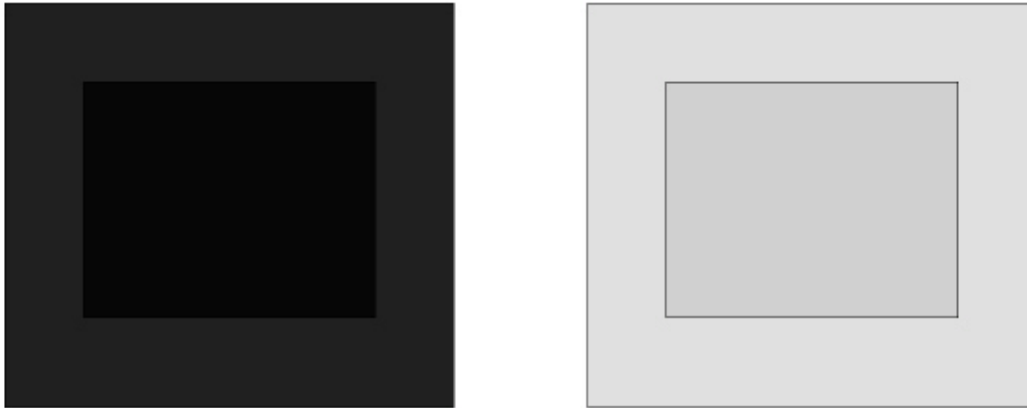
Fig. 5

The status of the liquid crystals changes by rotating the crystals quickly into a vertical position when an electrical signal is applied. When they are in that position, no light can pass through the LCD cell and the result is a dark dot. As soon as the electrical signal disappears, the crystals move back into their natural position and light can pass through the cell again. In Twisted Nematic LCD cells, switching between "ON" and "OFF" happens relatively fast compared to other LCD technologies. Therefore, TN LCD displays are known for their excellent response time which makes them very popular for gaming applications (see figure 5).

Twisted Nematic cells, however, also have some drawbacks. As can be observed, the crystals at the edge will not fully transition into a vertical state when an electric signal is applied. This prevents TN displays from having a high contrast ratio and vibrant colors.

In addition, the optical properties of the TN liquid crystals vary greatly relative to the viewing angle under which an observer looks at the screen. Even contrast inversion can occur, which means that an area of the screen that is brighter than its surroundings under a certain viewing angle may become darker than its surroundings under another viewing angle.

This phenomenon is commonly observed when you carefully tilt the screen of your laptop computer from the horizontal to the vertical position. Depending on the characteristics of your display, the contrast difference of the rectangles will change substantially. (If you are reading this paper on an LCD display, you can try this using figure 6.)



*Fig. 6: test image to visualize contrast differences under changing viewing angles*

This viewing angle dependency is a problem in medical imaging. Subtle lesions might become invisible at first glance depending on the radiologist's eye position relative to the screen. What's more, the viewing angle is often specified at a remaining contrast ratio of 5:1, which makes TN displays look better on paper than in reality.

To understand viewing angle we must first explain contrast ratio. LCD displays obtain their best contrast ratio when the observer looks perpendicular to the screen. This value can be for instance 400:1, which means that the brightest color (white) is 400 times brighter than the darkest color (black). A display with a maximum white luminance of 300 cd/m<sup>2</sup> will therefore have a black level of  $300/400 = 0.75$  cd/m<sup>2</sup>.

When comparing viewing angle characteristics, one has to be careful as most specifications will indicate a horizontal and vertical viewing angle of 160 (2 x 80) to up to 178 (2 x 89) degrees. At first sight, this might seem that one can look at the display under any angle and still see a good image. This specification, however, indicates the viewing angle where the original contrast ratio has dropped from the initial value of 400:1 to only 10:1. Needless to say, the image quality is not useful for medical imaging at this low of a contrast ratio.

Another disadvantage of TN liquid crystal displays is that if one of the transistors that generate the electrical signal for the cell becomes defective, a white dot will appear on the screen. The reason is that the light always passes through the LCD cell in the "OFF" position.

## 1.5 In-Plane Switching (IPS) technology

In 1996, Hitachi Displays, Ltd introduced IPS technology as a solution to solve these two primary disadvantages of Twisted Nematic liquid crystal technology: limited viewing angle and low-contrast. In an IPS LCD display, the long axis of the crystals is always oriented parallel to the glass panels. When an electrical signal is applied, the crystals rotate horizontally, i.e. in the same plane (see figure 7).

A major advantage of IPS is that it passes the light only in its "ON" position and blocks the light in the "OFF" position (when no electrical signal is applied). This means that when a transistor becomes defective the pixel will remain dark, which is less disturbing than a bright one.

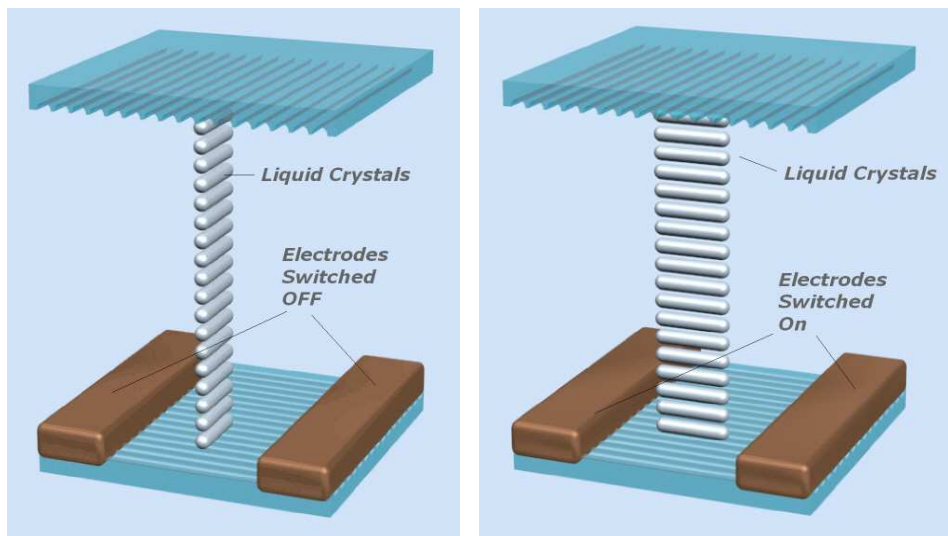


Fig. 7: viewing angle

As can be observed in figure 7, the IPS panel needs 2 electrodes to create the proper electrical field so that the liquid crystals can rotate in a horizontal plane. As an immediate result, the aperture of each cell becomes smaller as each electrode blocks some of the light coming from the backlight. A small aperture means that less polarized light can pass from the back to the front of the display. This drawback becomes more significant with increasing resolution (smaller cells) as the relative size of the two electrodes will block a relatively larger part of the light. A display using an IPS panel will therefore have a lower brightness than a TN panel when using the same backlight. As the electrodes also reflect some of the light, also the contrast ratio of IPS panels will be somewhat lower.

Several improvements from different LCD vendors to the original IPS technology have become available: Super-IPS (S-IPS), Dual Domain IPS and Advanced Coplanar Electrode (ACE). Dual Domain IPS was developed by IBM, while Samsung developed ACE. In the meantime, Samsung has abandoned ACE technology, while Dual Domain IPS panels are coming from IDTech, a subsidiary company of CMO, who bought the technology from IBM (Chi Mei Optoelectronics).

The majority of today's monochrome 3 and 5 MegaPixel medical LCD panels is manufactured by IDTech. Another vendor who recently entered the medical market with IPS panels is NEC. Their technology is branded as SA-SFT.

IPS technology gained a larger market momentum when LG Philips developed the S-IPS technology. This resulted in the market introduction of average priced 19" and 20" displays for computer graphics applications. However, cost reductions and trade-offs between switching speed and viewing angle have forced IPS out of this market segment. The technology is still available in the larger display sizes where the better viewing angle adds substantial value to the product.

The major advantage of IPS technology is its ability to preserve high contrast and color values under different viewing angles. For radiologists, contrast preservation is a must as they need to distinguish subtle lesions from a broad viewing angle. And as color becomes more and more important, accurate color reproduction under different viewing angles also becomes mandatory.

One of the drawbacks of IPS technology, however, is the response time. On current medical panels, the response time ( $T_{on} + T_{off}$ ) is 50 ms. For most medical viewing applications this was not a major issue as most of the time only static images were viewed. However, as dynamic imaging becomes more and more important, this specification needs to be improved.

## 1.6 MVA LCD technology

In 1998, Fujitsu introduced a technology called Multidomain Vertical Alignment. This was in fact a compromise between the Twisted Nematic and the In Plane Switching technology as the technology resulted in fast response times, relatively good viewing angles and very good on axis contrast ratios.

The principle is the following. When you look from the top to a cell that is switched half on, the crystals are oriented at 45 degrees and the cell will look gray. If you look from the right you will see the crystals under a straight angle and the cell will look bright. On the other hand, if you look from the left, your viewing angle is parallel to the crystals and the cell will look dark.

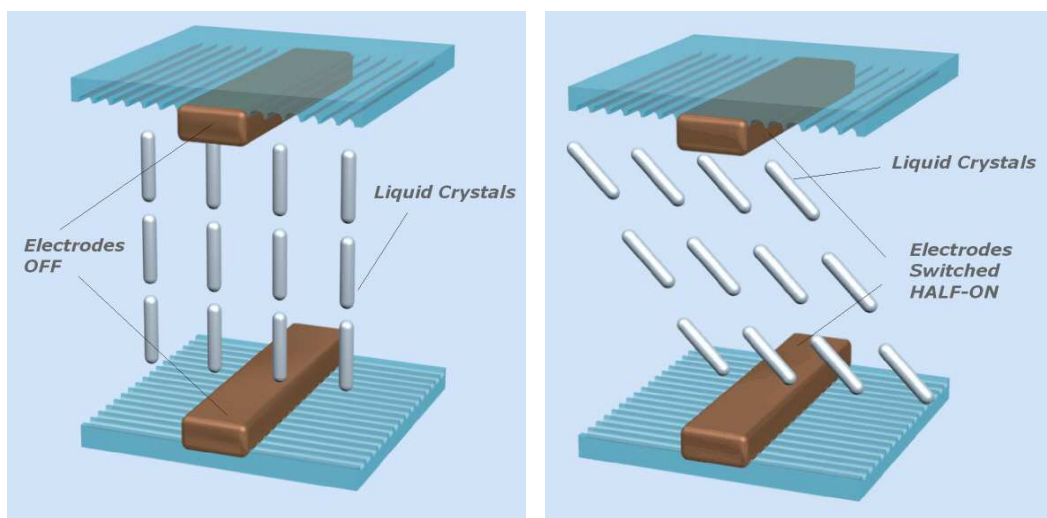


Fig. 8: half of a VA based LCD cell

Now imagine that you split each cell into 2 halves (domains) in which the crystals are oriented slightly differently, in such a way that for an observer the two halves work complementary. If you move your head to look at the screen from a slightly different angle, one domain will look slightly dimmer but this will be compensated with the second domain that looks equally brighter.

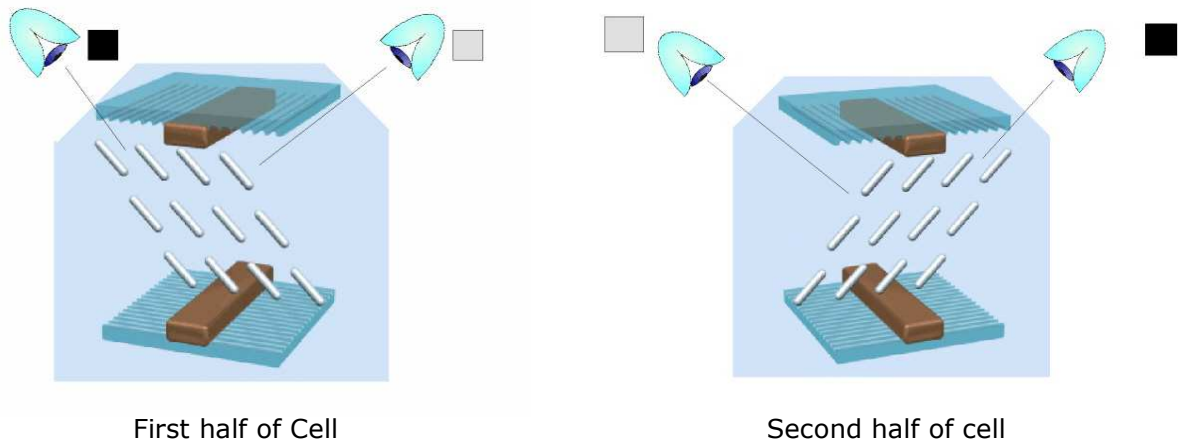


Fig. 9: improved viewing angle with VA technology

## 1.7 PVA matrices

PVA technology (Patterned Vertical Alignment) is based on the VA principle and was further developed and improved by Samsung. In the rest of the paper we will refer to these as VA (Vertical Alignment) technologies.

## 1.8 Building a complete LCD display

Figure 10 below shows a cross sectional view of a liquid crystal display. At the top of the drawing we can see the light source, which is usually made up of long, thin Cold Cathode Fluorescent Lamps (CCFL). These lamps generate unpolarized light. As we described in the previous section, we first need to polarize the light. That is why a polarizing filter is mounted between the light source and the liquid crystal. The actual liquid crystal is kept in a glass container formed by 2 extremely flat parallel glass plates. There are some additional layers that need to be in place before the LCD can function properly. On top of each glass plate, we find two additional layers:

1. The alignment layer to align the long axis of the liquid crystals with the direction of the polarizer. The alignment layer is mostly made of Polyimide (PI), a material which is known to be very stable under varying temperature conditions.

2. A conductive layer that can generate the electrical signals to turn the liquid crystal molecules. In most of the current LCD displays this layer is made of Indium Tin Oxide (ITO). The conductive layer needs to be very thin so that it is still transparent enough for the light to pass through it (only a few 100 Angstrom thick;  $1 \text{ \AA} = 10^{-10} \text{ m}$ ).

In practice, a complex pattern of conductive lines will be etched on the glass. This pattern will form the pixel matrix that is found on modern displays. Before the two glass plates are joined, the PI (Poly Imide) layers are rubbed at straight angles with respect to each other. This process ensures that the long axis of the rods will align better with the orientation of the polarizer that will be on top of it. The two halves of the display are then perfectly aligned, filled with liquid material and sealed to make sure the liquid does not leak.

Figure 10 shows an additional optional layer with color filters. On monochrome displays this layer is not used. On medical color displays these filters are used to split the light of each individual LCD cell (pixel) into three fundamental parts (red, green and blue). The pixel can then take any color by varying the relative amount of red, green and blue light.

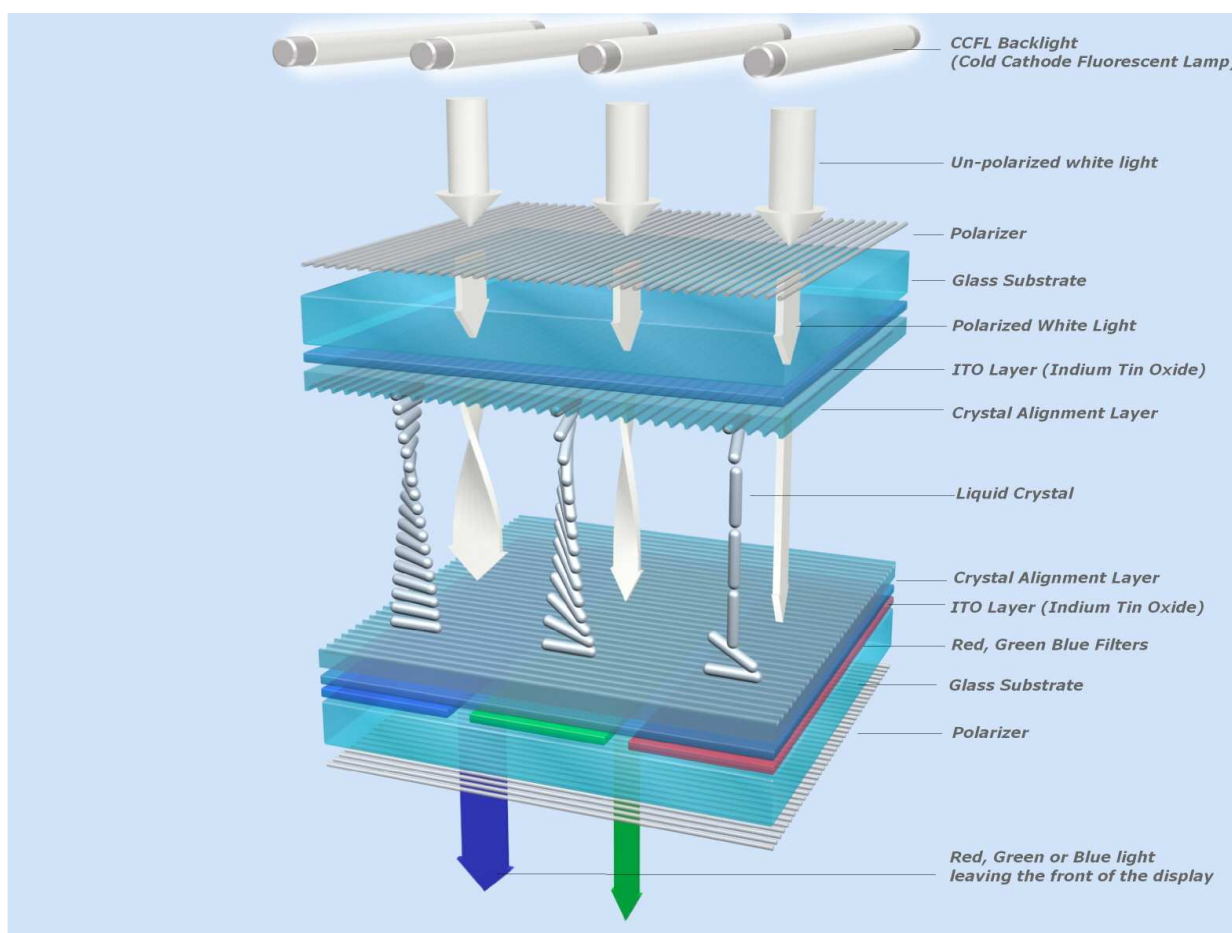


Fig. 10

## 2. IPS-PRO TECHNOLOGY FOR MEDICAL IMAGING



Fig. 11: Barco's Coronis Fusion 6MP DL features IPS-Pro technology

IPS-Pro is the next step in the evolution of LCD technologies in which a number of shortcomings of AS-IPS have been improved. As mentioned before, AS-IPS panels have a substantially lower aperture than other technologies. Especially in medical imaging, where high resolutions are used, this problem is very prominent as the non transparent parts of the cell take a relatively larger share of the area. As a result, less light can pass the cell, yielding a lower luminance. To achieve a higher luminance, one can use a more powerful backlight, but this will result in more energy consumption and additional heat issues.

A fundamental solution for this problem lies in increasing the aperture of the cell. This is one of the areas where IPS-Pro outperforms its predecessor, yielding an aperture increase of 25 %.

### 2.1 Brightness

Developed by Hitachi Displays, Ltd in 1996, IPS was the first LCD technology that brought a solution for the viewing angle issue. However, this solution compromised brightness, resolution, and on-axis contrast. In 1998, high-resolution S-IPS panels were introduced. High-resolution displays are a basic requirement for many medical applications. However, as luminance was not sufficient, applications were limited to monochrome medical displays. Moreover, since monochrome displays do not have color filters, the brightness is increased by 300%.

Subsequent technology improvements brought the brightness to levels that provided the minimum required for medical applications. The real breakthrough came with the combination of the IPS-Pro and Diagnostic Luminance (DL) backlight technology that yields brightness levels that are adequate for diagnostic medical imaging.

Figure 12 indicates the major improvements of IPS-Pro compared to AS-IPS technology. As can be observed, the aperture increase of the basic pixel is substantial. In practice, it comes down to a 25% increase in luminance compared to AS-IPS technology. In combination with Barco's innovative Diagnostic Luminance backlight technology the new IPS-Pro technology typically results in a maximum luminance of 800 cd/m<sup>2</sup> (233 fL). This level is equivalent to what is offered on today's medical monochrome displays, but this luminance on a color display opens a wide range of additional possibilities.

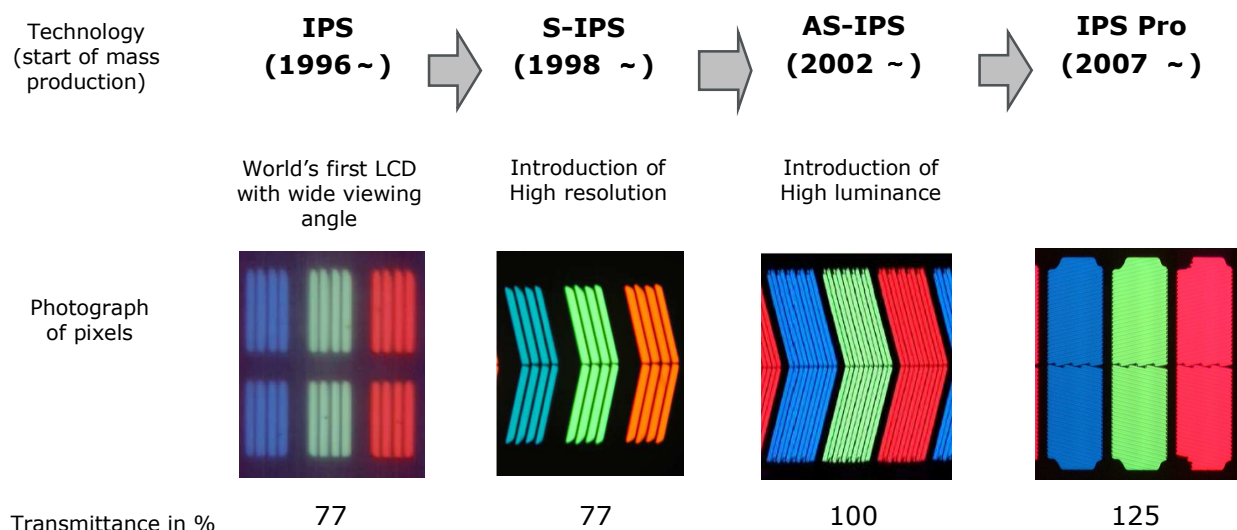


Fig. 12

IPS-Pro is capable of displaying modality images requiring color or viewing applications that use color to improve the productivity of the user interface. As the higher luminance is achieved by increasing the efficiency of the basic LCD cell, the new technology has a much lower energy requirement which makes it more environmentally friendly and reduces the operating costs.

## 2.2 Contrast

Historically, IPS yielded a lower contrast ratio than other panel technologies, mainly due to the liquid crystal alignment in the top layers and the additional optical scattering in the basic cell and color filters.

IPS-Pro has made a significant step forward by improving the basic cell design. As a result, it delivers a contrast ratio that is substantially higher than what has been achieved before. As can be observed below, the new cell design results in a typical on-axis contrast ratio (CR) that is double that of standard AS-IPS technology.

Radiologists need an excellent contrast ratio as it improves both accuracy and productivity. A better contrast ratio generally allows working in a darker environment, which in its turn maximizes the simultaneous viewing of a larger DICOM JND range.

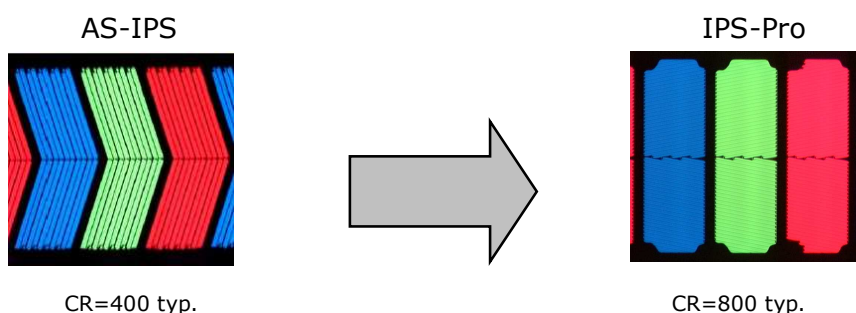


Fig. 13

## 2.3 Viewing angle

Probably the most important improvement of the IPS-Pro technology is the much better viewing angle. In fact, the viewing angle has been improved so markedly that we need to introduce a new, more representative specification. This specification is called the HCA or Half Contrast Angle.

HCA is viewing angle where the contrast has dropped to half the initial maximum value. The maximum contrast ratio is experienced when you look perpendicular to the screen.

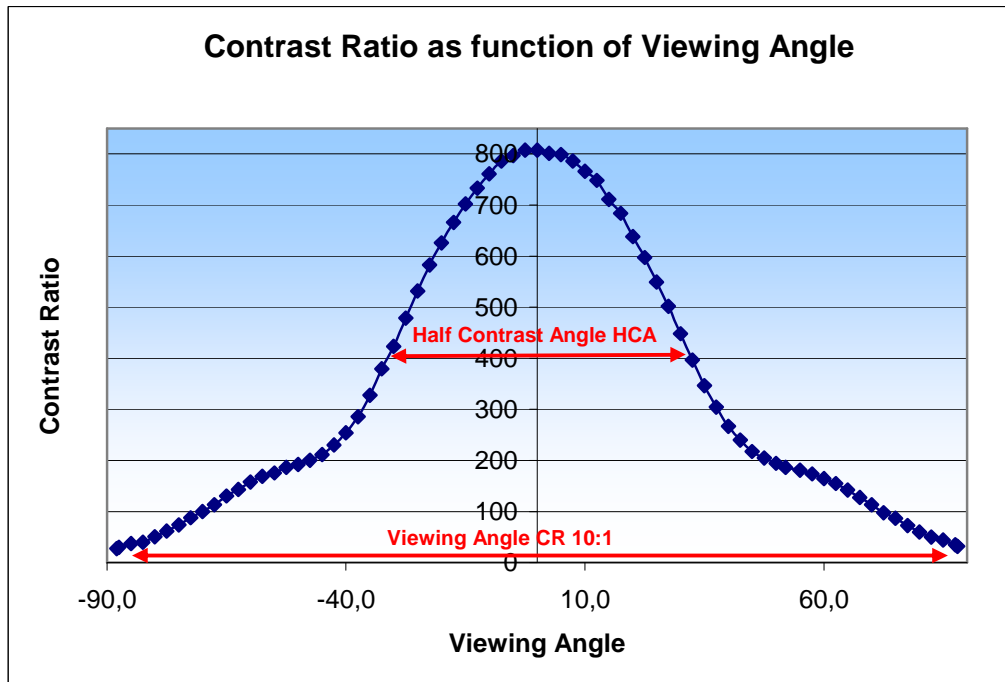


Fig. 14

The first advancement of IPS-Pro technology is the fact that the maximum contrast ratio reaches a much higher value (typical peak value) compared to AS-IPS technology. In addition, the viewing angle in which radiologists can observe a sufficient contrast is much wider. As a ground rule we could refer to the AAPM guidelines, stating that a minimum contrast ratio of 250:1 is required for diagnostic reading. This is the absolute minimum for a dark reading room. As soon as some ambient light is present, additional contrast headroom is needed to comply with the AAPM guideline.

The initial much higher contrast ratio already results in substantially better blacks, which in combination with the better viewing angle yields an unprecedented image quality even while looking at images in darkened reading rooms.

Figure 15 compares the 3 technologies that are used for diagnostic imaging (TN will no longer be considered).

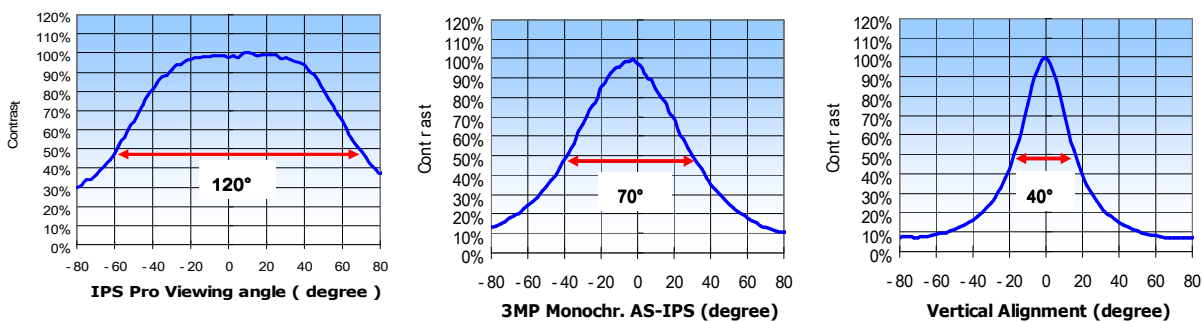


Fig. 15

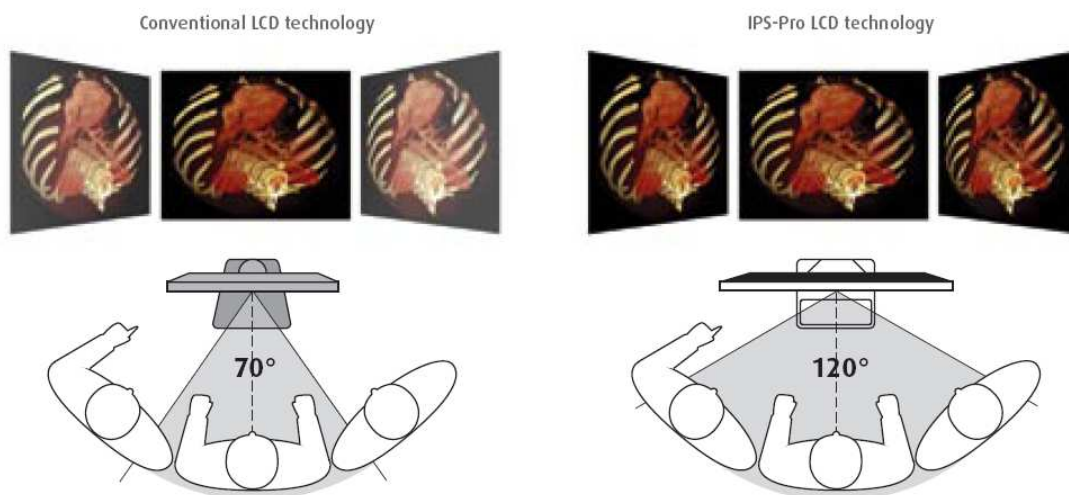
As can be observed in the graphs, the gain in half contrast viewing angle with IPS-Pro technology is substantial. The typical gain is 50 degrees, nearly twice the value achieved with IPS technology (from 70 to 120 degrees) and over 300% more than VA technology.

Since most medical display workstations contain 3 (and sometimes up to 5) displays, viewing angle is an important consideration.



Fig. 16

An additional advantage of the larger viewing angle is the ability for multiple users to see the images at the same time.



*Conventional LCD technology: colors and contrast values change substantially when looked at from an angle*

*IPS-Pro delivers diagnostic precision up to a viewing angle of 120°*

Fig. 17

Without a wide viewing angle, when multiple users are looking at the screens or when you are off angle, some subtle details will not be visible.

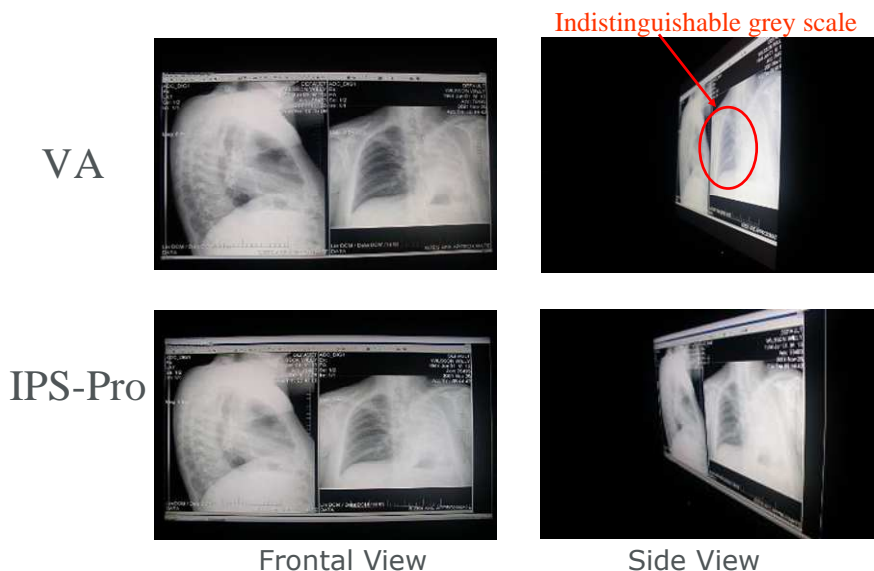


Fig. 18

## 2.4 Black level

Although the contrast improvement with IPS-Pro automatically leads to a better black level there is more to say about blacks on an LCD display.

When diagnosing in a dark reading room, the black level is not uniform across the screen. This behavior is a fundamental shortcoming of the LCD technology. As explained before, the LCD cell is a subtractive display technology. This means that the LCD cell acts as a light valve that blocks more or less light from an extremely bright backlight.

This light valve is far from perfect and, depending on the final quality of the manufactured cell, some light can still leak through the cell even when it is totally shut off. This light leakage at full black values is not uniformly distributed. Differences in cell structure and small differences in local mechanical pressure, temperature and other parameters substantially contribute to the non uniformities.

As IPS-Pro nearly doubles the contrast ratio, the black level becomes on average 2 times smaller. This means that, according to the DICOM GSDF curve, these variations in black uniformity become less noticeable as they will fall below the visual threshold level for the ambient light level in the reading room. IPS-Pro technology has a much better alignment of the crystals near the alignment layer and additional further improvements in the manufacturing process lead to this better black uniformity.

A less known phenomenon is that the viewing angle characteristics at these dark levels are totally different from those experienced at brighter levels. This can also be observed when going back at the experiment given in section 1.4 (the contrast impression with the dark and bright squares when tilting your display).

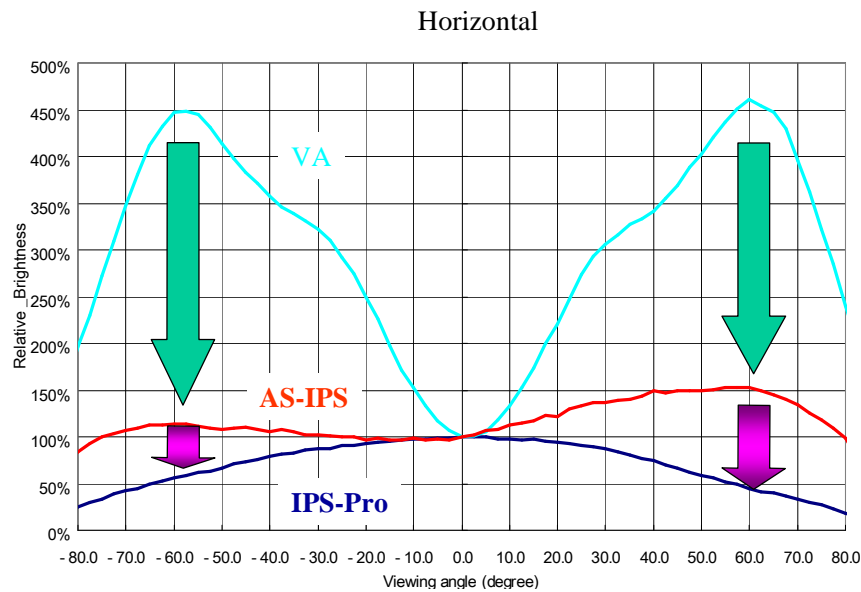


Fig. 19

Figure 19 shows the relative improvement of the black viewing angle for the different technologies discussed.

## 2.5 Gamma characteristics

With the introduction of more versatile color displays, we need to address some issues that are specifically related to color LCD technology. One of those is the gamma characteristic or the transfer curve from black to white. On monochrome displays, it was pretty easy as there was only one transfer function. This curve however also depended on the viewing angle.

This means that after re-calibrating the display function to DICOM Part 14, DICOM compliancy is only achieved when the observer looks perpendicular to the screen.

As soon as the observer looks off-axis, DICOM compliance is no longer guaranteed. The more the transfer curve of the display viewed under a certain angle differs from the transfer curve one gets while looking at the display straight on, the larger the deviation from the DICOM GSDF (Grayscale Standard Display Function) will be.

Because most color displays have 3 channels (red, green and blue), there are now three gamma curves, one for each color. Each of these curves can have a slightly different behavior under a certain viewing angle. This may cause an additional discoloration effect of a certain gray value while looking at the display under a certain viewing angle.

The angle dependency of the monochrome gamma function behavior is illustrated in figure 20 for a number of different viewing angles, both for IPS-Pro and VA technology. As you can see, IPS-Pro also offers a substantial advantage over a VA technology in its ability to keep the DICOM GSDF function more constant over a certain viewing angle.

To characterize this gamma dependency the term Gamma Shift by Viewing angle or GSV can be defined.

GSV is the largest deviation in percent of the gamma function measured for a 50% gray value when looking to the screen at a +45 or -45 degree viewing angle.

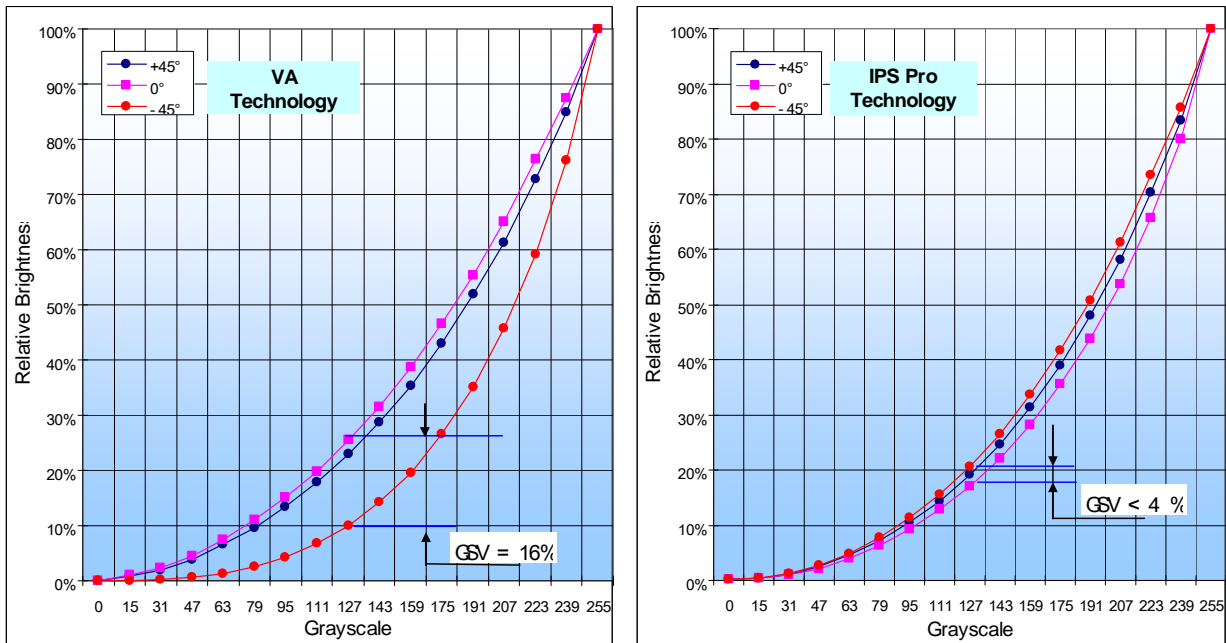


Fig. 20: Gamma shift value (GSV) under different viewing angles

IPS-Pro has a typical GSV of less than 4 % whereas VA typically has a GSV of 16 %. Regulatory guidelines such as DICOM, DIN, AAPM suggest that the display should be DICOM compliant within a certain deviation (10%) from the specified GSDF function. As can be observed from figure 20, only IPS or IPS-Pro technology is capable of guaranteeing this performance under a large viewing angle.

## 2.6 Switching characteristics

As mentioned earlier, IPS panels are characterized by relatively low speed when compared to TN or VA based liquid crystals. Thanks to improvements in cell structure and new LCD materials, the switching characteristics have been significantly improved on IPS-Pro LCD panels. On average, an improvement of nearly 300% has been achieved with the new technology as compared to the monochrome IPS panels that are now widely used for diagnostic viewing. For applications that use dynamic images IPS-Pro brings a significant improvement over the previous technology.

### 3. DICOM JND RANGE

Next to calibrated luminance, contrast ratio is also a very important characteristic of a medical display. The higher this ratio, the more DICOM JND's the display will be able to render. For an introduction on DICOM JNDs consult reference [2]

In case of a color IPS display, calibrated at a typical white luminance of 500, the black level will result in  $500/400 = 1.25 \text{ cd/m}^2$ . Guidelines published by the AAPM and DIN illustrate that the illumination level of the reading room can substantially reduce the contrast level by adding an unwanted amount of diffuse reflection to the display luminance. Imagine that the equivalent of  $1 \text{ cd/m}^2$  is added to the screen luminance for black and white. In that case, the contrast ratio would drop to  $(500+1)/(1.25+1) = 222.7$ . This is below the recommended AAPM value for diagnostic reading. The only way to comply is to reduce the ambient light so that the diffuse reflection drops to  $.75 \text{ cd/m}^2$ . When using an IPS-Pro display in the same environment, the black level would only be  $500/800 = 0.625$ . After adding the diffuse reflection the display would still offer a contrast ratio of 308, which is still higher than the recommended value. When used in a dark reading room, the DICOM JND range is substantially enhanced with IPS-Pro technology.

As illustrated on figure 21, the typical JND range on an IPS-Pro display featuring a Diagnostic Luminance backlight is substantially enhanced for the darker image values. Calibrated at  $500 \text{ cd/m}^2$  the first displayable JND for an IPS display is JND 81 corresponding with a luminance level of 1.25. ( $500/400$ ). For the IPS-Pro this corresponds with JND 54 or an equivalent luminance level of 0.625. ( $500/800$ ).

Compared to standard IPS displays without DL backlight, the difference in displayable JND range is even larger, because a substantial number of JND levels is lost in the high luminance range (typically a non-DL backlight is calibrated at  $220 \text{ cd/m}^2$ ).

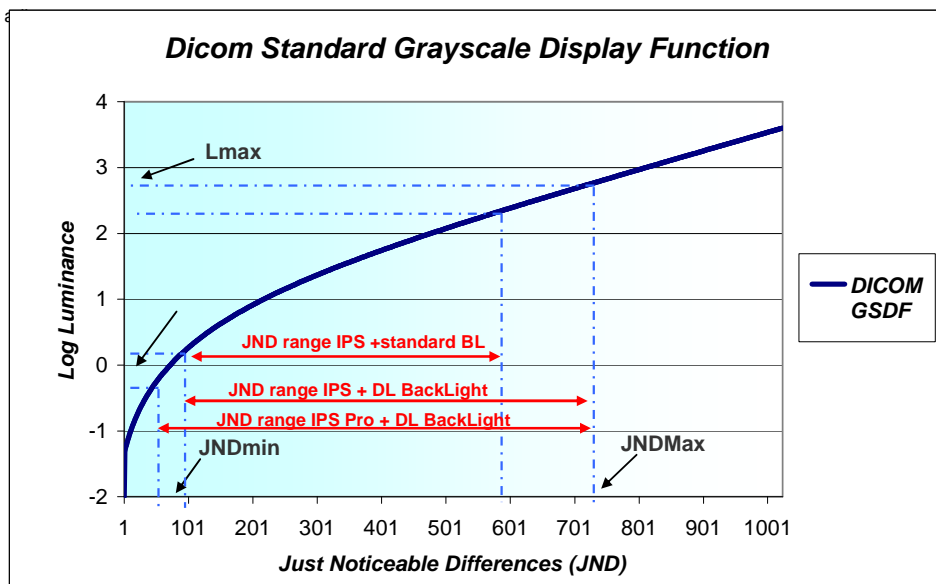


Fig. 21

#### **4. ENVIRONMENTAL BENEFITS**

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The growing environmental awareness has led to special attention for optimized energy consumption without compromising image quality. On average, IPS-Pro consumes 25% less power than the previous generation of displays using standard IPS technology.

In addition, the new technology has been developed using processes and raw materials that are compliant with the latest ROHS (Reduction Of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment) directives. The combined effect of these advantages actively contributes to a better protection of the environment.

#### **5. IMAGE ARTIFACTS**

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As can be expected from a next-generation technology, IPS-Pro further improves some known issues of LCD technology.

Image uniformity (for black, gray and white) for instance, has been further improved and yields an amazing performance compared to any other state-of-the-art panel. In combination with the new technology Barco's ULT (Uniform Luminance Technology) further reduces display non uniformities to a minimum level. For more information on ULT consult [3]

A second important issue typical for LCD displays is the total number of missing pixels. Even current medical panels are not free from pixel artifacts. This problem becomes more important as the resolution & complexity of the used technology increases. Current monochrome 3MP displays come with a maximum total number of missing pixels (dead and stuck) of fifteen. Reducing this specification on the IPS technology would substantially lower the yield of panels manufactured and would result in a price that would make LCD panels unaffordable.

The new IPS-Pro technology and related manufacturing process improves this specification by about 300 %.

## 6. CONCLUSION

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For medical diagnostic imaging, In Plane Switching LCD technology offers a number of important advantages and related clinical benefits over other LCD technologies. As a result, IPS has become the dominant system with the largest installed base of LCDs in medical imaging.

The recent introduction of the IPS-Pro technology further builds on this momentum and brings a number of important improvements. The most important of these improvements are summarized in the table below.

	<b>IPS</b>	<b>IPS-Pro</b>
<b>Relative Brightness (%)</b>	100	125
<b>Contrast Ratio (CR)</b>	400	800
<b>Half Contrast Viewing Angle (HCA)</b>	70	120
<b>Gamma Shift Ratio (GSR) (%)</b>	4	4
<b>Switching Characteristics (ms)</b>	50	18

## 7. REFERENCES

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- [1] White paper on Diagnostic color displays (G. Carrein, Barco Medical Imaging Division)
- [2] Grayscale Resolution: How much is enough (P. Matthijs, Barco Medical Imaging Division)
- [3] Effect of non-uniformity on DICOM GSDF compliance of medical displays T. Kimpe, Y. Sneyders BARCO -Medical Imaging Systems, Kortrijk
- [4] Solution for Non-uniformities and Spatial Noise in Medical LCD Displays by Using Pixel-Based Correction: Tom Kimpe, Albert Xthona<sup>1</sup>, Paul Matthijs<sup>1</sup> and Lode De Paepe<sup>1</sup>