第 3 卷　第 1 期　　中国光学与应用光学　　Vol. 3　No. 1
2010 年 2 月　　Chinese Journal of Optics and Applied Optics　　Feb. 2010

文章编号　1674-2915(2010)01-0027-06

Progress in display technologies and their applications

CHENG Yu

(*Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK*)

Abstract: This paper overviews some display technologies which play main roles on today's display market. And new technologies which may be used for tomorrow's display technologies have been discussed. New technologies will boost the development of display technologies.

Key words: display technology; LCD; PDP; OLED; DLP; fiber laser

1　Introduction

Display technologies play an important role in human's life because it is a very important way that human beings acquire information. Information is thought as the most significant feature of the 21st century. Cathode Ray Tube technology (CRT) is used to be the most popular way that information is conveyed. But now new technologies, such as Plasma Display Panels (PDP), Liquid Crystal Displays (LCD), Organic Light Emitting Diode (OLED) and Digital Light Processing (DLP) *et al.*, play main roles in our daily life. The truth to be told, each technology has its advantages and disadvantages. Moreover, current and up-and-coming inventions will make some fantastic electronic products in our daily life.

The display technologies have been motivated by the High-definition Television (HDTV) or "hi-vision" market all over the world. Also the need of large screen desktop display encourages the scientists to make more researches on the materials, electrons, optics, and methods *et al.* In this paper, some current technologies will be overviewed and several new technologies for display have been discussed too. Low cost, ultra-bright, large-viewing-angle, large screen, flexible, and more colourful will be the features of tomorrow's display applications.

2　Current display technologies

2.1　LCD display

Liquid crystals were first researched in 1888 by Friedrich Reinitzer[1], an Austrian botanist. Light is sent through the twisted liquid crystal structure curls following the molecular arrangement, and the light propagation can be modulated according to the changes of the orientation of the liquid crystals. That is why liquid crystal can be acted as a light modulator for display. LCD displays can be divided into passive matrix LCDs and active matrix LCDs (AMLCD) according to the circuits that are responsible for activating pixels. AMLCD is a very popular technology for large-size display. A typical AMLCD structure[2] is shown in Fig. 1.

Received date: 2009-10-12; Revised date: 2009-12-27.

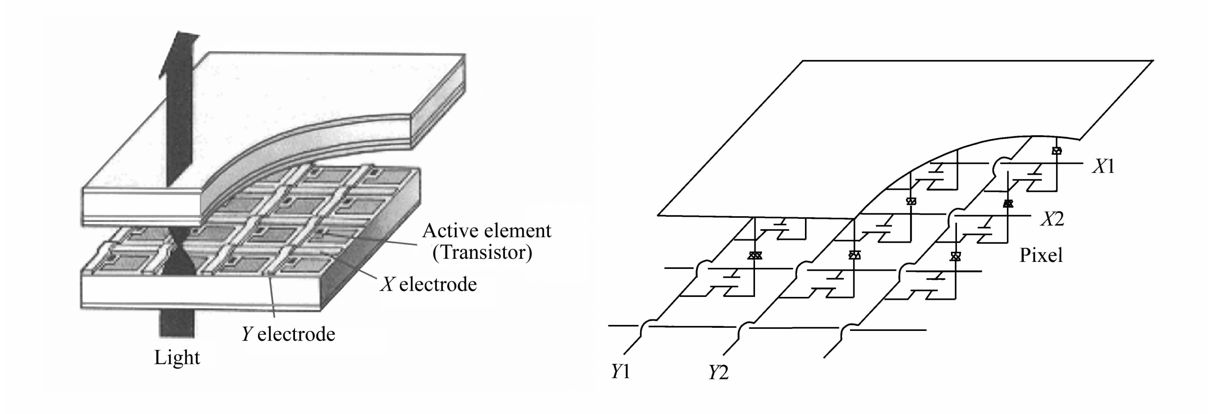

Fig. 1 Structure of AM driving display and the circuit.

Fluorescent lamps are widely used as LCD light sources for the reasons of low cost and high efficiency, but the lifetime is only 4 000 – 6 000 h[3]. Nowadays, LED seems to have better performance when it is used as the light source for an LCD backlight because it delivers displays that are brighter, more colourful and robust than ever before. LCD display technology can be used both for panels and projectors, but the LCD projector uses UHP lamps rather than fluorescent lamps. However, mercury (Hg) is not a green material and has the potential problem of damage to health. And a light source for the LCD technology need to be polarization to improve the efficiency. The light emitted from lamps or LED is unpolarized. The simple and efficient polarization conversion scheme using induced Surface-plasmon-Polariton (SPP) on metallic gratings is a good way to improve the efficiency without increasing the manufacture cost if silver- or aluminium-coated gratings are built on the surface of the reflector[4]. Compared with traditional CRT technology, the LCD display technology has advantages of cost and performance that the size is relatively small and more compact, hence it is suitable for flexible display requirements. Furthermore, LCD display technology requires no high-voltage power. Due to the reasons mentioned above, LCD display technologies are widely used. But it may have some disadvantages, for example, with the increase of the LCD projector brightness, the lamp with more power is needed. But the lamp life time decreases with the increase of the output power. Consumers may need to change the lamps by themselves which make the product inconvenient.

2.2 PDP display

The color PDP as shown in Fig. 2 was invented at the University of Illinois in 1946 by Prof. Bitzer and Prof. Slottow. The operating principle of PDP is that a visible light emitting phosphor is excited by the ultraviolet ray generated by the gas discharge. The inner space of the PDP panel is divided into numerous local cells. Each pixel has its address electrodes, display electrodes, RGB phosphors, xenon and neon gas mixture[5,6].

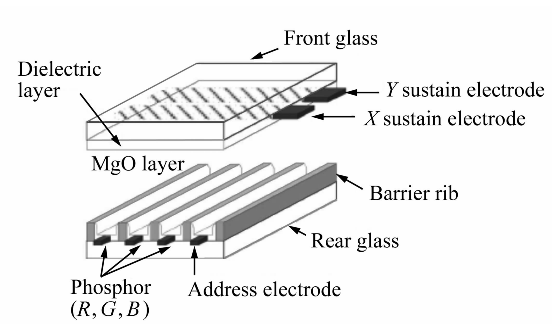

Fig. 2 Simplified structure of the PDP with three electrodes.

Owning to the novel operating principle, each pixel generates its own light and as a result, the viewing angle is large, and the image quality is superior. The cell structure of the PDP can be built bigger and bigger without changing any optical properties of the emission, therefore the PDP has the advantage to build ultra-large panel display. Comparing with OLED and LCD, PDP is ultra bright, so it has advantages in large screen size, wide viewing angle, long life, high contrast ratio, and its thinness makes PDP more suitable for a big-size display.

Professional manufacture, shipment and installation are needed for PDP due to the fragility of the plasma screen, and the increase of power consuming is its another disadvantage. As a results, the PDP may not be suitable for small size display.

2.3 OLED display

It is well known that OLED has many advantages, such as thinness display, light weight, display under low temperature, high brightness and wide-viewing angle, therefore OLED attracts much research interest all over the world. Other advantages such as fast response and significantly lower cost make them a potential candidate for the display in the furture. OLEDs are thin-film multi-layer devices consisting of cover glass, electrode (-transparent-cathode), function layer, electrode (transparent anode), and substrate (glass). A typical structure of OLED is shown in Fig. 3.

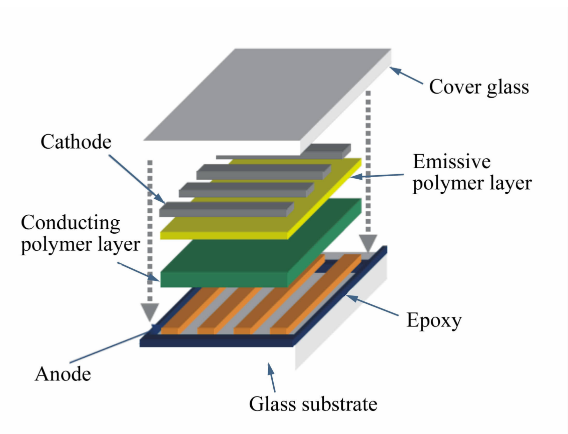

Fig. 3　Scheme of the typical structure of OLED.

Although OLEDs have many advantages in flexible display, they still have some problems. For example, red and green OLED films have longer lifetimes (46 000 – 230 000 h), while blue OLEDs currently have much shorter lifetime (up to around 14 000 h). The manufacturing processes are expensive, and water can easily damage OLEDs[7].

2.4 DLP Display

DLP offers the best picture in the four kinds of displays. The DLP optical system uses a digital micro mirror device (DMD) developed by Texas Instrument Co., and the DMD is a semiconductor light switch where fine driving mirrors are integrated. In the DLP display system, light is transmitted through a colour wheel before the light is incident to the DMD. The brightness of each pixel is determined by the time for which the light source illuminates the pixel, and the process is realized through Pulse Width Modulation (PWM). The advantage of the DLP display technology is ultra clear picture and "hi-vision" for large screen display[8]. DLP display technology also relys on light source such as UHP lamps or lasers.

There are two display technologies which do not need any light source, *i. e.* OLED and PDP, because they can emit RGB light themselves. But LCD and DLP display technologies require light source which is not perfect now. What's more, LCD and DLP display technologies are main commercial products available in the market. Therefore there is an ungent need for the developing of some new light sources.

3　New technologies for future's display technology

3.1 SHG RGB laser for display

Projection displays using laser have several advantages compared to techniques mentioned above. The biggest advantage is the large colour gamut which can be obtained. Other advantages are high contrast ratio and high brightness. It is also possible to obtain nice projection on curved surfaces due to the large focal depth of the laser beams. For low-power systems, like home theatres, the semiconductor technology is the most promising technique. Due to the high beam quality which can be obtained from the solid-state lasers, they will probably be competitive to semiconductor lasers even in the future. But, as one could suspect, the output powers were very low; the conversion efficiencies from the input pump power to the red and green powers were below 1%, and the conversion efficiency from the input pump power to the blue power was much smaller than 1%[9,10].

High power infrared emitting Optically Pumped Semiconductor Disk Lasers (OPSDL) with good efficiency and good beam quality are the basis for generating blue and green laser radiation by Second Harmonic Generation (SHG). Disk lasers based on these pump scheme achieve infrared output power of more than 1.5 W. Experiments with intracavity SHG are in an early stage, 300 mW of frequency doubled output power has been demonstrated[11].

Another RGB-OPO light source is highly efficient as it derives all three wavelengths from one drive laser. Four pump lasers with the total power of 128 W are employed to generate an average power of 30 W, 524 nm green pulse laser. Then this green laser is used as a pump to generate total 15 W RGB laser[12] (shown in Fig. 4).

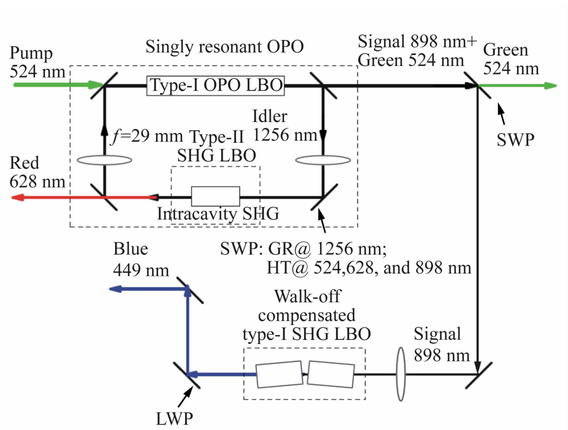

Fig. 4 Scheme of RGB-OPO light source.

Due to the rapid progress of NIR fiber lasers, especially Yb^{3+}-doped fiber lasers, fiber lasers also play a main role in display technology. A mixture structure of RGB laser schematic diagram is shown in Fig. 5. The researchers achieved low electric consumption and wide colour gamut by using the efficient and compact air-cooled green SHG laser unit and the new illumination optics for speckle noise reduction and low light power loss[13].

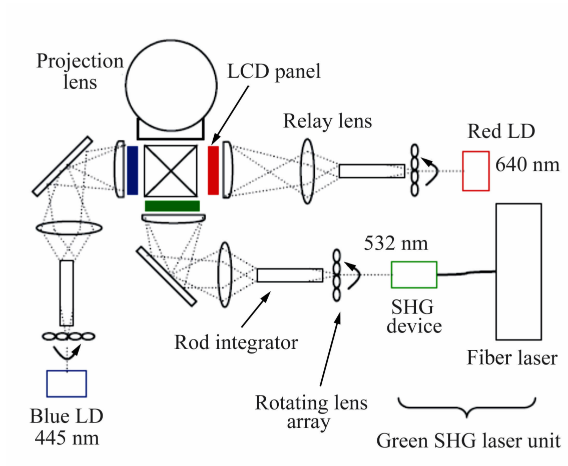

Fig. 5 Mixture structure of RGB laser schematic diagram.

3.2 RGB generation by photonic crystal fiber

Microstructure fiber is a research focus in all over the world. Novel idea and design method enable this fiber to have some special properties in optics. P. Horak *et al*. in ORC use a special designed PCF to generate RGB laser from one single fiber. The pump source in the experiment is a frequency-doubled Yb-doped fiber MOPA which generates 80 ps pulses at 530 nm with a repetition rate of 32 MHz and up to 2 W output power. Fiber parameters are $d/\Lambda \sim 0.935$ and $\Lambda \sim 2.5$ μm to 4.7 μm. And a total of 360 mW of RGB laser are obtained from this fiber[14].

3.3 Visible fiber laser by downconversion

The first visible fiber operated at the wavelength of 650 nm with Sm^{3+} doped silica optical fiber was reported in the University of Southampton in 1990. M. C. Farries *et al*. had successfully achieved a Sm^{3+}-doped silicate fiber laser which has a slope efficiency of 12.7% and output power more than 25 mW by argon laser pump. Recent research shows

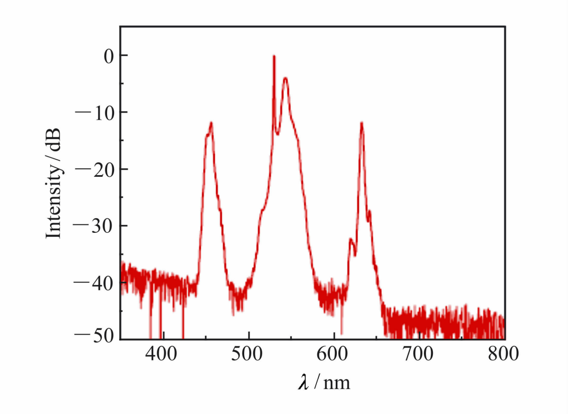

Fig. 6　RGB laser generated from a PCF fiber.

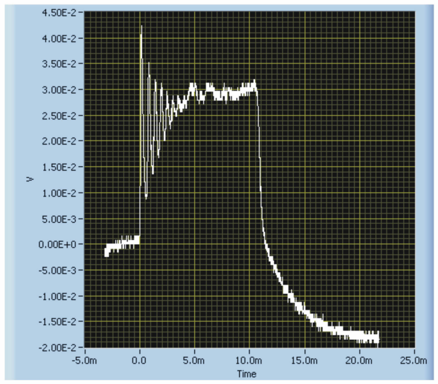

Fig. 8　Relaxation oscillation (the scale of x is millisecond).

that argon laser pump samarium fiber laser can be long lifetime running[15,16]. The pump used is an Ar^+ laser, which is expensive and low electric-optical efficiency. The samarium has even bigger absorption cross section at 405 nm than that of the 488 nm. The blue diode lasers are widely used in DVD writers, and they can act as a pump source for the samarium fiber laser as well. Therefore it is reasonable to use blue diode laser instead of Ar^+ laser as a pump source. The absorption spectra of Sm^{3+}-doped phosphor silicate fiber and the characterization of the diode laser pumped samarium fiber laser are shown from Fig. 7 to Fig. 9.

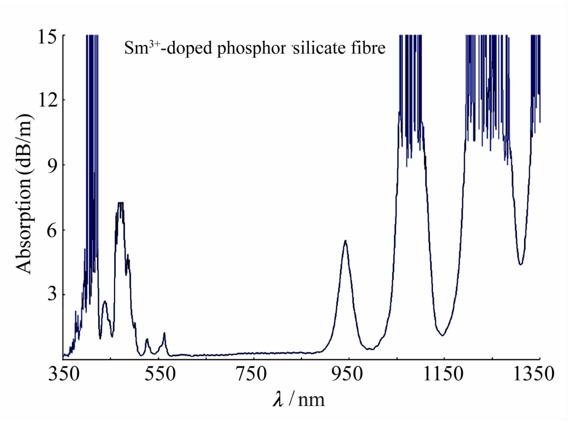

Fig. 7　Sm^{3+}-doped phosphor silicate fiber absorption spectra.

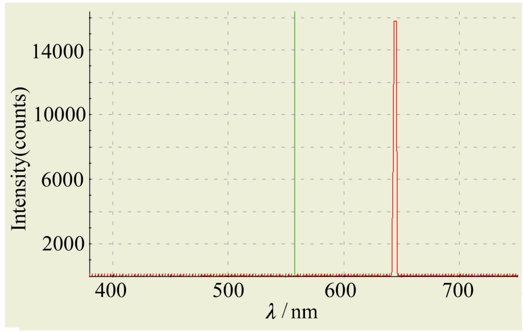

Fig. 9　Laser spectra of the blue diode laser pumped Sm^{3+}-doped phosphor silicate fiber.

Tb^{3+}-doped fluoride fiber laser was reported that a visible fiber laser operated at 542.8 nm when it was pumped at the wavelength of 488 nm. The output power of the 542.8 nm was 0.28 mW and a slope efficiency of 4.1% was achieved[17]. Fiber lasers have properties as a merit for display, such as diffractive limit beam quality and flexible delivery. Fiber laser may have as long lifetime as 30 000 h, which is the longest lifetime and less power consuming. Due to the advantage of modulation and power amplifier of fiber lasers, the RGB fiber laser may have more potential in the future's display application. Althought novel lasers have some advantages compare to traditional light sources, they are needed to improve the efficiency to make their advantage to be a merit.

4 Conclusions

In summary, four current display technologies have been overviewed. And the advantages and disadvantages of each technology have been discussed. One can see that the technology developing trend shows that LCD and DLP technologies are the most popular technologies. And new light source technologies may continue to boost the fast development of the display technologies. With the development of fiber laser technology, more and more low cost fantastic fiber laser products will be used for future's display technologies.

Reference:

[1] SLUCKIN T. Ueber die natur der kristallinischen Fl ssigkeiten und fl ssigen kristalle(The early history of liquid crystals) [J]. *Bunsen-Magazin*,7. Jahrgang,5/2005.

[2] KAWAMOTO H. The history of liquid crystal displays[J]. *Proc. IEEE*,2002,90(4):460-500.

[3] LEE Y-P,CHEN L,KOU P-J. The projector light source:ultra-high performance(UHP) lamps[C]//*Industrial and Commercial Power Systems Technical Conference IEEE*,Detroit,Michigan,2006,(s):1-6.

[4] TSAI CH-CH,WU SH-T. Efficient linearly polarized lamp for liquid crystal displays[J]. *J. Display Technol.*,2009,5(1):6-9.

[5] YI K-H,HAN S-K,CHOI S-W,*et al.*. A simple and highly efficient energy recovery circuit for a plasma display panel (PDP)[J]. *IEEE T. ind. ELECTRON.*,2008,55(2):782-790.

[6] LIN S Y,CHEN C L,LEE K. Novel regenerative sustain drivers for plasma display panel[C]//*IEEE Power Electronics Specialists Conference*,Fukuoka, Japan,1998,2:1739-1743.

[7] SHINAR J. *Organic Light-Emitting Devices:A Survey*[M]. College Park,MD: AIP Press,2004.

[8] LEE H K,Si CH J. DLP optical system:US,0035701 A1[P].2007.

[9] BRENIER A,TU CH Y,ZHU ZH J,*et al.*. Redgreen-blue generation from a lone dual-wavelength $GdAl_3(BO_3)_4:Nd^{3+}$ laser[J]. *Appl. Phys.*,2004,84(12):2034-2036.

[10] CAPMANY J. Simultaneous generation of red, green and blue continuous-wave laser radiation in Nd^{3+}-doped aperiodically poled lithium niobate[J]. *Appl. Phys. Lett.*,2001,78(2):144-146.

[11] STEEGMÜ LLER U,KÜHNELT M,SCHWARZ T,*et al.*. Compact semiconductor based RGB lasers[C]//10th Microoptics Conference(MOC'04),Jena, Germany,1-3 Sept. 2004.

[12] MOULTON P F,SNELL K J,LEE D,*et al.*. High-power RGB laser source for displays[EB/OL].(2002-02)[2007-03-20]http://www.qpeak.com/Papers/IMAGE02/Image%202002%20RGB%20OPO%20paper.pdf.

[13] MIZUSHIMA T,FURUYA H,MIZUUCHI K,*et al.*. L-9:late-news paper:laser projection display with low electric consumption and wide color gamut by using efficient green SHG laser and new illumination optics[C]//SID Symposium Digest of Technical Papers,2006,37:1681-1684.

[14] HORAK P,DUPRIEZ P,POLETTI F,*et al.*. Efficient white light generation in secondary cores of holey fibers[J]. *Opt. Express*,2007,15(7):3729-3736.

[15] FARRIES M C,MORKEL P R,TOWNSEND J E. Spectroscopic and lasing characteristics of samarium doped glass fibre [J]. *IEE Proc. J*,1990,137(5):318-322.

[16] CHENG Y,OTON C J,BOYLAND A J,*et al.*. Photodarkening of 488 nm-pumped Sm^{3+}-doped germanosilicate fiber laser [C]//CLEO Pacific Rim 2009,Shanghai,30 Aug-3 Sep 2009.

[17] YAMASHITA T,OHISHI Y. Amplification and lasing characteristics of Tb^{3+}-doped fluoride fiber in the 0.54 μm band [J]. *Jpn. J. Appl. Phys.*,2007,46(41):991-993.

Corresponding author:E-mail:yxc@orc.soton.ac.uk