10.2: A Controlled Lateral Volume Discharge for High Luminous Efficiency AC-PDP

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Abstract
Efficiencies measure greater than 2 lumens/watt in a PDP structure with auxiliary control electrodes creating lateral volume discharges. These sustain discharges can be more efficient than conventional surface discharges because they have a "positive like" column which occurs deeper in the PDP cell and is longer in space and time.

1. Introduction
The color ac plasma display panel (AC-PDP) is one of the most promising technologies for large-area flat panel displays, realizing 30 to 60 inches diagonal. There have been various intensive efforts for improving the brightness and luminous efficiency to compete with other technologies[1]. However, the low luminous efficiency is still one of the major problems of the present PDP. The luminous efficiency of PDPs are influenced by four processes[2]. These are VUV emission from the discharge, VUV transport to the phosphor, visible light conversion from the phosphor, and visible light output through the front plate. This paper involves improvements relating to combinations of the geometrical parameters of the PDP cell.

We have found some improvements for the conventional surface discharge used in present color PDP monitors but for several reasons we believe that this type of discharge will be limited in efficiency. To achieve higher efficiency we have therefore modified the discharge structure. The resulting discharge structures are not surface discharges. We have measured efficiencies with these discharge structures to be greater than two lumens per Watt if properly configured.

2. Geometry Modification
The structure of the panel can be almost the same as conventional three-electrode surface discharge type PDP but we have added some auxiliary electrodes. The sustain electrodes are formed on the front plate in parallel but widely spaced requiring no ITO with parallel auxiliary electrodes nearby. The dielectric layer and the MgO film are formed on the sustain electrode in the usual manner.

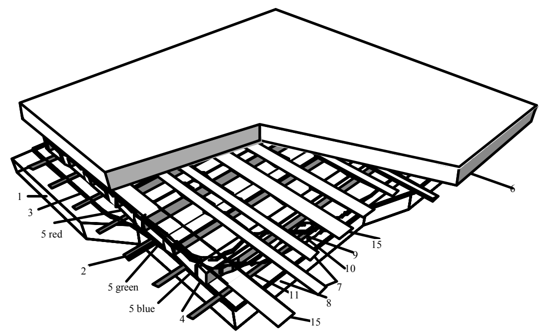

Fig.1. Schematic of a discharge cell with Auxiliary Control Electrodes

3. Results and Discussion
3.1 Standard Surface Discharge Operation
First we will review the operation of the standard surface discharge type AC-PDP which is explained as follows. The discharge is initiated at a narrow gap between parallel co-planar sustain electrodes. The gap is purposely as small as practical to keep the operating voltages low. During sustaining operation a wall charge has been collected on the surface which in combination with an applied voltage causes breakdown between the inner edges of the sustainer electrodes. Conceptually, this initial break-down creates ions and electron flow by secondary emission generating mostly heat in a region consistent with the Paschen minimum pd (pressure times "effective" gap).

The electric field distorts in the region towards the anode and electrons are accelerated through this field, colliding and exciting [Xenon] atoms in this region and producing UV. We have simulated this extensively with a fluid dynamic model in 2D and made animations. When the simulated UV output is plotted its first appearance is in this anode region and looks like a comet traveling towards the cathode from the anode. This is illustrated in Fig. 2 a).

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As current increases, several things happen. First, an ionizing corridor is formed to the cathode which continuously produces ionization, excitation generating UV, and heat as in Fig. 2 b). UV production in this region is not efficient. Next, electron activity and excitation in the anode region spreads rapidly across the anode as in Fig. 2 c). Then, as positive charge builds up at the cathode end of the corridor, the corridor moves outward along the cathode. Electron flow towards the anode remains where the corridor "was" making a path of excitation, which is fairly efficient in producing UV. The longer this path, and the longer it lasts while long, the more efficient is the overall discharge as it extends across the cathode as in Fig. 2 d). Finally, the entire cathode length is consumed and accumulated wall charge on the dielectric layer reduces the electric potential of the electrode and stops the discharge[5].

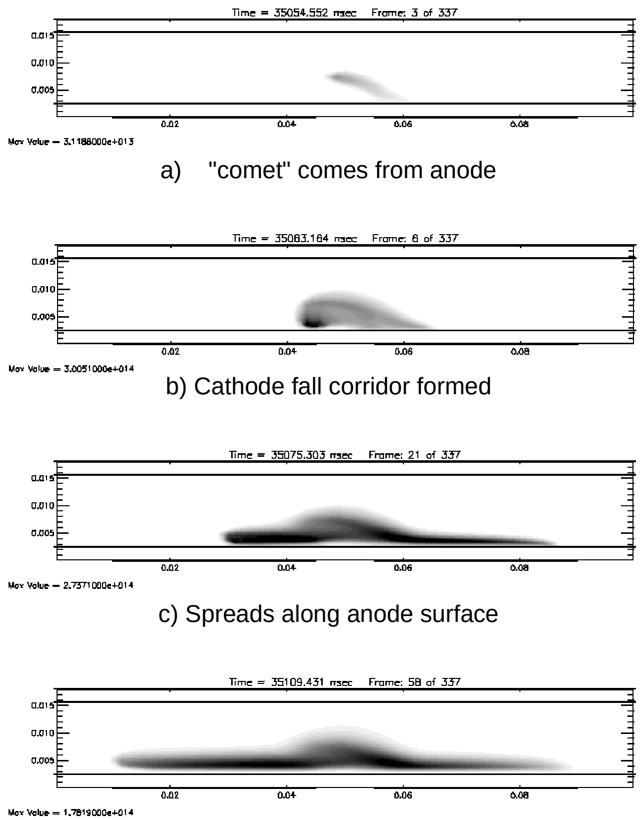
Note also that the entire UV producing action is along the surface. Consider an end view, or cross-section, of a surface discharge in 3D as illustrated in Fig. 3a). Nearly half of the UV produced will be absorbed by the surface just because it is at the surface. If we could bury the discharge deeper in the cell, as in Fig. 3b), much more of the UV could be incident on the phosphor and efficiency would be increased.

So the efficiency is influenced by the width of electrode, along which a discharge forms consisting of a cathode fall corridor plus a "positive column" like anode path. At a large electrode width, the UV production is greater and luminance is high. Luminance and luminous efficiency have previously been reported to increase because of large sustain electrode width[4]. Now there is a further detail. Usually, the sustain electrode consists of the transparent electrode and metal bus electrode. The discharge current flows from the electrode gap to the bus electrode but the bus electrode blocks the light output even though it consumes the power.

3.2 Making it More Efficient

Summarizing from our discussion, to make a more efficient discharge, we would like a long discharge path for a long time buried deep in the cell. Modifying the electrode parameters can create such a discharge structure. A simulation is shown in Fig. 4. Here we have two "bus" electrodes with no ITO, quite narrow and with a large gap between them. The discharge initiates not across the gap but from the address electrode as in 4 a). We studied the relationship between the electrode gap length and the efficiency of panel. It shows that the bigger electrode gap length, the higher efficiency[3]. However, it is usually impractical because of the higher driving voltage at the large electrode gap length. Furthermore, there is a limit because at some gap the voltage required will be too high and the discharge will occur only to the address electrode which is quite inefficient.

So we introduce some auxiliary electrodes to help us initiate, control, or guide the discharge. Entirely new discharge structures can be created in this manner. Such a case is illustrated in Fig. 5. In this case a 3-part discharge is made to occur. We have constructed such PDP devices and tested the efficiency with various waveforms and voltage amplitudes and measured efficiencies significantly greater than present commercial products. Such a result is shown in Figure 6. Although a higher voltage is required for the sustain electrode pair, it can be made independent of addressing, promising innovative and economical circuit design.



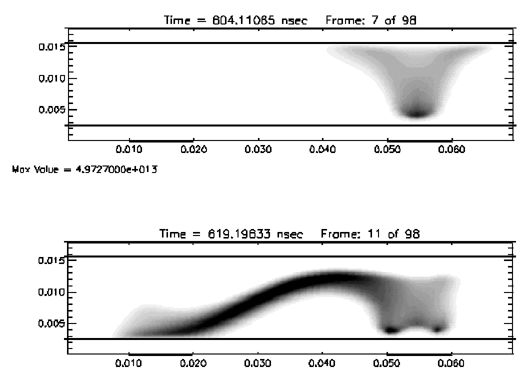
a) "comet" comes from anode

b) Cathode fall corridor formed

c) Spreads along anode surface

d) Travels along cathode surface

Figure 2. Surface Discharge (2D simulation of UV emission)



a)

b)

Figure 3. Lateral Volume Discharge (two phase)

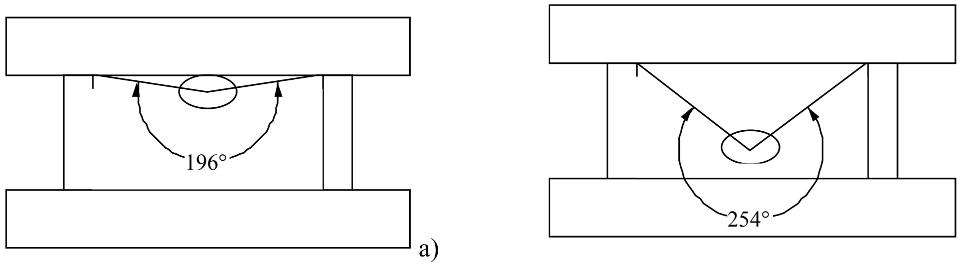
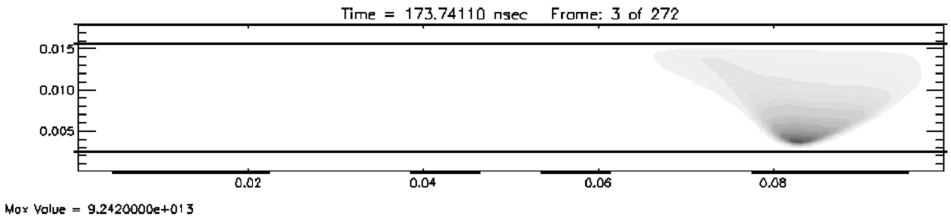
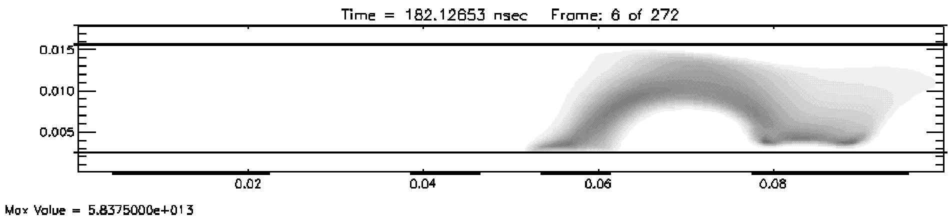


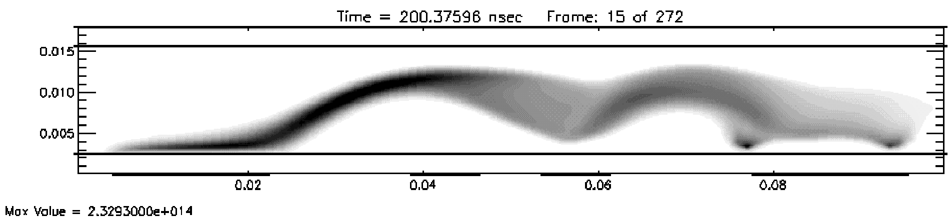
Figure 4. Illustrating Improved UV Utilization with Deeper Discharge Path



a) Comet initiates from address



b) Spreads laterally to control



c) Third path to sustain annode

Figure 5. Multi-Phase Lateral Volume Discharge (three phase)

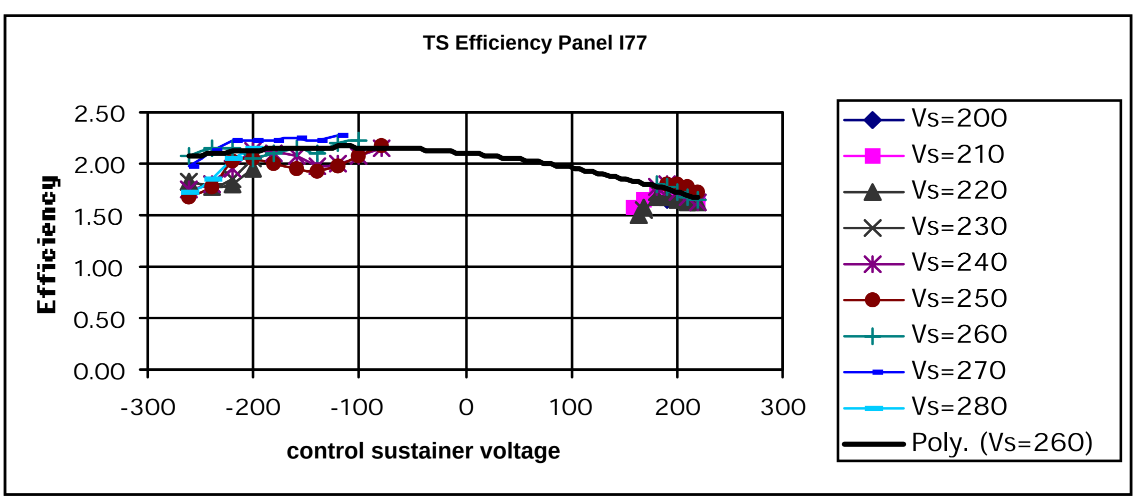


Figure 6. Measured Result of Experimental PDP – Efficiency(lm/watt) vs Control Voltages

4. Impact

We have been able to modify the PDP sustaining discharge structure by cell geometry and control of electric fields to significantly improve the luminous efficiency relative to conventional PDP design. Present commercial devices typically range between 1 to 1.2 lumens per Watt and we have measured greater than 2 lumens per Watt. For large area PDP this promises to be a practical method to apply toward a truly competitive large area display screen for HDTV and other large screen applications.

5. Acknowledgements

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