Experimental plasma display panels for measuring on VUV radiation wave-forms and concentration of exited atoms.

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Abstract

It is necessary to increase VUV radiation for improve luminous efficiency of PDP . It is important to know wave-forms of VUV radiation and density of exited Xe atoms or 1S4 and 1S5 of the cells. We survey on their measurement methods.

1. Introduction

The author studied on PDP from 1970 in NHK. In 1986 NHK made a target for a pulse memory DC PDP. A luminous efficiency of DCPDP is very low except for positive column type. Using negative glow type, the pulse memory PDP is also low efficiency. We started on basic studies to improve the efficiency and other performances. These studies consisted from experiments and theoretical simulations. In the experiments we started to measure on characteristics of cells especially on VUV radiation wave forms. After that, measurements on density of exited Xe atoms or 1S4 and 1S5 of the cells are made by Pr.Tachibana et al. On the other hand a simulation was made by Matsushita Electronics, Tachibana, and NHK. The simulation agreed with VUV wave forms .

The author joined Hyundai Electronics Japan in 1996 and started research on AC type. For AC type, measurements on density of exited Xe atoms are made by Pr. Tachibana and us. The author moved his company in 1998 and made two special panels, one is cross-sectional view panel and the other is 3D observable panel.

We survey on these panels and principal results.

2. Measurement for VUV radiation wave forms.(1)

2.1 Panels and methods.(2)~(5)

Four types of panel are made. These are DC-type with series resister and with He-Xe 10% 200Torr. Type I~ II panels are 1 mm pitch, 40x40 cells without auxiliary cell. Type III~IV are 0.7mm pitch,60x60 cells with auxiliary cells. Type I panel initially used a blue phosphor material $BaMgAl_{14}O_{23}$:Eu with a relatively short decay time of about 1 μs but was found to have an afterglow of VUV radiation. As a result, Y_2SiO_5:Ce (P47) with a further shorter decay time of 40ns was introduced into Type II panel, on which accurate measurements were carried out. A structure of type III panel is shown in Fig.2.1. Type IV has almost same structure of type III except for that front glass is sapphaire having VUV transparency.

A measuring configuration is shown in Fig.2.2.

In measuring with current, a problem was spikes (300 μA , 10 ns) caused by the capacitance between anodes and cathodes. They can be suppressed to 10 μA or less by adding the pulses whose polarity is opposite to that of spikes to the current signals to cancel the effect of spikes.

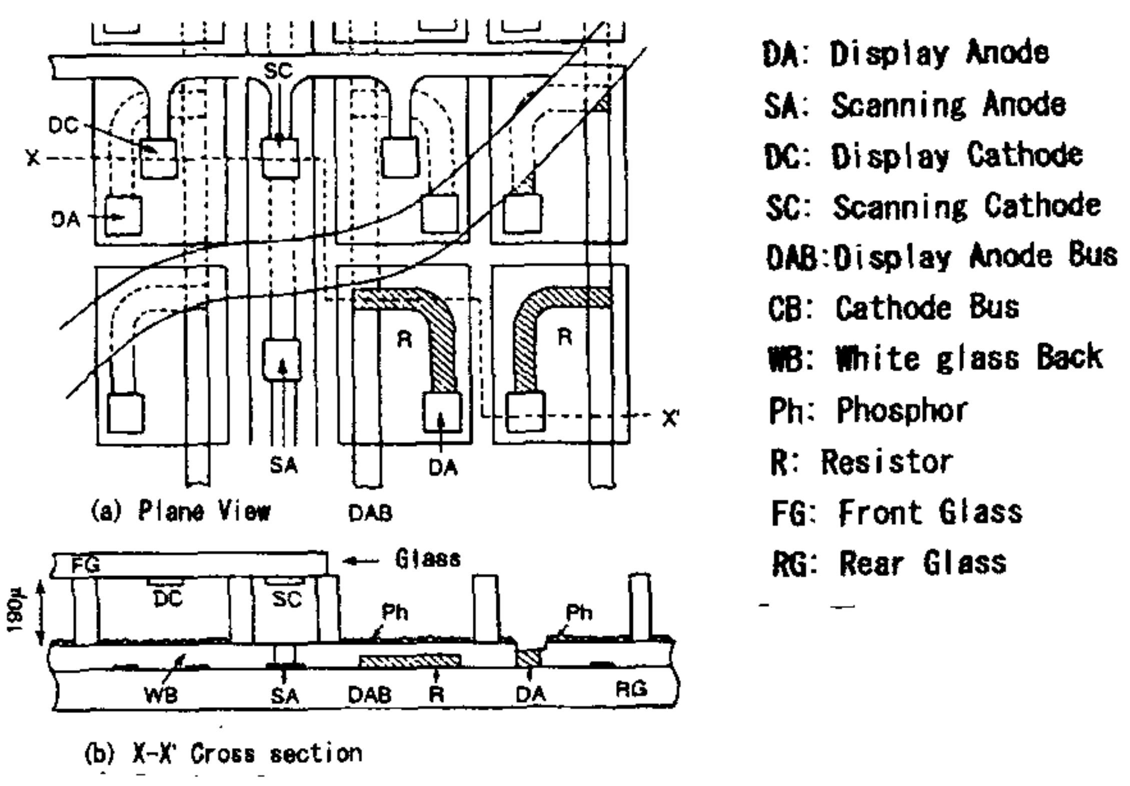


Fig.2.1 Panel structure used for the experiments.

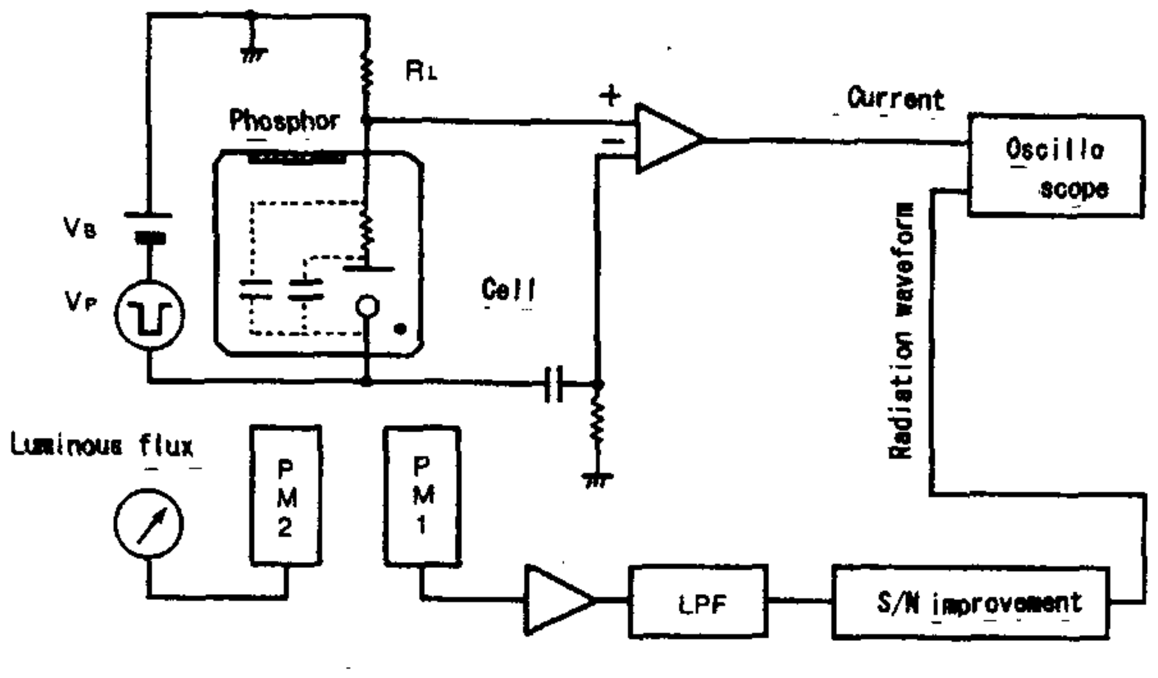


Fig. 2.2 Measurement configuration.

2.2 Measurements on type III panel.

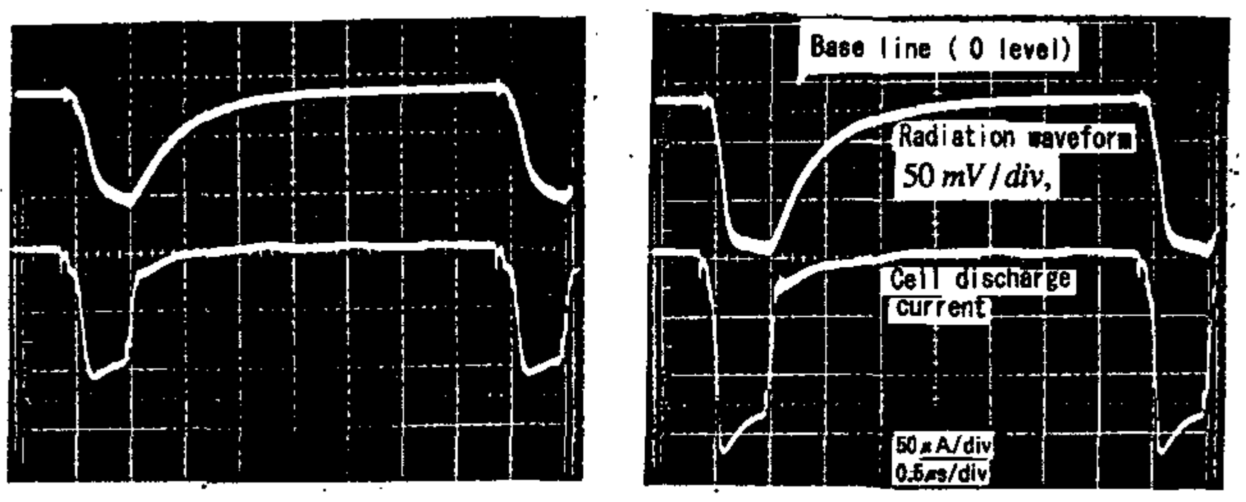
Typical examples of the VUV radiation waveforms for the pulse currents with **periods** T_0= 4 μs and **width** T_w=1 μs are shown in Fig. 2.3. Both the current and radiation waveforms are shown in the “downward” positive direction. Saturation was found on the radiation waveform when varying the current in Fig.2.3(a)-(b). A time constant of afterglow was found to be 0.6 μ s approx. A DC component observed in Fig. 2.3. We considered this as a component of VUV radiation with longer time constant mechanism. Fig. 2.4 shows a case, with T_0=60 μ s . Fig.2.4 (b) shows its vertical axis ten times that of (a). A longer time constant is 10 μ s approx.

This obviously shows that there are two different radiation mechanisms, which will be discussed later.

Afterglow wave form is expressed by

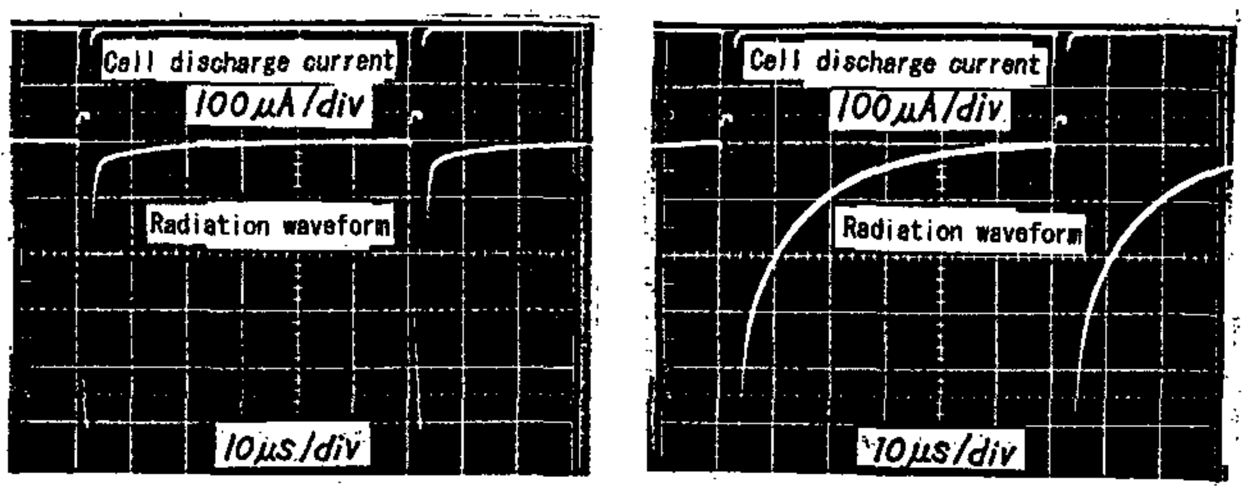
$$\exp(-t/\tau_1) + B\exp(-t/\tau_2).$$

where τ_1 = 0.5 μ s, τ_2 = 12 μ s and B = 0.06 - 0.2.



(a) With a pulse current of 100 μ A (b) 150 μ A

Fig.2.3 VUV radiation waveform (T_0= 4 μ s, T_w=1 μ s)



(a) (b) Magnification (x10) of (a)

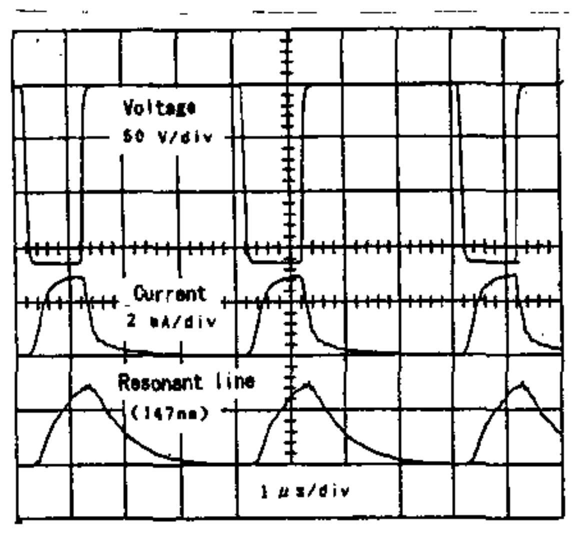
Fig.2.4 VUV radiation waveform (T_0=60 μ s, T_w=4 μ s)

2.3 Measurements on type IV panel.

The front plate (sapphaire) of the panel was connected to the spectroscope (VM502) through an O-ring. The radiation is detected by a photo-multiplier tube (R1220) whose output was fed to the integrator to largely improve the SN ratio. Measurements were then conducted with a gas exhaust and filling system connected to the tip tube of the panel so that gas components can be varied as required. These wave forms are given in Fig.2.5 and 2.6. Current per cell is 1/32 of the value shown because of 32 cells parallel driving.

The resonance line radiation time constant is about 0.6 μ s as expected for τ_1 and molecular line (172 nm)is 15 μ s as expected for τ_2.

Fig.2.7 shows the value of afterglow time constant, both with quantity of Xe (%) plotted on the horizontal axis. Fig.2.7 shows that the afterglow time constant of resonance line does not largely depend on the Xe content and that the time constant of molecular line decreases as the Xe content increases .



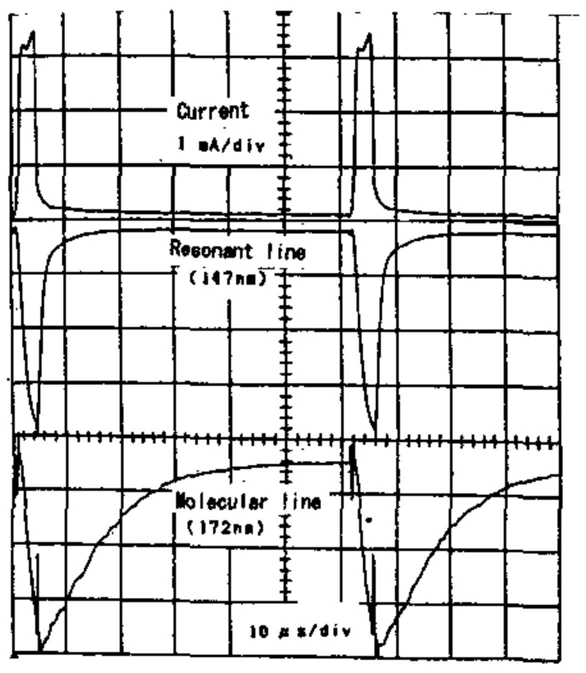


Fig.2.5 Wave forms of resonant line. Fig.2.6 molecular line.

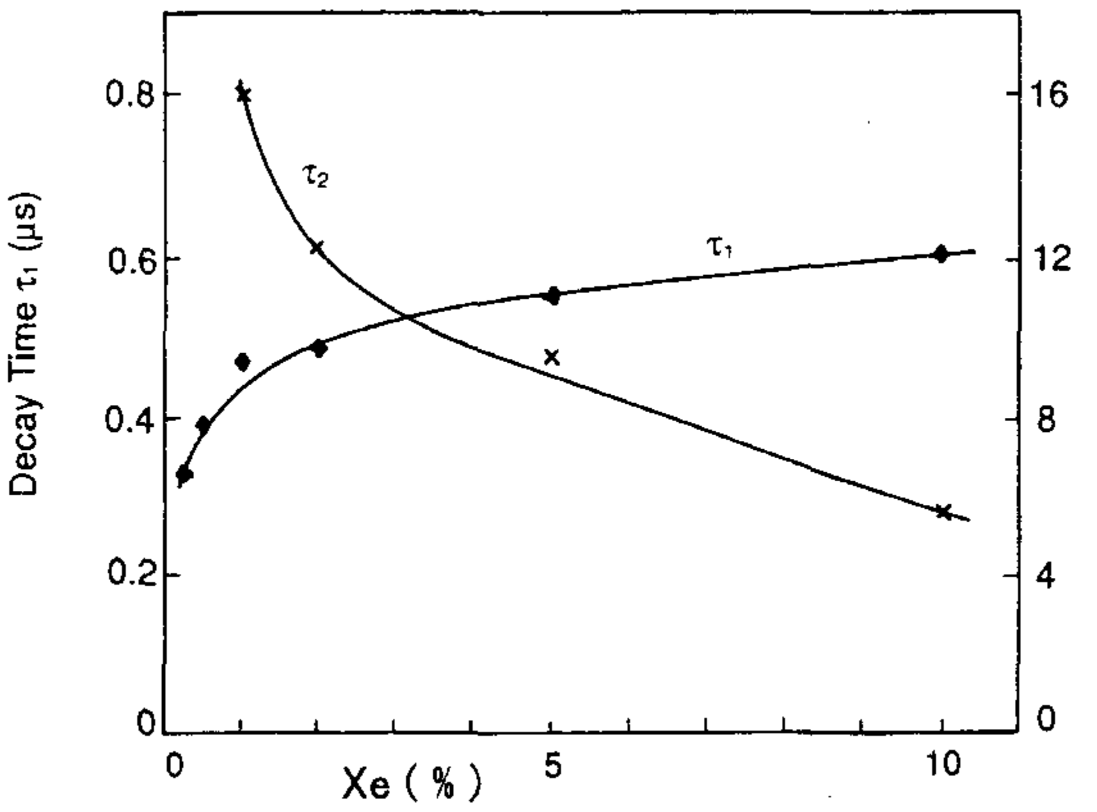


Fig.2.7 Decay time constant vs. Xe partial pressure ratio.

2.4 Discussions

(a) Estimation of the factor τ_1

It was found that τ_1 is due to the effect of imprisonment of resonance line (147 mm) of Xe. To verify this, we have evaluated the time taken to reach the phosphor surface. Approximating one dimensional slab , the effective radiation life time is given by[(6)]

$$\tau = 4.5\tau_u\sqrt{L/\lambda} \qquad (1)$$

where τ_u: Life of resonance line level Xer^* (3.7 ns) λ: resonance line wavelength (147 nm) and L: Gap of the discharge cell (167 μ m). Substituting the value in Eq.1. τ =0.55 μ s is obtained, proving that it is generally coincident with the value τ_1 observed by us.

(b) Estimation of the factors of τ_2.

A life of $Xemet^*$ is very long and a time constant of reaction Xe_2^* 2Xe + hv(173nm) is 0.1 μ s approx. It is found that τ_2 is coincident with time constant of three body collision reactions :

$Xemet^* + Xe + He \quad Xe_2^* + He \qquad (2)$

$Xemet^* + 2Xe \quad Xe_2^* + Xe \qquad (3)$

Calculated time constant is 10 μ s approx. for He-Xe 10%

200Torr. Fig.2.7 and a simulation(7)(8) assist these mechanisms. A role of memory effect of pulse driving is clearly Xemet*.

3. Measurement for density of exited Xe.(9)-(10)

3.1 Principle of method.

Data mentioned above have no information of VUV on space. For future CAD information on space is important. VUV radiations are transition to the ground state from Xer* (1s4), Xe$_2^*$. Since Xe$_2^*$ is formed by reaction in Eq.(2) and (3) from Xemet* (1s5), it is necessary to know densities of 1s4 and 1s5 as a function of space. A laser beam absorption method was developed for this aim. Fig.3.1 shows the principle of this method. When an IR laser beam having energy corresponding to 1s4 to 2p5 transition energy come to a cell 1s4 atoms absorb the photons and transit to 2p5 atoms. The density of 1s4 is calculated from the absorption amount. Similarly 1s5 transit to 2p6. The amount is several to 20 % in this cell. The experimental set up is shown in Fig.3.2.

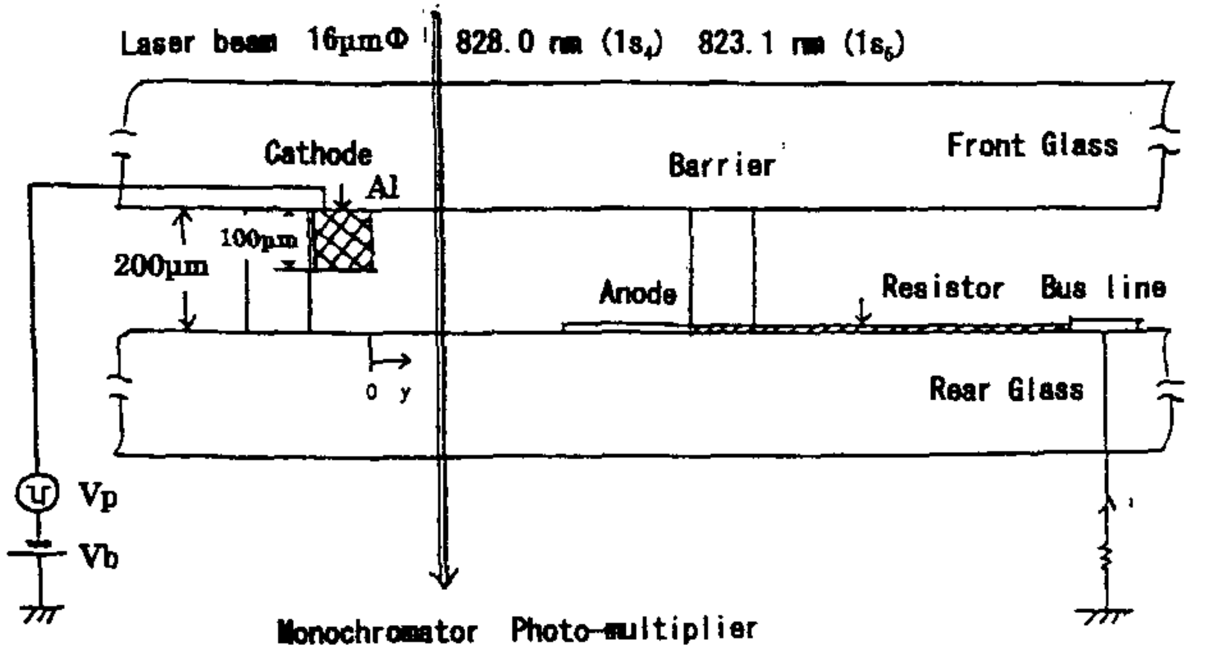


Fig.3.1 Laser beam absorption method.

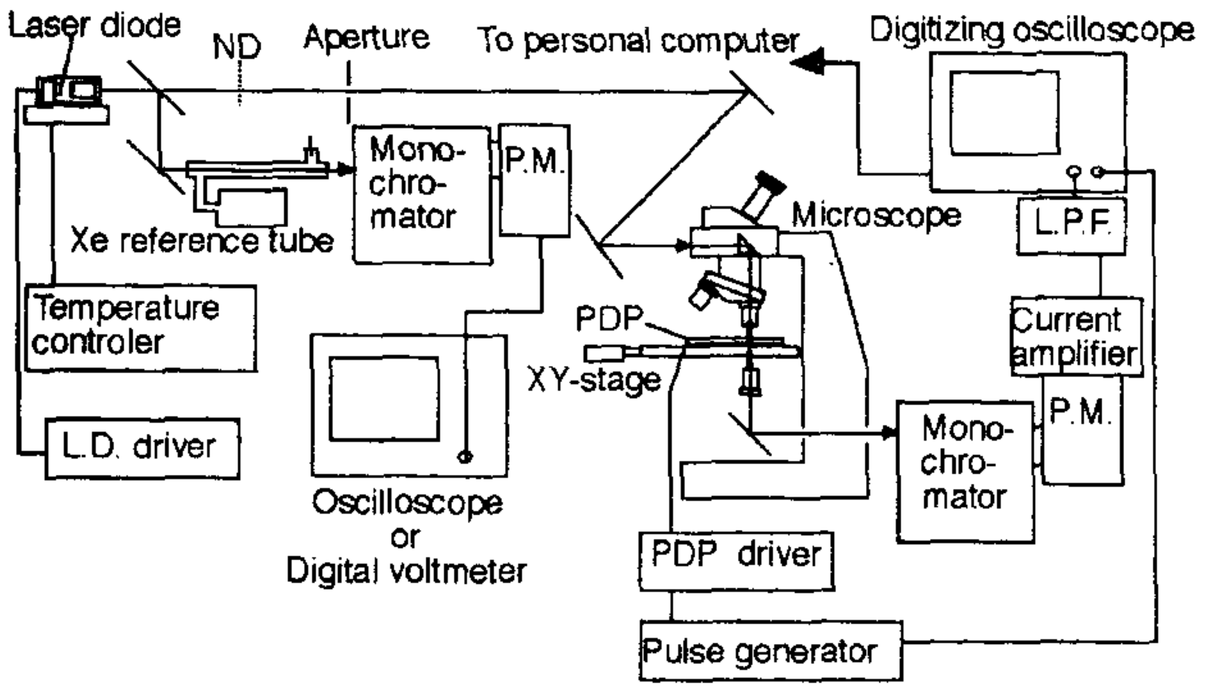


Fig.3.2 Schematic of the experimental set up.

3.2 Measurement for DC-type.(10)(11)

The structure of the unit cell and measuring point are shown in Fig.3.3. The panels have various cells which have different anode to cathode distance. The gas pressure is 27kPa and 47kPa He-Xe 10%. Driving pulse is with T$_0$= 5 μs period and T$_w$=1 μs. Fig. 3.4 shows an example of the measured data. Fig. 3.4 shows that a positive column is formed in the mid of the cell toward the anode. A panel having almost same structure cell is fabricated. A TV picture is displayed on the panel.(11)(12) Its efficiency is 0.6 lm/W but if adopt good emitter and operate lower current then the efficiency may increase to 3~4lm/W.

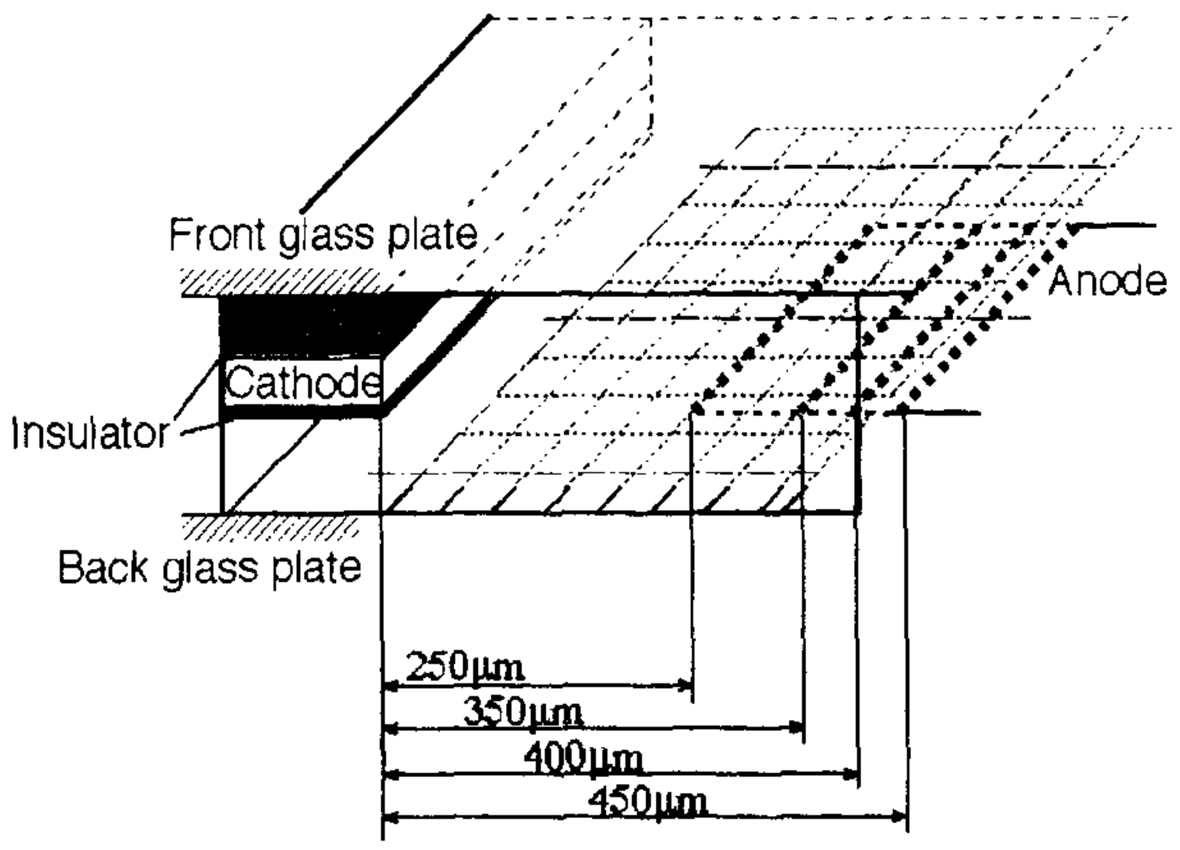


Fig.3.3 Structure of measured cell.

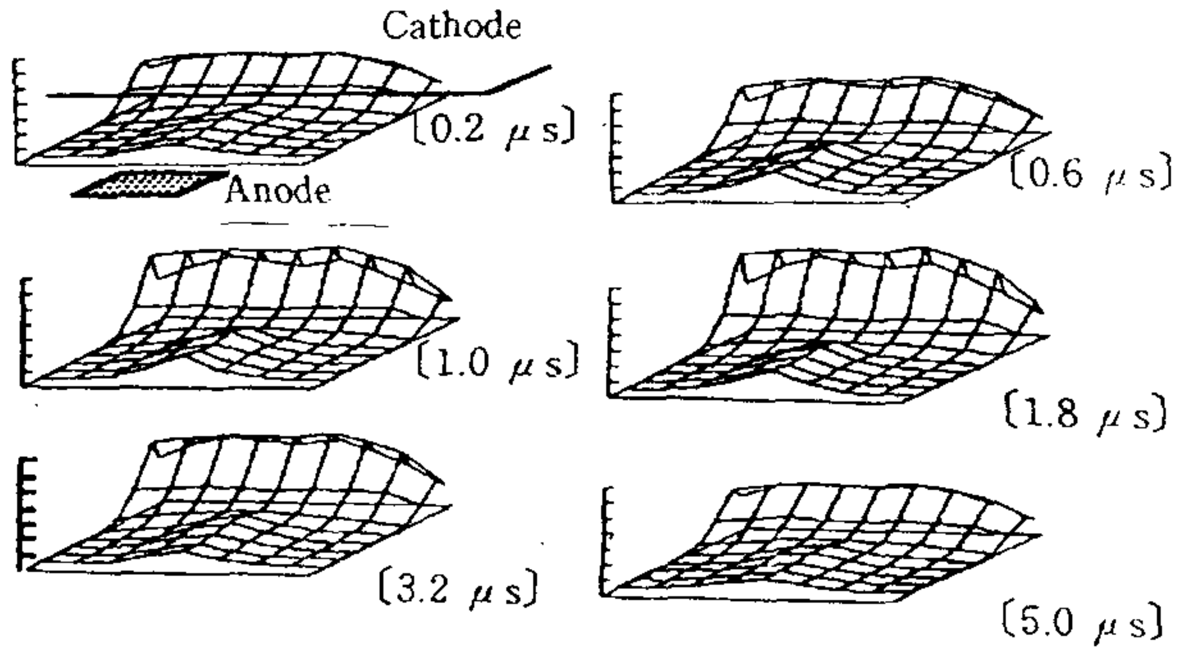


Fig.3.4. Density distribution of 1s5. (d=450 μm)

3.2 Measurement for AC-type.

(a) Standard type panel.(14)(15)

We started on standard type panel having 192x640 cells with 0.6x0.29 mm pitch ,Ne-Xe 10% 47kPa. It is found that decay time constant is 2.5 μs for 1s5 and 0.37 μs for 1s4. 1s5 roles pulse memory like action in sustain mode. Also there is a slow decay component remains in 1s4 caused by 1s5 to 1s4 transfer. Details of results are in references

(b) Panel for cross sectional view.(16)-(18)

A side view of the density of 1s4 and 1s5 is more important for us. The cell structure of the panel is shown in Fig.3.5. On the back glass plate, metal plate electrodes and barrier ribs are formed in parallel with a pitch of 1.2 mm. On the side plane of a cell chip,a pair of metal electrodes is printed and over-coated by dielectrics and MgO thin films in a layered structure. The cell chips are inserted in the slots between the ribs. Several combinations of four different sizes of the rib gap: 0.5, 0.75, 1.00 and 1.5 mm with three different sizes of the electrode gap: 0.05, 0.075 and 0.1 mm

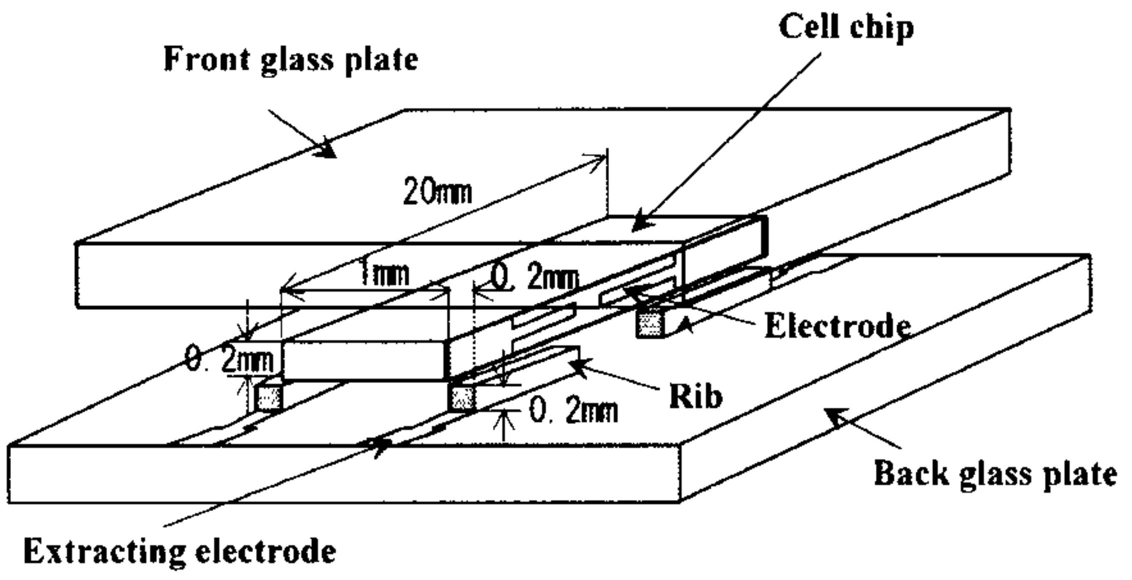


Fig.3.5 Cell structure of side view panel.

are formed on a panel. A mixture of Xe(4%) and Ne is filled at a pressure of 350 Torr. An aspect of break down was observed very clear. Also IR images observed. Measured results are shown in Ref.(16)-(18).

(c) 3D observable panel.(19)

A three-dimensional (3D) observation of behaviors of excited atoms in a unit cell are important for deeper understandings of discharge physics leading to improvements the efficacy of an AC-type PDP. We have designed and manufactured a special panel for this purpose. The structure and dimensions of our present panel for the 3D measurement is shown schematically in Fig.3.6 (a). In (b), the spatial distributions of Xe(1s$_5$) density are shown. Details are in ref. (19).

4. Conclusion.

As we surveyed there are good methods for measurement on exited Xe atoms. By these methods we can estimate an efficiency of a panel without large panel manufacturing.

Now we are going to test for new idea panel for example shown in Fig. 4.1. (20) Many researcher including us noticed that for higher efficiency more Xe content and lower discharge current.(21) This is the same problem on DC and AC type. A panel shown in Fig.4.1 is a solution of the problem. It has low firing voltage and current because of short firing discharge pass and a thick dielectric layer.

Also RF panels(22)(23) and DC panels can not be discarded. NHK demonstrated 4000 line TV on last May. Will PDP remain in next TV era ? If it is true PDP should have higher performances. The author believes that physics of cell will be more important.

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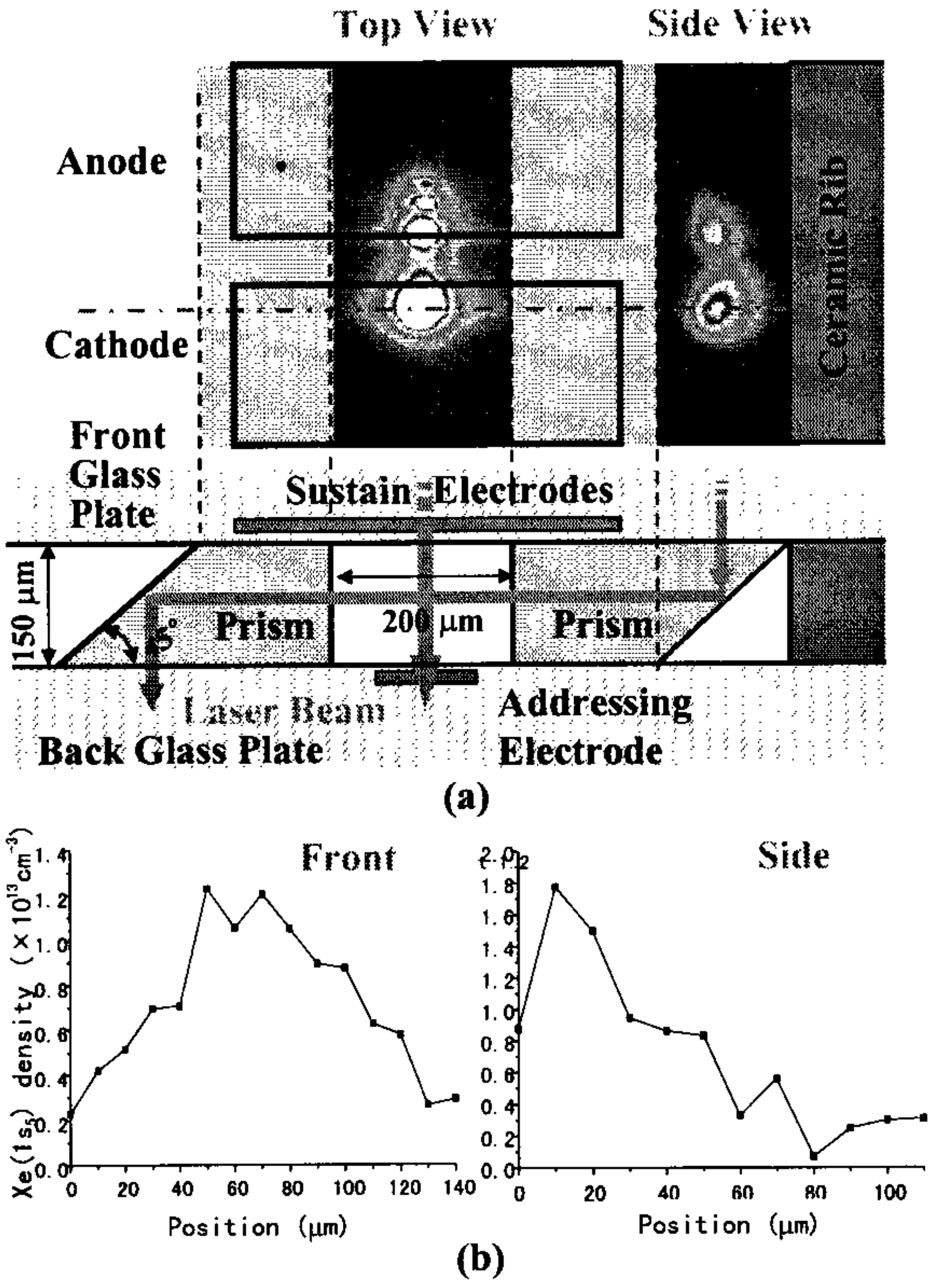
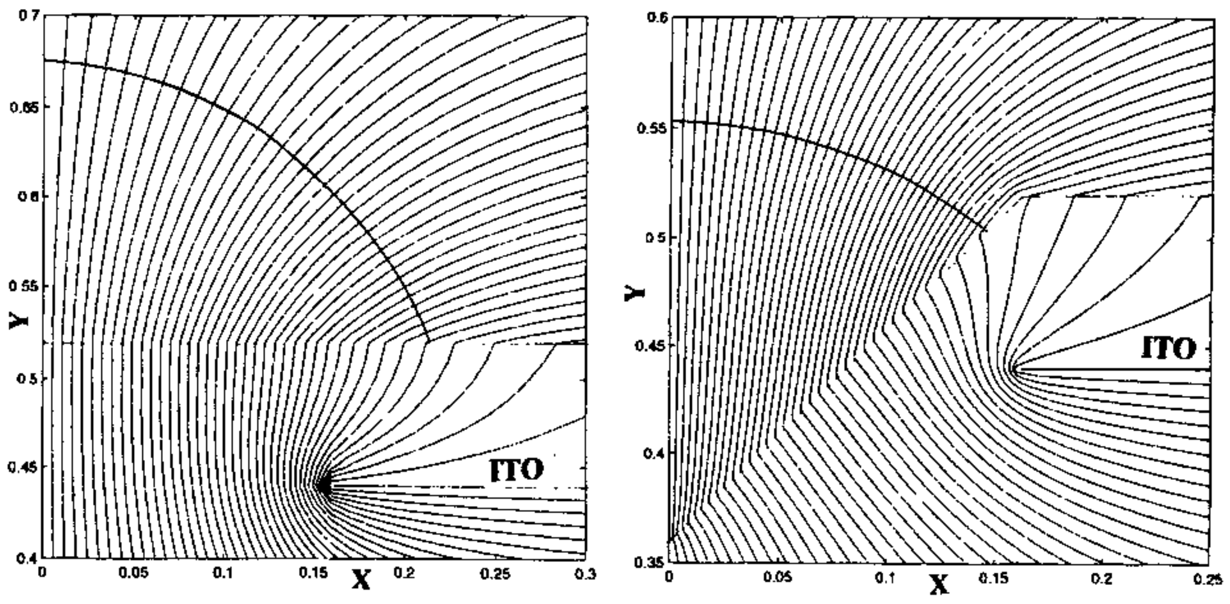


Fig. 3.6 3D observable cell.



(a) Standard cell. (b) Low voltage and low current type

Fig.4.1 Equipotential contour and electric lines of force of cross-section of cells.

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