A flat thin display with RF electron generation

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Abstract

We report on a new type of a flat and thin display with a secondary emission electron source. In this display device electrons are multiplied between two secondary emission plates under a high frequency electric field. This principle has a few important advantages over a field emission display: the emission comes from flat plates, which reduces the lifetime problems of ion bombardment of field emitter tips. Furthermore, the electron emission is space charge limited which gives a uniform electron distribution. The electrons are extracted from the source and accelerated to a phosphor screen to generate light. Gray levels are made by pulse width modulation.

1. Working principle

Flat-panel displays have been a research topic for many years. Although LCDs and PDPs are coming up for the TV market, there are still many issues to solve. Field emission displays can solve some of these issues such as a large viewing angle, high brightness and simultaneously a low black level and high efficiency. However, field emission displays have an issue in lifetime and uniformity. By replacing the electron source by a more robust and uniform one, these obstacles can be solved. The secondary emission source has the potential to do this.

The secondary emission source is based on the Multipactor [1]. This effect can occur at the walls in microwave tubes and can be a source of powerloss, and in dramatic cases can destroy the device. A Multipactor uses secondary emission to multiply electrons. Secondary emission is the process in which free electrons with a certain amount of energy collide with the surface of a material which causes new electrons to escape into the vacuum. In the RF display an alternating RF voltage is present between two parallel plates. The frequency is matched to the time of flight of these electrons. Electrons are accelerated and thus gain kinetic energy due to the electric field caused by the RF voltage between the plates. If the electrons collide at the plate with enough kinetic energy, more free secondary electrons are generated. Before the electrons fall back into the plate the electric field is reversed and the electrons move to the first plate again at which the same process repeats itself. Thus the electrons go back and forth from one plate to the other, thereby increasing the number of electrons by secondary emission at the surface of the plates. The time of flight of the electrons, and hence the operating frequency, depends on the applied voltage between the plates, the distance between the plates and the space charge induced by the electrons. To generate light, a part of these electrons is accelerated to the phosphor screen, which is shown in Figure 1. Electrode 2 is a grid which contains holes through which electrons can be accelerated to the phosphor screen. Extra grids can be added as row and column selections for making a matrix display.

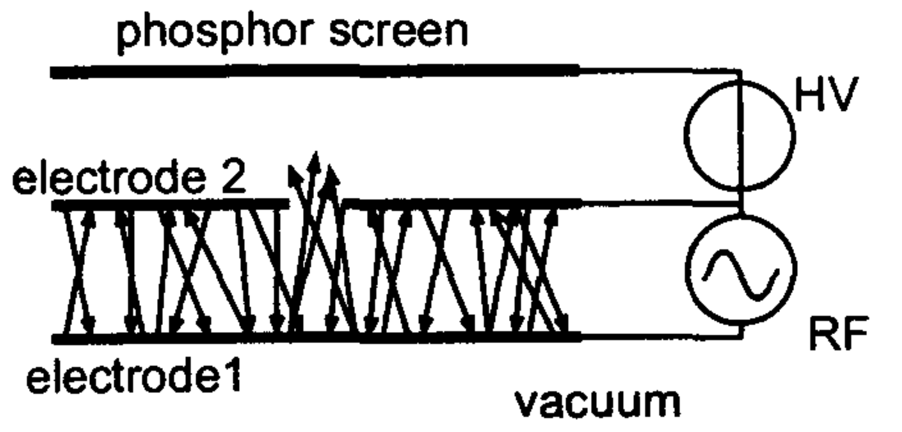

Figure 1: Electrons are multiplied, extracted and accelerated to a phosphor screen.

2. Devices

The secondary emission yield determines the required driving voltages and emission current. A part of the electrons will be accelerated to a phosphor screen for making light, thus a part of the electrons is extracted from the RF cavity. Therefore, at least one of the surfaces, at which the electrons will be multiplied by secondary emission, needs to be conductive so that new electrons can be replenished to the surface. In most devices aluminum has been used as electrode which after oxidation results in a secondary emitter with a secondary emission coefficient ranging van 2 to 9 [2].

In Figure 2, the layout of two different devices has been depicted. On the back glass plate and the grid, aluminum row electrodes are structured which have been oxidized to obtain a high secondary emission coefficient. At a distance of about 2 cm a grid from glass has been positioned that contains powder blasted holes at a hole pitch of 0.5 mm. The geometrical transmission of the grid is about 5%. The first RF device has only one grid which is covered with aluminum. No addressing is possible with this device, but it shows the secondary emission principle. In Figure 3 a photograph is shown of this device which has been switched on.

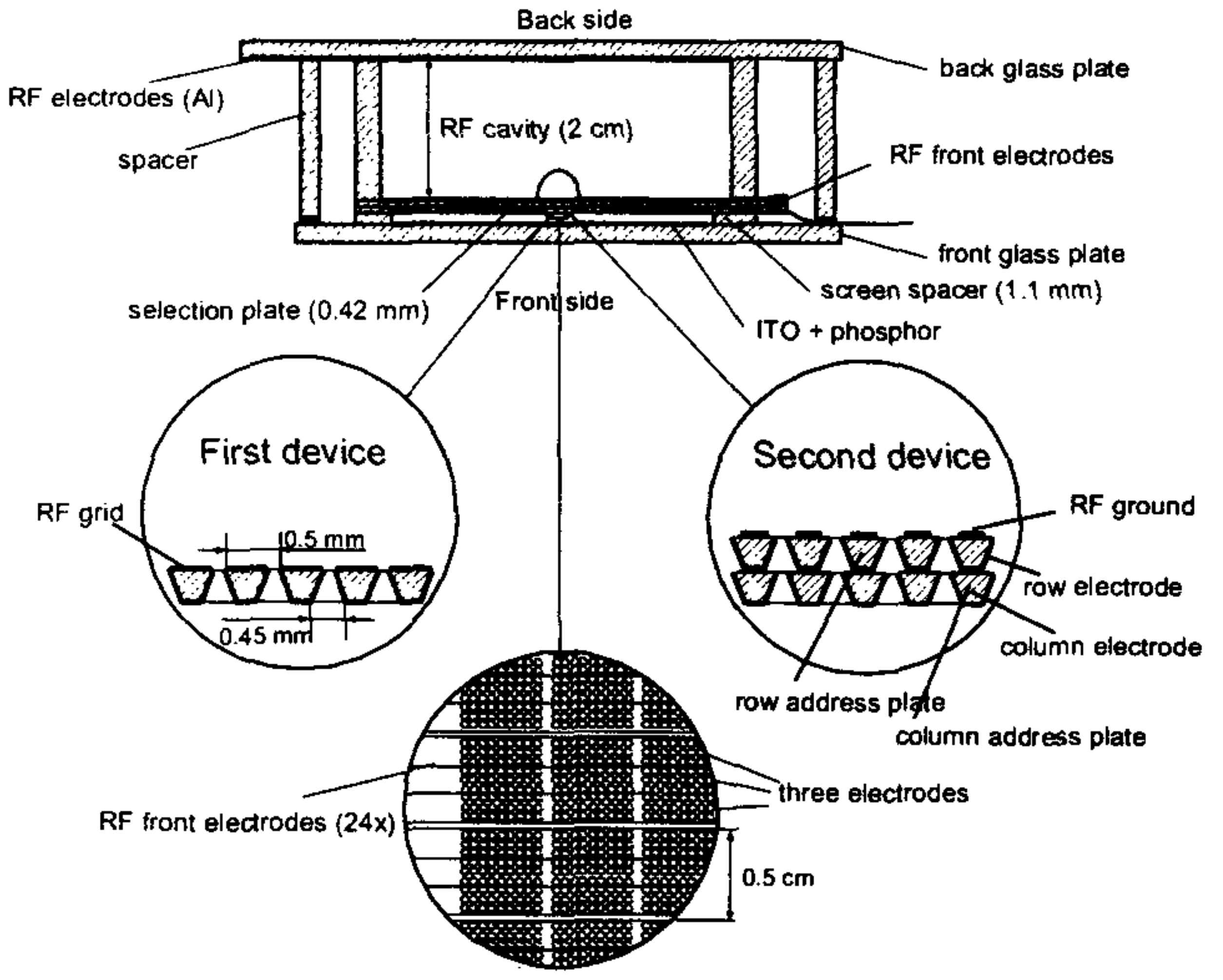

Figure 2: A schematic of two RF display devices. The hole pitch is 0.5mm and the total display area is 4x4 cm. Between the phosphor screen and the grid there is a glass screen spacer with a thickness of 1.1 mm.

The second RF Device has both column and row selection plates with 24 electrodes each for row and column drivers. This device can be matrix addressed. The RFD ground and row selections are combined on one glass plate to increase the transmission of the grid by increasing the "Durchgriff". This makes it possible that a higher current can be extracted from the RF cavity without a higher RF voltage. All electrodes are made from aluminum. The phosphor voltage was limited to about 500 V due to back scatters from the phosphor screen which resulted in flash overs, which can be solved as shown in [4].

Figure 3: The first RF device giving light.

3. Measurements

In Figure 4 the current has been measured as function of the RF voltage for a frequency of 74.4 MHz for various row voltages, V_1, and with the column voltage, V_2 at 200 V. The "Durchgriff" through the row grid will be small due to the metalization in the hole of the row grid which shields the RF cavity from variations of the column voltages. In Figure 4 we can see that the current increases as a function of the RF voltage. It was also observed that the current increases as a function of the frequency. The required row voltage for pinching off the current to the phosphor screen becomes more negative if the RF voltage increases. This can be expected since the energy of the electrons in the RF cavity upon impact will be higher for higher RF voltage. Thus a lower

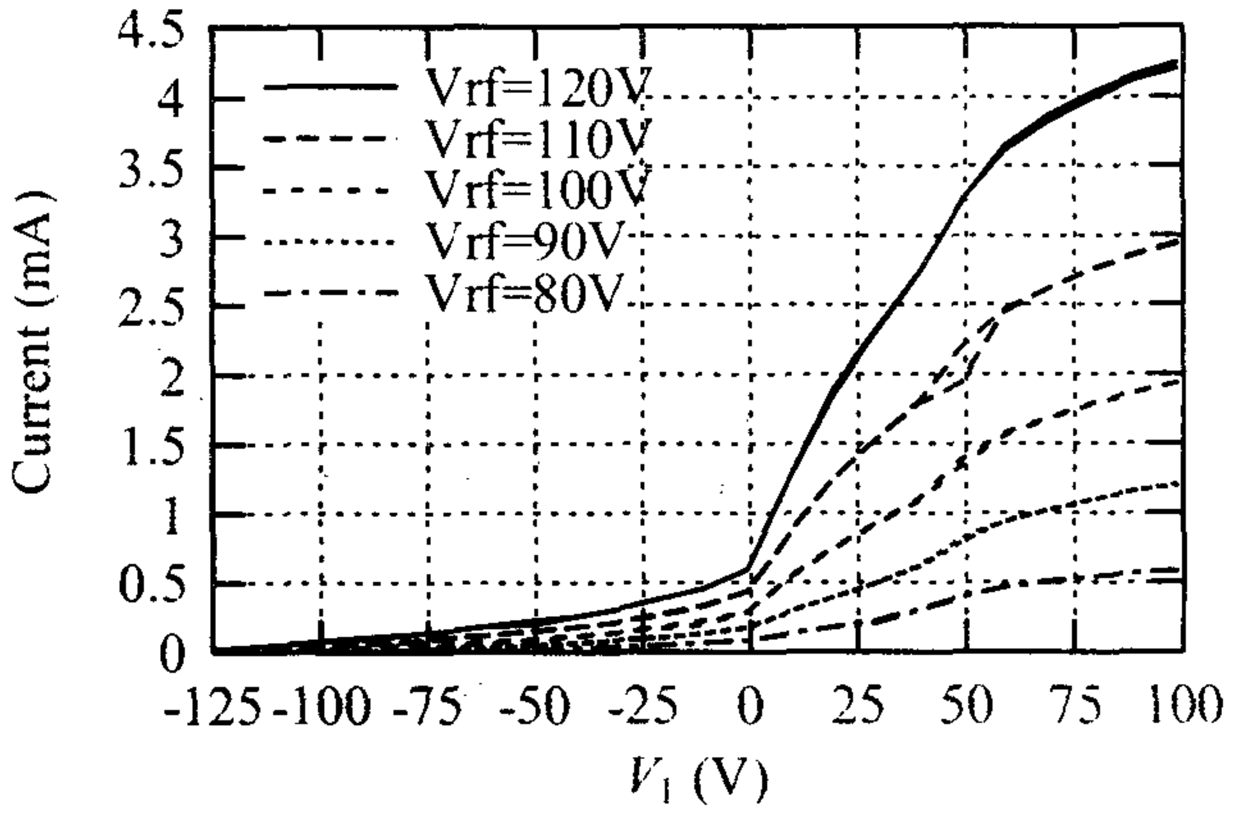

Figure 4: Measurement of the current vs the voltage for various RF voltages as a function of the row voltage V_1 with the column voltage V_2= 200V at a frequency of 74.4 MHz.

RF voltage reduces the required row voltage swing. For generating a specific current two possibilities exist. The RF voltage can be increased. This requires a higher row blocking voltage similar but negatively in polarity to the peak amplitude of the RF voltage. A second possibility is to increase the frequency. In the latter case also the depth of the RF cavity must be reduced. A lower RF voltage makes it possible to obtain a lower blocking voltage and thus reduce the (row) driver costs. What the optimum, row voltage, RF voltage, depth of the RF cavity and frequency is for a specific RF current has not yet been analyzed.

In Figure 5, the situation is shown if both the row voltage, V_1, and column voltage, V_2, is varied with an RF frequency of 69.4 MHz. The column voltage is varied from -120 to 130 V and the row voltage is varied from -50 to 50 V in steps of 25 V. This shows that the display can be addressed line at a time. This can be seen with the variation in the current with the row voltage V_1 which selects a current for a row by changing the voltage of the row from -50 V to 50 V. and by modulating the current of a pixel in this row with the column voltage V_2 between -100 and + 150 V. What we can also see is that the current reaches a plateau for lower row voltages of V_1 of -50 V to 0 V. It can also be seen that the current shows a supra-linear behavior up to a voltage where it starts to flatten. This means that a gamma is present in the panel when using amplitude modulation with V_2 in the range of -50 V to about 100 V.

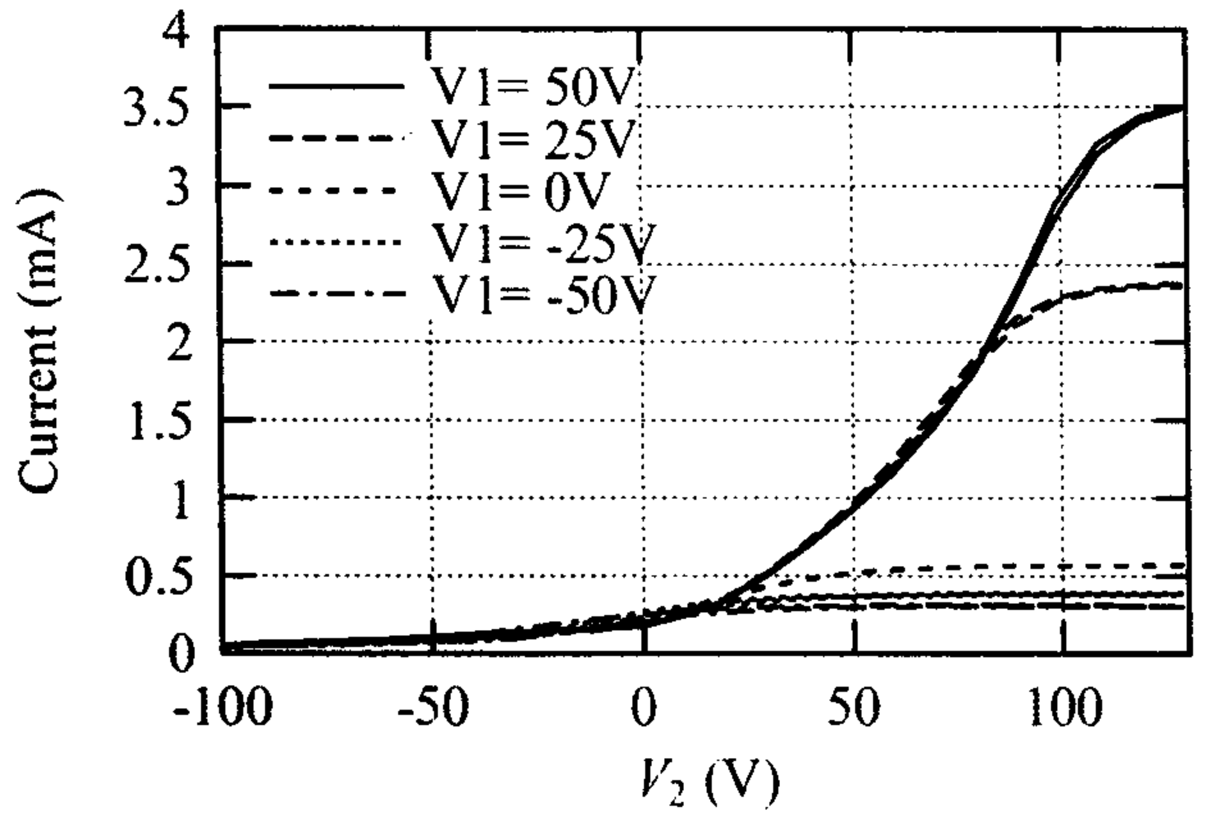

Figure 5: Measurement of the current vs column voltage V_2 for a RF voltage of 86 V and a row voltage V_1 of -50, -25, 0 25 and 50 V for a frequency of 69.4 MHz.

4. Display application

For a display application several aspects are important such as peak white level (about 1000 cd/m^2) and creating gray levels. In [4], an average screen current for full white of 9 μA/cm^2 is required to obtain a brightness of 1000 cd/m^2 for white D_{65} with 4.5 kV phosphor voltage and a phosphor efficacy of 11 lm/W. This leads to a requirement for the current. With the RF device a peak current to the screen of 12 mA or 0.75 mA/cm^2 has been shown at an RF voltage of 200 V. This is comparable to a brightness of about 150 cd/m^2 when it is used as a television screen with line-at-a-time addressing. The current can be increased by optimizing the secondary emitter of the RF cavity. In [3], an oxidized aluminum-magnesium film has been investigated which has a secondary emission coefficient of about 6 at 400 eV. Using this material we have obtained a similar screen current of 12 mA with a lower RF voltage of 150 V. We did not combine this with a device configuration according to the second device. thus with increased "Durchgriff" to increase the transmission. Optimization and/or increase of the frequency and depth of the device also leads to a higher screen current.

Gray levels can be made with pulse width modulation (PWM) or with amplitude modulation by varying the column voltage. In the figures 6 to 8 some photos are shown of a working RF display with several patterns. Figure 6 is a gray ramp in which 8 gray levels have been made with PWM. Figure 7 shows a picture also with 8 gray levels showing the matrix addressing capability of this display, and Figure 8 shows a checkerboard pattern on the display.

Figure 6: The display with a gray ramp without gamma correction; the vertical black bar is the start of the gray ramp.

5. Efficacy

The efficacy of the RF display is estimated by connecting the display to an RF oscillator. The current

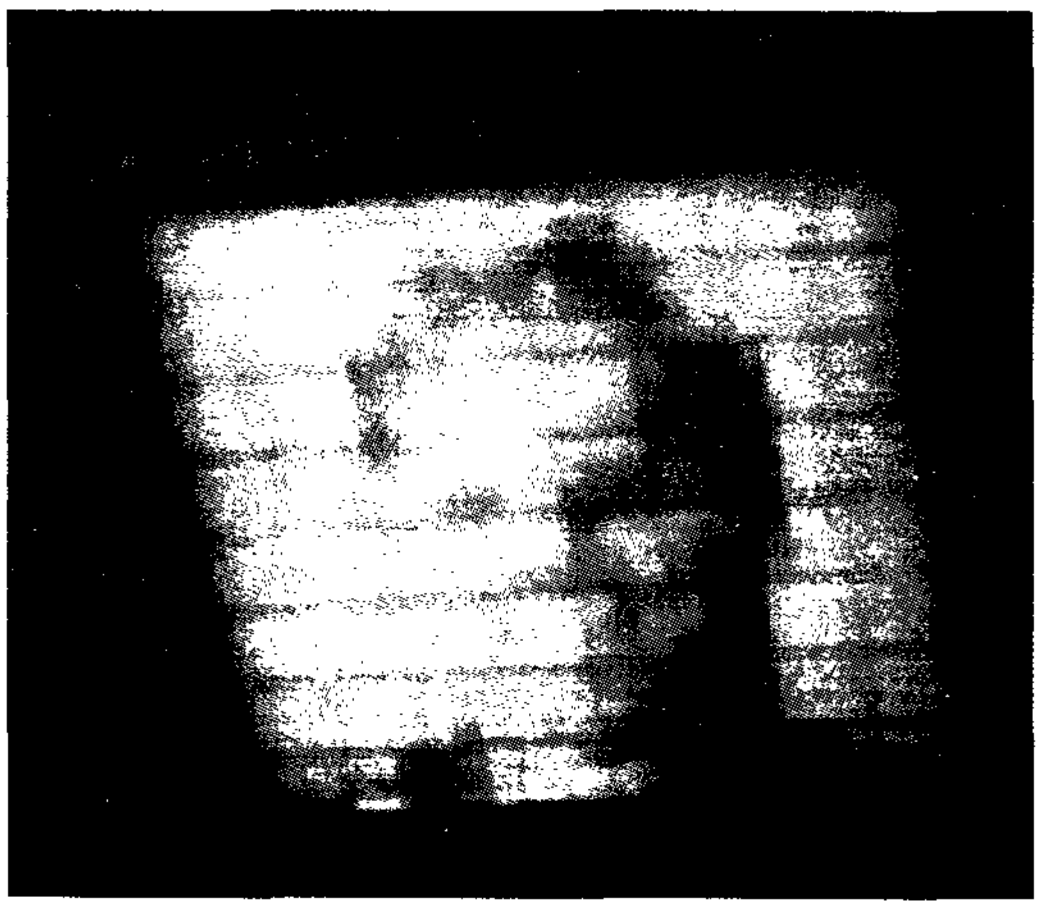

Figure 7: The display showing a picture of the author.

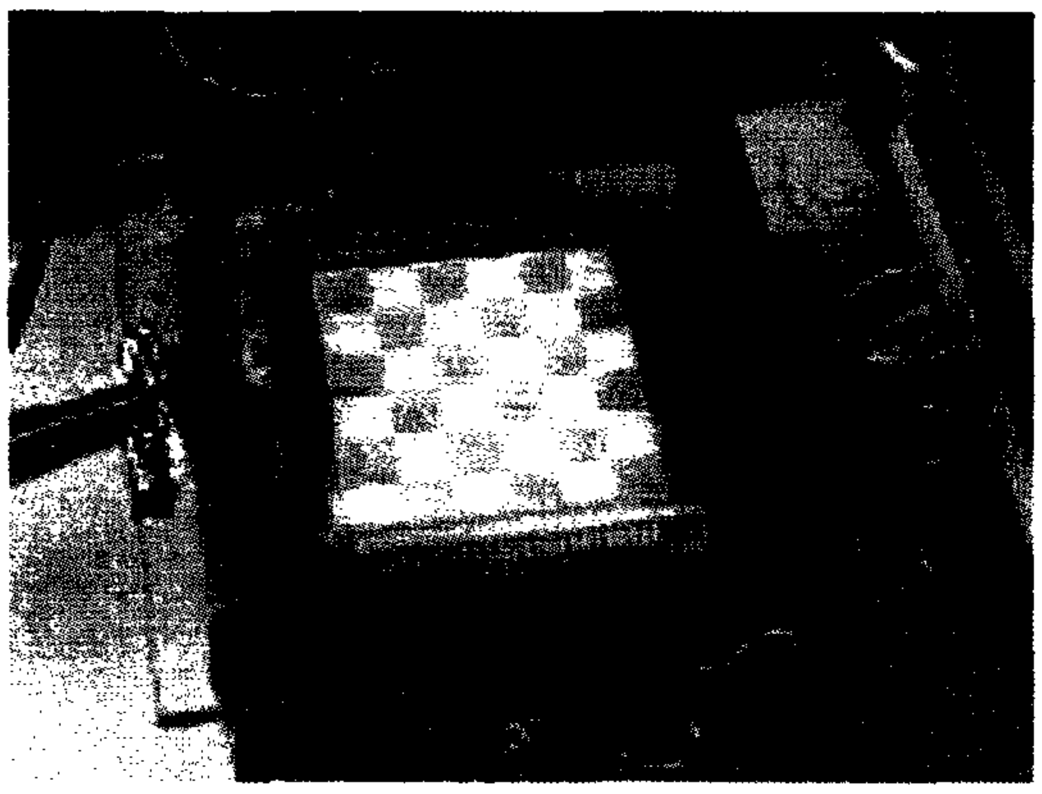

Figure 8: The display with a checkerboard pattern.

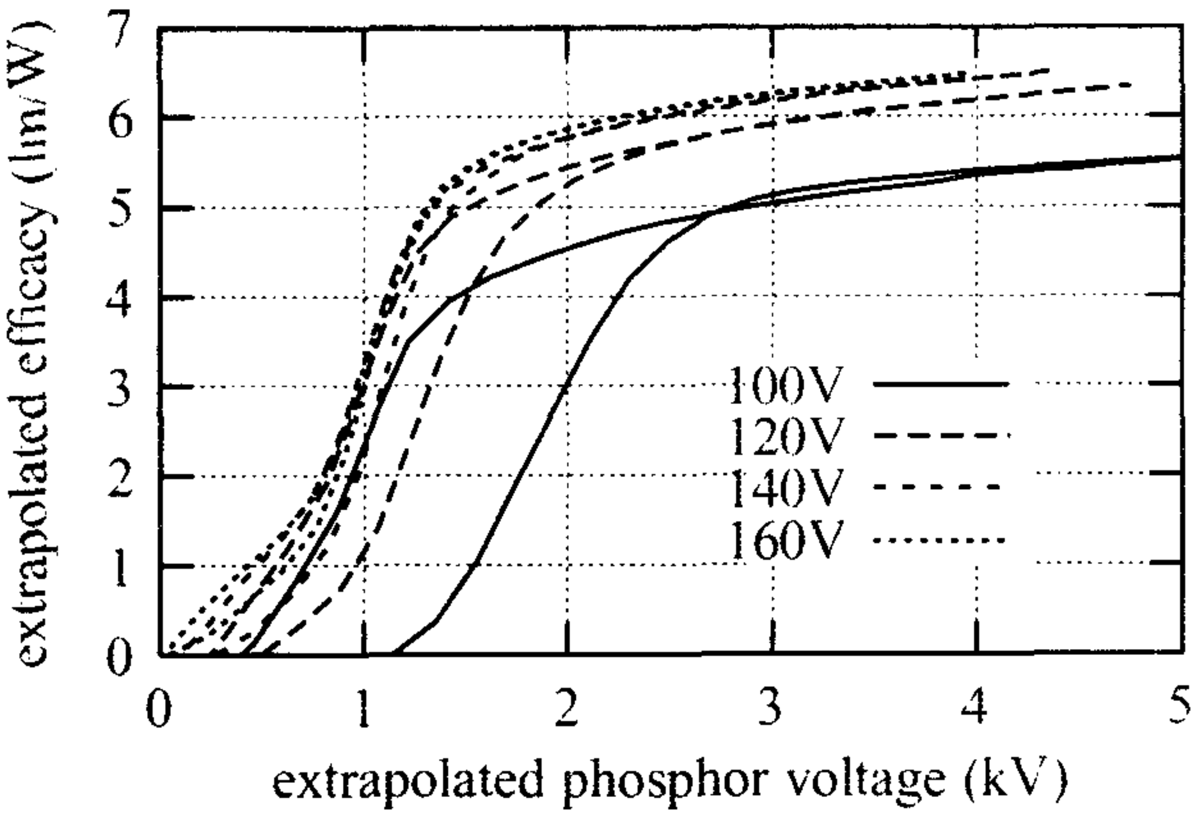

Figure 9: The extrapolated device efficacy for various oscillator voltages.

devices could only handle low phosphor voltages of about 500 V, so to estimate the lumen efficacy we have to extrapolate the measured values. By extrapolating the measured phosphor voltage to a high voltage supply of 5 kV, V_{HV}, which is a reasonable target for a flat thin CRT [4]. The extrapolated efficacy, η, can be calculated as:

$$\eta = \eta_{ph} \cdot I_{scr} V_{HV} / (I_{osc} V_{osc} + I_{scr} V_{HV}),$$

in which $I_{osc} V_{osc}$ is the power dissipation in the oscillator. This is the measured voltage and current of the power supply of the oscillator. The power dissipation of the phosphor screen is the measured current to the phosphor screen I_{scr} times the extrapolated screen voltage V_{HV}. Note that the power dissipation of the oscillator includes the power dissipation of both the Multipactor and oscillator itself. It is assumed in this paper that with the phosphor screen at 4.5 kV a phosphor lumen efficacy for white D_{65} is 11 lm/W [4]. In Figure 9, the extrapolated lumen efficacy has been shown. All measurements have been done on a device without row and column grid. Note that the extrapolated efficacy in Figure 9 reaches almost 6.5 lm/W almost independent of the oscillator voltage. Only for the lowest oscillator voltage this is a little bit lower with 5.5 lm/W.

6. Conclusions

The Multipactor principle can be applied for making a flat thin display which can be an alternative for a field emission display. It has the advantages that it has a uniform electron distribution and is less vulnerable to ion bombardment. The experiments show that a display with real time video can be made with an efficacy of 6.5 lm/W. We can obtain brightness of at least 150 cd/m^2 with a high voltage phosphor screen of about 4.5 kV. Increase of the brightness can be obtained by increasing the frequency and optimizing the secondary emission. The thickness of the Multipactor (i.e. distance between the plates) for a given frequency, RF voltage and display current must still be optimized to have the highest efficiency.

7. References

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