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Behaviour of an imaging tube during short light pulse illumination

K. Szabó, P. Richter, E. Lőrincz

Technical University of Budapest, Department of Atomic Physics, 1521 Budapest, Budafoki ut 8, Hungary.

Behaviour of a Vidicon imaging tube in case of short (ns) illumination in a wide range of intensities was studied. Charge on the retina was proportional to light energy and blooming created a spot with a uniform charge density.

1. Introduction

New types of solid state imaging devices have appeared recently due to a rapid development of industrial robots. These devices are also used widely in video measuring systems. There, however, appear some special measuring problems, where imaging tubes can be also used:

i) measurement of $X-Y$ coordinates of one or more moving points,

ii) tracking of moving points,

iii) determination of dimension or orientation of larger spots, etc. [1].

These measurements are used in a lot of new applications of imaging devices, such as: pattern recognition, filtering, robot vision [2], digital photography [3], etc.

Hundreds of articles concerning this topic have already appeared, but most of them deal with data processing systems only. However, in some cases physical properties of the imaging device determine principally the performance of the measuring instruments.

One of these measurements and the related results of experiments are described here.

The position of a short (ns range) focused light pulse on a target had to be determined. The distance between the target and the camera, and the reflection coefficient of the target was allowed to vary in a wide range, so the energy of the light pulse reaching the sensor could vary from 10^{-12} J to 10^{-9} J. This great dynamic range and the shortness of the light pulse raised some questions concerning the applicability of imaging tubes in our task.

The possibility of using the storage property of an imaging tube was examined. Measurement of position could be carried out by time interval measurement from the vertical synchron signal. A 256×256 matrix was used on the retina, so the dimension of a pixel was approximately 20×20 microns.

2. Experimental

The determine the applicability of the vidicon tube to its task some dynamic parameters of the camera had to be examined. During normal operation these parameters are not important, so the data sheets usually contain limited information about them. The most important questions were:

i) what are video signal transients, generated by ns duration light pulses, like,

ii) how does the imaging tube behave in the case of strong saturation by short light pulses.

Block diagrams of the experimental set-ups are shown in Figs. 1**a** and 1**b**. Light sources were He-Ne and Nd:YAG lasers with the following parameters:

He-Ne – 5 mW, cw,

Nd:YAG – 5 mJ, pulse length = 10 ns, Q-switched.

The continuous beam of the He-Ne laser was modulated by an AO modulator. The pulse length could be varied from 1 ms to 10 ms. As light intensity could be adjusted by neutral density filters, we could produce pulses of the same energy but of different duration. The Nd:YAG laser had a fixed pulse length (10 ns), but its energy could also be adjusted by neutral filters.

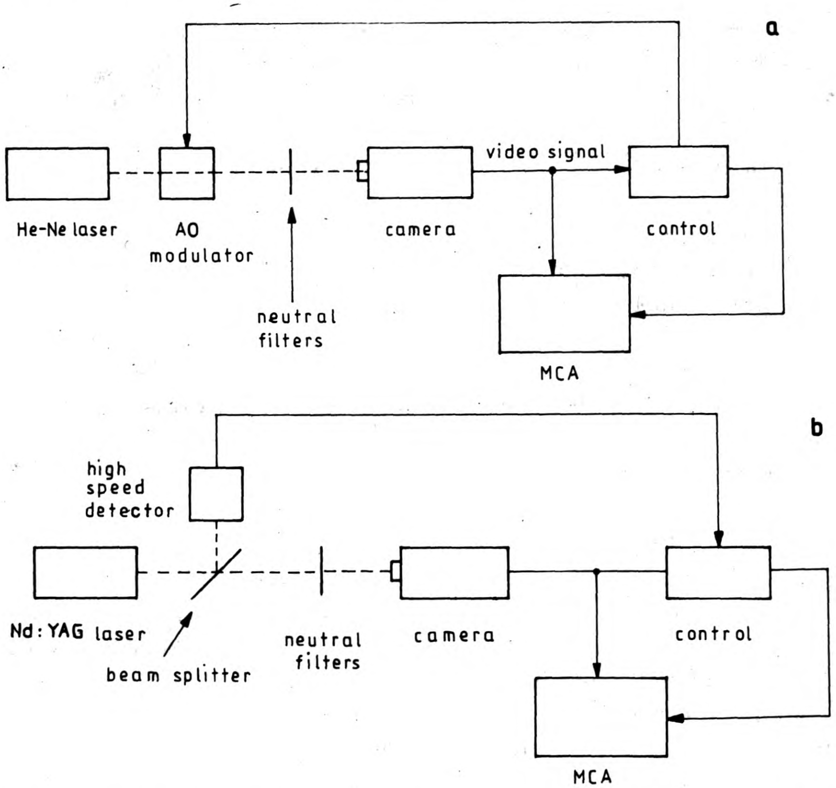

Fig. 1. Experimental setups for measuring video signal transients: **a** – He-Ne cw laser with AO modulator, **b** – Nd:YAG pulsed laser

A Toshiba E5052(S) type silicon target imaging tube was used in our experiments. The camera's electronics was made by HTSZ (Minilux TV 11–23 A.2.). Data were recorded by an ICA–70 multichannel analyzer, and a Phillips 2210 digital storage oscilloscope, respectively. Measurements were controlled by a home made electronics. This instrument was connected to the camera and counted the rows and pixels during scanning. One field consists of 312 rows, in each row there are 512 pixels. For the measurement we used only a 256×256 matrix. The instrument displayed the actual position of the electron beam, when the video signal exceeded a pre-set comparator level. In addition, it gave a sampling signal for the analyzer or a starting signal for the oscilloscope at a fixed position during scanning.

3. Video signal transients

In Figure 1**a** the measurement was synchronized to the camera. The starting signal controlled the AO modulator, through which a light pulse reached the camera. The pulse length t_1 and delay relative to the synchron signal t_2 could be adjusted. After this pulse the amplitude of the video signal was measured and stored by the analyzer at the same pre-set positions of the subsequent fields. In Fig. 1**b** the measurement was started by a high speed detector.

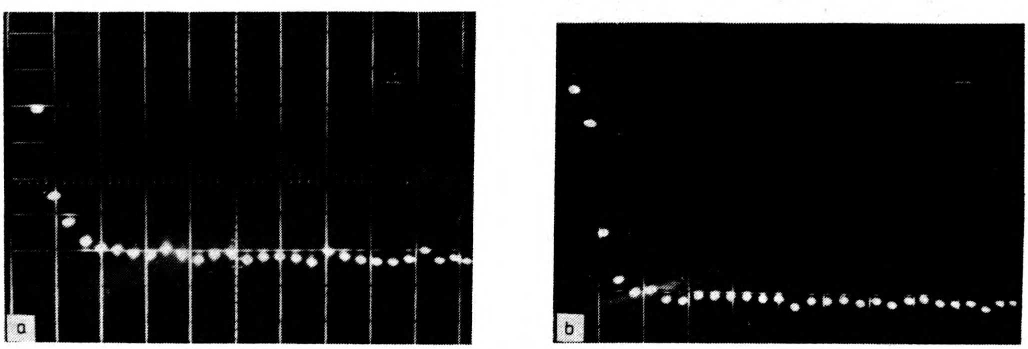

Fig. 2. Image lag below saturation. Vertical axis: amplitude of video signal in arbitrary units. Horizontal axis: 50 ms/div. Energy of pulse 10^{-12} J. Pulse lengh = 4 ms (**a**) and 10 ns (**b**)

We got exponential decay curves shown in Fig. 2, which are in good agreement with those given in paper [4]. Even below the saturation exposure information is stored for the duration of 2–3 fields. The results were the same when using pulses of different lengths but of the same energy (Fig. 2). It appears that behaviour of the camera is determined by the light energy only, and that it does not depend on the pulse length in a wide range (10 ns–10 ms). Thus, the camera can be used also for measuring extremely short light pulses. In addition, our measurements have proved that delay time t_2 does not affect results, i.e., the charge stored on the retina is influenced only by the reading electron beam.

3.1. Image lag in the case of a strong saturation

The experiment described before was repeated with pulses of higher energy so that they caused saturation. Time dependence of the video signal is shown in Fig. 3. The

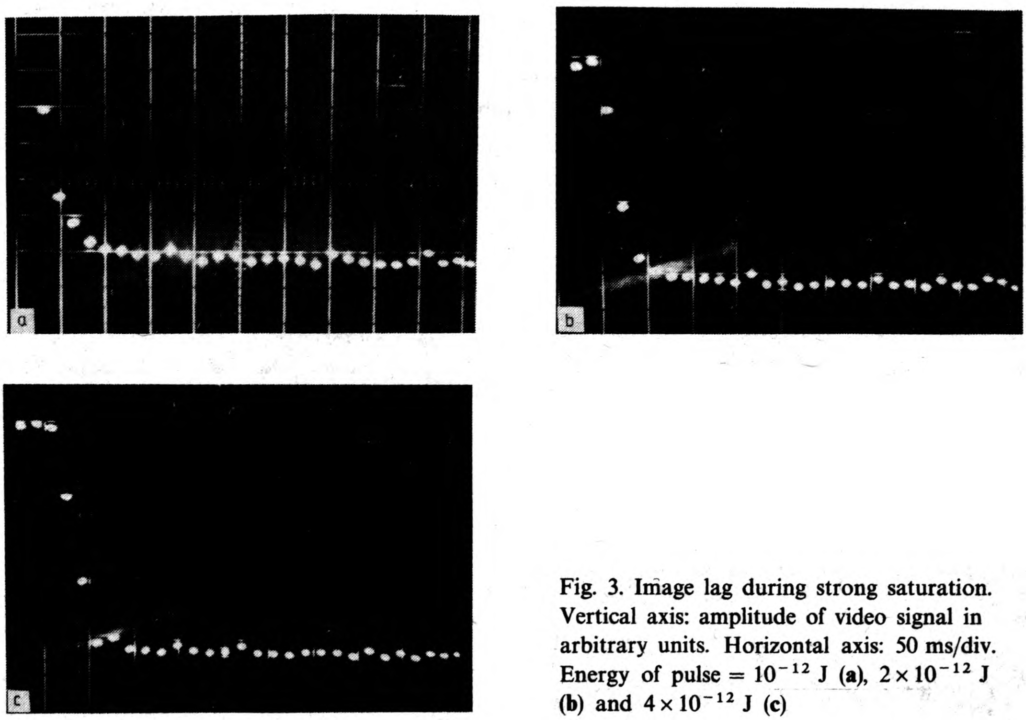

Fig. 3. Image lag during strong saturation. Vertical axis: amplitude of video signal in arbitrary units. Horizontal axis: 50 ms/div. Energy of pulse $= 10^{-12}$ J (a), 2×10^{-12} J (b) and 4×10^{-12} J (c)

higher the energy was the longer the saturation lasted, and the time constant did not change (Fig. 3). It means that the amount of charges held on the Si target by one diode may be much greater than that which could be carried away by the electron beam during one scan.

3.2. Blooming due to strong saturation

During strong saturation the focused, originally small, spot is spread. This effect causes some problems, when the spot position is measured simply by a comparator, since then the result is false.

This effect was examined in the experimental setup shown in Fig. 4. The measurement was started by using a high speed detector. Our instrument started the four channel digital scope always at the same scan position. In this way the scope stored the same part of the next 4 fields.

It was observed that the spot centre did not move. This is a useful information for the position evaluation. However, while measuring image lag in this case it has been stated that all the points of the large spot disappeared simultaneously and no

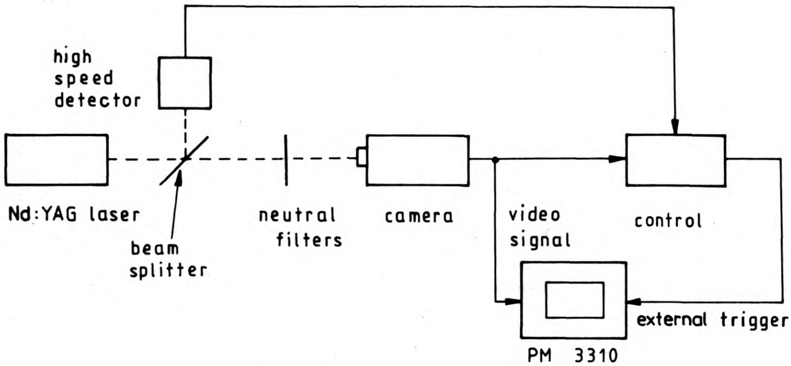

Fig. 4. Experimental setup for measuring the blooming effect

contraction of the spot could be observed. This observation indicates that within the spread spot a uniform charge density is formed in a time shorter than the duration of one field.

4. Conclusions

Experimental results can be interpreted as follows:

Charge (Q) formed on the retina is proportional to the incident energy (E). This relationship can be written in the form

$$Q = n \times a \times q$$

where: q — charge amount carried away from the retina by the electron beam during one scan, a — number of pixels covered by the spot, n — number of scans needed for the complete discharge of the retina. q is a constant characteristic of the camera, a and n depend on the incident energy

$$a \sim E^c, \quad n \sim E^d$$

where $c < 1$, and $d < 1$, but $c+d = 1$.

Our experiments have shown that the silicon target camera can be used for position measurement of short light pulses in a wide intensity dynamic range. However, during evaluation of position blooming must be taken into consideration.

References

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Поведение изобразительной лампы при освещении короткими импульсами света

Исследовано поведение видиконной изобразительной лампы в случае облучения короткими импульсами света (нс). Заряд на сетчатке был пропорциональный световой энергии, размыв создавал пятно с однородной плотностью заряда.