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READOUT AND PROCESSING DEVICES FOR PICOSECOND STREAK CAMERAS

C. CAVAILLER, N. FLEUROT, D. MAZATAUD, R. VERRECCHIA

Commissariat à l'Energie Atomique, Centre d'Etudes de Limeil,
B.P. n° 27, 94190 Villeneuve-Saint-Georges, FRANCE.

ABSTRACT

The use of streak cameras in laboratories working on Laser Fusion is still too often limited by the long procedure required for film processing before delivering an useful diagnostic.
Here we present different ways (vacuum low level TV tube, linear solid state array of photodiodes) developed in our laboratory to readout the images of streak cameras.
They provide time resolution in the 10 ps range, with one to 32 spatial channels and may be interfaced with the computer data acquisition system now used in Limeil.

I - INTRODUCTION

The complete diagnostic in laser matter interaction experiments requires to characterize both the laser input pulse on the target (energy, time profile, duration..) and the experimental plasma parameters (analysis of target emissions in the infrared to U.V. and X-ray range, electrons and ions, neutrons, etc...).

Here we present the work undertaken at Limeil to improve the time resolution diagnostics with streak mode. In order to achieve this purpose, two complementary ways of development have to be simultaneously carried on..

. The first one consideration consists in developing a high resolution image converter tube (I.C.T.) called P600 which is described in an other communication.

. The second one is related to data handling and processing : in order to avoid the time-consuming processings required by the photographic film, we have designed two different automatic readout devices respectively adapted to single and multichannel time resolved analysis of luminous phenomena /1/, /2/.

II - SINGLE CHANNEL RETICON READOUT DEVICES

We define the single channel readout of streak camera as the mode in which a single point of the photocathode is analysed along the time axis on the screen (no spatial resolution).

II-1. Reticon readout device

In order to designe an inexpensive device we have just adapted a commercialy available solid state detector to our requirements which are essentially : maximum sensitivity, triggering capabilities. We chose the RETICON RC 1024 SF, which is a linear array of Silicon sensors, because of the following reasons :

- Sensitivity : the most important point rely on the availability of a fiber optic plate (model 1024 SF) mounted on the input face of the detector. This allows an efficient direct optical coupling to the fiber plate of the streak I.C.T., giving an overall equivalent light gain high enough to ensure a large dynamic in the picosecond time range.

- Pixel shape : each elementary sensor has a rectangular shape of 1 to 100 aspect ratio (25 µm x 2.5 mm) which is particularly well adapted to match streak readout requirements :
  . the 2.5 mm dimension of each element is aligned along the spatial axis of the image ; this produces a 100 times integration effect (compared to standard 25 µm elements) which improves the signal to noise ratio by a factor of ten ;
  . along the time axis, each pixel is 25 µm long and represents resolved elements varying approximatively between 1 ps to 25 ps for standard inverse sweep speeds ranging from 40 $ps.mm^{-1}$ to 1 $ns.mm^{-1}$. This corresponds to at least four or five pixels for sampling each resolved elements on the screen of the I.C.T. and seems satisfying. The useful length is nearly 25 mm.

- Triggering : a special readout cycle has been added to the standard Reticon circuit in order to provide the external triggering of the device. This contributes to reduce the dark current noise and improve the dynamic range.

- Mechanical package : a special readout and its circuit were mounted in a mechanical holder which replaces the classical film holder and which ensure a good coupling between the two fiber optic plates.

- Display : for this experimental phase, we display tne analogic signal directly on a standard oscilloscope. An automatic processing and display unit is now being studied and will make the acquisition easier.

II-2. Performances

This device can be mechanically coupled with either to a TSN 505 camera (R.T.C. XX 1370 image converter tube) or to a TSN 503 camera (R.C.A. 73435 coupled to an I.T.T. microchannel intensifier). In this last configuration we have illuminated the S20 photocathode through a Fabry-Perot etalon providing a train of successive pulses decreasing by a factor of 2 in amplitude and separated by 200 ps ; Fig. 1 shows the signal displayed by the oscilloscope : it is possible to observe 8 laser pulses of 40 ps using this Reticon readout device.

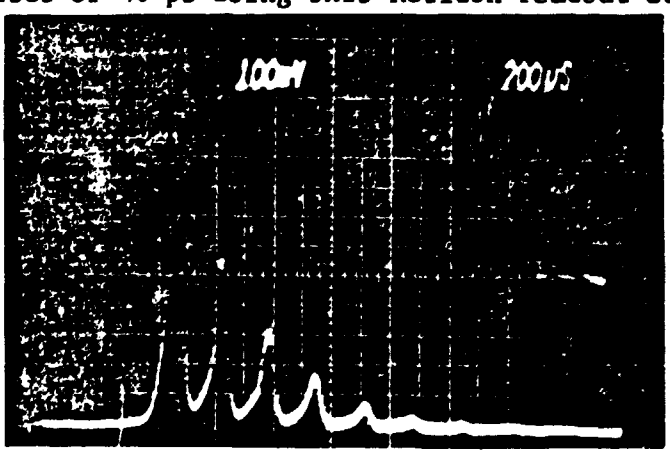

Fig. 1. Reticon readout of a laser pulse using a TSN 503

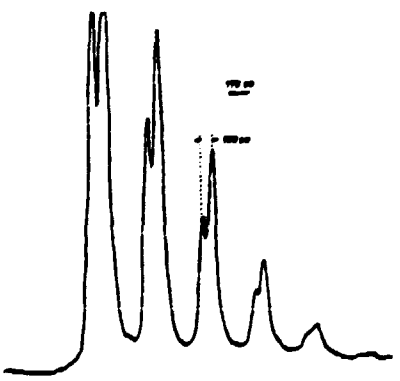

Fig. 2. Temporal profile of OCTAL laser pulse through a Fabry-Perot Etalon

This first encouraging result is very promising because, with a limited hardware it is possible to avoid the use of photographic film and the temporal shape of the luminous phenomenon under study can be available in the same way than for a standard oscilloscope, but with picosecond time resolution.

III - MULTICHANNEL DATAIC READOUT SYSTEM

III-1. Experimental DATAIC (Four channels)

This experimental system has been previously discussed /1/. It allows the direct readout of the images of a TSN 503 with a 2 inches standard Image Isocon TV tube coupled by a fiber optic plate to the streak I.C.T. of the TSN 503. Four spatial channels can be analysed along the slit of the photocathode with 512 points along the time axis for each one.

- Experimental results

We have taken advantage of the demonstrated performances (time response : 13 ps ; dynamic range 100 to 150, /1/) in order to control the output pulse shape of the large 8 beam glass laser (OCTAL) used at Limeil for laser matter interaction experiments.

A part of the 1.06 µm output laser pulse is converted to 0.53 µm by a KDP crystal and directed to the photocathode of the camera through a 500 ps Fabry-Perot etalon (designed to calibrate pulses decreasing by a factor of two). Several hundreds temporal profiles of OCTAL laser output beam have been recorded (Fig. 2.) and each one was delivered within the two minutes following the laser shot ; this allows an immediate detection of any kind of undesirable modulation as it can be observed in Fig. 3.

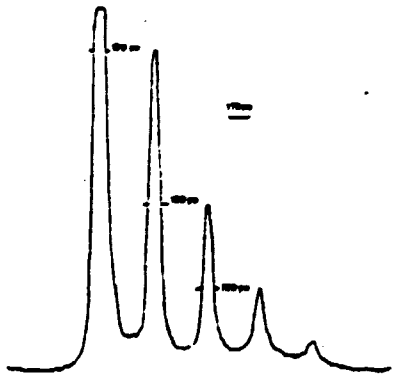

Fig. 3. Modulated temporal profile of OCTAL Laser

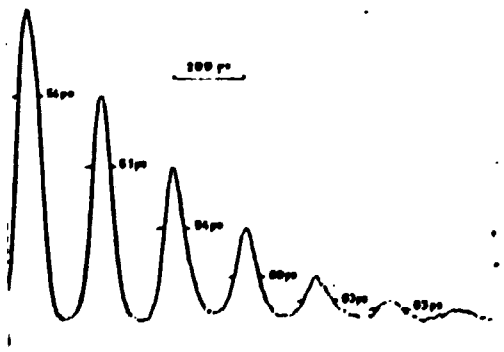

Fig. 4. 1.06 µm, 54 ps laser pulse recorded with DATAIC system

- Infrared detection

This system proves its efficiency in the infrared spectral range : a P500 S1 I.C.T. sensitized in an R.T.C. structure by Mrs F. GEX and Mr ALEXANDRE (Laboratoire LALLEMAND, Observatoire de PARIS) is now replacing the S20 R.C.A. image tube. A 1.06 µm and 54 ps YAG laser pulse can be recorded without the help of any image intensifier between the streak tube and the TV tube (Fig. 4.) ; this first result give us confidence in the development of our program in the infrared spectral range.

III-2. Standard DATAIC system (32 channels)

- Structure of standard DATAIC

The standard system has been redesigned with THOMSON-CSF and NUMELEC-S.E.I.M., taking into account the experience of the prototype built in Limeil and the spatial resolution of this system has been extended up to 32 channels in the acquisition unit ; the microprocessor which is in charge of the system is now able to perform correction of the black level, non uniformity in the light gain and non linearity of the transfert function of the camera.

- Performances of Standard DATAIC

The standard system was tested in the S20 TSN 505 with an R.T.C. XX 1370 I.C.T. and has shown :
. a time resolution of 8 ps ;
. a dynamic range > 64 for $\tau \simeq 40$ ps.
It is at least 100 times more sensitive than the experimental DATAIC (the XX 1370 has a built in microchannel plate intensifier) so it can be used for any kind of low light level experiment.

This system will be soon converted in the X-ray range (1-10 keV. It will work with an R.T.C. P500 X image converter tube to be used for diagnostic of plasma experiments, coupled to the 16/40 solar data acquisition system already used for other diagnostics purpose.

IV - CONCLUSION

Two systems are now able to readout the images of streak cameras from the infrared to U.V. spectral range :
. a low cost, single channel device, able to replace a fast oscilloscope, but with a much better rise time or equivalent bandwidth ;
. a more performant multichannel readout system, competitive with standard cameras, able to work either in the local mode or directly interfaced with the more powerful computers used for data acquisition and processing.

These two systems, which are complementary, have now to be adapted to the specific constraints of X-ray streak camera detection.

We want to acknowledge the contribution of Miss O. MARTIN and Mr B. MERIC for their help in the development of Reticon device.

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