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Nanosecond gating of an optical multichannel analyzer

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An optical gating pulse of 30 ns width combined with an electronic gating pulse of 50 ns width has been found to give a near perfect performance of a gated silicon intensified vidicon detector. The magnification as well as the focusing properties are found to be close to the real-time behavior and the small changes that do occur in the gated mode can be corrected for in the data analysis.

INTRODUCTION

Observations of fast varying optical signals require a detector system with the possibility to isolate short time periods. Presently available multichannel analyzing systems using intensified vidicon detectors impose problems in the response function when the detector is used in the gated mode. It occurs frequently that a light source is turned on for a long time of, e.g., several microseconds, while the detector is to observe periods of the order of tens of nanoseconds due to the rapid variations of the conditions in the light source.[1] Thus, the detector must be blind during most of the time even though the light source is on. A different problem arises in the detection of a small fast signal on a high long lasting background level. This situation also imposes the requirement for a detection system that is registering only during the time the signal comes, so that no undesired integration of background light is performed.

We have investigated these problems carefully by gating an optical multichannel analyzer electronically as well as optically and in detail studied the behavior of the detector response for different conditions. We have developed a system which, as will be seen, can be used with pulses of a few nanoseconds to some hundred nanoseconds. This has a wide application range in experiments where time-resolved detection is necessary. We can mention our immediate application, which is to detect a spectrum of pulsed laser light scattered from a dense plasma.[1] Furthermore, experiments concerned with the atomic processes in the plasma, e.g., ionization, excitation, and recombination processes need time-resolved detection systems.[2]

I. DETECTOR

The detector, an optical multichannel analyzer (OMA) consists of a doubly intensified silicon vidicon tube (ISIT) with a linear array of 500 channels. The sensitivity of the ISIT tube is fairly constant between 3500 and 8000 Å (0.04–0.07 counts/photon according to specification). In a continuous mode (real time) the de-

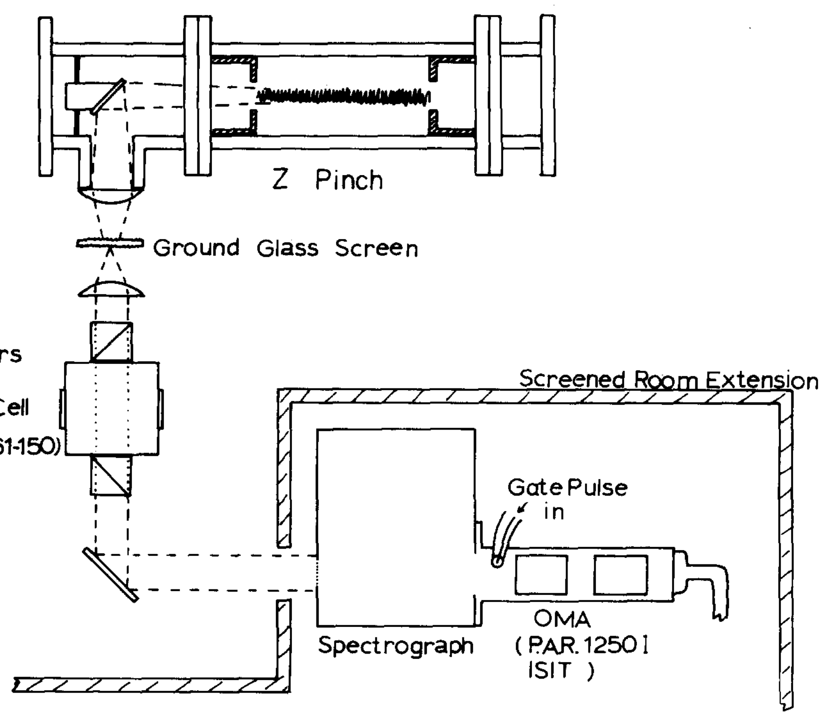

FIG. 1. Experimental setup for the testing on the OMA detector. The spectrograph is set to zero order reflection and a pulsed white-light source (*Z*-pinch) is used with the gating pulse.

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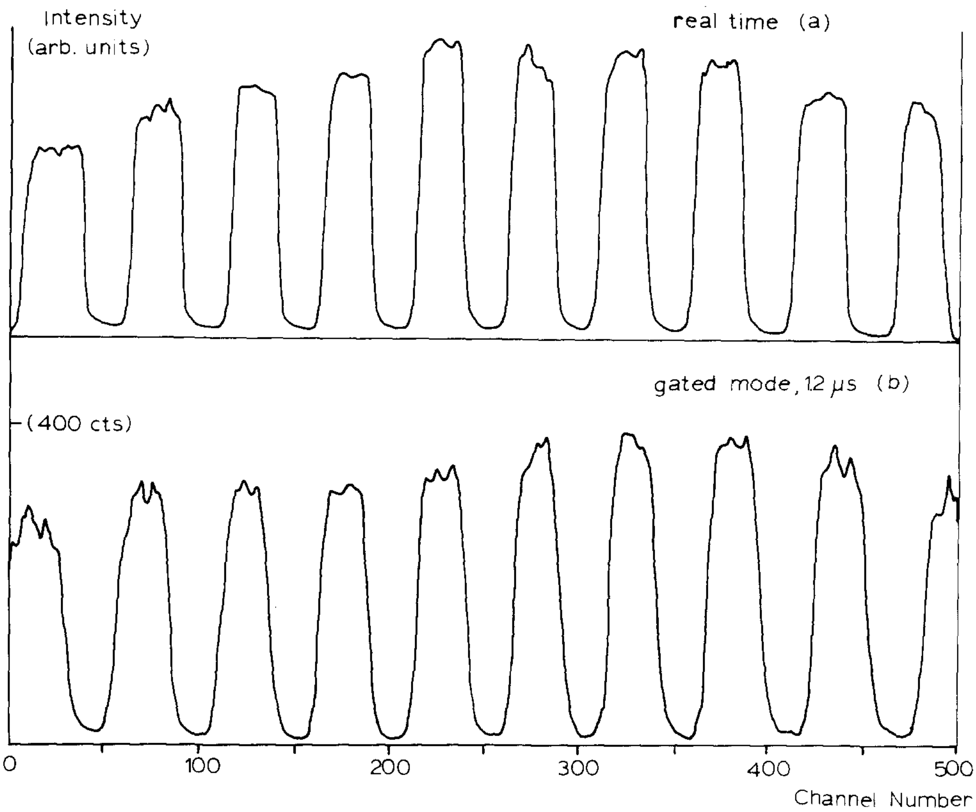

FIG. 2. The intensity response from the 500 channels, using a ten-slit package as entrance slit to the monochromator. (a) shows the real time behavior, (b) shows the detector signal in gated mode using a 1.2 μs electronical gating pulse. The intensity level in real time is kept well below saturation.

tector is scanning the channels in 32 ms with a time between sweeps of 768 μs. Thus the detector is registering most of the time. The accelerating negative voltage $\sim$ 8 kV is applied directly to the photocathode. The total sensitive area of the detector head is 12.5×5 mm. The detector can correct for dark current due to thermal effects as the optical signal is acquired. Each channel is divided into a light and a dark half and a special scanning pattern allows the two parts to be electronically subtracted and integrated to obtain a voltage proportional to exposure. Background due to stray light can be stored in a second memory and subtracted using the arithmetic logic. The maximum number of counts that can be registered is $\sim$5000, where each count corresponds to $\sim$20 photons reaching the detector. If the detector is used in the gated mode the gate is synchronized with the readout beam which is being held off until the gate is over. Furthermore, in order to read off the total signal, the read-out beam is allowed ten passes before the next gate can open the detector. For further details concerning the characteristics and behavior of the OMA detector we refer to the manual which is available from Princeton Applied Research.

The detector is mounted directly in the focal plane of a monochromator. The experimental setup is shown in Fig. 1 where the pulsed light source consists of a z-pinch.[1] The optical system is shown schematically. In order to test the performance of the detector system the monochromator was set to zero order and a package consisting of 10 slits ($\sim$63 μm wide, $\sim$63 μm apart) was

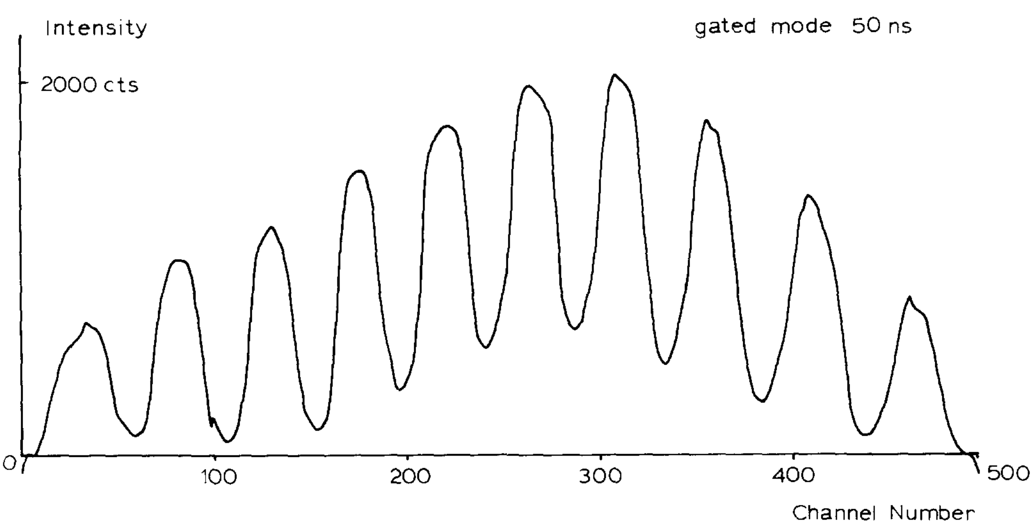

FIG. 3. The intensity response from the OMA in gated mode using a 50 ns electronical gating pulse. The setup is the same as for Fig. 2.

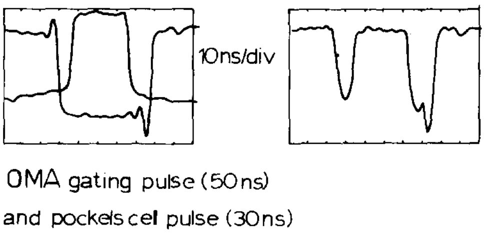

FIG. 4. The combined gating pulse consisting of a 30 ns optical gate and a 50 ns electronic gate. The pulse height is adjusted to 1.2 kV. An addition of both pulses is shown to the right.

mounted as entrance slit to the monochromator.[3] The light pattern as registered by the detector in real time with this setup is shown in Fig. 2(a). White light was used to eliminate any dependence on wavelength and to get a uniform illumination of the slit package in real time using the optical setup shown.

II. GATING OF THE DETECTOR

The original gating circuit in the OMA head of the ISIT 1205 I tube was modified. First, in order to reduce possible noise on the fast high voltage pulse reaching the photocathode, the pulse input contact was moved from the rear end of the detector head to the point closest available at the gating switch. Second, the modifications suggested by Simpson *et al.*[4] were incorporated, including changing the termination resistor of

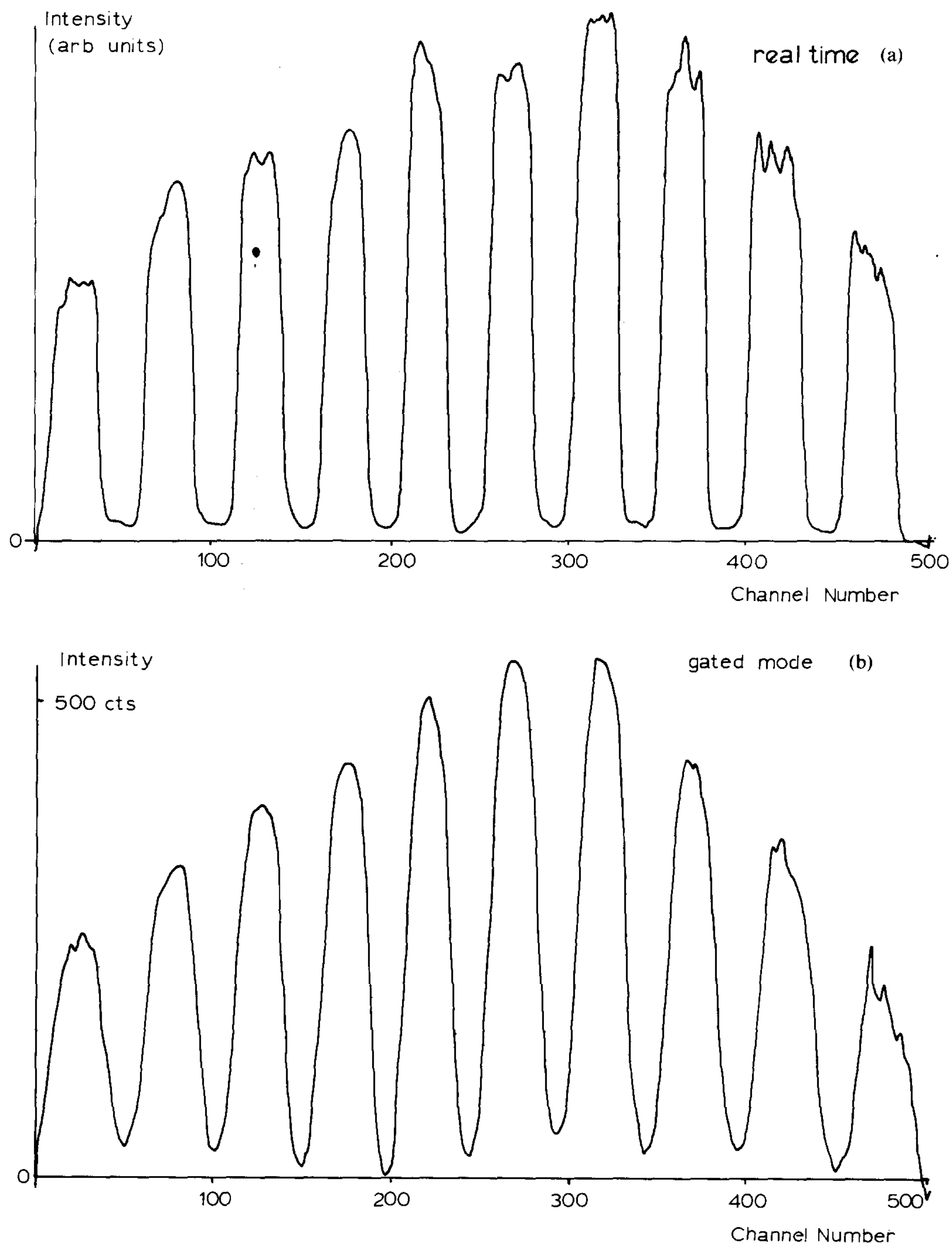

FIG. 5. The intensity response from the 500 channels using the combined gating pulse from Fig. 4. The setup is the same as for Figs. 2 and 3. The complete absence of any underlying background level in the gated mode is noticeable.

the gating pulse so that a 50-Ω termination was achieved. The high-voltage pulse applied to the photocathode, −1.2 kV, was supplied from a 50-Ω cable discharging directly into the OMA head termination.

III. MICROSECOND GATING PULSE

If the gating pulse can be in the time scale of a microsecond or longer it can be seen from Fig. 2(b) that the detector response is very close to real time behavior aside from a stretching of the channel number scale. This can easily be taken into account in the analysis of a spectrum.

IV. 50 ns GATING PULSE

The performance of the detector when the pulse length is decreased to 50 ns is shown in Fig. 3. It is obvious that there are serious distortions in the response function when the detector head is only gated electronically:

(i) the intensity distribution is severely distorted for the whole spectrum and depends on the intensity level,
(ii) the resolution is destroyed and a background level is rising under the central portion of the spectrum, and
(iii) the wavelength distortion is inhomogeneous and depends on the intensity level.

These response distortions of the detector system make it necessary to apply extensive correction procedures to the raw data before a reliable intensity distribution can be achieved.[5] It is reasonable to assume that the distortions arise during the rise and the fall of the gating pulse. The defocusing effects are presumably caused by the incorrect and time-varying voltage applied to the photocathode. This conclusion is in agreement with the results of Simpson *et al.*[4]

V. COMBINATION OF OPTICAL AND ELECTRONICAL GATING PULSE

One way to eliminate the distortions coming from electronic gating is to use optical gating with an electro-optical switch (Pockels cell). The optical gating results in no distortions in the spectrum; however, the contrast ratio is low, leading to serious noise problems. The electronic gating, on the other hand, results in distortions across the spectrum; however, the contrast ratio is high. Ideally one would like to combine the distortion-free switching characteristic of an optical gate with the high contrast ratio of an electronic gate. We attempted to achieve this by combining both gating methods. In order to let a light signal reach the detector only during the time the electronic gating pulse voltage was constant, an optical gate (Pockels cell) was added to the system, fitting the 30 ns gating pulse for the Pockels cell temporally into a 50 ns pulse for the electronic gating as shown in Fig. 4. The voltage of the electronic pulse was adjusted so as to give the least

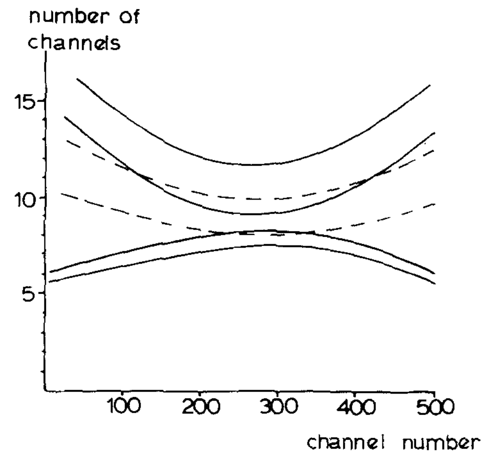

FIG. 6. A comparison of the focusing properties for the three investigated cases. The number of channels on the rise and fall of the slit image is shown as a function of channel number for the three cases. The upper solid shows the electronically gated mode, the lower solid curve shows the real time behavior and the dashed one shows the results from the combined gating pulses.

distortions over the whole spectrum. The timing of the pulses was achieved with discharging krytrons. It is seen from Fig. 4 that the high voltage level of the gating pulse is stable during the 30 ns the Pockels cell is open. The optical surface of the Pockels cell was antireflection coated for 6943 Å and there will be certain reflection losses when the Pockels cell is used at other wavelengths (even though the voltage across the crystal is changed in proportion to the wavelength). The performance of the detector in this mode is shown in Fig. 5 and is in satisfactory agreement with the real time response function.

It should be noted, however, that the intensity level is relatively low in order to get this real-time response curve. We have found that for the ISIT detector the linear response levels off at an intensity level close to 2000 counts even though the detector should be able to handle ~5000 counts according to manufacturer specifications. Thus the focusing properties of the detector are highly sensitive to the intensity level as well as the properties of the gating pulse. A measure of the resolution can be obtained by counting the number of channels observed between maximum and minimum counts if a sharp shadow is imaged onto the OMA. This is shown in Fig. 6 where the number of channels on the vertical rise and fall of each slit in the ten slit package has been plotted versus channel number for the real time (lower curve), for the electronic gate (upper curve), and for the combined gating pulse (dashed curve). The width of the curves shows the uncertainty in this measurement. It is evident that a change in the focusing occurs even with a stable combined gating pulse.

VI. RESULTS

We have experimentally verified that the distortions appearing when gating an OMA detector electronically arise from the exposure during the switch-on and switch-off. To overcome this drawback we have developed and tested a gating system for an intensified vidicon detector where the focusing and magnification remain almost unchanged for pulses down to 30 ns. It is found that a low intensity level as well as a constant voltage pulse are very important for the detector performance. This gating system could be used for nanosecond gates by simply shortening the optical gate as needed.

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