CERN-Data Handling Division
DD/83/2
March 1983

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(Submitted to Nuclear Instruments and Methods)

DD-jt

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ABSTRACT

The Optical Fiducial Volume Trigger system (OFVT) has been developed for use with the Rapid Cycling Bubble Chamber (RCBC), serving as a vertex detector in the European Hybrid Spectrometer (EHS). Its purpose is to decide whether an interaction took place within the useful (fiducial) volume of the chamber. In this way it complements the main interaction trigger which lacks the necessary accuracy of vertex localisation. The system can reduce the cost of film material, film treatment and scanning by up to 60%, the precise saving being dependent on the experimental conditions. The principle of the optical track detection by linear diode arrays is described, as well as details of the hardware construction. The properties of the system are discussed on the basis of results from the first run with RCBC.

1. INTRODUCTION

The Optical Fiducial Volume Trigger (OFVT) was designed for the European Hybrid Spectrometer (EHS), which is installed in the north area of CERN Geneva, and uses a particle beam generated by the 400 GeV Super Proton Synchrotron (SPS). EHS is a two lever arm spectrometer of 40 m length combining about 20 independent particle detectors for momentum measurement and identification of particles originating from nuclear events (ref. 1). A Rapid Cycling Bubble Chamber (RCBC) located inside a 3T superconducting magnet serves as a target for the injected particle beam and as a vertex detector for the events. Several types of bubble chambers are used alternatively. The OFVT system was designed for the largest of them, RCBC, which has a diameter of 80 cm. RCBC is equipped with three photographic cameras which take stereoscopic views of the tracks. To ensure that only photographs of interesting events are taken the cameras are activated only when an event trigger indicates that an interaction has taken place. This fast trigger, however, is incapable of localising the position of the interaction vertex with sufficient precision and only about one third of the events so triggered are situated within the useful volume of the bubble chamber. It is the purpose of OFVT to determine whether an event which caused the trigger was actually within the fiducial volume and to veto the trigger if this was not the case.

The OFVT system yields the following benefits:

1.1 FILM SAVING

Several hundred thousand photographs have to be taken for a typical physics experiment. In addition to the scanning costs, one frame (3 views) costs at least one Swiss Franc for film material, film processing and handling. Therefore a reduction of up to two thirds of the triggered photographs results in substantial savings per experiment.

1.2 MORE EFFICIENT USE OF ACCELERATOR TIME

Once the cameras have taken a photograph, the film has to be advanced. This takes longer than the time between two RCBC expansion cycles. Inhibiting useless photographs results in a reduction of the total dead time, so that more useful pictures can be taken and the accelerator time used more efficiently.

1.3 REAL-TIME CHECK OF TRACK QUALITY IN RCBC

As described later, OFVT looks at the tracks in the bubble chamber at each expansion and displays on a monitor the profiles of the tracks. Therefore any degradation of the track quality, otherwise only evident after the routine development of film test strips, can immediately be detected. This again contributes to the saving of film and of accelerator time.

This paper describes the design of the OFVT hardware. The implementation of the OFVT system for physics experiments is explained in ref. 2.

2. WORKING PRINCIPLE OF OFVT

The particle beam which enters the bubble chamber is focussed into a horizontal band of 100 mm height and 10 mm thickness (fig. 1). Shortly after beam injection the OFVT system looks at two narrow vertical strips across the beam, one near the beam entrance and the other one near the beam exit (strips A1 and A2 in fig. 1). It detects and memorizes the coordinates of all tracks crossing the strips in a direction parallel to the beam. In the meantime the trajectory of the beam track which caused the event trigger has been roughly calculated from the data of two upstream wire chambers (U1,U3), so that only a small part of each strip needs to be examined to search for the corresponding track pulses. On the basis of the presence or absence of the expected track pulses, it is decided whether the interaction took place inside or outside the fiducial volume. The decision logic is explained in ref. 2.

The detection of the track elements is performed in the following way. Once the tracks have grown to a sufficient size, the chamber is illuminated by an electronic flash via a semitransparent mirror placed in front of the objective lens. A layer of Scotchlite on the back of the chamber retrodirects the incident light through the semitransparent mirror into the objective lens. The lens forms a brightfield image of the beam plane in which the tracks appear as shadows. In the image plane two linear diode arrays are positioned so that the images of the strips to be examined fall upon the arrays. The tracks are formed by individual bubbles, the spatial density of which varies statistically around a mean value. To reduce the corresponding variations of the signal amplitude the tracks are integrated optically over a length of 11 mm. This integration is achieved by combining two effects. First, an array of long rectangular diodes is used (each 750 μm X 15 μm). Secondly, a cylindrical lens is placed in front of each array, compressing the image in the direction of the track by a factor of 3. This, in conjunction with the 5.3 : 1 optical demagnification of the objective lens has the result that the area covered by one array in the chamber is 150 mm X 11 mm, each of the 1872 cells covering a width of 0.08 mm. (fig. 1 bottom right).

It should be stressed that in the image plane the scale perpendicular to the beam tracks remains unaffected by the cylindrical lens. Therefore the track widths and the distances between tracks are not changed.

Fig. 2 illustrates the procedure of track element detection in a practical case. The upper part shows an overall view of the chamber. On the lower part one sees oscillograms showing the track pulses from arrays A1 and A2, mounted on enlargements of the corresponding parts of the upper photograph.

3. TIMING

The flash for the RCBC cameras is fired 1.5 ms after the event trigger (fig. 3). The veto from OFVT must be available before this moment.

The total time required by OFVT to produce a decision after its flash is triggered amounts to 600 μs, made up as follows:

100 μs	OFVT flash duration
200 μs	array read-out, track detection and digitisation
300 μs	logic decision
600 μs	total

During the first run of OFVT it was found that the OFVT flash delay could be as short as 300 μs which then leaves a comfortable time margin of 600 μs (see fig. 8).

4. OFVT REFERENCE WIRE

A 150 μm diameter reference wire for OFVT is mounted in the beam plane of the chamber parallel to the beam tracks.

It serves the following purposes:

- to adjust the optical focus;
- as an absolute spatial reference;

- for on-line checking of the OFVT system quality by monitoring the corresponding pulse from the arrays;

- as a reference for the on-line monitoring of the track quality in the chamber.

On the photograph of fig. 2 the reference wire appears as a continuous line whereas the tracks are composed of individual dots. The corresponding pulses can easily be distinguished from the track pulses.

5. THE OFVT HARDWARE

The OFVT system is divided into four parts which are located at some distance from each other.

The OFVT Camera is mounted in front of one of the small windows of the bubble chamber. It contains the optics, the diode arrays with their associated electronics, the flash box and a sensor to measure the flash intensity.

The Video Unit fastened on the magnet body of the bubble chamber near the camera contains the electronics required for the treatment of the array signals before they can be sent to the Counting Room.

The flash power supply, the water and air cooling systems as well as auxiliary electronics such as power supplies for the camera and the video unit are installed in two racks placed at a distance of 10 m from the chamber. At that distance the magnetic field is low enough (0.03 T) not to disturb the functioning of transformers and motors whereas the two units mentioned previously must work in a field of nearly 3 T.

In the counting room, connected via 50 m long cables, is installed the electronics for the final signal treatment, linked to the ESOP special processor which executes the trigger algorithm, and to the EHS Data Acquisition Computer. In this room there is also a display monitor showing the stored track signals. Another display is located in the control room of RCBC.

In the following the essential parts of the OFVT hardware are described in more detail.

5.1 THE OFVT CAMERA

5.1.1 Camera layout

The OFVT camera is subject to the strong magnetic field of RCBC and to vibrations caused by the chamber expansion system. It must fit into the limited space between the magnet body, the photographic cameras and the camera plate. Furthermore, it has to be accessible at any time for servicing without disturbing the RCBC camera system. These requirements explain the particular form of the camera and its method of mounting.

Fig. 4 shows the camera. It is mounted on a ramp, which in turn is bolted onto the magnet body. On this ramp the camera can be moved by means of a lead screw into and out of the working position. To ease the installation of the camera, the ramp can be pivoted around its centre point. On the upper left side of fig. 4 one can see the flash box with the cables and the pipes for the water cooling of the flash.

5.1.2 Optics

The optical layout of the camera is explained with reference to fig. 5. The flash (13) illuminates the chamber using a water cooled "nonimaging reflector" (12), like those designed for the flashes of the main RCBC cameras, following principles discussed in ref. 3. The surface of the reflector is coated with a cold mirror. After passing through a venetian blind (14) the light is reflected by another cold mirror (15). Whereas the two cold mirrors remove the heat radiation of the flash, the precise spectral filtering is performed by the filter (16).

Half of the filtered light passes through the semitransparent mirror (3) to illuminate the chamber through the main window (1). The other half is reflected into the light trap (2). The light which returns from the chamber after having been retrodirected by the Scotchlite at the back of the chamber is reflected by the semitransparent mirror (3) into the objective lens (4).

The objective lens projects an image of the beam plane onto the arrays (9) via the cylindrical lenses (8). The two mirrors (6) and (7) fold the optical path into the available space. For test purposes the mirror (7) can be replaced by a semitransparent one, which allows exposure of photographic film (11) simultaneously with the arrays.

There are three glass windows and 220 mm of liquid hydrogen in the optical path. The main window (1) is 170 mm thick. The two small windows of the safety tank and of the vacuum tank are 38 and 32 mm thick, respectively. To avoid reflections of the flash light into the objective lens the small windows are tilted by 7 degrees relative to the beam plane. The incident angles of the light rays into these plane parallel plates vary between 6 and 29 degrees. The resulting field curvature is coped with by providing for a separate focus adjustment of each array. The astigmatism caused by the windows and the liquid hydrogen is fortunately directed along the tracks since the optical axis of the OFVT objective lens is perpendicular to the beam centre line. Thus it even aids the optical averaging along the tracks. Had it been necessary, the astigmatism could have been corrected by a long focal length cylindrical lens placed directly behind the objective.

5.1.3 Chamber illumination

The spectral bandpass filtering (600 - 700 nm) of the flash light mentioned under 5.1.2. serves two purposes: It prevents exposing the film of the RCBC cameras which is sensitive to light of up to 600 nm and it keeps the chromatic aberrations of the uncorrected cylindrical lens within reasonable limits. With this optical system including antireflection coating on the chamber windows, and an objective aperture of f:11, about 15 joules are required for the flash to cause 80% saturation of those array diodes which are not "obscured" by particle tracks in the chamber.

The flash power supply is placed outside the strong magnetic field in which the flash has to work. To minimize radiated electromagnetic interference with the RCBC camera electronics, coaxial cables are used to transmit the energy for the flash (max. 50 joules at 30 Hz) and the trigger pulse (20 kV). These cables are 15 m long. The required short flash duration (35 μs full width at half intensity) leads to peak currents of about 2 kA. Therefore a special low impedance coaxial cable was designed and constructed (0.2 ohms, 1.4 μH over 15 m) to keep the energy loss in the cable below 20% of the total energy. The flash tube and its reflector are cooled by a closed deionised water circuit. Because both electrodes of the flash tube, with a potential difference of up to 1000 Volts between them, are immersed in the cooling water, care has to be taken to maintain a low water conductivity ($< 10^{-7}$ S). This is achieved by means of an ion exchanger.

5.2 ELECTRONICS

5.2.1 The diode arrays

The image detectors used in the OFVT camera are RETICON RL-1872F/30 self-scanned monolithic linear photodiode arrays packaged in a 22 pin dual-in-line ceramic housing with a flat top quartz window.

Each diode acts as a capacitor which is discharged by exposure to light. The current which is required to re-establish the original charge is proportional to the exposure and thus contains the signal to be extracted during the read-out of the array. For this procedure the diodes are switched successively to one of four video lines. Thus the video output consists of four synchronous trains of 468 charge pulses which are interlaced in time. The reason for the use of four video lines is to keep the array output capacity at an acceptable level. The disadvantage of needing four separate video channels is compensated by the lower processing speed within each channel. The read-out sequence is controlled by an on-chip shift register which requires only a four-phase clock and a start pulse to initiate the read-out.

5.2.2 Diode signal read-out electronics

The timing constraints of OFVT require that the array data has to be read out fast. The achieved rate of 10 MHz allows read-out in less than 200 μs. The read-out electronics was very carefully optimized for a maximum signal-to-noise ratio.

Signal-to-noise optimisation

The amplitudes of most of the spurious signals are independent from those of the useful diode signals. The first measure to optimize the signal-to-noise ratio is therefore to provide for a maximum amplitude of the useful signal. This is done by adjusting the flash light so that the diodes are nearly completely discharged during one exposure. In the following a brief account is given of the different noise components which are of practical significance, and the means applied to minimize them.

Read-out noise

Random noise arises from pick-up on the clock, start, reference and video lines, as well as from noise in the charge-to-voltage converter and other analog signal processing circuitry. This noise component is minimized by careful circuit layout, thorough grounding, shielding, decoupling and by the use of low noise components.

Thermal leakage (dark signal)

The diode arrays are subject to thermal leakage current which adds a signal to that resulting from the exposure to light. At room temperature a leakage current contribution of 1% of the saturated output signal is reached after 40 ms. In other words, if this 1% limit has not to be exceeded, consecutive read-outs must not be separated by more than 40 ms. In fact, the time between read-outs is variable and can be many seconds. The problem of thermal leakage is solved by performing a read-out immediately before the exposure. This process acts as an erase operation in the course of which the read-out data is disregarded. This erase procedure also removes spurious signals due to the RCBC flashes.

Fixed pattern signal (background)

A fixed pattern signal originates from feed-through of the transients of the complementary clock driver signals onto the video lines. The glitches so produced are always present and independent of the signal amplitudes produced by the exposure of the array to light. The effect can be minimized by carefully adjusting the relative phases and amplitudes of the clock driver signals.

Another contribution to the fixed pattern noise arises from the differing sensitivities of individual photodiodes. This component is proportional to the exposure. Finally, with the exception of the reference wire, any constant structure in the optical image of the photodiode arrays can be considered as fixed pattern noise. It can be due to spatial non-uniformities in the chamber illumination, of the Scotchlite or "dirty" surfaces in the optical path. These three effects are additive. Since they are constant it is possible to compensate for them. Basically the compensation consists of reading and memorizing the background and subsequently subtracting it from the video signal at every read-out. The manner in which this is done is explained in 5.2.3 below.

Exposure variations

Shot-to-shot variations of up to 10% in the light output from the flash tube have to be coped with. The problem arising from this is that a constant background gets subtracted from a variable signal. It was solved in the following way. A sensor mounted in the camera image plane measures the light intensity of each flash pulse. The integrated intensity, which is proportional to the total light energy, is stored digitally. The signal so obtained is used in the Background Subtraction unit to scale the amplitude of the background signal, before it is subtracted from the video signal.

5.2.3 Functional description of the OFVT electronics

The OFVT electronics is described with reference to the block diagram of fig. 6.

The diode array and the cylindrical lens form a pre-adjusted block which is mounted into the frame of an Array Unit. To focus the image of the tracks onto the array the position of the whole array unit is adjustable (fig. 7).

The electronics board mounted inside the frame of the array unit contains four charge-to-voltage amplifiers to which the four previously mentioned video output lines are connected. Since the charge pulses are of very low level, careful layout and screening of these amplifiers is essential. Line drivers transmit the pulses via coaxial cables to the Video Unit. The electronics board unit also contains a generator for the four-phase clock signals driving the array read-out. These clock signals must have a good symmetry and have stable phase and amplitude relationships in order to minimize feed-through to the video signal. The pulse generator is controlled by a clock and a start signal from the Control Sequencer (see below). The array unit is furthermore equipped with a very low noise voltage reference which serves to recharge the diode capacitances to their reference levels.

The Video Unit further processes the voltage pulses from the array camera in four separate channels. The pulses are integrated to obtain a signal proportional to the exposure of the corresponding diode. The result of this integration is stored in a track-and-hold circuit. The track-and-hold outputs of the four channels are combined by an analog multiplexer into a single 10 MHz boxcar type video signal where each box amplitude corresponds to the amount of light received by the associated diode.

The combined video signal is transmitted to the Background Subtraction Unit where a signal proportional to the constant background is subtracted from it. The background signal is obtained by a normal exposure and read-out cycle with no particle tracks present. It is digitized and stored in a digital memory, the Background Store. See dotted signal path on fig. 6. From there it is transferred, via the ESOP microprocessor, to the ND 100 computer. The same operation is repeated several hundred times and the data are averaged. After suppression of the reference wire signal, this average background is sent back, again via ESOP, into the background store, where it remains unchanged until updated by repetition of the sequence described.

During normal operation the Background Store is read out, converted to its analog form, scaled in its amplitude according to the last exposure and subtracted synchronously from the video signal which contains the tracks. The Background Subtraction unit provides as a result of this operation the subtracted video signal, composed of the track and the reference wire pulses.

The Track Detection circuit first filters the subtracted video signal in a sine-square filter (ref. 4) with a half amplitude duration of 250 ns. This corresponds to about two thirds of a typical track width. Thereafter a clamping circuit is used as a base line restorer and for clipping baseline noise at a fixed amplitude. Finally a double delay-line discriminator converts the analog track pulses into "true width" constant amplitude rectangular pulses.

In the Track Position Memory the position of the track pulses are digitized. The leading and the trailing edge coordinates of each track pulse are read from a synchronous position counter and stored in the memory. The position is digitized with a precision of half an array diode width.

5.2.4 Synchronisation of the OFVT electronics

Fig. 8 shows the electronic timing cycle. It is generated by the Control Sequencer. When an event trigger arrives, the OFVT flash delay is started and a scan start pulse for an array erase function is issued. At the end of the flash delay time an illumination trigger pulse is sent to the trigger subsection of the flash power supply and the flash tube is fired, thereby illuminating the bubble chamber and exposing the diode arrays. One hundred μs after the illumination trigger, when the flash light has completely decayed, a new scan start is generated in order to initiate the read-out of the diode arrays. The Scan Control unit generates all the necessary synchronous control and clock signals for the array cameras, the video units and the data memories.

5.2.5 Display system

During each diode array read-out a digital transient recorder stores the video signals. Continuous display output signals are produced and fed to two CRT-displays, one in the counting room and the other in the RCBC control room.

5.2.6 Test features

The OFVT electronics is partly located on or near RCBC and is subject to its strong magnetic field. The other parts are in the counting room. The magnetic field, difficult access and physical separation call for precautions to be taken in view of system check-up, setting-up and trouble shooting. For that purpose a number of test features have been built into the system. These include the possibility of illuminating the diode arrays by LED-diodes in the camera assembly, a track simulator and several test generators. The electronic system can therefore be tested independently of RCBC. The most complete and convenient tests are run under computer control. With the exception of the track position memory, the correct functioning of the complete hardware can be checked off-line.

5.2.7 Interlocks and status signal

Cooling circuits, power supply voltages and the flash high voltage are monitored and an interlock logic provides the necessary protection in case of a dangerous component failure. The complete interlock status is displayed.

Signals derived from the Light Sensor pulses and processed in the Exposure Meter circuitry are fed to two counters. One totalizes the number of flash triggers and the other one indicates the number of flash triggers resulting in an inadequate light level. A flash monitoring circuit detects spurious triggering or failures of the flash and sends corresponding status information to the RCBC control room.

6. FIRST RUN OF OFVT ON RCBC

During the picture taking period of experiment NA 23 in August 1981 OFVT was put into operation for the first time. The aims were:

- to test the hardware;
- to write track coordinates onto magnetic tape from a sufficient number of pictures for subsequent off-line analysis.

The following results were achieved:

- The system ran smoothly;
- The track coordinates from 11 500 expansions were recorded on tape, using flash delays from 300 to 2000 μs. Data from 80 000 more expansions were recorded with a flash delay of 800 μs;
- The on-line display of the array signals showed that the track pulses were considerably bigger than expected from the predictions (see 6.2.4);
- The on-line display of the track pulses turned out to be a very valuable means of monitoring the working conditions of the bubble chamber in real time. Therefore it was decided to install a slave display in the RCBC control room.

6.1 ANALYSIS OF THE DATA RECORDED DURING THE FIRST RUN

The data recorded during the first run were analysed in order to:

- determine the efficiency of track detection as a function of flash delay, i.e. of bubble size;
- to evaluate the reproducibility of the optical imaging, i.e. the stability of the optical- mechanical system;
- develop off line the algorithm for generating the fiducial volume trigger, and to apply it to the recorded data in order to check its efficiency.

Details of this analysis are reported in ref. 2. The results especially concerning the hardware performance are summarized in the following.

6.1.1 Track detection efficiency

Beam tracks were detected with 100% efficiency at all flash delays between 300 and 1200 μs.

6.1.2 Reproducibility of the optical imaging

With a stable bubble chamber temperature and magnetic field the position of the track signal originating from the reference wire was stable within $\sigma = 40\ \mu m$. This is only half the size of one array cell, referred to the beam plane in the chamber. The background signal of the arrays was also very stable so that the same background compensation could be used for several hours.

6.1.3 Trigger efficiency

Applying the trigger algorithm discussed in ref.2 the following results were achieved:

- 80 to 90% of the "good" events were accepted;
- 60 to 70% of the events outside the chamber were rejected;
- The fraction of pictures containing good events increased from 30% without OFVT to 55 % with OFVT.

6.2 COMPARISON OF THE RESULTS FROM THE FIRST RUN WITH PREDICTED VALUES

6.2.1 Calculated track width

The track width d can be calculated from the working conditions of the chamber using the formula

$$d = 2A \sqrt{t}$$

where t is the bubble growth time. A is a constant depending on temperature T, static pressure p1 and maximum expanded pressure p2 of the hydrogen during the expansion cycle. Following R.L.Turner (ref.5) one finds A = 43 (for $T = 26$ K, $p1 = 6.3$ bar, $p2 = 2.2$ bar, and when d is in μm and t in ms). Thus the diameter of the bubbles would have been only approximately 50 μm after a growth time of 300 μs, which was the shortest flash delay used during the run.

G.Harigel et al. (ref. 6) measured the bubble diameter in several chambers and found that it was actually larger than calculated by R.L.Turner by a factor between 1.6 and 1.8. Hence the bubble diameter after 300 μs would be approximately 85 μm.

6.2.2 Measurements of track width and bubble density on film

The diameter of about 85 μm was in fact also found by measuring the bubble size on photographs taken by the RCBC cameras after a flash delay of 1.5 ms and calculating the value for a growth time of 0.3 ms by multiplying the result by $\sqrt{(.3 \text{ ms} / 1.5 \text{ ms})}$.

The bubble density after the 0.3 ms OFVT flash delay was found to be between 30 and 40 bubbles per cm. This value was determined in two ways which produced similar results. The first method consisted in counting the number of "blobs" per cm on the photograph taken 1.5 ms after the event and extrapolating to the delay of 0.3 ms, following R.Newport (ref.8).

A "blob" originates either from a single bubble or from several coalesced bubbles. In the second method the bubble density is determined from the working conditions of the chamber following G.Horlitz et al (ref. 9).

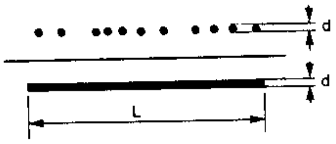
6.2.3 Measurements of track pulse heights on the optical bench

During the development of OFVT its optical system was modelled on an optical bench. All important elements were included: the chamber with its windows and the Scotchlite on the rear surface, the objective and cylindrical lenses, the mirror and optical filter as well as the flash system. The only simplification was that wires in air replaced the tracks of bubbles in liquid hydrogen. Fig. 9 shows the signals from a diode array onto which the images of wires with diameters between 20 μm and 0.5 mm were being projected. In the lower part of the figure are shown the signal amplitudes as a function of wire thickness.

6.2.4 Prediction of the pulse heights expected from bubble chamber tracks

From the results shown in fig. 9 predictions were made of the pulse heights to be expected from bubble chamber tracks. For this purpose it was assumed that the signal amplitude from a track composed of bubbles would be smaller than that from a wire of the same diameter by a coverage factor C :

$$C = \frac{\text{total projected bubble area}}{\text{projected area of wire}} =$$



$$= \frac{\pi.d.n}{4L}$$

where n = the number of bubbles in track length L.

It was subsequently demonstrated experimentally that this relationship of signal amplitudes holds good when strings of opaque discs in air are used to simulate bubbles. The validity of this simulation has been experimentally verified by B.Sukiennicki and H.Barney (ref. 7).

W.Welford (ref. 10) took the same model as the basis for his calculations of the contrast and shape of bubble images in bubble chambers with bright field illumination.

6.2.5 Measurements of track pulse heights from the bubble chamber and comparison with predicted values

On the optical bench the signals produced by 80 μm wires were about one third smaller than those from 150 μm wires, while in the bubble chamber the same ratio of amplitudes was observed between signals from 80 μm wide tracks and the 150 μm reference wire. Thus the expected diminution of the track signals due to the bubble structure did not in fact take place. At 30 to 40 bubbles cm^{-1} and 85 μm bubble diameter the coverage factor is $C = 0.20$ to 0.27 which leads one to expect a reduction in signal amplitude by a factor of four to five. It is not yet clear why the pulse heights from real tracks are so much bigger than predicted by the model.

ACKNOWLEDGEMENTS

The idea of The Optical Fiducial Volume Trigger arose in discussions with B.Powell, R.Settles and Ch.Roos (ref. 11).

At the early stages of the project J.Skura wrote a computer program for predicting the efficiency of the OFVT system and for optimising the positions of the arrays.

The authors thank K.Geissler for his very valuable contributions to the discussions about the optical system.

The project would not have been successful without the constant support and encouragement of L.Montanet.

R.Newport furthered the work during the whole development through many discussions.

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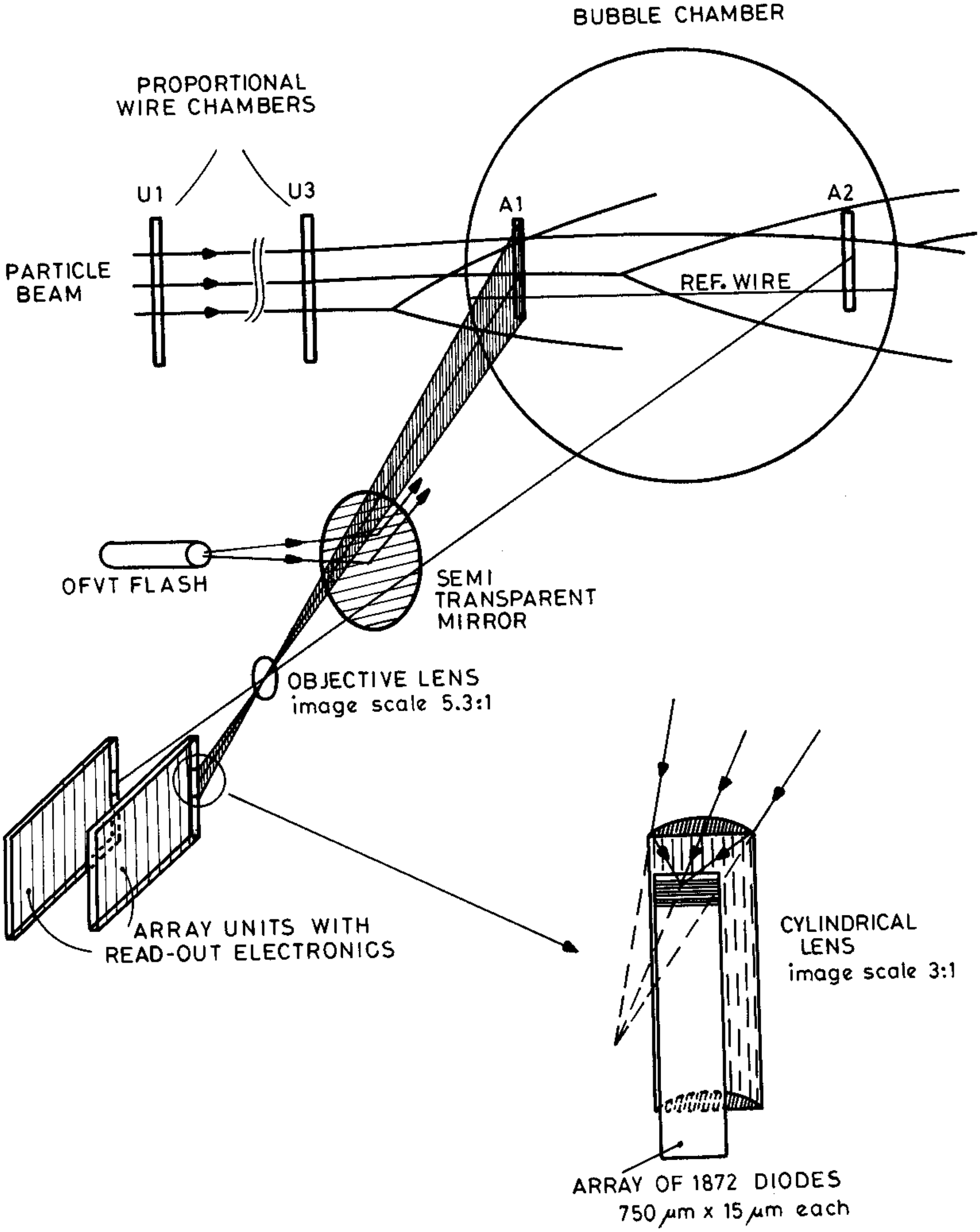
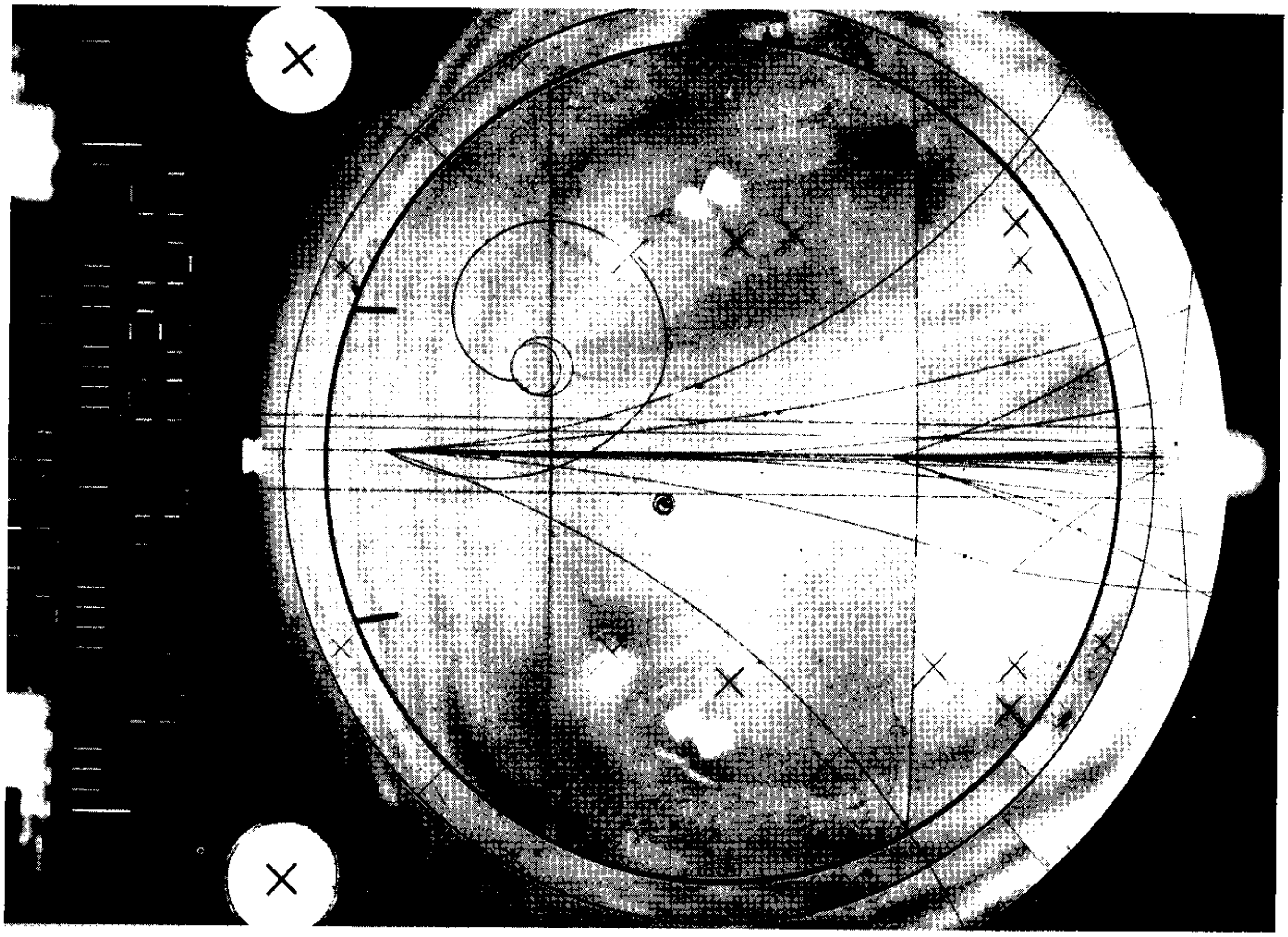
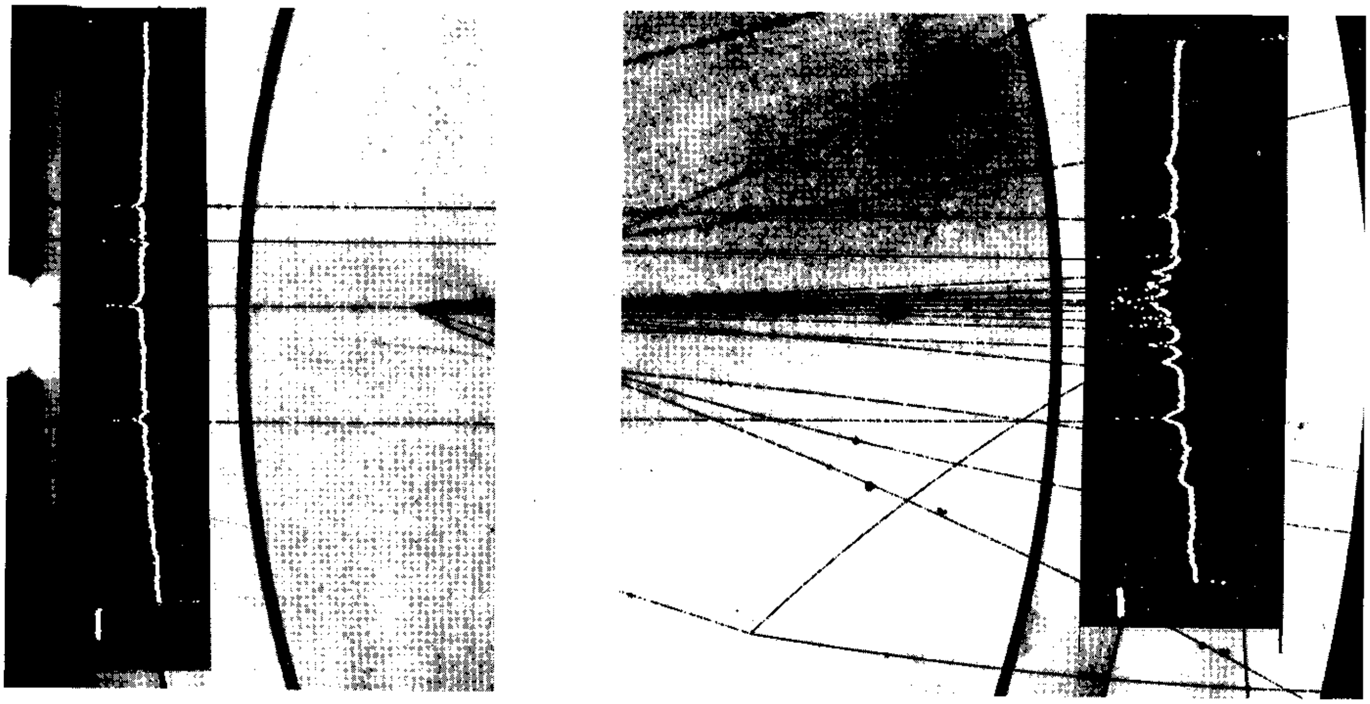


Fig. 1 . Optical principle.



Photograph of RCBC



Enlargement of the areas looked at by the two arrays, one at the entrance (left) and one at the exit (right) of the chamber with the corresponding oscillograms showing the track pulses.

Fig. 2.

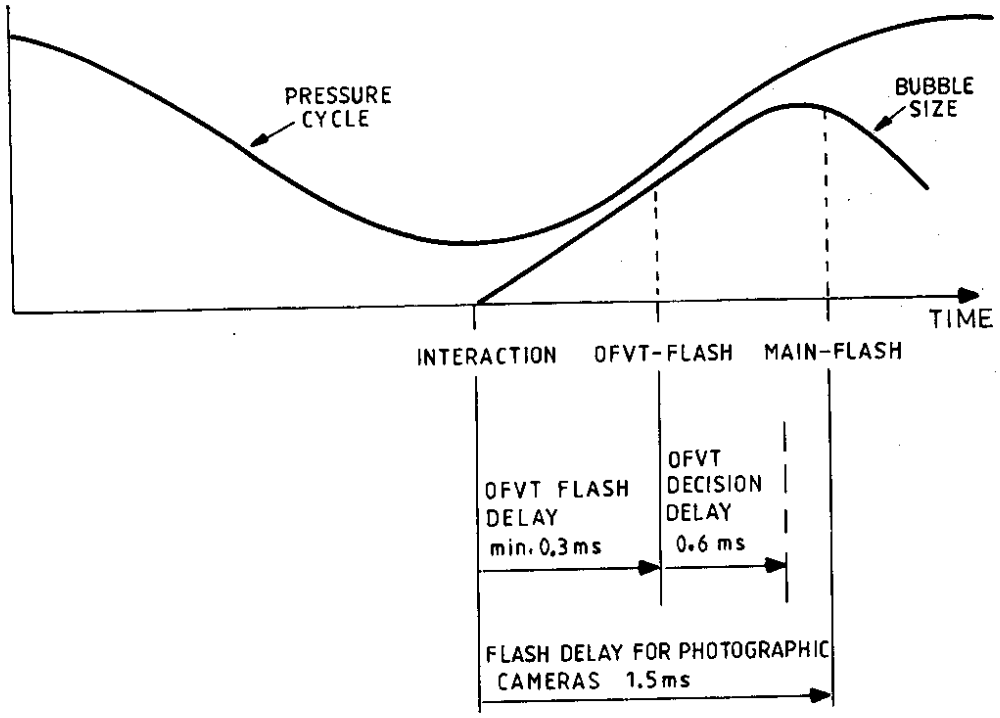


Fig. 3 . RCBC cycle and OFVT timing.

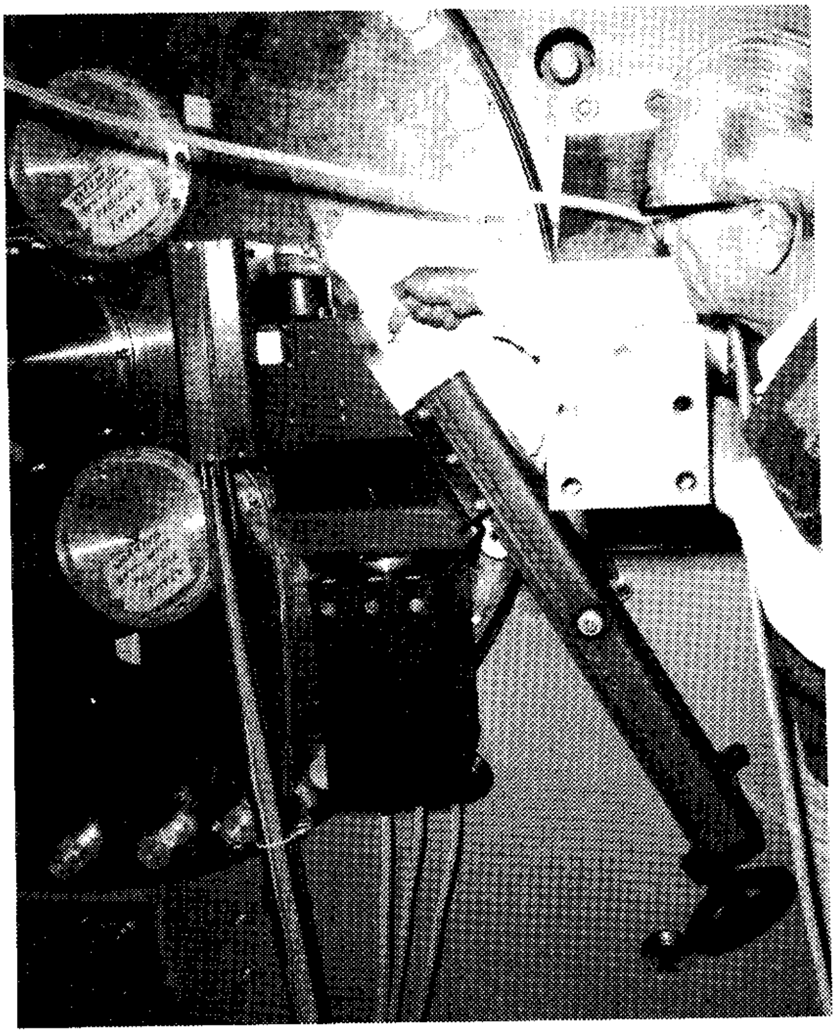


Fig. 4 .
OFVT camera
mounted on RCBC.

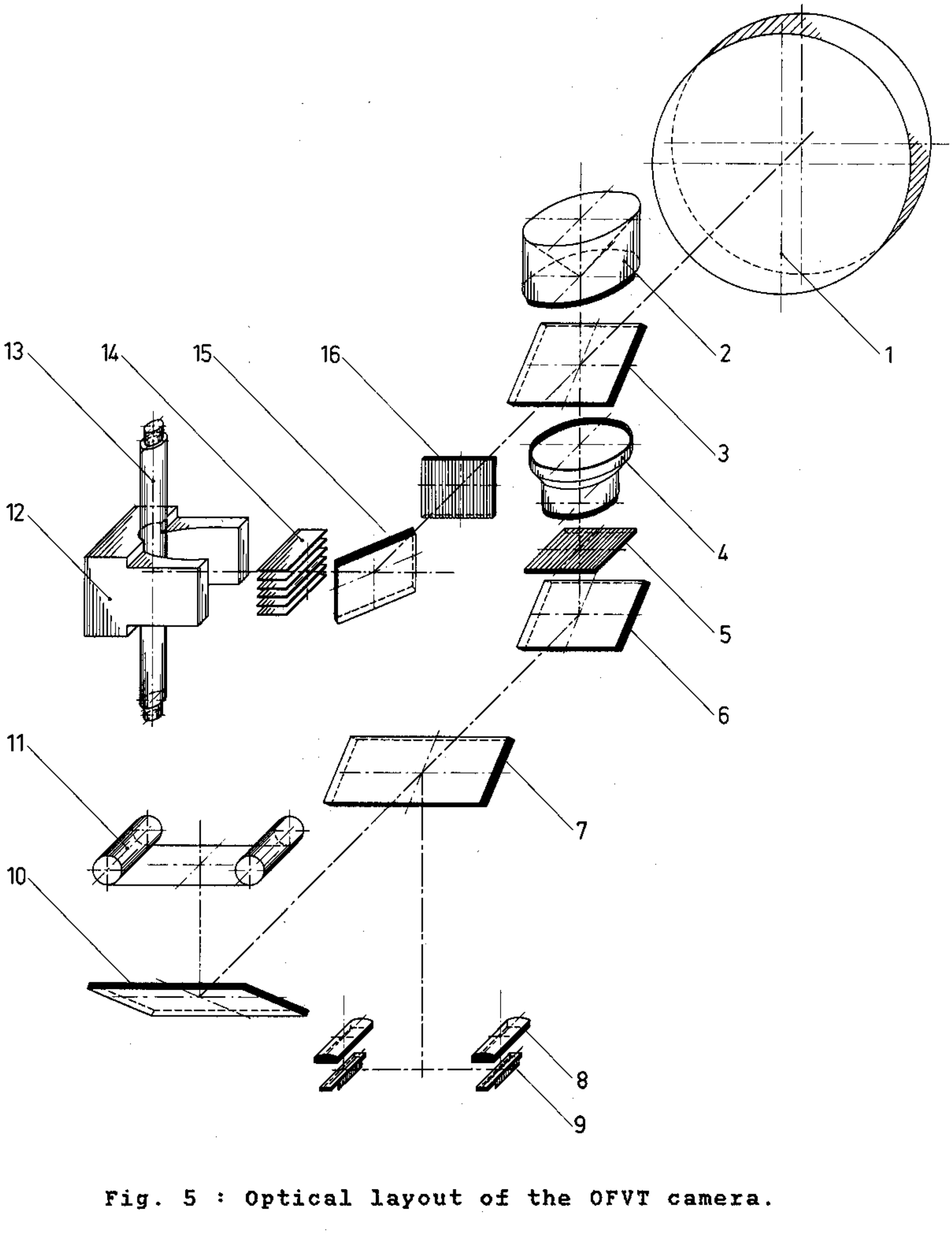


Fig. 5 : Optical layout of the OFVT camera.

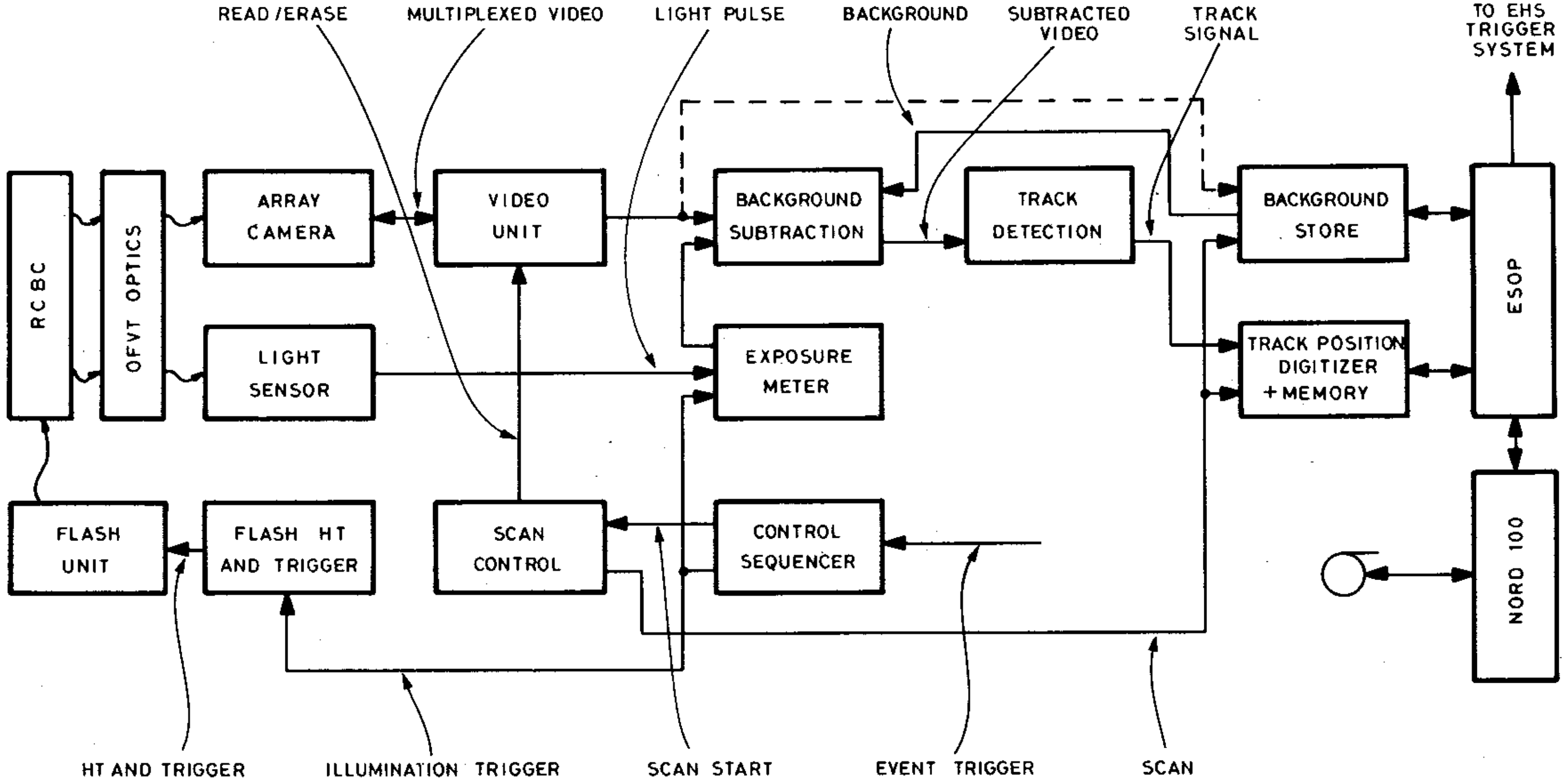


Fig. 6 . Block diagram of the OFVT electronics.

Fig. 7 . Array Unit

This assembly is mounted in a double frame support. The inner frame can be adjusted with respect to the outer one in order to optimize the focussing of the track image on the diode array.

The diode array and the cylindrical lens are located on the left hand side of the inner frame.

The semicircular section of the circuit board contains the charge-to-voltage converters and line drivers for the video signals and the clock drivers for the array read-out. On the right hand side of the board one sees, from top to bottom, the four-phase clock generator, the voltage regulators for the array bias and the clock amplitudes as well as the power line filters.

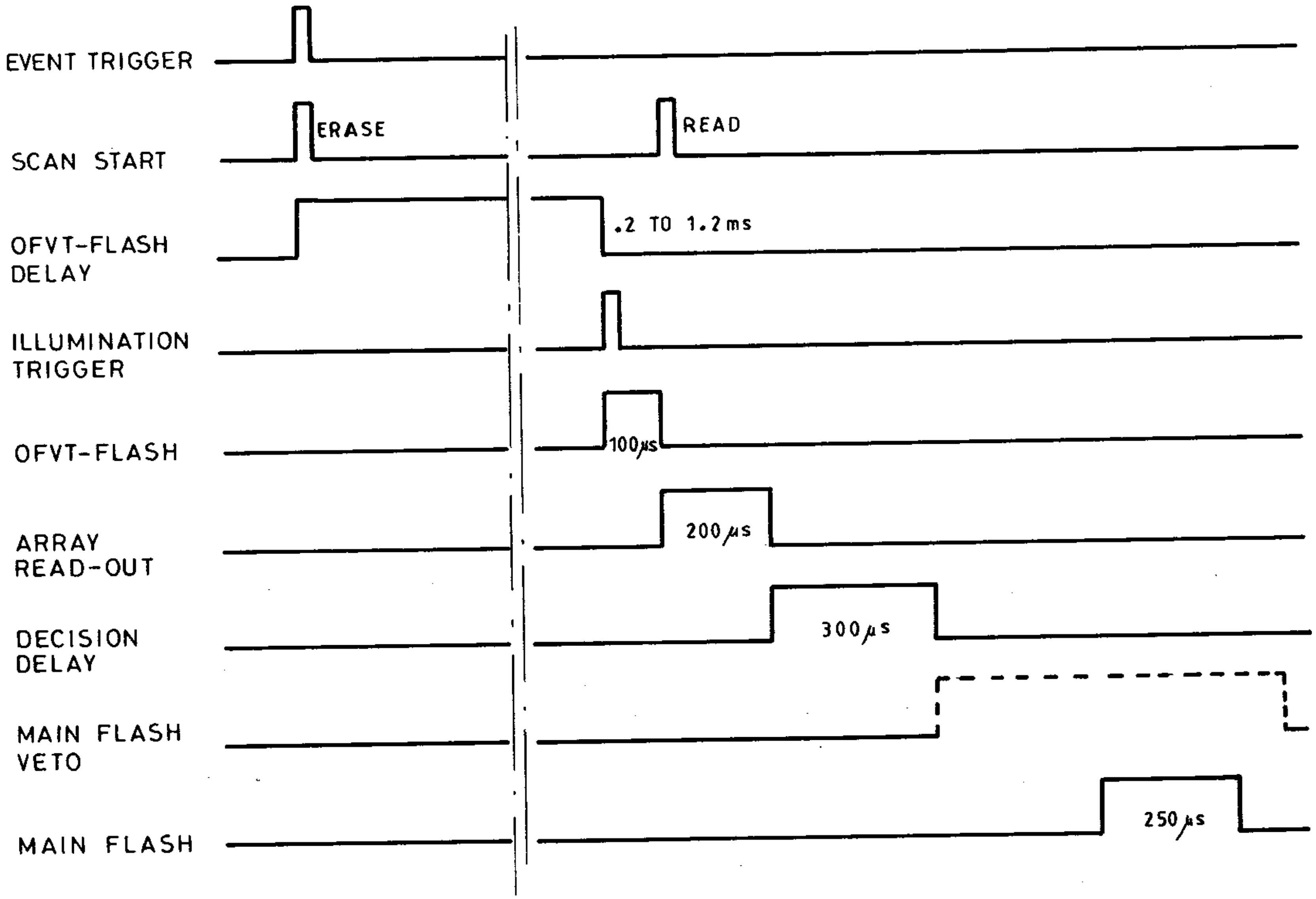
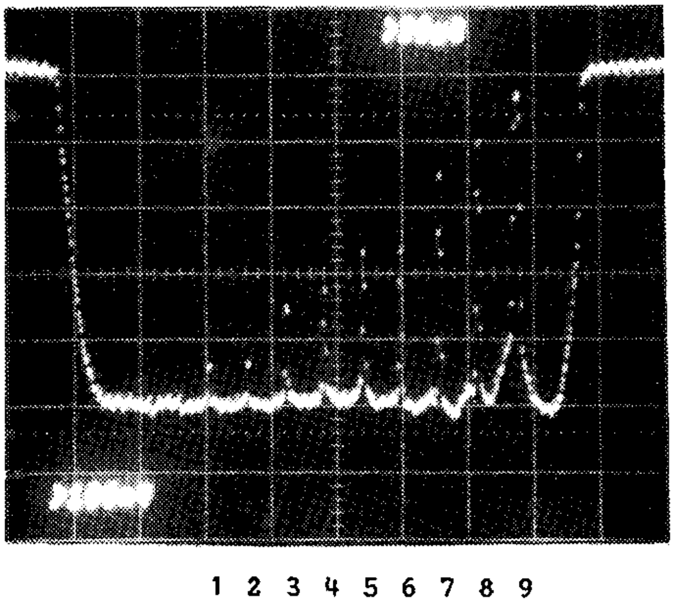


Fig. 8 . Electronic timing cycle.



	diameter of the wires
1+2	20 [µm]
3+4	60
5+6	100
7	160
8	220
9	480

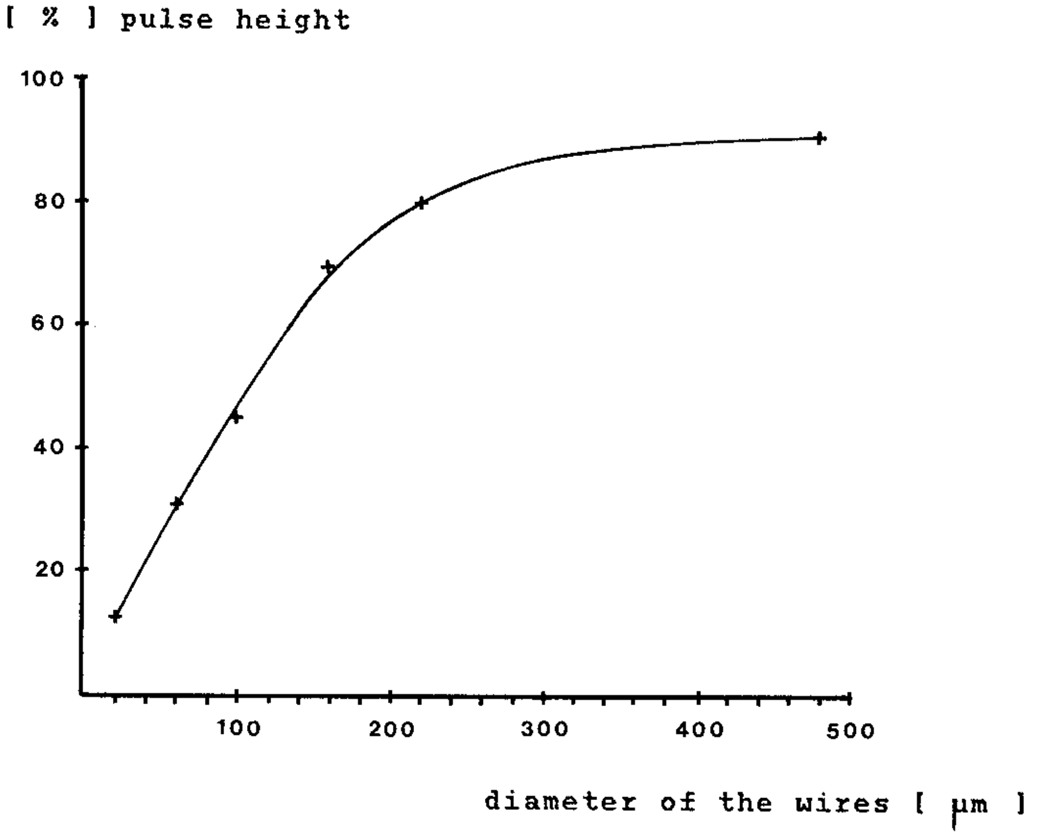


Fig. 9 : Track pulses caused by solid wires simulating tracks on the optical bench.