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A CAMERA SHUTTER USED IN HIGH RESOLUTION BUBBLE CHAMBER PHOTOGRAPHY*

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ABSTRACT

A cylindrical rotating shutter for a high resolution bubble chamber camera is described. It eliminates several undesirable effects of interference from the low resolution photography system.

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Recent interest in the study of heavy, short lived particle production has led to the operation of several bubble chambers in a mode emphasizing high spacial resolution. [1] This is achieved by raising the liquid temperature and flashing the illumination early. More bubbles develop, but they grow more slowly, and are photographed while small. In hydrogen, bubble diameters of 30-60 μm are used routinely at 60 - 90 bubbles per cm. These conditions have been found adequate for studying charmed particle production, including the measurement of lifetimes.

In some instances, particularly in larger chambers, it is desirable to have both highly resolved images of small bubbles and a low-resolution picture of the later, more expanded, tracks. This latter, more conventional, image, which may be a stereo triplet, is used for three dimensional and momentum measurement. It also efficiently pinpoints events which can then quickly be found on the large format high resolution frame where charm signatures may be sought.

The SLAC 1-m hydrogen bubble chamber has been engaged in such research in a laser back-scattered 20 GeV gamma ray beam. In this case the high resolution camera flash is at 150 μsec after the ∿60 nsec beam pulse, while the low resolution 3-view stereo cameras flash 3 msec after the beam. The durations of the flashes are about 50 and 200 μsec respectively. The chamber uses a Scotchlite [2] retroreflective optical illumination system for both sets of cameras.

Several forms of interference between the two sets of cameras occurred, to the detriment of the high resolution bubble images. These were spoiled because of direct reflection from the surfaces of the large, 3 msec, bubbles when the low resolution camera flashed. This highlight was superimposed on the high resolution, small diameter, bright field images and severely distorted them or rendered them almost invisible. The use of a gelatin filter at the high resolution lens, together with a boost in the high resolution flash, eliminated this difficulty by altering the relative balance of the Scotchlite and bubble - reflected illumination. This, however, was hardly acceptable on two counts. First, the image quality deteriorated, especially off the lens axis. Also there was an inadequate amount of available illumination for the high resolution film, leading to low contrast tracks, despite high voltages and therefore relatively short lifetimes of the flash tubes.

Additional factors were that one of the stereo triplet flash tubes gave a reflection on the high resolution film in such a place that part of the fiducial volume was obscured. Also, the general scattered light level from the low resolution flashes raised the average density of the high resolution film and decreased its contrast further.

Because the general technique, if not the details, may be of use elsewhere, an account of the solution is given here. It takes the form of a shutter on the high resolution camera which is open at the time of its flash, but closes within the ∿ 2.5 msec before the low resolution flash occurs. With this operating, and no intervening filter, the high resolution lens can perform optimally and with minimal waste of fiducial volume.

The shutter is a rotating, black anodized, aluminum cylinder with a rectangular slot cut through it (Fig. 1). It is mounted two thirds of the way between the 360mm focal length lens and the 35mm x 150mm film platen. Magnetic fields in the area are typically ∿ 100 gauss. Rotating at 3600 RPM, the shutter turns from full open to closed (45°) in 2.08 msec.. This would allow some flexibility in timing, but flexibility is unnecessary in the present application. At SLAC the bubble chamber operates at some integer division of a basic 180-Hz accelerator repetition rate — recently 10 Hz or 12 Hz. By keeping the shutter synchronous with the accelerator timing pulses, it can accept any bubble chamber frequency, and requires only to be synchronized so that it closes at the correct phase of the chamber cycle.

SLAC is essentially synchronous with the electrical power lines, and tests have shown that a synchronous motor (with a means of initially rotating to the correct phase) would be adequately stable for the purpose. However, the motor available when the work commenced was a DC motor of about 150 watts output. This is controlled by turning its power on and off in response to timing signals. The motor-shutter axle position is sensed by a light emitter - detector pair straddling a ring of equally spaced holes on a small wheel on the axle. The basic 360 Hz synchronization signal from the accelerator is digitally multiplied up to correspond to the rate at which the holes should pass the sensing head. The multiplied signal is made to turn on the motor power, and the following hole signal turns it off. If the interval is too short, the power is on for a shorter period, slowing the motor and increasing the time interval, and vice versa, leading to stability. The DC voltage level is tuned to give approximately a 50% duty factor.

It was found that stability was excellent with a set of 24 holes in the wheel, corresponding to 1440 Hz. Closing time jitter was typically a few tens of microseconds.

The "shutter open" position is detected by a signal from one of another set of two diametrically opposed holes on the timing wheel. This system uses a separate light sensor head. Its signal is required to be in time coincidence within ± 112 μsec with the beam delivery signal from the accelerator. If 20 of these position hole signals pass sequentially without a beam coincidence when the wheel is rotating at the correct speed, the electronics prevents the power-off signals (from the timing holes) from being applied for a short time, thus speeding up the motor. Another attempt is then made to synchronize, and the process is repeated until successful.

An illustration of the results of using the shutter is attempted in the comparison shown in Fig. 2.

The use of such a device at a non-synchronous, long flat-top, accelerator would mean that the "open" position be rephased by up to ± 90° during every energy ramp. It is of interest to consider how quickly this can be done.

Minimizing the inertia, and using a propulsion system with substantial restoring force to synchronism, are the requisites of fast response. Such operation is unnecessary at SLAC and the system is not intended for fast rephasing. Nonetheless the shutter phase can be rotated stably by one timing hole (15°) at a time in less than 50 msec. per step. That is, less than 300 msec per 90° shift. An alternative would be to use a synchronous motor whose body is rotated to reposition the pole pieces — and therefore the "shutter open" position. It would be possible, if preferred, to alter the phase of the applied line power, while some control is also possible with the amplitude of the applied voltage.

The shutter described above has so far been used for 4×10^{7} bubble chamber pulses, and 4×10^{5} pictures. Its accumulated experimental inefficiency has been less than 0.2%. It represents a relatively inexpensive and effective solution to several simultaneous difficulties.

REFERENCES

[1] J. L. Benichou et al., Nucl. Instrum. Methods 190 (1981) 487; K. Abe et al., SLAC-PUB-2870, Jan. 1982, submitted to Phys. Rev. Lett.; E. Ramseyer et al., University of Berne Preprint, March 1982, submitted to Nucl. Instrum. Method.

[2] Trademark of 3M Company, St. Paul, MN, USA.

FIGURE CAPTIONS

1. Drawing of the shutter axle assembly.

   Components shown are the shutter body with bearings on either side, the timing wheel with the timing light package astride it, and the motor. Note that the timing wheel hub acts as a coupler between motor and shutter axles. The scale shown represents 5 cm.

2. A comparison of frames exposed just before and just after the introduction of the shutter. A representation of the full frame and a magnified view in the poorest optical region (the downstream end) are shown: a) with shutter; b) without shutter.

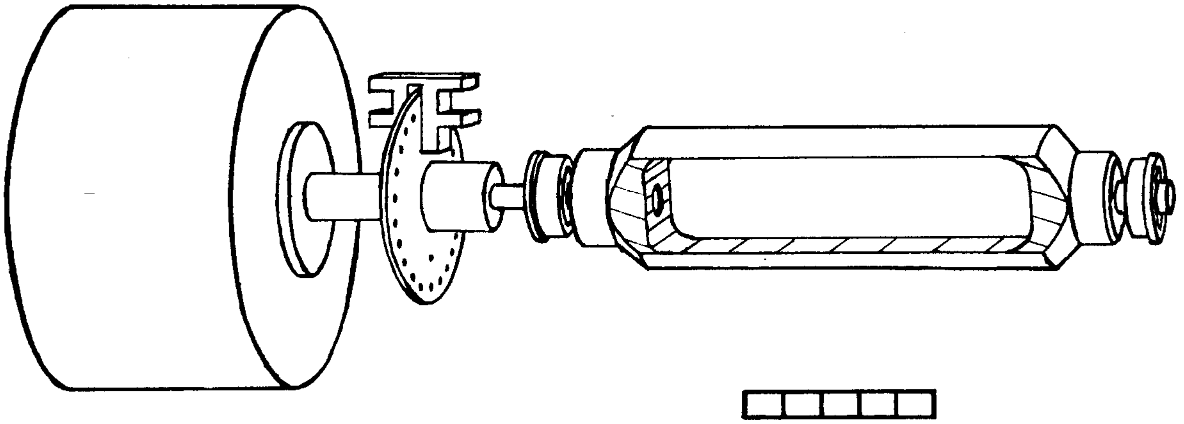

Fig. 1

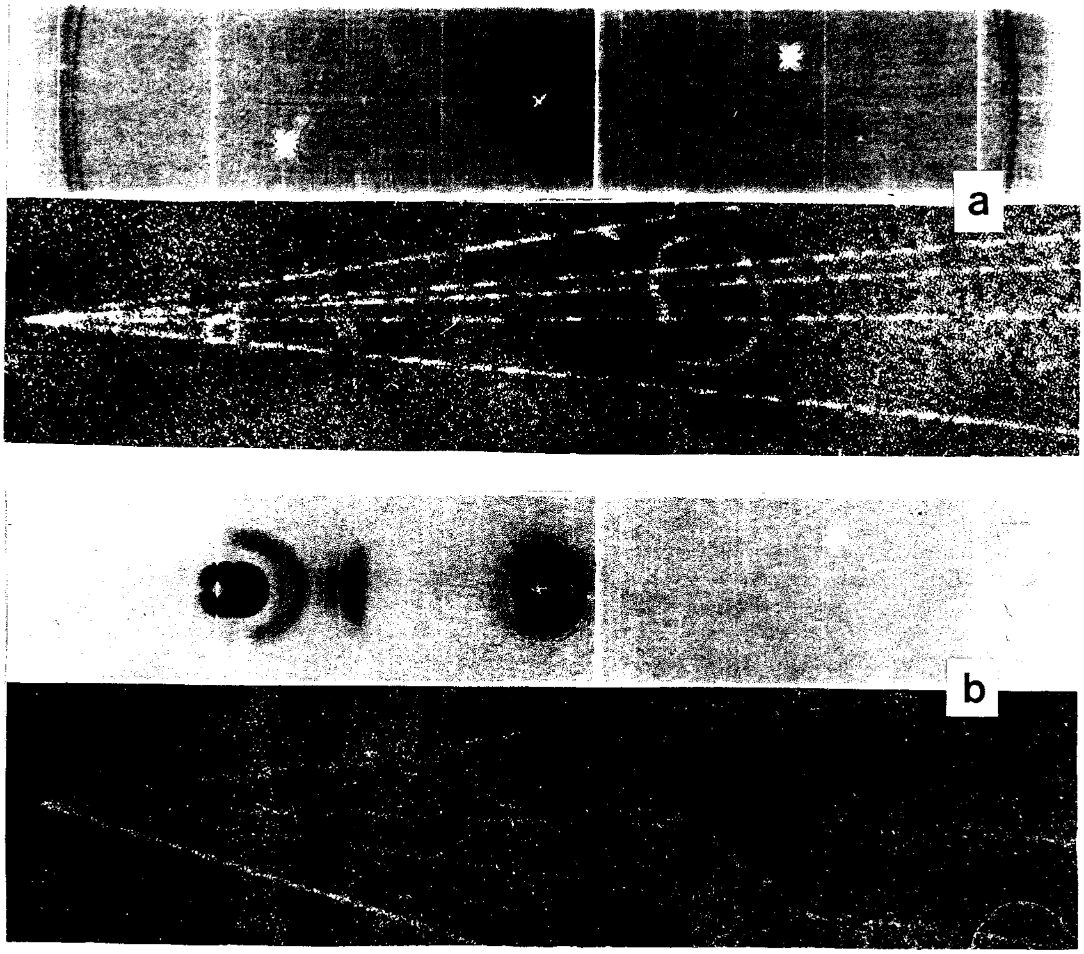

Fig. 2