DOUBLE SWEEP STREAK CAMERA FOR LEP

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Abstract

A streak camera has been built with two orthogonal deflections allowing the stacking of up to 50 streaks on the screen of the readout CCD. The slow sweep can be varied from one extreme where all bunches are recorded sequentially, to the other extreme of interspacing them to cover up to 20 synchrotron periods. Required bunches are gated with a pulsed bias of the photocathode. The time resolution has been measured with a picosecond laser pulse and is better than 6 ps F.W.H.M. First results of multishot pictures taken at LEP are reported.

INTRODUCTION

LEP short bunches require a very precise instrument to detect their fine structure. The σ longitudinal is of the order of 12 mm (40 ps) depending on machine conditions. Fortunately LEP positrons and electrons yield a lot of synchrotron light [1, 2, 3] in bending magnets. Since the emitted photon pulse has the same shape as the corresponding bunch of particles, its observation will gather information relevant to the beam itself.

A streak camera (S.C.) is able to measure a single light pulse with a resolution of a few picoseconds [4, 5, 6] . The one procured for LEP is devoted to analysing synchrotron radiation pulses in the visible spectrum [1].

According to the requirements one wants to record all successive bunches separated by 22.5 µs, or a given bunch at every revolution (89 µs), or the same bunch every n^{th} revolution. And because the digitization of one image of the S.C. takes a long time (~ 20 ms), the data cannot be digitized after each shot. However, thanks to the four plate streak tube, different events can be registered in different locations on the phosphor screen, and the full image received on a C.C.D. camera can be analysed subsequently at a standard TV rate. The most complexe image could be made of 50 streaks representing different bunches of e^+ and e^-, taken at different turns.

PRINCIPLE OF THE DOUBLE SWEEP STREAK CAMERA

Streak Cameras (S.C.) have been the subject of many publications.[4, 5, 6, 7]. Figure 1 explains the functionality of the S.C. now in use at LEP.

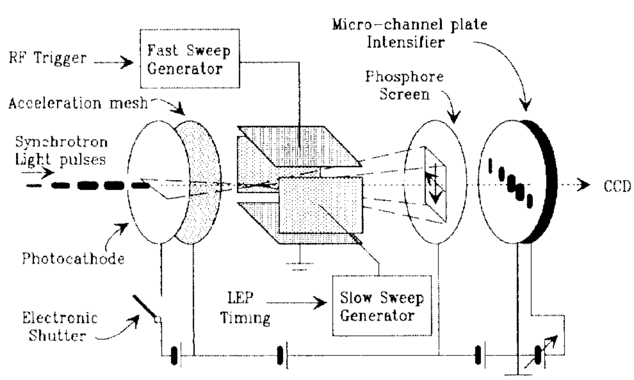

Fig. 1. Setup schematic of the streak camera for LEP

Incident photons produce an emission of electrons from the photocathode, in proportion to their intensity. After acceleration in the streak tube these electrons are swept by the application of a high voltage pulse with a rise time of 1 ns to one set of electrodes, converting at the phosphor screen temporal information into spatial information. A micro-channel plate intensifies the image of the phosphor which is then recorded by a C.C.D. camera. A second set of electrodes inables the writing of the next pulse in another column on the phosphor screen.

The LEP streak camera is provided with a fast internal pulse bias of the photocathode which acts as an electro-optical gate, improves the signal to noise ratio and allows the selection of pulses.

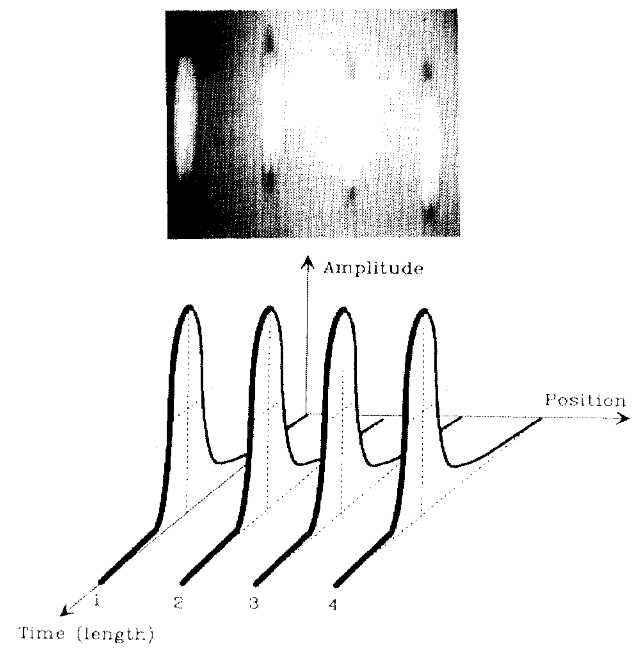

Fig. 2. Typical image on C.C.D.screen and 3-D view of the recorded intensity as a function of time and position.

The LEP S.C. was produced by the firm ARP [5], preliminary acceptance tests were made with a picosecond laser at Strasbourg, and final tests were performed with LEP synchrotron light .

TEST OF THE STREAK CAMERA WITH A PICOSECOND LASER

The time calibration of the fast sweep was made with a Perrot-Fabry plate [6] giving a known time delay. We measured 1.36 ps per pixel at the fastest sweep (Fig. 3).

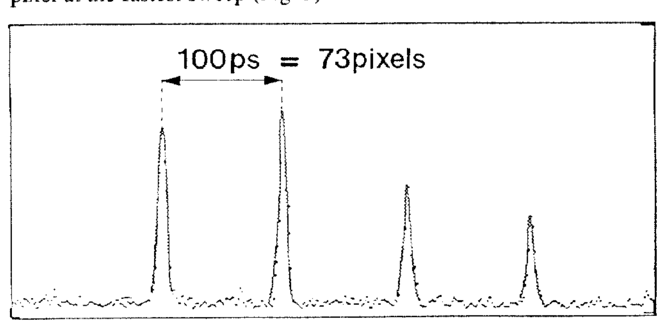

Fig. 3. Calibration of the streak camera fast sweep

A picosecond laser pulse measured with the S.C. has shown a F.W.H.M. of 6 ps which means that the resolution of the instrument is at least as good as that. Moreover the linear range is better than 40 and was evaluated by increasing the input light level until the measured pulse width increased by 20 %.

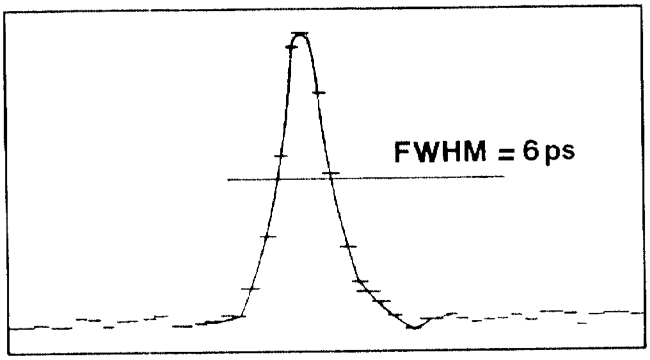

Fig. 4. Result of a resolution test made with a picosecond laser pulse

TEST OF THE STREAK CAMERA WITH LEP SYNCHROTRON LIGHT

Synchrotron light produced by the low field bending magnets reaches the underground optical laboratory through the optic channel described in Ref.[3] and has been used extensively for the tests presented below.

Synchronization of the S.C. with the wanted bunch was done by precise timing derived from LEP acceleration Radio Frequency signal [8]. A fast electronic programmable delay module has been developed to select :

a) the number of bunches per turn
b) the number of turns
c) the number of repeats of this sequence.

This electronic module generates signals for the fast sweep, for the slow sweep and for the electro-optic gate. Electron and positron bunches can be recorded alone or simultaneouly.

The software provided by the firm ARP displays images at the speed of 25 pictures per second which allows the visualisation of bunches in real time. Another facility permits the examination of the profile of any given bunch in a composite image.

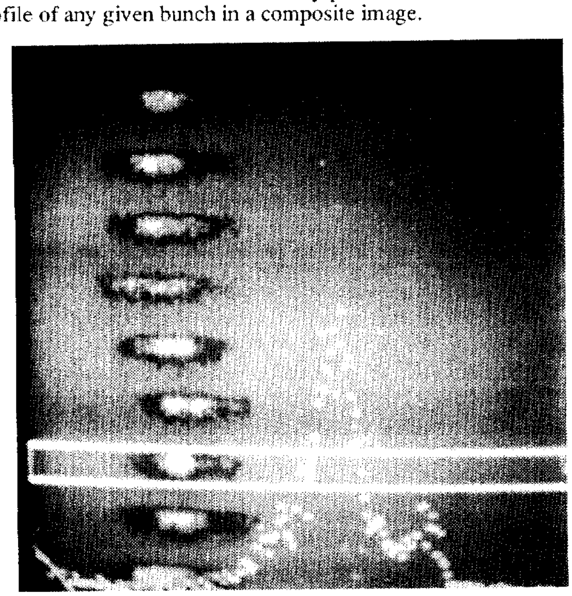

Fig. 5. Streak camera picture of a bunch in LEP seen at nine consecutive turns. The time scale is horizontal and there is a zoom on the third bunch shape

Figure 5 was recorded in December 1989 when LEP beams were unstable. The longitudinal shape changes from turn to turn. At the third turn $\sigma \approx 20$ ps only, which indicates that some oscillations are taking place inside the bunch.

Next three pictures represent one bunch seen for 19 turns and performing a synchrotron oscillation with an amplitude of about two sigmas. When zooming on different turns one sees that the longitudinal shape changes with the phase of the oscillation.

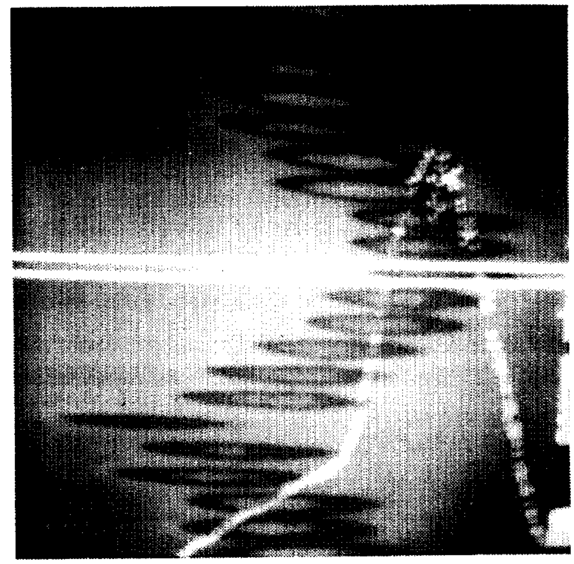

Fig. 6. S.C. picture zooming on a synchrotron phase $\phi=-90^{\circ}$

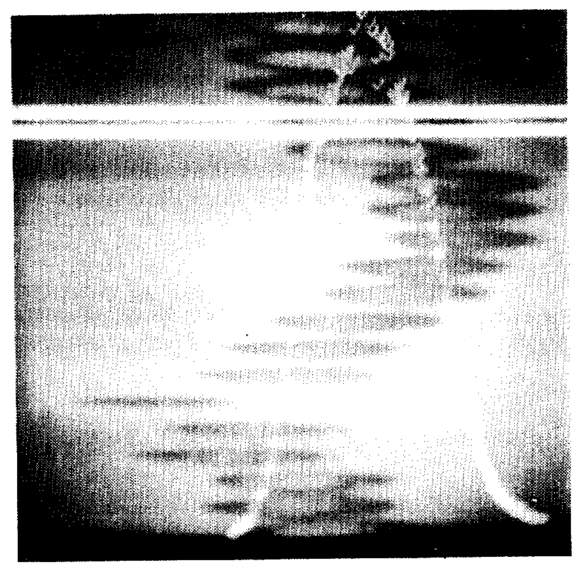

Fig. 7. S.C. picture zooming on a synchrotron phase $\phi=0^{\circ}$

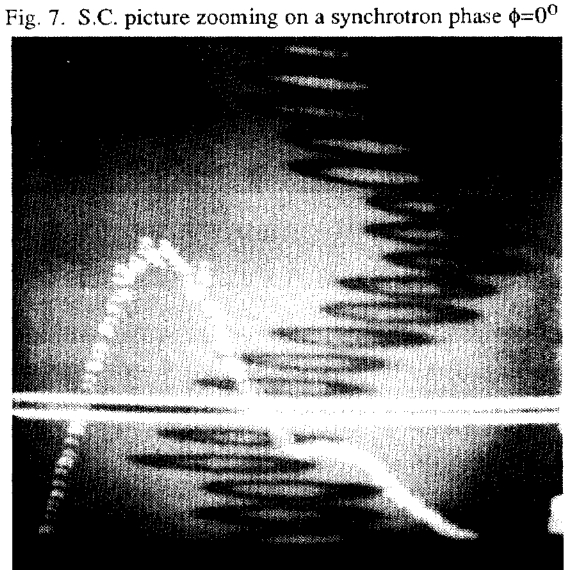

Fig. 8. S.C. picture zooming on a synchrotron phase $\phi=+90^{\circ}$

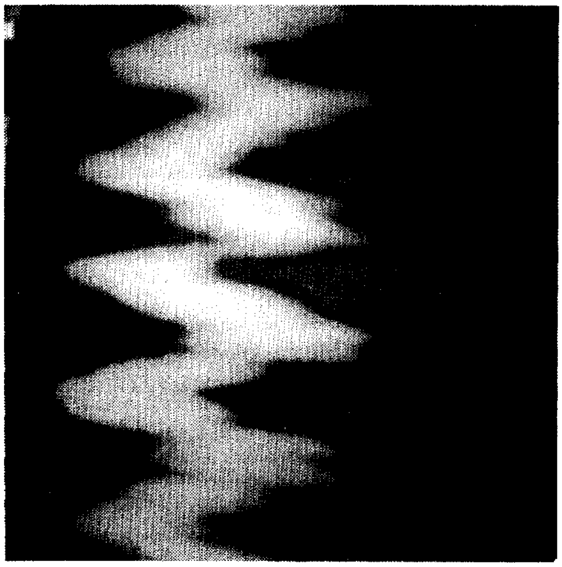

Fig 9. S.C. picture of a bunch seen for 64 turns. The different turns cannot be separated but the synchrotron oscillation is clearly visible.

CONCLUSIONS

Test made with parasitic synchrotron light coming from the low field dipoles on both sides of the long straight section LSS1 have demonstrated that the performances of the LEP double sweep streak camera are well adapted to bunch shape measurements during machine development periods.

During this Summer, the set-up will be completed by tuning in a mini-wiggler optic channel which will allow proper beam cross-section imaging in the optical laboratory. This transverse (x, y) image will be analysed by a UV detector at the same time that the streak camera registers the longitudinal shape using the visible part of the spectrum.

Synchronizing the two detectors should allow the observation of synchro-betatron oscillations.

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