HOLOGRAM SCANNING AND MEASURING DEVICE

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ABSTRACT
In the High Energy Physics area, the Charm hunting needs the use of Holography to perform recording of optical information with high resolution and large depth of field. The scanning and measuring of bubble chamber holograms reveal a bunch of problems, occurred either by the holographic technique itself or by recorded event topology.

The kink detection, the magnification, the optical and video improvements and the "Z" motion will be checked. The final lay-out with the optical, video, and mechanical set-up will be described.

INTRODUCTION
At the previous meeting on the APPLICATION OF HOLOGRAPHIC TECHNIQUES TO BUBBLE CHAMBER PHYSICS, held at RUTHERFORD Laboratories in January 1981, we presented ideas and tests to solve some of the emerging problems to scan and measure holograms. Now, we check deeper the problems and describe our lay-out for a holographic scanning and measuring device.

1. THE THIRD DIMENSION
   1.1 The "Z" Motion

   The X and Y motion is a well known and solved problem in standard measuring device. As this motion can be done in a horizontal plane the moving mass is not critical. The "Z" depth motion, orthogonal to the previous ones is then vertical. One can minimize the vertical moving mass, or fold horizontally, by mean of a mirror, the vertical light beam (lengthening the optical path). In fact, the following solutions are possible:
   - moving the film gate
   - moving the camera with its lens
   - moving a set of mirrors
   - moving only an object lens whereas the camera and the camera lens remain steady.

   We use the last set-up. In this case
   - the moving mass is low
   - the moving lens position is disconnected from the steady camera position
   - the use of a zooming lens here allows zooming on several cameras with different magnifications.
1.2 The "Z" localization

It is sometimes difficult to locate an information in depth in the hologram. Thus, the use of multi-synchronized cameras set up has been tested, each of these displaying another plane in depth. The picture of each camera is displayed in another colour on the same colour video monitor. Thus, the operator sees 2 or 3 successive superimposed planes of the hologram, each in a different colour and with a defined depth of field. Moving in depth to find an event shows successive patterns where the colour of the focused plane looks bright and sharp on the background coloured fringes of the out-of-focus planes. By this way, it should be easy to get a reflex knowledge for backward or forward motion on "Z" axis.
2. **THE MAGNIFICATION**

2.1 **The optical magnification**

The choice of the right magnification is very important for the performance of the scanning/measuring device. Assuming that we give up the optical display for speckle and laser power problems, the first order parameter for resolution in video technique is defined by the vidicon characteristics: about 600 to 800 discrete discernable lines in the middle of its target. This number is coherent with the number of scanlines (625 at all, but only 575 are really used to pick up the picture). For a standard 3 x 4 TV picture, an area of about 12 x 16 mm can be scanned on the vidicon target. The resolution is then 20 to 25 microns in each direction. If 5 microns bubbles must be seen, a 4 times linear optical magnification must be achieved by the lens (if the reconstructed hologram has the same size as the object). That means also that the displayed part of the bubble chamber represents a 12/4 x 16/4 = 3 x 4 mm area for 5 microns resolution.

Thus, a low optical magnification (< 4)
- locates macro information easily
- but loss of the resolution because of the vidicon target characteristics

A high optical magnification (> 4)
- shows no loss of resolution
- but information is difficult to locate because only a small area is displayed

A motion in X and Y direction to scan the whole fiducial volume seems inconvenient. A better solution is to use several video cameras to get simultaneously different magnifications. One can also use a zoom lens on one or several cameras.

Our solution uses one ZOOM lens only for several cameras, which performs a 25 times optical continuous magnification range. For example, a range from 0.8 times to 20 times displays an area from 15 x 20 mm to 0.6 x 0.8 mm.

The VIDEO magnification, about 20 times, must obviously be added.

**Our choice**

The WILD M400 MACRO-ZOOM lens 3) has been chosen. The focus range is 1 to 5 i.e. a focus length from 50 mm to 250 mm. The object focusing distance to the front plane is 102 mm. The numerical aperture is 0.027 to 0.115. Additional lenses extend from 0.5 to 2 x the upper characteristics. The overall magnification is \( M = \frac{F2}{F1}, \)

\begin{align*}
F1 & \text{ being the object ZOOM lens focus length and} \\
F2 & \text{ being the camera lens focus length}
\end{align*}

Thus, for a "one camera set up", we would choose the magnification range 1.5 to 7.5 times or 2 to 10 times.

For, a "two cameras set up", although a continuous magnification range from 0.8 to 20 times can be achieved, an overlapping of the camera ranges leads to the following magnifications.

Camera 1 : 1 to 5 times (12 x 16 to 2.4 x 3.2 mm)
Camera 2 : 3 to 15 times (4 x 5.3 to 0.8 x 1 mm)
THE OPTICAL ZOOMING

CAMERA 1

CAMERA 2
Superimposing the two pictures in two different colours should be tested. It could allow to check easily if a straight track goes on to the vertex or not (see 3.3).

2.2 The Video Camera A.G.C. improvements

In an "in line" bubble chamber hologram, the energy of a focused track is very high. Furthermore, there is an important variation of the background density within the hologram, and a rough step of full intensity light between the holograms during the film motion. The Automatic Gain Control circuitry is in charge of adjusting the vidicon sensitivity to the grey level scale, i.e. to the light variations. This contrast control function must be very performing and tuned for the considered holograms.

2.3 The Video Camera resolution improvements

The quality of scanning and measuring is strongly related with the quality of the video camera. That's why we improved its resolution.

The video display screen size is a fixed parameter. So, increasing the correlated target size improves the resolution by increasing each pixel size on the vidicon. This is done by increasing the gain of the deviation amplifiers which improves the scanned area size by a ratio of two at least.
2.4 The switchable ANAMORPHOSIS \(^1,^2\)

As pointed out in January 1981 at the RUTHERFORD Meeting on Holographic Techniques, the standard 3 x 4 TV picture ratio may not be the best one for High Energy purpose. The events generally present a jet pattern and "opening" the event separates the different tracks. Furthermore, the goal of charm detection needs good sensitivity to small angular deviations. These purposes are performed by ANAMORPHOSIS, that means by squeezing the particle beam direction (Y) and stretching the perpendicular direction (X). This has been done in our video cameras by switching the gain of the deviation amplifiers, tuning thus the scan-line length and distance on the vidicon target, the scanning of the video monitor remaining standard. A X/Y magnification ratio of 4 can easily be reached but care must be taken to the scanned area size. A too small size burns out the vidicon target. We chose the following values.

- Useful one inch vidicon target diameter : 20 mm
- Standard scan size : \(8 \times 12 = 108 \, \text{mm}^2\)
- Improved " " : \(12 \times 16 = 192 \, \text{mm}^2\)
- Anamorphosized " " : \(20 \times 7 = 140 \, \text{mm}^2\)

**SCANNED AREA ON THE VIDICON TARGET**
ANAMORPHOSIS

Vidicon target size

standard scanning size

correlated displayed area on the T.V. screen

anamorphosized scanning size

correlated displayed area on the T.V. screen

Displayed pictures
3. THE KINK DETECTION

3.1 The ANAMORPHOSIS

The switchable anamorphosis of our cameras improves by itself the direct kink detection. Nevertheless, its efficiency is limited to a few degrees.

3.2 The Radius Technique

Sergio Natali, from Bari (Italy) developed a new strategy of kink hunting, performed by mechanical translation and rotation of his film gate.

He assumes that the considered tracks are straight lines and the aim is to find tracks which miss the vertex, looking from their end.

The idea takes use of the integration in time operated by the vidicon, the display screen and the human eye. Thus, moving fast along a straight track parallel to it, shows a continuous straight steady line whereas background and non parallel or crossing tracks disappear at all or show moving flares.

The kink hunting sequence is the following:
- Localization of the vertex
- Positioning the vertex in the rotation center of the device
- Translation onto the end of the event.
- Positioning the track on the reference cross by rotating the event around the vertex which remains in the rotation center of the device
- Fast translation from the end of the track towards the vertex along a straight line.

If the track has no kink, it is displayed as a steady straight line.

If there is a kink, i.e. a deviation compared to the straight line, the display shows the deviation as a shift on the screen. The displayed line moves perpendicular to its direction. This principle is very sensitive for kink projections on a X Y plane.

A variation of this technique can be used if a kink is suspected.
- One places the rotation center on the track "after" the supposed kink
- One detects the end of the track by translation and rotation and moves along it to be sure that it is well positioned.
- One goes toward the vertex and looks if the vertex is missed or not.

The same process can be performed by software control of the stages motions in real time.

We perform this technique by an optical way which requires no real time computing power for scanning, and no sophisticated mechanical motions. The rotation is done by a WOLLASTON device whereas the translation occurs by reflection on a rotating mirror. The results can be compared to those of the mechanical set-up. The use of anamorphosis should even increase the sensitivity.
Rotating an event around the vertex by mean of a Wollaston

Optical magnification: 5x

Displayed area: 2.4 x 3.2 mm
TRANSLATING AN EVENT ALONG A GIVEN DIRECTION FROM LEFT TO RIGHT BY MEAN OF A ROTATING MIRROR

Displayed area: 2.4 x 3.2 mm

Optical magnification: 5x
3.3 The superposition technique

This technique consists in superposing one wide angle video picture in one colour with a second small angle video picture from a second camera in another colour on the same colour display. The wide angle camera shows the general sharp track direction which is compared to the local track direction given by the small angle camera.

One can always know where the vertex is, and a kink should appear as no parallel display of the track in the two colours.

This idea is an extrapolation of that developed on a graphic basis by H. Drevermann at C.E.R.N. ⁹, but we did not test it yet.

4. THE GENERAL LAY-OUT

As shown in the picture, one can mention the following components in the present status.

4.1 The laser ⁶)

- SPECTRA - PHYSICS MODEL 120 (USA)
- Hélium-Néon Red
- 5 mW at 632,8nm
- Telecope SPECTRA - PHYSICS MODEL 332 with a lens of F = 6.1 mm and a pin hole diameter of 15μ
- Lens for parallel beam with focus length : F = 140 mm; diameter : 63 mm
- Beam diameter : about 50 mm

4.2 The film gate

Vacuum film clamping is used

4.3 The X, Y motion

It is horizontal and moves the film gate. Measuring least count is 2 microns.

4.4 The ZOOM LENS ³)

- WILD M 400 (Switzerland)
- It has been described earlier. Its motion is vertical over a length of about 100 mm.
  The focal range is 5.

4.5 The video cameras ⁷)

- SOFRETIC (France) 1 Inch Vidicon tube
- 625 2 : 1 interlaced scan lines
- Automatic sensitivity control range 1000/1
- Target sensitivity : 2 Lux (.2 Foot-candle)
- Resolution in center : 750 points
- Scanning direction switchable top-bottom, left-right
- Anamorphosis 4/1 Switchable (modification made)
4.6 The other components

- One WOLLASTON diameter: 30 mm
- One rotating mirror
- One camera lens $F = 250$ mm for low magnification
- One camera lens $F = 750$ mm for high magnification
- One semi-transparent mirror to split the light to the two cameras used for the moment.

CONCLUSION

The suggested set-up is in the test status now. It should be considered as a step for a scanning and measuring device. In the final state one can imagine that the full power of colour video displays could be used to feed a maximum of useful information for the operator ("Z" localization, different magnifications superimposed, alphanumeric messages, graphic information, touch panel, light pen and so on). Main improvements can be done on the real time process control and data acquisition of the device. Autofocusing and optical or video filtering should be tested.

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