A MEASURING DEVICE FOR HOLOGRAMS FROM LARGE VOLUME BUBBLE CHAMBERS

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ABSTRACT

Measuring full-size reconstructed holographic images of bubbles from a large bubble chamber presents problems of size, rapid location of the desired event, and precise measurement of a local region. We present a conceptual design of a practical system using computer-controlled mirrors to align the desired vertex region along the axis of motion of a vidicon whose field of view includes the local region. Precise measurements of short-decay paths are then made by fine adjustments of the vidicon position. This method requires normal stereo photography for scanning and preliminary reconstruction of the event.

INTRODUCTION

The advantages of high resolution in detecting short-lifetime decays, and the advantages of holographic photography in preserving depth of field with high resolution, are well known. The use of small bubble chambers with holographic photography has been demonstrated in hadron beams; e.g., by the BIBC group. Progress has been made with somewhat larger chambers (e.g., the HOLEBC chamber development), also designed for use with hadron beams. In this area of small or medium-sized bubble chambers (or streamer chambers) for use with hadron or photon beams, where the volume to be photographed is small, holography has been pushed with the greatest vigor and with promise of early success.

In neutrino physics the beam-target volume cannot be made small; neutrino beams are difficult to focus or collimate. Yet neutrino interactions are one of the cleanest and best sources of charmed particles, and "beautiful" particles are expected at higher energies; Charm plus Beauty yields at the Tevatron should constitute at least 10% of neutrino events, as compared to 1% of photon interactions and 0.1% for hadron beams. Thus, for bubble chambers, which can accommodate only a few interactions per picture, a large bubble chamber in an intense neutrino beam may be more useful for studying charm and beauty events in detail than a small chamber rapidly cycled in a hadron or photon beam.

As an example, the approved E646 15-foot bubble-chamber heavy-liquid (Ne-H_2) experiment planned for the Tevatron beam dump anticipates the following number of events in a 200,000-picture run with 2×10^{18} protons of 1000 GeV energy incident on the dump:

1200 tau neutrino CC interactions
5600 electron neutrino CC interactions
8400 CC muon neutrino events
10 "beauty" particles

The prompt neutrino interaction yield per incident proton expected in E646 with 1000 GeV proton is estimated to be $\sim$ 100 times greater than previous BEBC beam-dump experiments at 400 GeV. The prime objective is to verify the existence of the tau neutrino and study its interactions. A systematic study of electron neutrino interactions is also feasible. If the mystery of "neutrino oscillations" is not yet solved by Tevatron turnon, this beam-dump experiment's results on the relative numbers of ν_μ, ν_e, and ν_τ events may contribute to the solution.

The advantages of holography are clearly indicated for Tevatron neutrino beams in bubble chambers: with the present 15-foot conventional optics, the bubble size and resolution are about 500 microns. (The resolution can be improved to $\sim$ 200 microns by sacrificing depth-of-field.) Due to the short lifetime of the tau, only a small fraction of tau decays is expected to be visible decays with conventional optics. With holography one can hope to achieve resolution better than 50 microns over the full-chamber volume. Since the median decay distance for the tau-lepton in the Tevatron beam-dump experiment is about 800 microns, holography can improve both the yield and quality of the detectable signal for taus. It may also make it possible to detect "beauty" decays, which are expected to have even shorter decay distances.

PROBLEMS WITH LARGE VOLUME HOLOGRAPHY

Holographic photography over a large volume poses difficulties not encountered with small volumes where "direct-view" holography (i.e., film area comparable to cross section being photographed) is practicable. The Welford scheme of two-beam holography in Scotchlight-illuminated bubble chambers has been tested at RHEL[1)] and at BEBC[2)] and appears to be feasible, but requires special optics and modifications to the chamber. A different method has been proposed by Baltay[3)] for the 15-foot chamber as shown in Fig. 1: the laser beam enters at the bottom of the chamber via a diverging lens, and the direct and scattered amplitudes are recorded on the film without any focusing lenses. Preliminary bench tests of this idea at Columbia appear encouraging, and an engineering test with the 15-foot chamber at Fermilab is planned in 1982.

Another problem with large-volume holography is connected with viewing and measuring the holographic image. In principle, when the hologram is projected with CW laser light, the full-size bubble images will be produced in space over the original volume of the bubble chamber. The 20 m^3 fiducial volume of the 15-foot chamber presents quite a problem to scan for small bubbles! Furthermore, conventional measuring methods would require moving a high-precision measuring device over large regions of space. This is obviously impractical.

We have devised a scheme for avoiding these problems, which appears to us to be practical. First of all, one does not scan the holographic image but relies on conventional three-view pictures (the three "normal" stereo cameras of low resolution) to locate interesting events. Stereo reconstruction determines their spatial coordinates with the usual precision of bubble-chamber event reconstruction. Secondly, one uses this information to establish which specific region of holographic image space should be viewed at high magnification. Mirrors are adjusted (by computer control) to view the vertex (or other restricted region of interest). Precise measurements can then be made of decay distances on the full-size bubble image.

A schematic drawing of the proposed system is shown in Fig. 2. The hologram is illuminated with a CW laser of nearly the same wavelength as the pulsed laser used in the initial exposure. This will reproduce the real bubble image in space by the interference of coherent light from all parts of the hologram. The total image will occupy a volume in space relative to the hologram corresponding to the bubble-chamber volume, including angles up to 40 degrees from the optic axis. However, by using plane mirrors tilted at the proper angle, the image in question can be brought into the "measuring volume" where the vidicon is located. This "measuring volume" is cylindrical with its axis located above a one-dimensional track upon which the vidicon cart rides. This cart can be moved to bring the image within the field of view of the vidicon, and the magnified image can be displayed on a TV monitor.

This method has the advantage that the mirror directs the narrow cone of interference rays from the hologram in the direction of the vidicon, so that only a slight swiveling of the vidicon is required to align it for optimum viewing. A lens can be used between the bubble's real image and the vidicon for greater magnification. Measurement of the decay distances can be made on the TV monitor, or directly in space by moving the vidicon with the points in question centered in the field of view.

Computer-controlled motion is essential for this scheme to work, and the spatial coordinates of the localized region must be known reasonably accurately in advance from the stereo photographs.

SOME CRITICAL ELEMENTS OF THE MEASURING MACHINE

The mirrors involved must be very flat, and their motion smoothly and accurately controlled. The angular accuracy of mirror setting required to position the image of a bubble well within the aperture of a vidicon (2.5 cm) at a typical distance of 400 cm is only $\sim$ 1 milliradian; such mechanical motion (two angles) is easily made and measured. Incremental shaft encoders with accuracies of better than 1 part in 10^5 per revolution are now available. Thus with computer control of mirror position the vertex can be positioned accurately within the field of view and moved about with computer control.

The measurements on the reprojected image can be made either (1) on the magnified CRT image or (2) by moving the vidicon by precision x-y stage to bring several points to the center of the vidicon (cross hair). The former method is more convenient but the linearity and CRT are not involved. In the latter method, the non-linearities of the vidicon movement is the only limitation. In either case the image of bubble on the vidicon may be magnified: typically, x10 at the vidicon and x200 on the CRT. Thus a 50 micron diameter bubble image would appear as 500 microns at the vidicon and 10 mm on the CRT. This is a convenient scale for viewing and making measurements. Short-decay distances would be magnified to a scale where their detection would be readily done on the CRT; angles could be enhanced by making the transverse magnification greater than the longitudinal magnification.

STATUS OF THE PROPOSED MEASURING MACHINE

At the present time this is just a proposal, although development funds have been sought and a preliminary design has been sketched. It is our intention to compare this proposal with other methods of measuring large-chamber holograms during this conference, and then choose the best method for further development for the 15-foot chamber holograms.

ACKNOWLEDGMENTS

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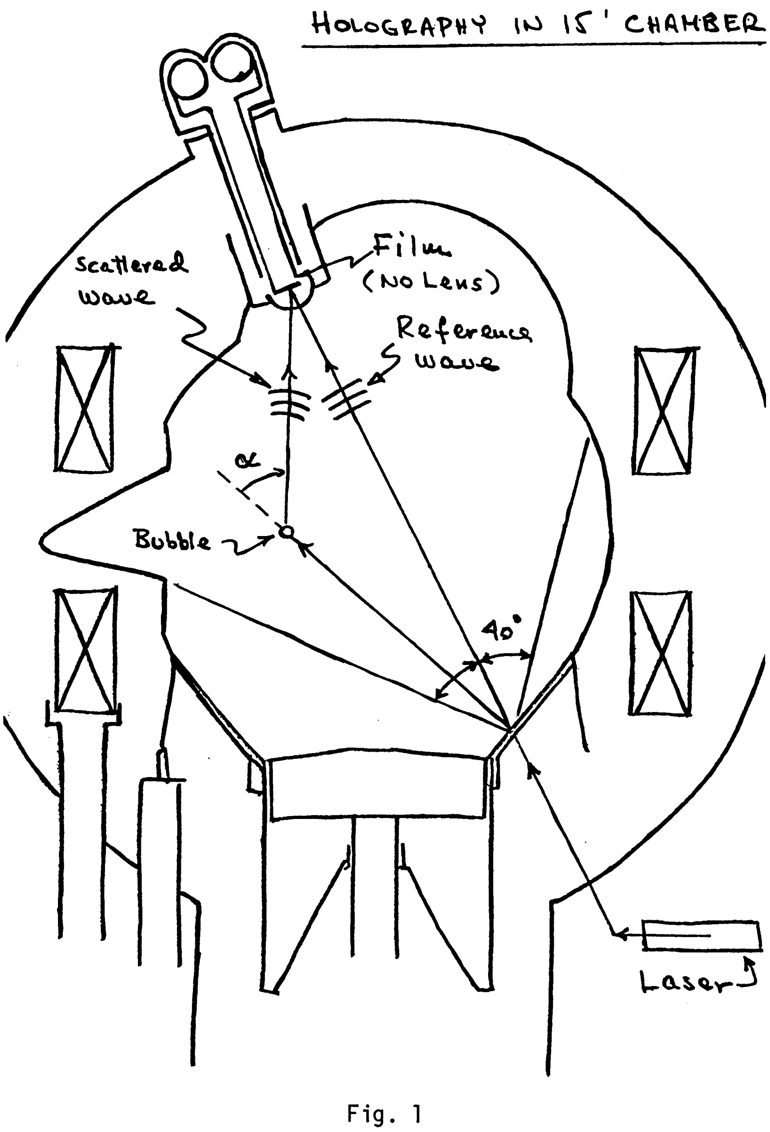

Fig. 1

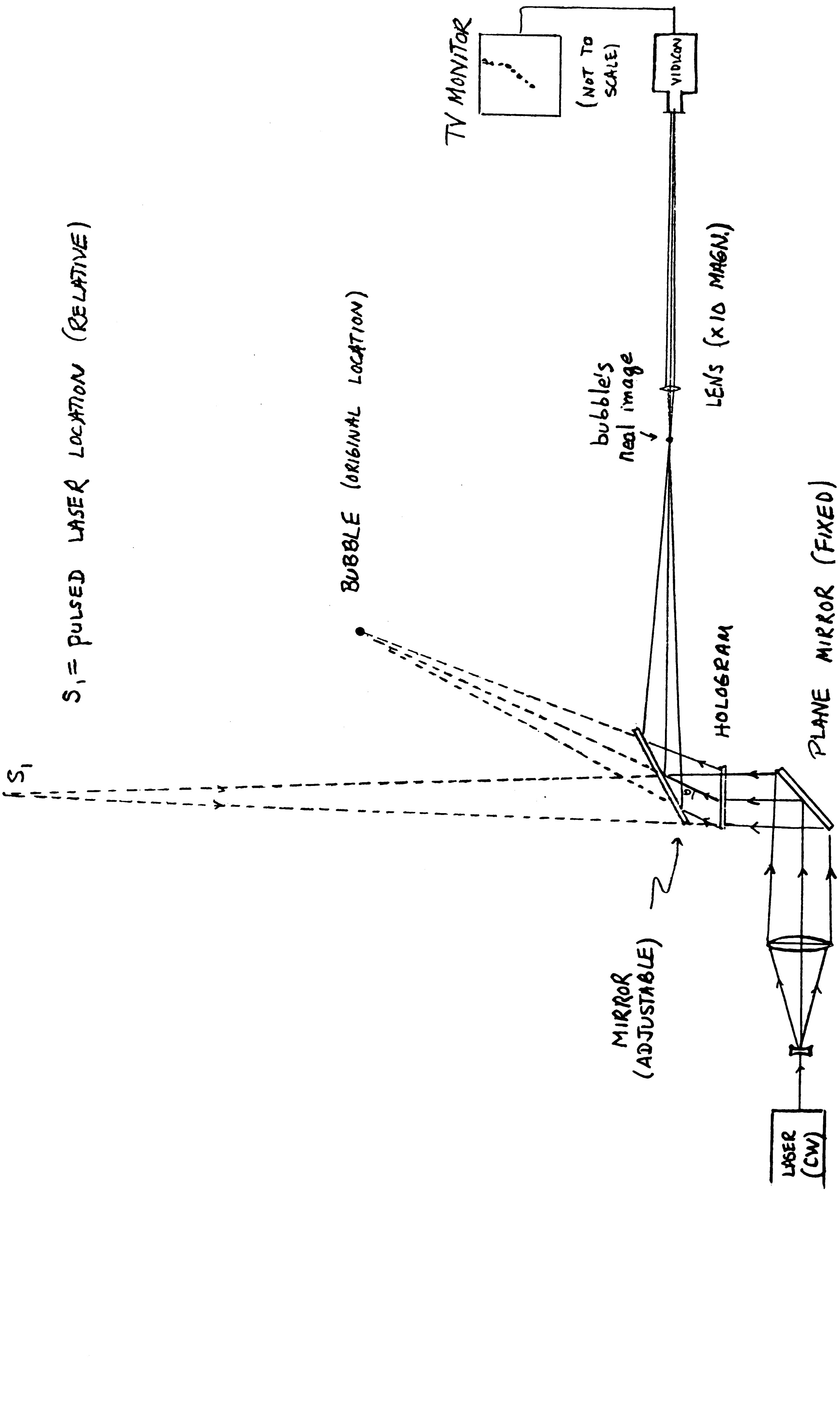
S₁ = PULSED LASER LOCATION (RELATIVE)
S₁
BUBBLE (ORIGINAL LOCATION)
TV MONITOR
(NOT TO SCALE)
VIDICON
bubble's real image
LENS (X10 MAGN.)
HOLOGRAM
θ
PLANE MIRROR (FIXED)
MIRROR (ADJUSTABLE)
LASER (CW)

Fig. 2