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HOLOGRAPHIC RECORDING OF COSMIC RAY TRACKS IN BEBC

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ABSTRACT

We report on a successful test of holography in the Big European Bubble Chamber (BEBC) at CERN, which was performed in 1983(*). During the test of a modified in-line scheme we recorded, with the help of a Q-switched ruby laser (~ 3 J), bubble tracks longer than 1 m. These tracks, produced by cosmic rays, appear at random time and place inside an illuminated cone with 15° half angle (~ 3 m^3). The smallest bubbles, which were recorded with good contrast and replayed in a very simple set-up with an argon-ion laser, had a diameter of ≥ 120 μm FWHM. The present test result presents an improved resolution of a factor of five compared to conventional photographs. The technique will eventually be used to complement the conventional bubble chamber optics in the search for a direct verification of the existence of the ν_τ and in the study of neutrino production of short-lived charm and beauty at Tevatron energies. Unsolved problems, in particular the heating effects of the bubble chamber liquid by the high-power Q-switched laser and approaches to reduce the laser-induced boiling, are being studied, and one particular aspect will be discussed in the following paper.

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1. EXPERIMENTAL ARRANGEMENT AND RESULTS

An in-line holographic scheme was tested in BEBC on a parasitic basis during a physics run for a neutrino oscillation experiment. This test, during which ca. 100 holograms were taken, is considered to be a feasibility study. Its shortcomings are mainly inherent to the fact that no particle beam was available (less than one interaction during 10 000 expansions!). Therefore, measurements could only be made on cosmic ray tracks. They are indicative for the possible gain in resolution in large volumes over classical photography. The optimisation of bubble densities along particles tracks in a real experiment with proper timing of photography, as well as more sophisticated replay optics may yield more reliable results and, hopefully, an even higher resolution and improved contrast than during this first test.

Since the experimental set-up and results have been published [1], we limit ourselves here to the discussion of selected topics concerning necessary improvements of our technique for physics experiments in the 15-foot bubble chamber at the Fermilab Tevatron.

The real image of replayed holograms reveals a periodic variation in contrast along the tracks. The most likely cause is the short and unstable coherence length of our prototype laser (mostly only several millimetres for actual holograms), which can be overcome by a commercial holographic laser with typical coherence lengths in excess of 2 m. This variation can also be caused by some circular pattern in the light output of the diverging lens, due to minor defaults during its manufacturing.

Sometimes we observed "double images", looking like closely parallel tracks. The phenomenon can most easily be explained by the existence of two reference beams, the second unwanted beam being produced by light scattered off the lens mount and/or parasitic boiling on the mount.

We never obtained a Gaussian beam profile in the far-field (15 m), for which the light diverging lens was designed. In addition we had some physical, non-stationary obstruction inside the chamber liquid in the light pass between the last amplifier and the lens. This prevents us from determining the beam balance ratio from our experiment, and, consequently, does not yet allow for a final estimate of the laser energy needed to illuminate a considerably larger volume than photographed in our BEBC test. Only a better quality laser, an appropriate optical beam transport system, a differently designed diverging lens together with a modified mounting can give the required answers during a new test run.

The development of replay optics, which accounts for the effects of the fisheye windows and the refractive index of the chamber liquid, and which uses a continuous laser of the same wavelength as the recording ruby laser, will allow for the determination of the obtainable resolution.

2. CONCLUSIONS

We have demonstrated that bubble tracks with $\geq$ 120 μm can be photographed with good contrast in a large chamber with a modified in-line technique. We did not encounter adverse effects from the magnetic field, and the quality of the image was hardly affected by speckles. Apart from the minor difficulties outlined above, we had, however, a serious problem with laser-induced boiling. This did not affect the quality of the holograms, but caused considerable fogging of the conventional photographs and disturbed the thermodynamic stability of the bubble chamber. Approaches to overcome this adverse effect are being studied experimentally [2].

REFERENCES

[1] H. Bjelkhagen et al., Nucl. Inst. & Methods in Physics Research, 227 (1984) 437-451.

[2] G.G. Harigel, these proceedings, pg.