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TEMPERATURE SENSITIVITY OF A NIKON APO-NIKKOR LENS

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The work described in this note was carried out for an experiment at the SLAC 1-m. Hydrogen Bubble Chamber Hybrid Facility. The requirement was to photograph the bubble tracks of charged particles before the bubble diameters had grown beyond 40 - 50 μm. This was done in the usual way by silhouetting the tracks against a retroreflecting sheet at the back of the bubble chamber. Flash tubes were placed close to the camera lens, and were fired about 200 μ sec after passage of the charged particles. (The bubble chamber hydrogen was run at about 29^{o}K to control the rate of growth of the bubbles.)

The intervening physical media were:

175 mm of liquid H_2

277 mm of parallel sided BK7 glass

1686 mm of vacuum

32 mm of quartz vacuum window.

After these materials, the camera could be mounted in room air, subject, however, to being purged continuously with air because of the hydrogen area safety rules.

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The choice of lenses was a 610 mm Nikon Apo-NIKKOR f/9 lens. Two of these were needed, each to image about half of the bubble chamber fiducial length, with a demagnification of 2.67. The images were recorded on 35mm film in a specially constructed transport and vacuum platen assembly.

Focussing was accomplished by reference to film taken of beam interactions. The beam, of 20 GeV gamma rays, was 3 mm in diameter while the camera depth of field at f/13.5 was 5.3 mm (Rayleigh's Criterion). The focus adjustment was made by the use of shims to change the lens-to-film distance.

When the data collection run had settled down and the camera mounting and focussing was believed stable, it became clear that the bubble images were not remaining in focus over a time interval of several hours. It was eventually found that:

(a) There appeared to be a day - night shift of the focal plane;

(b) The beam position was stable relative to the bubble chamber within a fraction of a millimeter;

(c) The camera platen position was stable relative to the bubble chamber to within about 0.15 mm. This is effectively in image space, however, and corresponds to 0.9 mm in object space.

(d) The shift in the plane of focus, however, amounted to about 5mm from day to night, being closer to the camera during the night. This was determined by hand measuring events on the film.

Calculations of linear expansions caused by the 17^{o}C to 25^{o}C maximum temperature excursions observed could not reproduce the size of the effect within a factor of about five. The largest effect - from the aluminum lens mounting barrels which support the lenses from the platen structure - is actually in the opposite direction. Estimated effects for the lens itself, using typical expansion and refractive index changes for optical glasses, were very small.

The only possibilities not yet excluded, however, were thermally induced distortions of the fused silica vacuum window or of the lens. The vacuum window is gasketted by rubber and PTFE, and is therefore not subject to distortion forces from its flange. Consequently a test was made on the spare lens. It was set up to view an array of 30 μm diameter wires spaced at object distances increasing by 2.54 mm from each other. The image was viewed by a x 40 microscope. The conditions were subsequently improved by using 20 μm diameter wires and a x 100 microscope. Note that the Rayleigh criterion resolution of the lens (which was set up with a 2.7 demagnification as in the experiment) should be 33 μm at f/13.5. Note also that the depth of field of the microscope was substantially smaller than the depth of focus of the NIKKOR lens. The lens and microscope were held relatively stable on a granite table.

The room temperature was varied in the range 15^{o}C to 25^{o}C. Results were clear and repeatable under two illumination conditions. Both dark field with light reflected from the wires, and bright field with Scotchlite[1] retroreflector, were used.

The effective object distance moved 6mm for a 10^{o}C shift in temperature, lengthening at higher temperatures.

This corresponds to a change in the lens focal length of 45 μm per degree C, or a fractional change of 7.3 x 10^{-5} per degree C.

Since this is presumably associated with lens distortions, attempts have been made to study image quality at the extremes in the temperature cycle. The results so far are inconclusive. Any such effects are probably too small to be important to the present bubble chamber experiment.

Changes of the effective object distance of the order of 1-2 mm were seen, however, occasioned by aperture changes in the range f/16 to f/9. This should be borne in mind if the lens parameters are altered in the future.

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[1]trademark of 3M Company, St. Paul, Mn.