PRELIMINARY TESTS ON HOLOGRAPHY IN BEBC

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ABSTRACT

A collaboration has been set-up between the Institut de Recherche in St. Louis (ISL), the Rutherford Appleton Laboratory (RAL), and the BEBC Group at CERN to study possibilities for application of holographic techniques in BEBC. Laboratory tests and a first trial in BEBC have shown that holograms can be recorded with a two-beam set-up adapted to the optics system of the chamber. The object beam passing through the fish-eye windows illuminates the chamber; after reflection from the Scotchlite panel at the bottom of BEBC it falls through a large-aperture lens onto the film plane. The reference beam is projected directly onto the holographic film plane without passing through the chamber liquid. First results are presented on the influence of the BEBC magnetic field, vibrations of the BEBC expansion system, and on the limitations on resolution to be expected. An outlook is given of future plans for trying to feed a test program on holography into the physics program of the chamber.

1. INTRODUCTION

The ISL-RAL-BEBC Collaboration has been studying the possibilities for application of holographic techniques in BEBC[1)].

2. EXPERIMENTS AT ISL

At the beginning of this year several experiments were carried out at ISL by H. Royer[2)].

2.1 Set-up

Figure 1 shows the set-up provided in the laboratory. A krypton laser is used. The beam laser is divided by a prism into two beams: the object beam and the reference beam.

2.2 The object beam

After the beam splitter the object beam lights up a panel of Scotchlite, via small mirrors falls back on a lens, and finally illuminates the holographic plate which is between the real image and the lens.

2.3 The reference beam

After the beam splitter the reference beam lights up three mirrors and falls on the plate at an angle of about 30°. In fact the plate is inclined in order to be perpendicular to the angle of the two beams.

2.4 Characteristics of the set-up

Distance object to lens	2 m
Distance Scotchlite to lens	4 m
Total optical path	8.9 m
Diameter of the lens	150 mm
Focal length of the lens	750 mm
Aperture of the lens	F = 5
Diameter of the holographic image	50 mm
Demagnification	0.6

Diameter of the illuminated Scotchlite	150 mm
Wavelength of the krypton laser	Λ = 6470 Å
Ratio of light between reference beam and object beam	
on the hologram	2/1
after the beam splitter	1/25
Energy of the laser	1.5 mJ

2.5 Results of the experiment

Several holograms of 50 μm wires made of brass (see Fig. 2) were taken with a very good contrast and it is very difficult to perceive a difference between the real image and the holographic image.

The slides were taken from very poor polaroids but remain quite good.

3. EXPERIMENTS AT CERN

After these very encouraging tests which proved that with a very simple lens and Scotchlite it was possible to see clearly wires of 50 μm, we decided to plan an experiment in BEBC during a technical run in June[3].

3.1 Experimental layout (Fig. 3)

The Big European Bubble Chamber (BEBC) in which first holographic tests were made contains 36 m^3 of liquid hydrogen. The chamber body is surrounded by two superconducting coils providing a magnetic field of 35 kG.

On top of the chamber there are five windows, each consisting of three hemispherical components (fish-eyes). Two window components are made of quartz and the third component, which is in contact with the hydrogen, consists of BK7 optical glass. The interior of the chamber is covered with Scotchlite, a material designed to reflect light along its incident direction with a very small angle of diffusion.

At the bottom of the chamber there is a floating disc hiding the moving piston which produces the necessary underpressure causing the liquid to boil along the particle track.

The operating conditions of the chamber during the holographic tests are given below:

Chamber liquid	H_2
Chamber temperature	26.8 K
Chamber pressure	4.8 kg/cm^2
Refractive index of liquid	1.1
Magnetic field	0 to 1.8 T
Length of expansion cycle	100 ms

3.2 The set-up

The model of the set-up (Fig. 3) that we constructed was not very different from the one used at ISL.

3.3 The lasers

The compressors of BEBC generate heavy vibrations in the total area around the chamber. A pulsed laser is therefore needed to record the holograms even without the expansion system. The laser used was the ruby one built by H. Royer. Its characteristics are

Emitted wavelength	6943 Å
Energy per pulse	1.5×10^{-3} J
Pulse duration	20×10^{-9} s
Coherence length	1.5 m
Beam divergence	0.5×10^{-3} rad
Repetition rate	0.02 Hz
Electronic trigger	Pockels cell

In fact we needed a continuous krypton laser to align the ruby laser and the optical systems of the two beams.

3.4 The light beams

As already stated, we decided to choose holography with separated beams (see Fig. 3). The beam from the ruby laser is therefore split into two beams: an object beam and a reference beam.

The heavy shocks produced by the movements of the piston during expansion and the high magnetic field around the chamber are likely to upset the adjustment of the two lasers or even damage them.

The lasers therefore were placed far away from the centre of the chamber and on independent supports. Magnetic shielding was provided by AMCO casings, which also facilitated the pressurization demanded by the safety standards in a "hydrogen area".

The beam laser is separated into two beams by a beam splitter -- a glass prism of 30′ angle -- reflecting 4% of the light on each surface. Therefore the transmitted light is 92%.

In fact we needed a telescopic system giving an enlargement of ½ to reduce the effects of the divergence and eliminate light losses.

3.5 Object beam

The beam transmitted through the beam splitter is subsequently passing via a mirror mounted on the camera frame to the bottom of the camera shaft at a distance of about 4 m. After bypassing mechanical obstacles constituted by the camera it illuminates, via a set of a prism and mirrors, and a diverging lens (f = -20 mm, diameter 10 mm), the bottom of the chamber (see Fig. 4).

Diffused by the Scotchlite the light is directed back through the fish-eye and the photographing lens (a 150 mm focal length componon, f/5.6 aperture) illuminating the holographic film.

The entrance pupil of the photographic lens is mounted at the centre of curvature of the fish-eye to reduce the aberrations. The total optical distance of the object beam from the beam splitter is about 12 m.

3.6 Reference beam

The beam reflected by the beam splitter is used as a reference. The intensity of the beam is compared to the object beam intensity which is very low owing to the small aperture of the lens, to the Scotchlite, to the hydrogen, and to the fish-eyes.

As the reference beam is not passing inside the chamber, it has to have an optical path outside the chamber in order to satisfy the coherence conditions necessary for holographic recording. The reference beam is sent to a mirror located about 3.5 m away from the beam splitter, returning after reflection and entering the camera shaft. At the bottom of the shaft a prism and mirror system reflects the beam on to the film via a short focal length diverging lens (f = -12 mm). The angle between the object beam, hitting the film at right angles, and the reference beam is 30°.

3.7 The holographic film

We decided to take holograms with one camera of BEBC, and we modified the camera mounted in the shaft number one. We used Agfa 10E75 film with the following characteristics:

Size	70 mm
Substrate thickness	185 μm
Backing	polyester
Perforation	standard but made to order
Spectral sensitivity	up to 750 nm
Absolute sensitivity	2 $\mu J/cm^2$

The film was developed in a Kodak versamat automatic machine for 5 min using D19 developer at 30 °C. It was thus possible to double the sensitivity of the film as compared to normal development, so as to compensate for the low energy of the ruby laser.

4. PROBLEMS ENCOUNTERED DURING THE SETTING UP OF THE OPTICAL SYSTEM

We used an output power of 600 mW with a krypton laser. Unfortunately, the power losses, of the order of a factor of 1000 when passing the krypton laser beam through the ruby laser, forced us, especially for the reference beam which used only 4% of the light, to install a third laser (helium neon) of 5 mW downstream of the ruby laser.

The different divergences of the krypton, of the helium neon, and of the ruby lasers required a systematic correction to be introduced into the adjustment of the afocal system. This correction could not be checked inside the camera shaft.

The coherent length of the ruby laser used is of the order of 1.5 m. The optical paths of the light in each beam (totalling more than 20 m) therefore had to be adjusted to within 10 cm to ensure that the fringes of the holograms were recorded with a contrast that was acceptable for the whole field. As the regions within the shaft and in the chamber (about 12 m) were completely inaccessible, the *in situ* measurements and the estimates according to the drawing had to be calculated very carefully to obtain the necessary precision.

The energy of the light pulse provided by the ruby laser is a basic parameter which cannot be altered during testing. The value we measured *in situ* was 1.5 mJ. There were no means to measure the energy received by the hologram from either the reference beam or the object beam. Tests performed with single and multiple exposures showed that the reference beam was luminous enough, but light intensity was lacking in the object beam. The diameter of the object field had therefore to be reduced to one quarter to assure a sufficient level on the hologram.

Realignment of the light beams on the 6 mm diameter diaphragm at the bottom of the camera shaft was also necessary when the magnetic field of the chamber was raised. Slight movements of the metal parts, due to the magnetic field, even on top of the chamber, required readjustment of the optical system.

Finally, the movement of the chamber expansion piston caused considerable vibrations which, with our layout of the optics, prevented us from recording holograms of tracks during chamber expansions.

5. RESULTS OBTAINED

5.1 Hologram without magnetic field or expansion

Figure 5a shows the hologram of the pupil of the photographic lens. As this aperture is lit only by the light reflected from the Scotchlite, some interesting conclusions may be drawn from this image. The luminosity of the image indicates that the fringes of the hologram have been recorded with good contrast, and that the difference of optical light paths between reference and object beams is still considerably less than the coherent length of the ruby laser for the field of view concerned.

The high-luminosity diffusion properties of the Scotchlite, already demonstrated in the preliminary tests without hydrogen, are confirmed. It also illustrates that the ratio of beam intensities, between reference and object beams recorded in the hologram, seems to be close to optimum[4)].

5.2 Study of the effect of the magnetic field

Further holograms, taken at five different values of the magnetic field, show that the luminosity of the reconstituted images is remarkably stable. The values of the magnetic field were 0, 1000, 3000, 10,000 and 18,000 G.

5.3 Tests with expansion

As has been said, the vibration produced by the piston movements throws the set-up out of adjustment during the expansion cycle. It was thus impossible to record holograms in these conditions. Although this is a purely technical problem, it will have to be dealt with very carefully, in view of the considerable nuisance caused.

6. INTERPRETATION OF RESULTS OBTAINED

6.1 Laser energy

All holograms were recorded with a laser energy of 1.5 mJ. With this energy, only 1/16th of the desired total field could be illuminated. The losses by reflection, produced by the double passage of the object beam through the fish-eye, may be estimated at about 50%. Moreover, the aperture of the componon lens was fairly small at f/5.6. It would be feasible to fit a lens with double the aperture (f/2.8), giving adequate resolution with monochromatic light, and this would increase the light by a factor of four. Nevertheless it would be preferable to develop the film under normal conditions. A laser energy of 12 mJ would have to be used to holograph the intended total field of 1 m^2 in BEBC.

6.2 Image resolution

The small size of the reconstituted field prevented us from covering the area in BEBC where two 300 μm wires were stretched in the chamber. A 500 μm thick vertical wire reconstructed on the hologram with poor contrast (see Fig. 6) indicates that the small size of our lens aperture, spherical aberrations of the fish-eye windows, parasitic light reflected back from the window surfaces, and dust accumulated in the fish-eyes still represent severe limitations that have to be overcome in the future. Finally, the difference in wavelength between recording and reconstituting the holograms may account for an additional loss of quality in the image.

Figure 7 shows that the reference beam was very dirty.

7. EXPERIMENTS WITH THE FISH-EYE AT THE RUTHERFORD APPLETON AND ISL LABORATORIES

After the experiment in BEBC we wanted to test the set-up in the laboratory especially with the fish-eye.

At Rutherford we used an argon laser. We took a hologram of a 125 μm wire with a very poor contrast; but the direct image was very poor too. We had many problems with the vibrations which prevented us from taking a hologram with a long exposure time.

At ISL we recorded a wire of 200 μm with a relatively good contrast. In fact it is very difficult to see a difference, once again, between the two pictures.

After these tests we could say that it was possible to record a wire of 300 μm in BEBC even with a fish-eye and with a standard lens if we had enough light[5)].

8. LAST EXPERIMENT IN BEBC

We have just tried to take a hologram in BEBC with Royer's laser. We removed the camera from its shaft and used a very simple system with a holographic plate. Unfortunately the flash tube of the amplifier of the laser exploded and we could not record any hologram.

We tested our set-up with success during the expansions and we repeated the tests of May to see that the intensity given by the Scotchlite through the lens was the same at any value of the magnetic field between 20,000 G and 0 G.

We saw the fringes on the Scotchlite only moving, growing, and disappearing. These were probably due to the birefringence of the mylar which covered the Scotchlite.

9. CONCLUSIONS

We have come to the following conclusions:

i) The Scotchlite is very convenient for recording holograms in BEBC.

ii) The fish-eye with a very large aperture lens calculated to correct its spherical aberrations will give a resolution probably better than 80 μm in a volume of 1 m^3.

iii) The Faraday effect will not prevent us from taking a hologram in BEBC.

In fact for our purpose we need a very powerful pulse laser which should be able to work in a magnetic field and during the expansions of the piston of the chamber.

We need to design a very sophisticated system to align the two beams in the very restricted space inside the fish-eye (a few mm), i.e. an electronic system.

It is also clear that we need to do many tests with a laser in the laboratory at CERN before starting a new experiment in BEBC.

REFERENCES

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5) H. Royer, F. Pouyat and W. Seidl, Premières expériences holographiques dans BEBC, Note CERN/EF/0475, 20 July 1981.

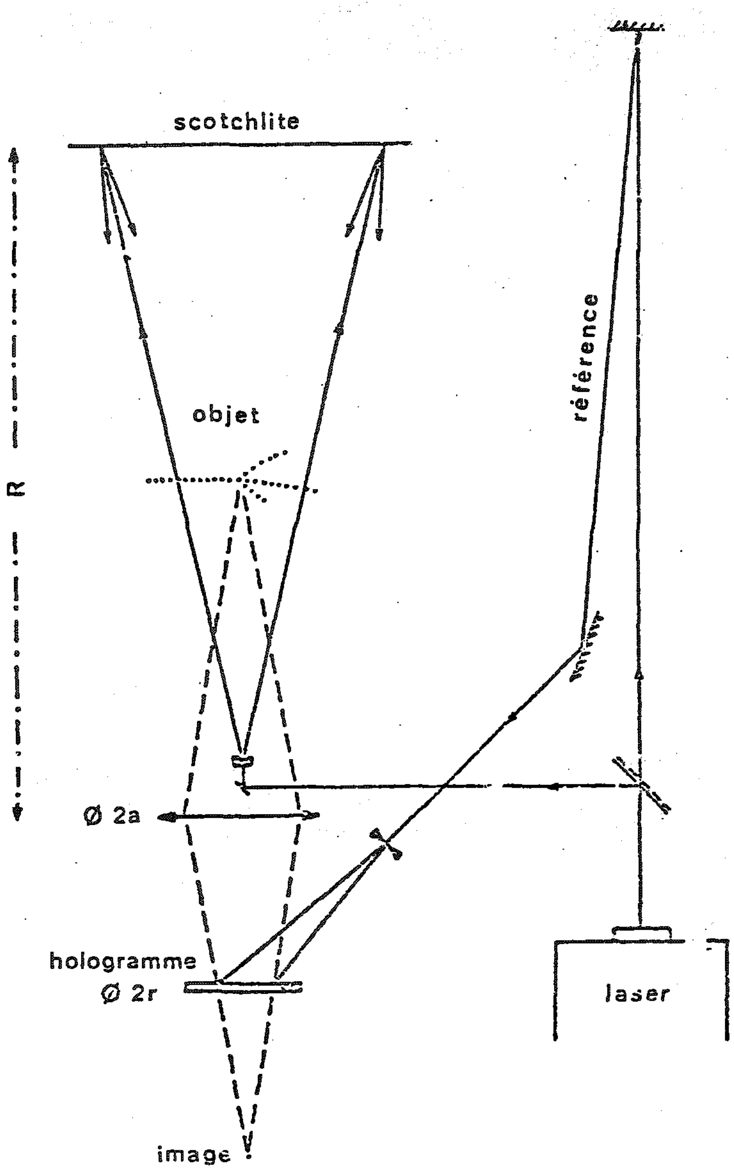
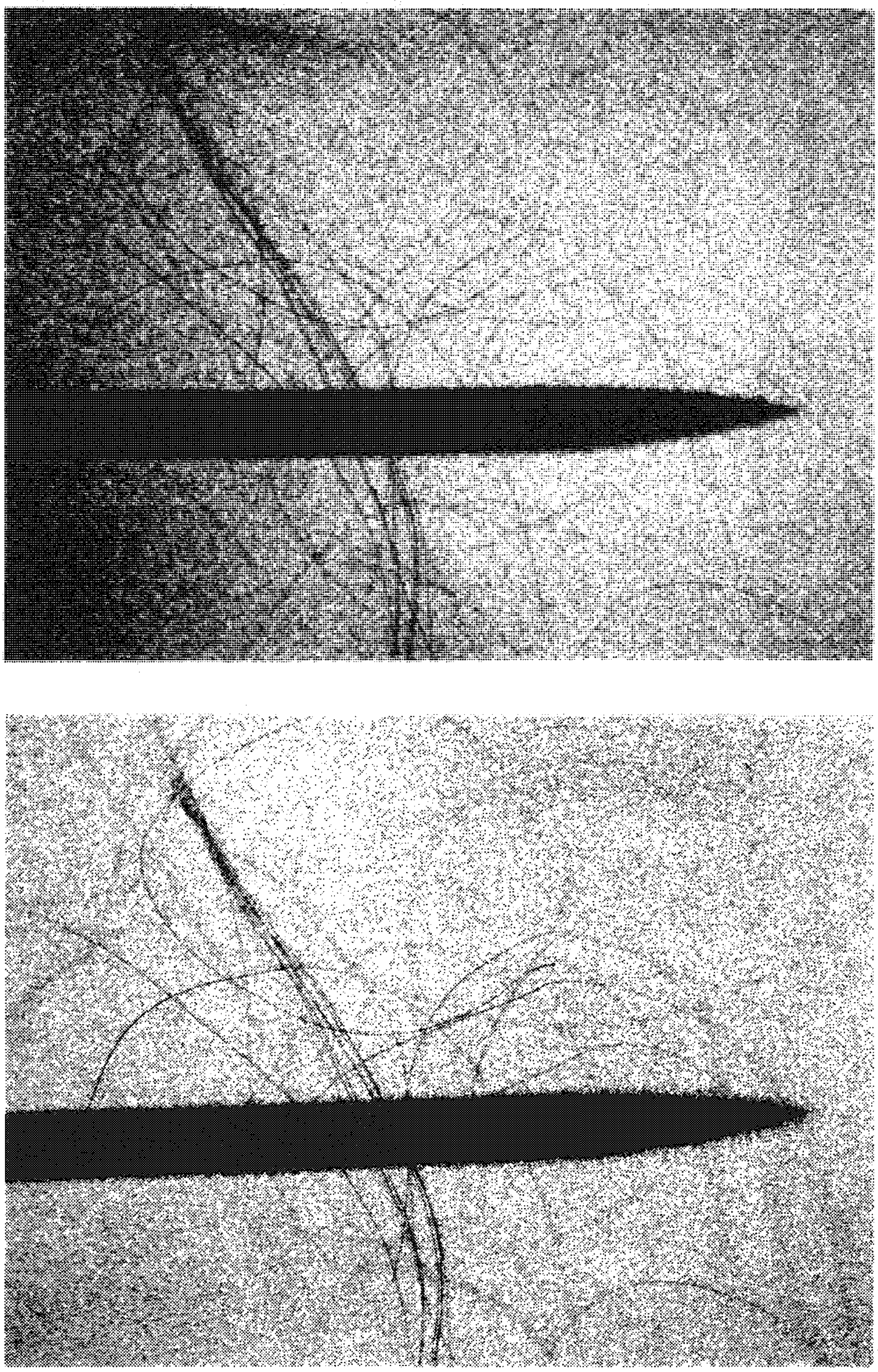


Fig. 1 Layout of the test in the laboratory



a)

b)

Fig. 2 a) Picture from hologram of 50 μm wires
b) Picture of 50 μm wires with classical optics

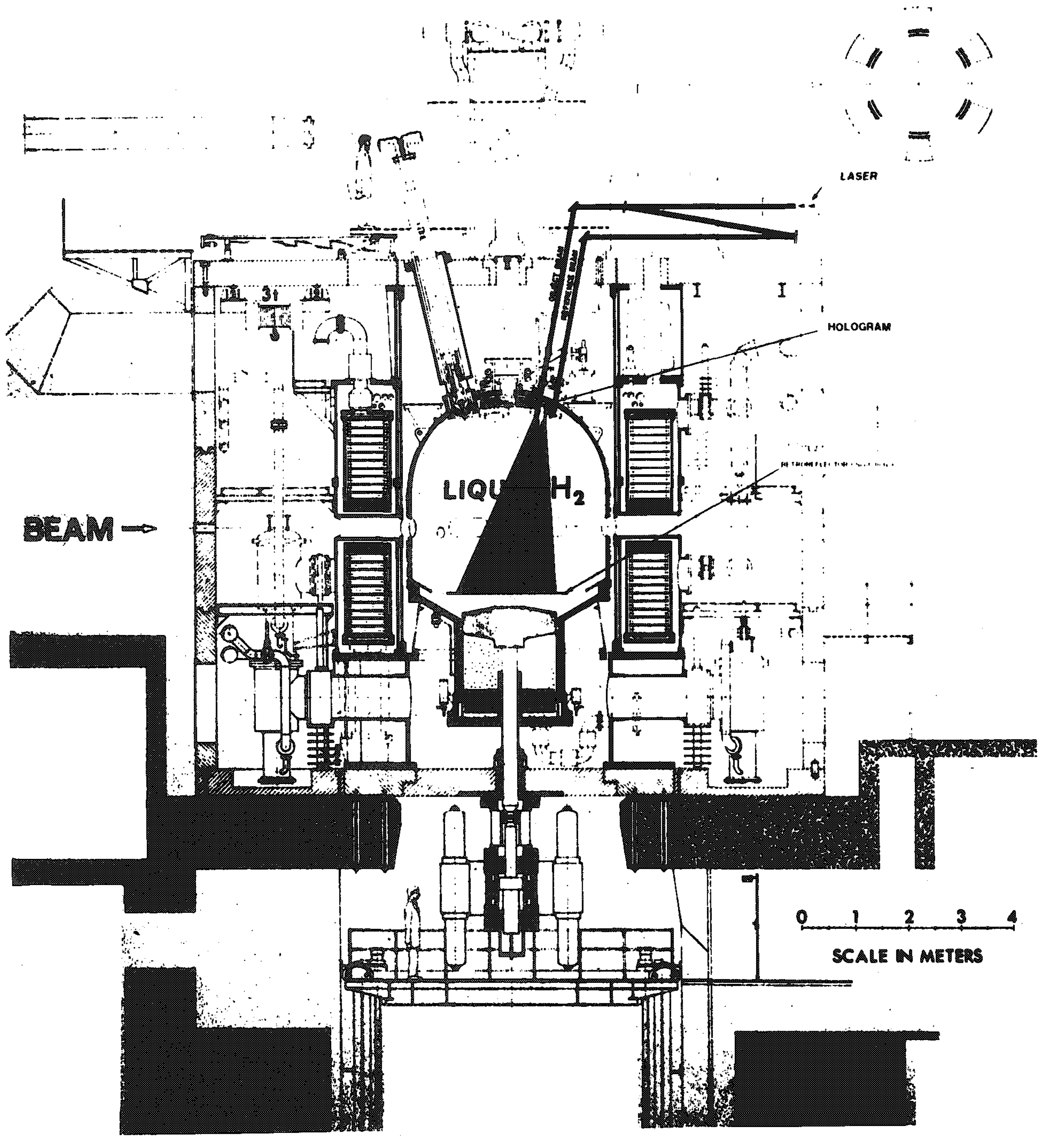


Fig. 3 Experimental layout at BEBC

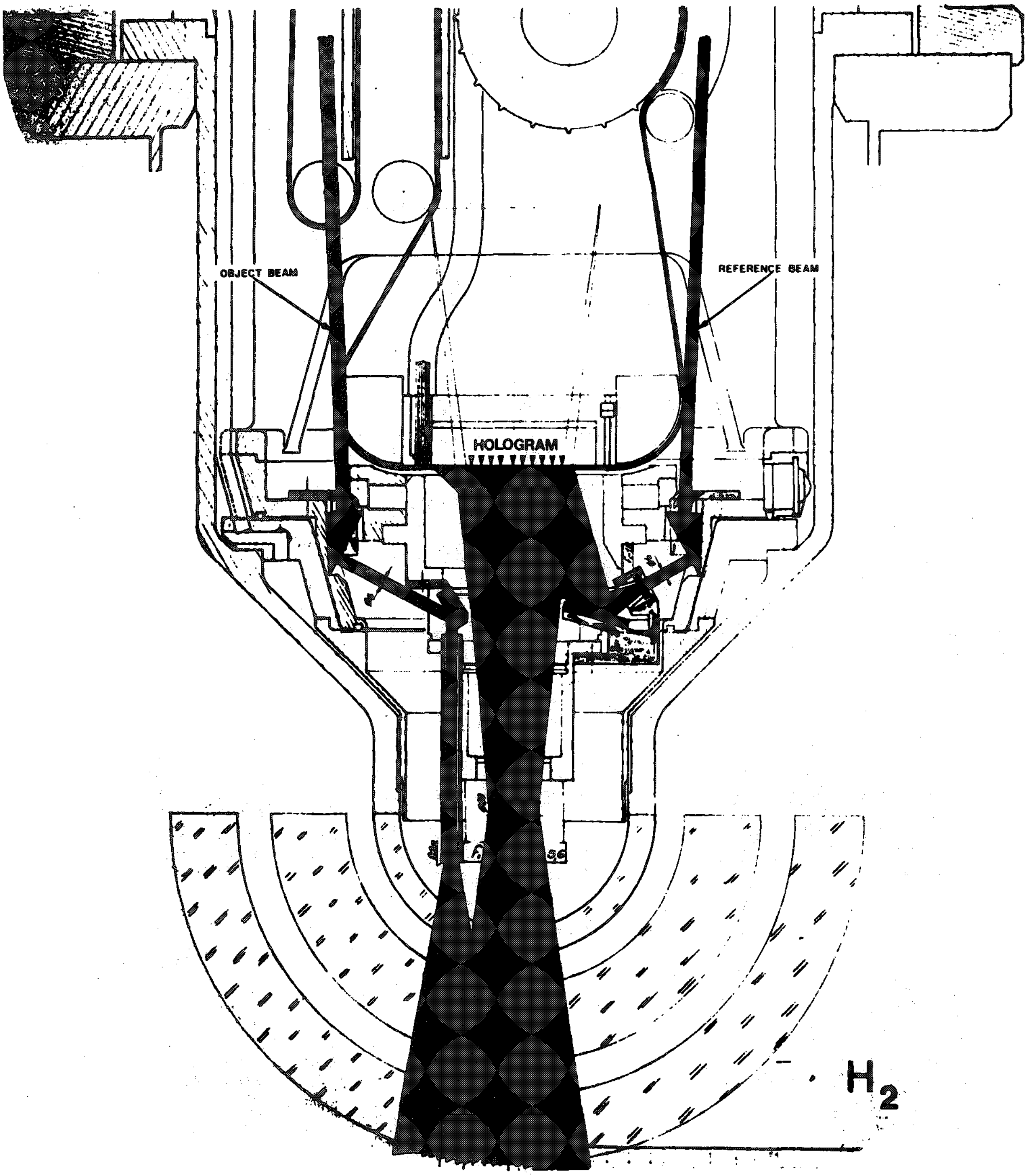


Fig. 4 Holographic set-up at BEBC

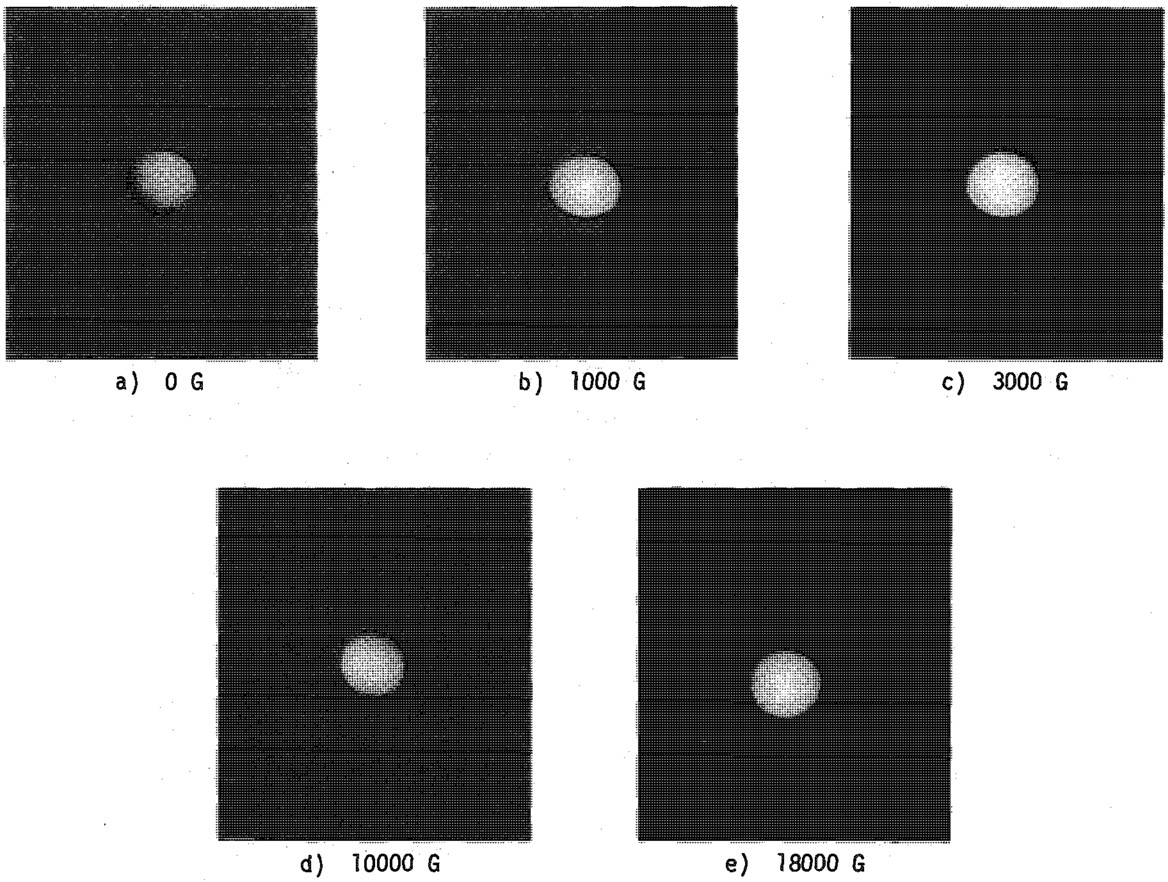


Fig. 5 Holographic image of the pupil of the lens for several values of the magnetic field

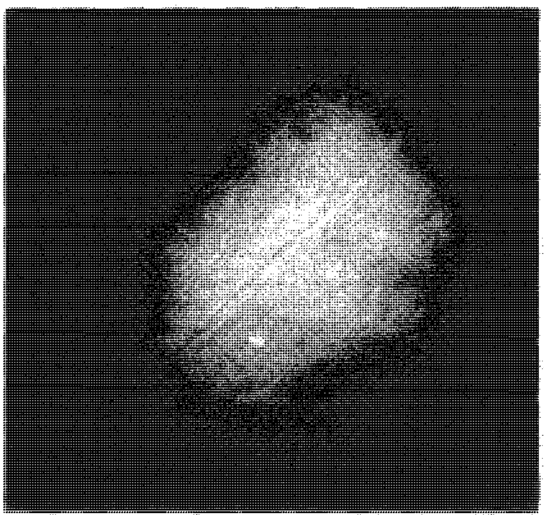


Fig. 6 Holographic image of 500 μm wire

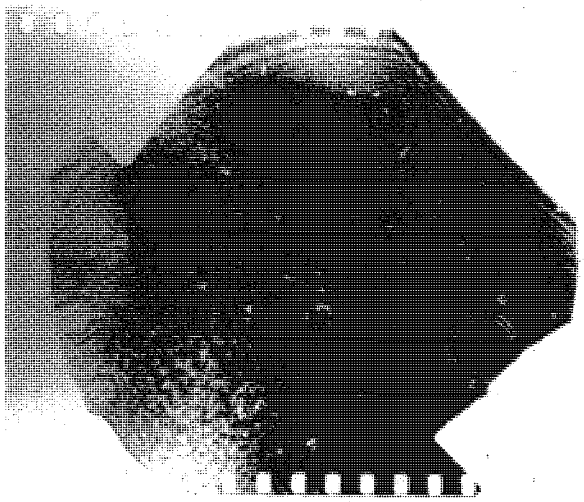


Fig. 7 Hologram of the reference beam