SYSTEM 2000 for HOLOGRAPHY

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Holography of large volumes using holographic scatter plates

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The possibility of producing front illuminated holographs of volumes large enough to allow holographic portraiture represents an important development in the field of holography. Here, a description of an experimental method used is given.

Using a pulsed laser it is now possible to obtain holograms of up to about 8 m hemisphere, and work is in progress at Marchwood to evaluate the process for such applications as recording nuclear reactor core regions prior to commissioning, to allow subsequent re-construction for simulation of in-reactor handling problems. Holographic recording of the distortion of turbo-generators under load, and even holography of the core region of in-service nuclear reactors is being actively considered. For all these applications the upper limiting dimensions of recordable volume are set by two factors: the coherence length of the pulsed laser radiation, and the ability to provide sufficient illumination at the extremities of the recorded volume. The first of these two requirements is met by careful laser design, to provide Tem_{00} single frequency operation, inevitably at the cost of laser power output. The second requirement can be met by building multi-stage oscillator amplifiers to increase the laser output at a cost of several thousand pounds per joule. Hence it is important to use the available illumination as efficiently as possible.

Illumination of holograms

Figure 1 illustrates the method of taking a side-band Fresnel hologram. Light from the laser is split into 'main' and 'reference' beams and their relative intensities adjusted so that the illumination falling on the holographic plate due to the reference beam is several – between 5 and 10 – times greater than the reflected main beam intensity. In this case 'split beam' illumination was used to light the scene being recorded. This is equivalent to using two flash bulbs in normal photography, and helps improve all round illumination. After processing, the holograph is reconstructed by providing a reference beam similar to the original one and viewing the virtual image. A photograph of a a typical reconstruction is shown in Fig. 2 and serves to demonstrate the high noise level typical in such a reconstruction. The noise results from imperfections in the original main beam arising from scattering centres in the laser itself and on the optical elements employed.

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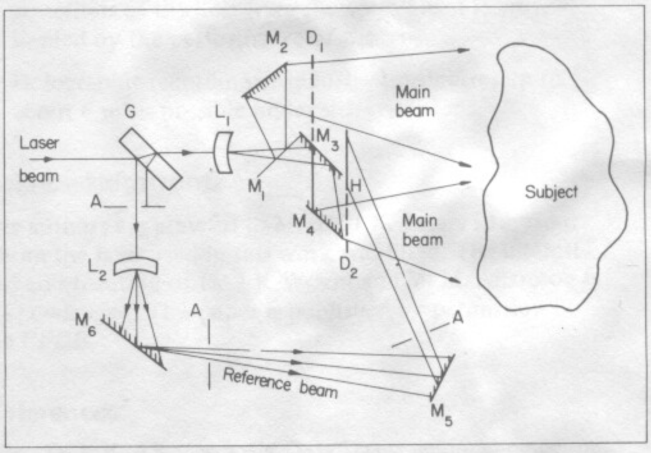

Fig. 1 Experimental arrangement for recording holograms

A less noisy hologram can be achieved by using a ground glass diffusing screen at D_1, D_2, (Fig. 1). In this way an extended source of coherent radiation is obtained and the importance of imperfections in the laser beam is much reduced.[1, 2] Fig. 3 illustrates the improved image quality obtained this way. This reduced noise level is not, however, obtained without cost. The plane of the extended source of main beam radiation has the roughness of the ground glass screen and this serves to degrade the maximum resolution obtainable in the reconstructed holograph.[3] Furthermore the ground glass screen scatters light in all directions with the consequent significant loss of illumination of the volume being recorded by the hologram.

Holographic scatter plates

Gates[4] has described how it is possible to construct a highly efficient, small-grained, scattering screen by taking a hologram of a 'master' scatter plate. Although Gates' paper concentrates on certain specialized applications, it is apparent that holographic scatter plates can have significant advantages over conventional diffuser screens.

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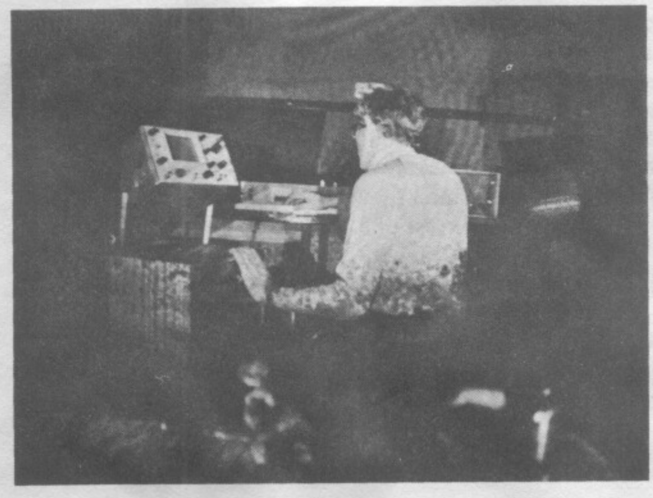

Fig. 2 Photograph of reconstructed hologram obtained using no diffusing screens at D_1 and D_2 (Fig. 1)

The scattering efficiency of the hologram is not governed by that of the 'master' so that a glass plate, lightly diffused with fine scattering centres can be used to produce a highly efficient 'fine-grained' holographic scatter plate in which most of the incident light, of the same wavelength, is scattered. The scattering angle can be carefully controlled, so that the scattered beam is used efficiently to illuminate a chosen volume. Numbers of identical plates can be made in this way, so that great care can be expended in manufacturing the 'master'. In the holographic scatter plate light scattering occurs throughout the thickness of the photographic emulsion, with very little absorption, so that high laser power densities can safely be used.

In the experiment described, the ground glass screens used to take the hologram shown in Fig. 3 were replaced by holographic scatter plates and a similar hologram was taken. Fig. 4 shows a photograph of a reconstructed scene. The plates had a designed scattering angle of 10° which, added to the main beam divergence angle of ~ 70° provided efficient illumination of the subject matter. Because of this increased efficiency only 3 J laser output was required instead of the 6 J required to take the hologram used for Fig. 3. There is also a marked improvement in the quality of lighting and the resolution obtained using holographic

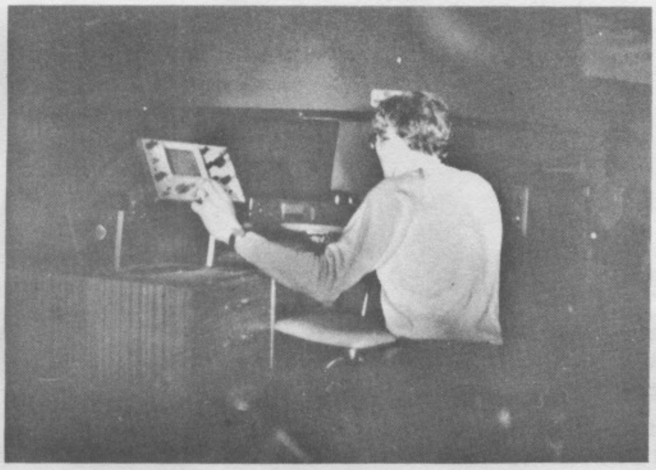

Fig. 3 Photograph of reconstructed hologram obtained using ground glass diffusing screens. Laser output 6 J

scatter plates, as illustrated by Figs 4a, b, c. Fig. 4a, taken with a wide angle lens shows the very wide coverage of the subject which has been obtained. In this hologram the recording plate H (Fig. 1) was actually mounted behind, but above, the glass block G with suitable screening of light scattered from the optical elements. The retort clamp visible in Fig. 4a centre left is a reflection in mirror M_2 of the clamp in the centre foreground. Fig. 4b, taken with a 180 mm tele-photo lens shows sufficiently fine detail in the jacket for the individual threads to be resolved, while Fig. 4c illustrates that good quality photographs of the foreground can also be obtained from the reconstruction.

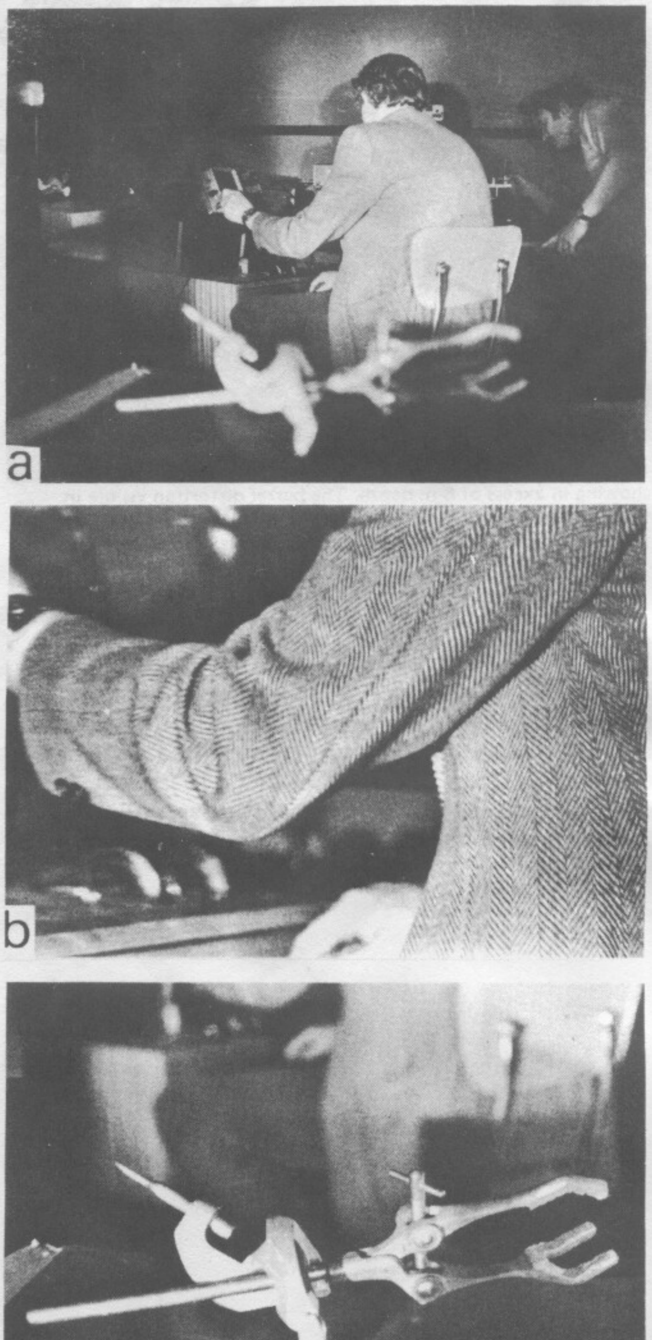

Fig. 4 Photograph of reconstructed hologram obtained using holographic scatter plates. Laser output 3 J. a – Wide angle view F = 28 mm at f/5.6; b – Telephoto view of jacket F = 138 mm at f/5.6; c – Close-up view of foreground F = 50 mm at f/2.8

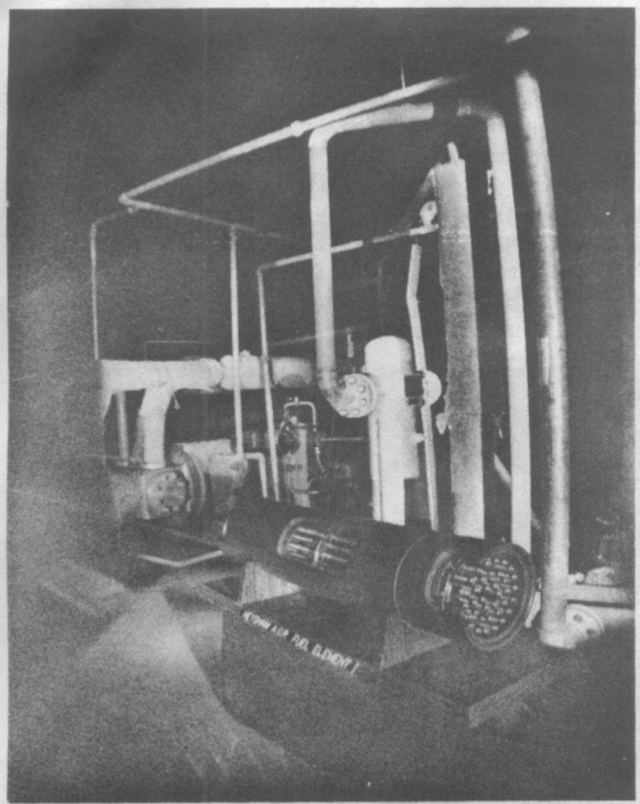

Fig. 5 Photograph of reconstructed hologram of industrial site showing in excess of 6 m depth. The barrel distortion visible in this view is due to the wide angle lens used to photograph the reconstruction. Reconstruction camera details: $F = 28$ mm $f/11$

Holography of large structures

The laser used for this work was a ruby laser fitted with a pockel cell Q switch. A maximum output of 10 J in a single axial and longitudinal mode could be obtained. Manufactured by J.K. Lasers Ltd, it consisted of a 10 × 0.6 cm oscillator rod followed by two amplifier stages using 20 × 0.6 cm and 20 × 1.5 cm ruby rods. In order to test the feasibility of using the equipment on an industrial site, and also to determine the maximum volume over which a hologram can be obtained, arrangements were made to record a portion of the compressor house at a nuclear power station. As the building could not be blacked out, or heated, the holograms were taken at night in sub-zero temperatures. The hologram obtained shows a maximum depth of reconstruction in excess of 6 m (Fig. 5). The granular effect visible in this photograph is 'laser speckle'. This is generated in the camera recording the image and is due to the small aperture ($F/11$) necessary to achieve the large depth of field. The camera lens used was a 24 mm focal length wide angle design; barrel distortion due to this wide angle lens is visible in the photograph.

Conclusions

1. Holographic scatter plates used as diffusers in a holographic camera can result in higher resolution holograms, and a significant saving in the laser power level required to illuminate a given subject.
2. The resolution of photographs obtained from reconstructions of the hologram shown in Fig. 4 is only limited by the performance of the lens.
3. Holographic recording of industrial structures up to about 6 m^3 is possible under site conditions.

Acknowledgements

The authors are grateful to Messrs J.K. Lasers Ltd, from whom the laser used in this work was hired. The interest and co-operation of Dr J.K. Wright and Mr M. Adamson is acknowledged. This paper is published by permission of the CEGB.

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