HOLOGRAPHIC RECORDING ON POLAROID'S POLAPAN CT

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Polaroid's continuous tone black and white 35 mm reversal-film Polapan CT is shown to be an ideal and convenient holographic instant recording material, if carrier frequencies of less than 50 mm^{-1} are used The measured characteristic curve shows the optimum contrast index of $\gamma = -2$ Diffraction efficiency is shown to reach values of 3 percent A matched filter experiment using Polapan CT is presented

1 Introduction

For recording a thin amplitude hologram, e g , a VanderLugt filter, a reference beam is added to the object wave front to form an interference pattern, whose modulus squared is registered, e g , by photographic film Hence, the H&D curve of an ideal holographic material has a slope of $\gamma = -2$, i e , the material transforms an input energy linearly into an amplitude transmittance The reconstruction of such an ideal hologram results in the following terms

– The object and the conjugate object wave fronts in the 1st and −1st diffraction orders

– The autocorrelation of the reference wave and of the object wave front, both forming the 0th diffraction order The support of this term is twice the support of the object

The supports of both terms determine the minimum carrier frequency

A photographic material with $\gamma = -2$, however, is in general not used for producing Fourier holograms, because it needs tedious reversal processing Therefore, negative film is usually used Its nonlinearity causes several unwanted effects

– Nonlinear distortion of the object wave To mitigate this effect the modulation index of the hologram should be low This increases noise

– The support of the 0th diffraction order becomes much larger due to the presence of higher correlation products Therefore, a higher carrier frequency is needed This requires higher quality lenses, e g , in a filtering arrangement

– Large areas of low exposure produce a low density In practice this may cause stray light problems

It follows, that the quality requirements (noise, resolution) are much lower with a $\gamma = -2$ reversal film than with an ordinary negative film, provided that the same hologram quality is desired

In 1984 Polaroid introduced their 35 mm system Among the three different films available there is also a continuous tone b/w reversal film, intended for pictorial photography and reproductions Polapan CT This film comes in the usual 35 mm cartridges and has 36 exposures Its speed rates as ASA 125 The total processing time, including unloading the camera, is less than 5 min After that time the film is already dry and can be used instantaneously Furthermore no dark-room is needed Results from measurements and experiments with this film are now presented

2 Measurements

We measured the H&D curves of two different batches of Polapan CT, yielding curve 1 and curve 2 of fig 1 These curves are arbitrarily shifted against each other along the log E axis The films were exposed with Ne-He laser light (633 nm) and the density D was measured with specular light of the same

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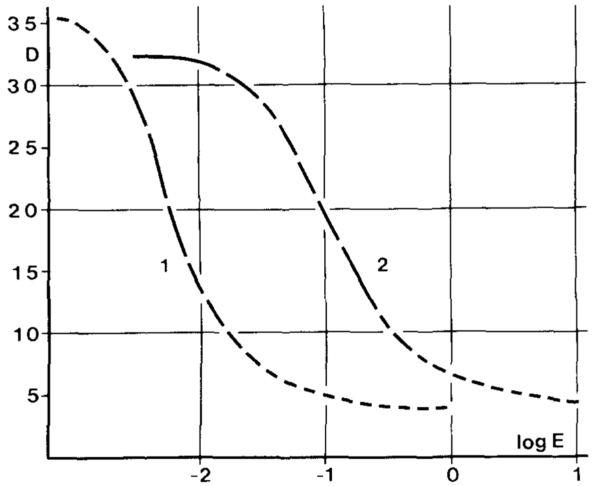

Fig 1 Characteristic curves of two different Polapan CT emulsions (positions with respect to log E axis are arbitrary)

source For convenience, exposure was varied by adjusting exposure time Obviously emulsion 2 has a slope of exactly $\gamma = -2$ 0, while emulsion 1 has higher contrast Since the value of the γ of emulsion 2 also coincides with Polaroid's data sheet, we consider curve 2 to show the "normal" behaviour of Polapan CT The following measurements and experiments have been made with this emulsion 2 In fig 2 curve 2 is redrawn in a log E versus amplitude transmittance diagram

The curves of fig 1 reveal unpleasantly high fog densities This is partially due to the greenish film base, which causes an additional red-density

To test Polapan's dynamic behaviour, we recorded two-beam interferograms and measured their diffraction efficiencies η, defined by the intensity-ratios between the 1st diffraction order and the input beam In fig 3 the efficiency η is plotted as a function of exposure at the lowest recorded frequency of 15 mm^{-1} Also shown in fig 3 is the intensity in the 0th diffraction order normalized to the input intensity as a function of exposure With the optimum exposure interferograms with frequencies of f_0 = 15 mm^{-1} to 90 mm^{-1} were recorded and evaluated The resulting curve is shown in fig 4 The diffraction efficiencies are quite high for frequencies up to about 50 mm^{-1}

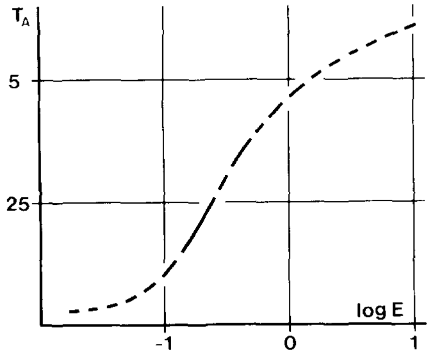

Fig 2 Amplitude transmittance diagram of emulsion 2

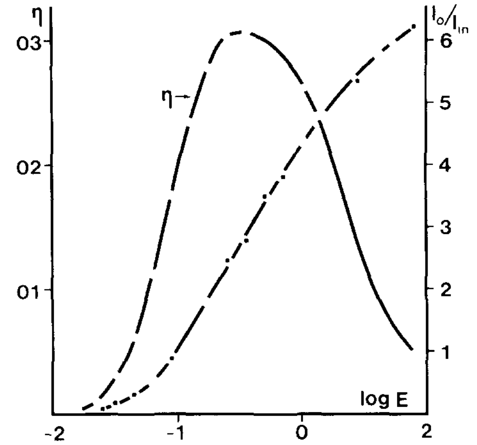

Fig 3 Influence of exposure on diffraction efficiency η and on the intensity in the 0th diffraction order, for a spatial frequency of 15 mm^{-1}

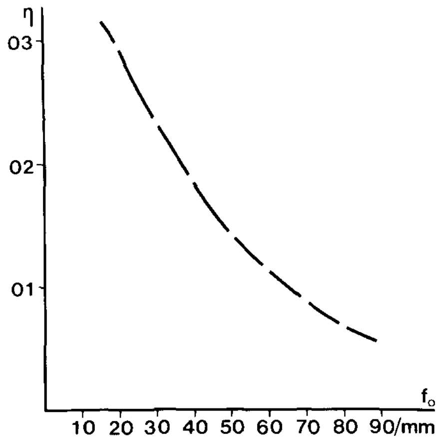

Fig 4 Diffraction efficiency η versus spatial frequency f_0

3 Experiment

Polapan CT was first used by us for the following sophisticated correlation task The input for a coherent optical correlator was a piece of 16 mm cine film (8 frames), with 15 point-like objects in each frame Ten of these points move at random, while 5 points travel the same path in parallel Given that path, the original location of the 5 points should be detected Fig 5 shows both the input sequence and the sequence

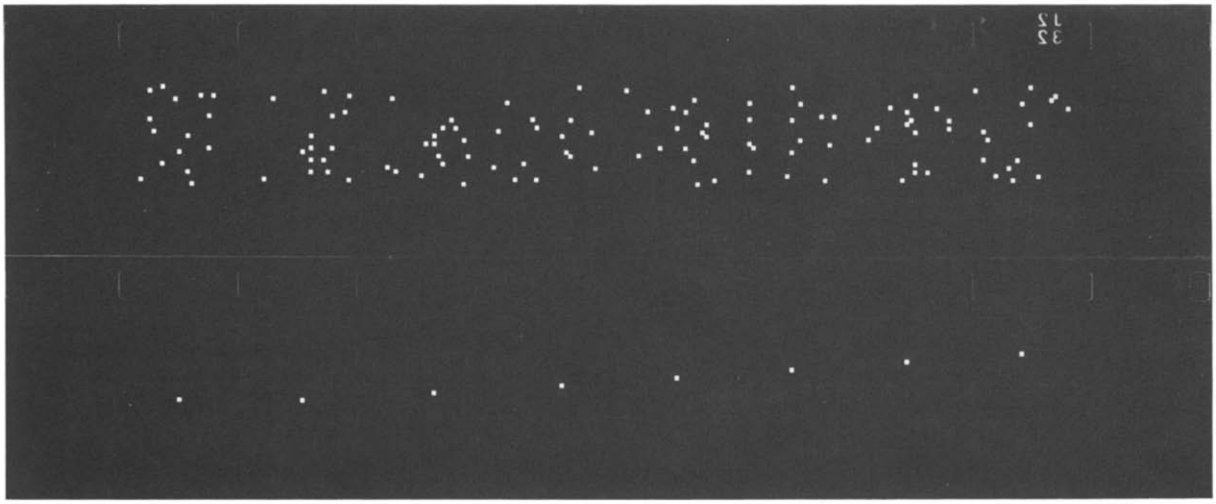

Fig 5 Input sequence (top) and search sequence (below)

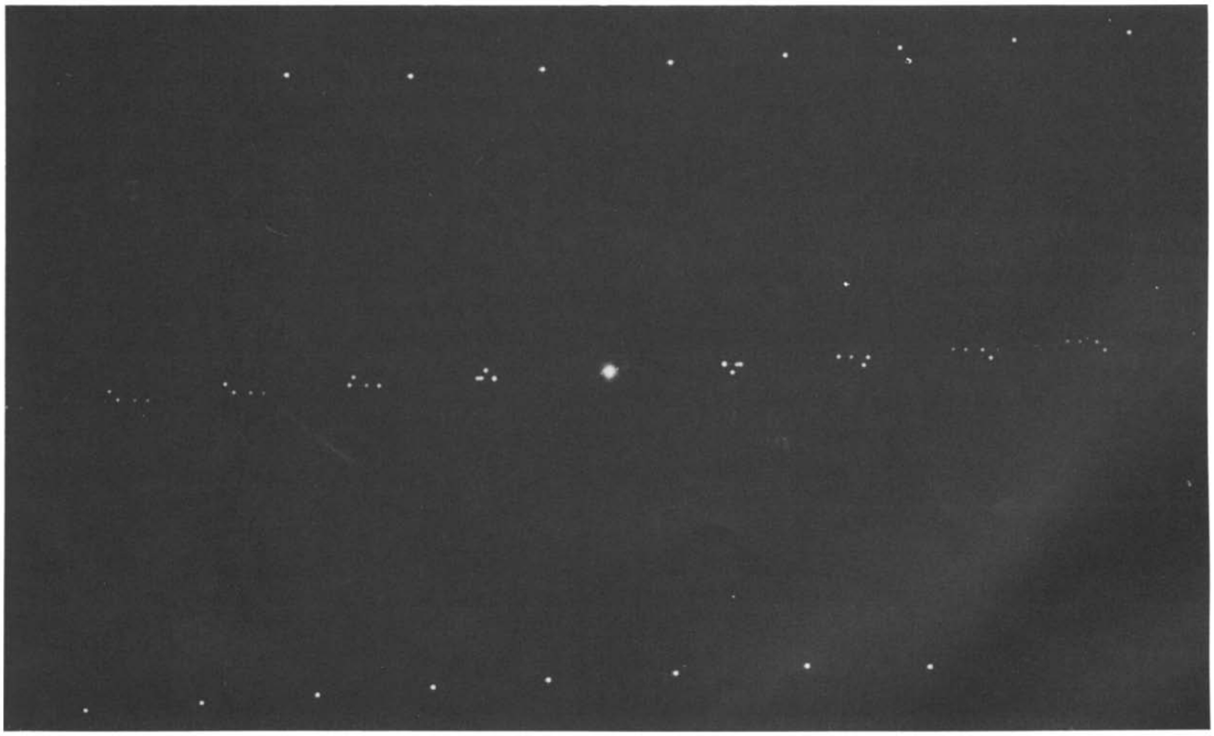

Fig 6 Point response of the matched filter made from the search sequence

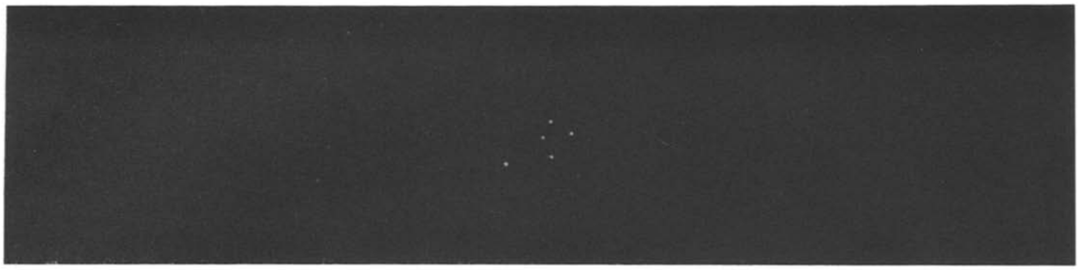

Fig 7 Correlation results Five points are detected (no threshold was applied for this photographic print)

of a single point travelling the known path (search sequence) We recorded a Fourier hologram of the whole search sequence on Polapan CT with a carrier frequency of approximately 30 mm^{-1} The point response of this filter hologram is shown in fig 6 Note that besides the exact reconstructions of the search sequence and its flipped version the autocorrelation of this sequence is seen in the 0th diffraction order, without any other disturbing terms Applying this matched filter to the input sequence yields the correlation result of fig 7 Clearly the 5 points have been detected Although the point response of the filter has a large support (8 frames of 16 mm film make approximately 60 mm), no immersion gate was necessary

4 Further applications

The ideal H&D curve of Polapan CT, with $\gamma = -2$, allows its application also in a joint transform correlator or in the two-step autocorrelator, based on the recording of power spectra

Another interesting field of application is its use as a "quasi real-time" optical light-valve The film can be exposed either with incoherent or coherent light and be read out by laser light Processing time can be cut down to 2 min by integrating the processing device into the camera, allowing a frame cycle of 3 3 s This is only practicable if a time *lag* (not the *required* time per frame) of 2 min is tolerable

We should mention that a photographic material with such properties is extremely convenient for applications in the fields of education and teaching Other authors [1] have noted this very advantage of Polaroid films before They describe experiments of "hand-held holography" using Polaroid P/N film With the one stop faster Polapan CT, however, it would not even be necessary to "hold one's breath" [1] during exposure

Acknowledgement

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References

[1] G W Stroke, A Funkhouser, C Leonard, G Indebetouw and R G Zech, J Opt Soc Am 57 (1967) 110