TECHNICAL INFORMATION

HOLOGRAPHIC FILM

E.K. SACHTLER –
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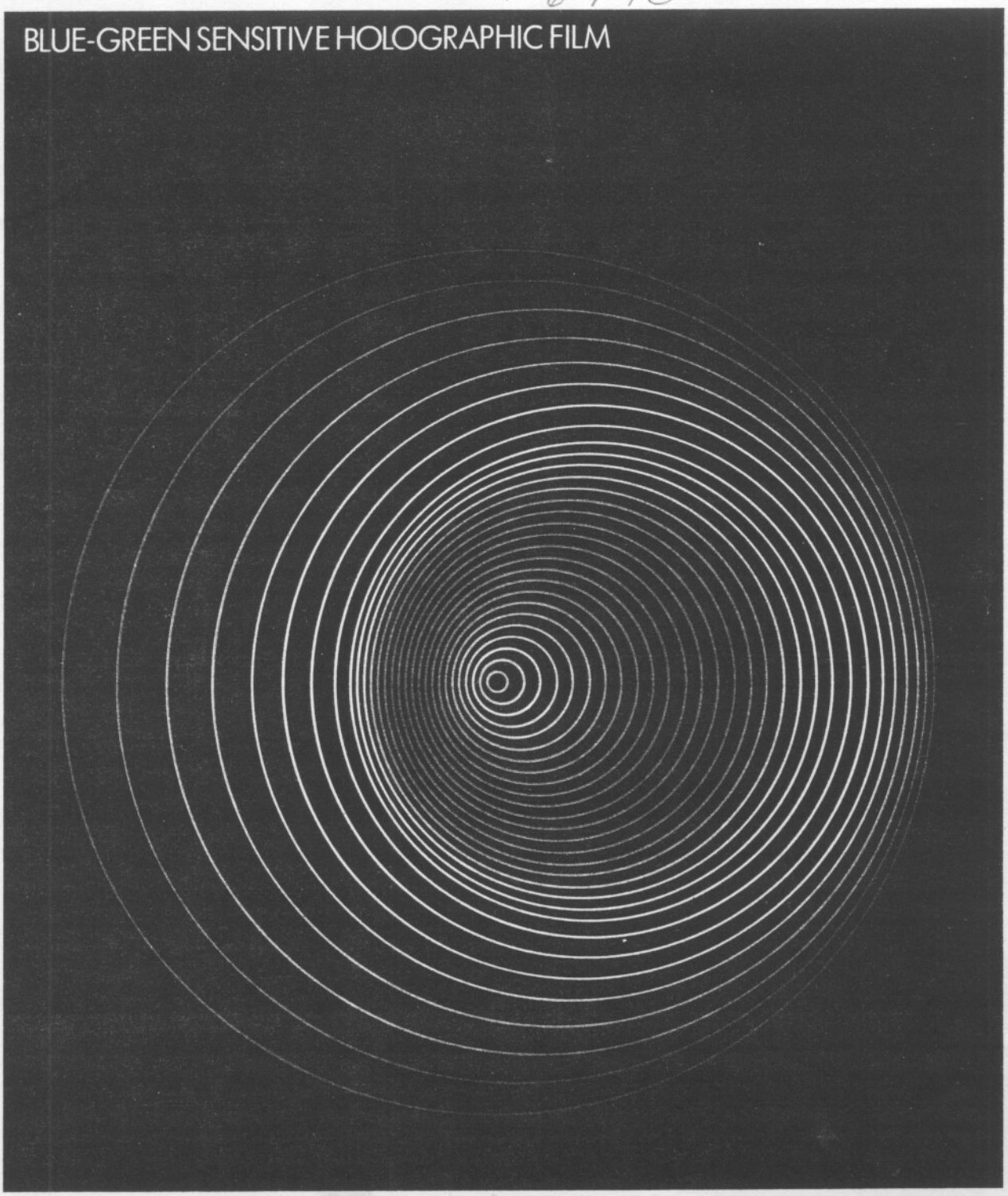
SP679C N.J.

WENDY ERICSON

BLUE-GREEN SENSITIVE HOLOGRAPHIC FILM



ILFORD

1 INTRODUCTION

ILFORD has over a century's involvement in photography. Today, this is reflected in a black and white range of films and papers that is world renowned. Alongside this commitment to quality exists a similar striving to innovate.

In many ways, the company's development has mirrored the development of photography: ILFORD has consistently been at the forefront of sensitised photographic materials manufacture. In addition to the more familiar range of general purpose photographic materials - black and white and colour - processing chemicals, equipment and accessories, ILFORD manufactures sensitised emulsions for a variety of specialised applications. These are as varied as aerial photography, electron microscopy, autoradiography, and more recently, holography.

Holography is now rapidly growing into a most important new communications/imaging medium; ILFORD is advancing its research effort to match this growth so that it can offer dedicated materials, processing solutions and accessories.

Holographic plates were first produced by ILFORD in the early 1970s. More recently, interest has increased because of a joint venture started between ILFORD and Applied Holographics, in the manufacture of new holographic emulsions and modified processing chemicals needed to complement their unique holographic mass replication system.

Recent advances in ILFORD UFG (ultra fine grain) emulsion technology enable holographic materials to have extremely fine grain, outstanding resolution and exceptionally low scatter characteristics. Other advances provide another important characteristic: extremely high signal to noise ratios may be achieved, in both the transmission and reflection modes, which result in unprecedentedly high diffraction efficiencies.

Such features have been incorporated into two new films for customer use, namely, ILFORD HOLOGRAPHIC FILM SP672, a blue-green sensitive film and ILFORD HOLOGRAPHIC FILM SP673, a red sensitive film.

This leaflet describes SP672 holographic film; for information on SP673 holographic film, please refer to publication 15718.

2 FILM DESCRIPTION

This film is sensitised over the range ultra-violet to yellow-green (560nm), so that it is ideal for use with a wide range of popular lasers, such as the Argon ion and frequency doubled Neodymium:YAG lasers.

SP672 holographic film has an ultra fine grain emulsion, an extremely high resolving power of greater than 7000 cycles/mm, and extremely low scatter characteristics. Optical transmission of the film is high, ie 60% at 514nm, and well within the requirements for making excellent quality Denisyuk type reflection holograms.

Principal areas of application include:

Transmission and reflection display holograms;
Mastering for embossing;
Holographic optical elements (HOE);
Underwater holography;
Holographic movies;
Non-destructive testing;
Blue and green elements in full-colour holograms;
Security labels.

In both the transmission and reflection mode, this film allows holograms to be made that exhibit a very high signal to noise ratio (up to 97% diffraction efficiency in both transmission and reflection have been observed).

2.1 Storage

Unopened packages of SP672 holographic film should be stored in a cool, dry place, preferably 10°C (50°F) or below. If stored in a refrigerator, remove packages at least three hours before opening to enable the film pack to reach room temperature and thus avoid problems associated with condensation forming on the surface of the film, such as emulsion softening.

2.2 Safelight recommendations

SP672 holographic film should be handled in dark red safelight illumination such as the ILFORD 906 safelight or equivalent used in an ILFORD DL10 darkroom lamp. This should be fitted with a 15W bulb. The minimum recommended distance of the safelight from the film is 1 metre.

2.3 Physical characteristics

The emulsion is coated on a thick 200 micron (8/1000 inch) triacetate base to eliminate the problems of birefringence in the substrate. The unprocessed emulsion layer is 7 microns thick.

SP672 holographic emulsion is also coated on 175 micron (7/1000 inch) polyester substrate, which is more chemically inert as well as being more dimensionally stable.

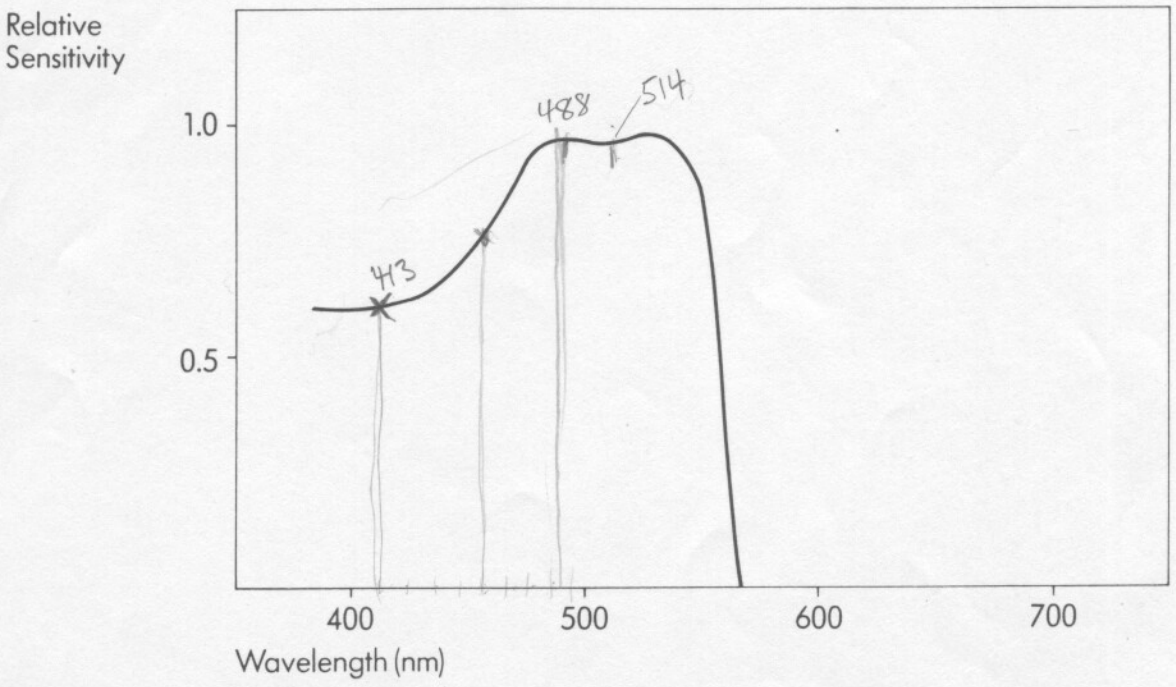
2.4 Resolution

SP672 holographic film has a resolution in excess of 7000 cycles/mm, as indicated by the recording of a Lippmann-Bragg hologram at 457.9nm.

2.5 Spectral sensitivity

SP672 holographic emulsion is sensitised over the range ultra-violet to yellow-green (560nm). This makes it particularly useful when making holograms with a wide range of popular laser types, such as:

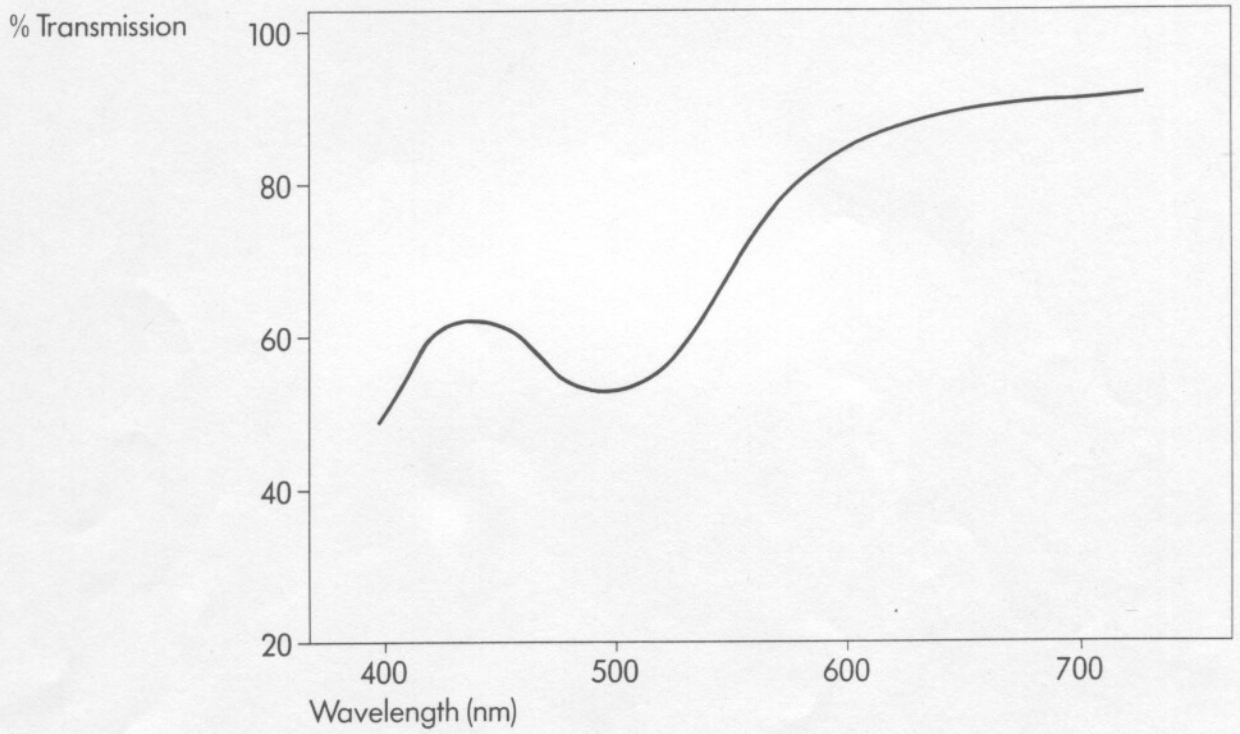
Helium Cadmium (442nm);
Krypton ion;
Copper vapour (pulsed output);
Gold vapour (pulsed output);
Xenon ion;
Argon ion;
Frequency doubled Neodymium:YAG lasers;
Frequency doubled ruby lasers.



The above curve shows the spectral sensitivity of SP672 holographic film to white light (flash exposure 10^{-4}s).

2.6 Spectral transmission

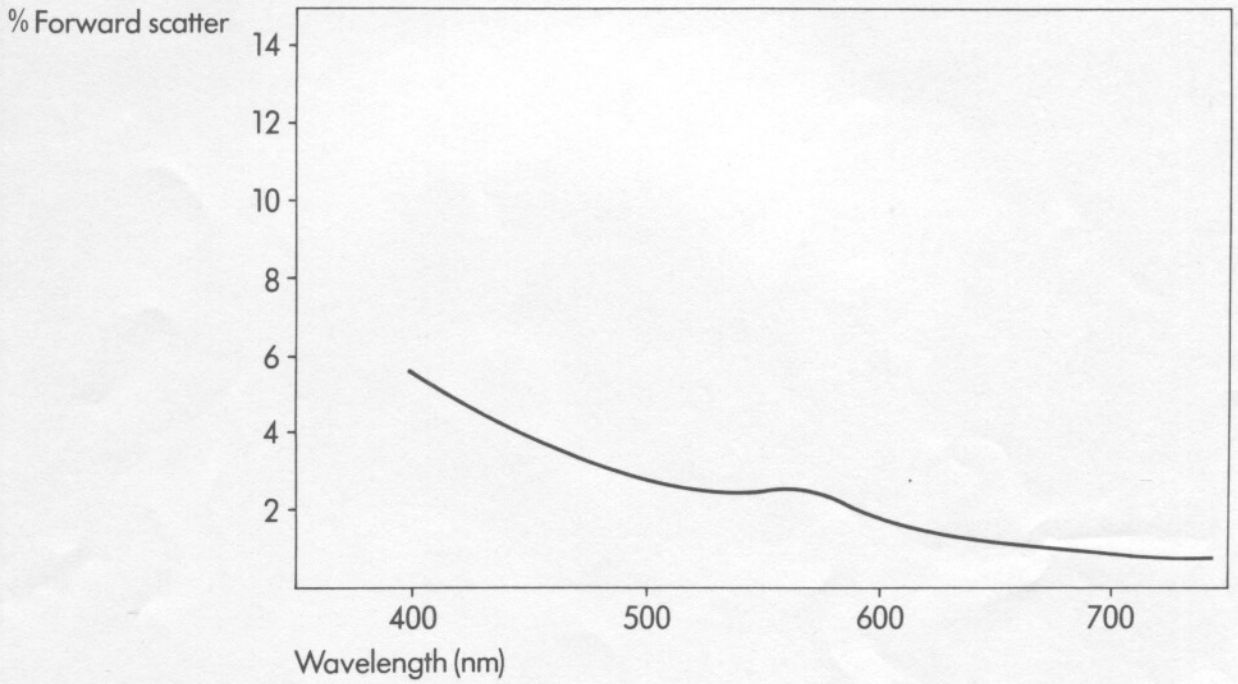
The curve below shows the percentage transmission of the unexposed film as a function of wavelength.



2.7 Scatter

The intrinsic scatter of the unexposed emulsion of SP672 holographic film is sufficiently low to enable it to meet the demanding resolution requirements for Lippmann-Bragg recording, even in the blue spectral region. This same low scatter means that diffraction efficiencies comparable to dichromated gelatin can be achieved through high fringe modulation and this, coupled with low post-processing scatter, yields exceptionally high signal to noise ratios in the final hologram.

The curve below shows the ratio of scattered light to total transmitted light for the unprocessed emulsion of SP672 holographic film throughout the visible spectrum. Scatter was measured by comparing the ratio of total transmitted light to forward scattered light in a spectrophotometer fitted with an integrating spheroid complying to CIE specifications.



Note

$$\% \text{ Forward scatter} = \frac{Is}{It+Is} \times 100$$

It = Intensity of transmitted light
Is = Intensity of forward scattered light

2.8 Speed characteristics

It is not practical to recommend a single effective exposure for SP672 holographic film as this depends upon laser wavelength and processing technique.

When working with this film, it is recommended that an initial series of trial exposures be made to determine the correct exposure time best suited to complement the exact laser set-up and processing conditions. During such trial work it is important to ensure that the processing recommendations given in section 5 are followed carefully, so that a generally high level of image quality is obtained at the outset. Deviations in processing may then be made to suit individual requirements.

SP672 holographic film has excellent latent image stability. While it is good practice to process film as soon after exposure as is practical, this cannot always be achieved, eg when exposing at the end of the working day or when making a large number of holograms. When working in these or similar conditions, ILFORD SP672 holographic film may be exposed one day and processed the next.

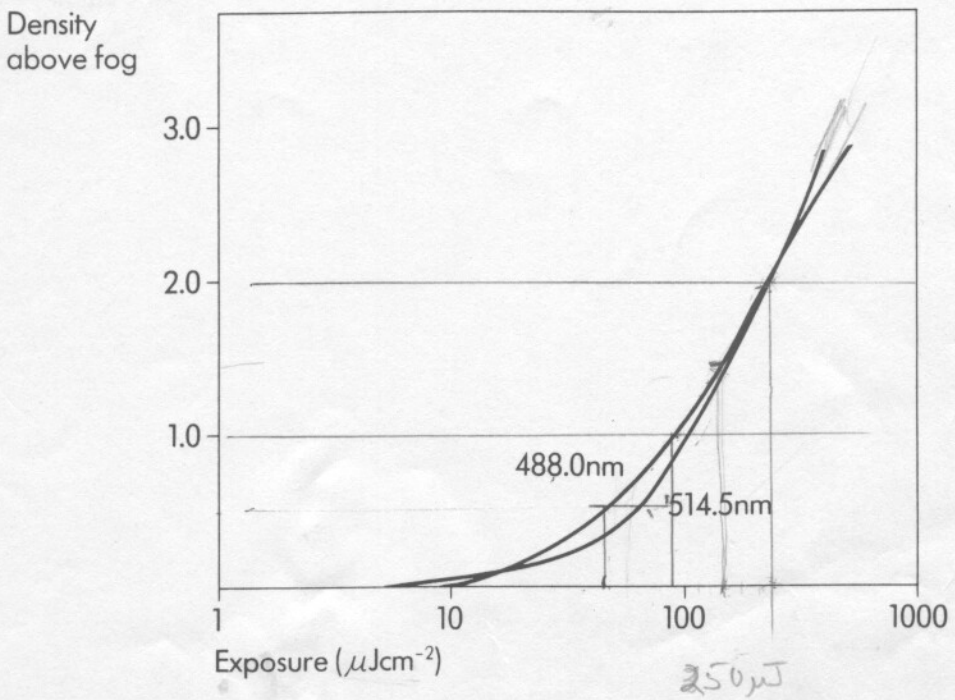
2.9 Diffraction efficiency

The practical limit of diffraction efficiency for SP672 holographic film is currently unknown. However, a diffraction efficiency of 97% with negligible scatter has been achieved using this film. This result was obtained by use of a fringe locking device during exposure.

In this context, diffraction efficiency is used to express the fraction of the unscattered light emerging from the emulsion layer that contributes to the desired holographic image. It is thought that practically achievable values with SP672 holographic film are restricted by the recording and processing techniques rather than by any limitations of the emulsion.

2.10 Characteristic curves

The curves below have been produced from SP672 holographic film exposed at 514.5nm and 488.0nm. Both films were developed in ILFORD SP678C holographic developer for 2 minutes at 30°C (86°F).



3 REFLECTION HOLOGRAMS

Specific processing recommendations are given below; refer to section 5 for general notes.

Table 3.1 summarises the processing sequence for making reflection holograms. All times are given at 20°C (68°F) with constant agitation, unless otherwise stated.

Table 3.1 Processing sequence for reflection holograms

Stage	Product/chemical	Recommended conditions
Development	Pyrogallol	3 minutes with constant agitation
Stop bath	ILFORD IN-1	Dilute 1+39, 30 seconds
Bleach	Ferric sodium-EDTA	4 minutes at 30°C (86°F), or until all the silver density has been removed
Wash		2 minutes in a good supply of fresh running water
Iodide bath	Optional*	2 minutes
Final rinse	ILFOTOL	A few drops added to de-ionised or distilled water; squeegee film
Drying		In clean, warm air not above 40°C (104°F). Natural drying at room temperature may be done with care

* If this treatment is used, omit the final rinse. See section 5.2 for details.

It is currently recommended that pyrogallol developer and a rehalogenating bleach are used during processing to inhibit layer shrinkage. Published formulae exist for rehalogenating bleach baths based on ferricyanide or p-benzoquinone and these give excellent results but cannot be recommended on grounds of safety in handling. ILFORD recommends a more satisfactory bleach bath based on ferric sodium-EDTA complex. This has been found to give excellent results when used with SP672 holographic film.

It should be noted that SP672 holographic film shrinks by 10% by the simple act of wetting and drying but the use of the developer/bleach combination described above will help to compensate for the shrinkage.

3.1 Pyrogallol developer

This is the most commonly used developer when making holograms with green sensitive holographic material. There are two generally accepted reasons for this. The first is that pyrogallol is a tanning developer, that is, it minimises emulsion shrinkage during processing (see above). Secondly, it leaves a brown stain which masks the scatter arising from the emulsion or bleach. If SP672 holographic film is correctly processed it will produce only negligible scatter so the pyrogallol stain is not helpful and may be removed to produce brighter holograms. This removal may be done at the end of the processing sequence by rinsing the film first in a 1% solution of potassium permanganate and then in a 1% solution of sodium metabisulphite.

Pyrogallol developer can be made up as follows:

Part A	
Pyrogallol	6g
Ascorbic Acid	6g
Water to make up to	500ml
Part B	
Sodium Carbonate	30g
Water to make up to	500ml

Mix equal volumes of Part A and B immediately prior to development and process for 3 minutes at 20°C (68°F). Adjust exposure and development times for control of final image colour.

Important
Once Parts A and B have been mixed, the solution is unstable. It should be used immediately and discarded after use.

3.2 Ferric sodium-EDTA bleach

This is recommended for processing reflection holograms to achieve optimum results, and may be made up as follows:

Ferric sodium-EDTA	100g
Potassium bromide	10g
Water to make	1 litre

Ensure that the ferric sodium-EDTA is completely dissolved before addition of the potassium bromide.

Ferric sodium-EDTA bleach forms a stable solution and can be partially regenerated by prolonged exposure to air (ie by leaving the solution in a dish or opened bottle overnight).

4 TRANSMISSION HOLOGRAMS

Specific processing recommendations are given below; refer to section 5 for general notes.

Table 4.1 summarises the processing sequence for making transmission holograms with SP672 holographic film. All times are given at 30°C (86°F) with constant agitation, unless stated otherwise.

Table 4.1 Processing sequence for transmission holograms

Stage	Product/chemical	Recommended conditions
Development	ILFORD SP678C	Dilute 1+4, 2 minutes
Stop bath	ILFORD IN-1	Dilute 1+39, 30 seconds
Bleach	ILFORD SP679C	2 minutes
Wash		2 minutes in a good supply of fresh running water
Iodide bath	Optional*	2 minutes
Final rinse	ILFOTOL	A few drops added to de-ionised or distilled water; squeegee film
Drying		In clean, warm air not above 40°C (104°F). Natural drying at room temperature may be done with care

* If this treatment is used, omit the final rinse. See section 5.2 for details.

4.1 ILFORD SP678C holographic developer

This new product is recommended for developing transmission holograms, and is designed for dish processing at 30°C (86°F). SP678C holographic developer should be diluted 1+4 with water. A standard development time of 2 minutes is recommended, with constant agitation. This time can, of course, be modified with experience. ILFORD SP679C holographic bleach is recommended when working with this developer.

SP678C holographic developer has a good processing capacity, and for normal work, a large number of holograms may be processed before there will be a noticeable loss of quality. For the best working conditions no more than 5 8x10 inch holograms should be processed in each litre of working strength solution.

4.2 Standard developers

When working with a standard developer such as Kodak D-19 or Tetenal Dokumol, it is important to bleach the film using a ferric nitrate bleach. The formula for this is given below.

Ferric nitrate	100g
Potassium bromide	30g
Water to make	1 litre

4.3 ILFORD SP679C holographic bleach

This is recommended for use with ILFORD SP678C holographic developer and should be diluted 1+4 with water to give a working strength solution.

SP679C holographic bleach has a good processing capacity, and for normal work a large number of holograms may be processed before there will be a noticeable loss of quality. For the best working conditions, no more than 20 8x10 inch holograms should be processed in each litre of working strength solution.

5 PROCESSING NOTES

Careful attention should be given to proper processing techniques, regardless of the material to be processed.

When preparing processing solutions, ensure that mixing vessels and processing dishes have been thoroughly cleaned before use. Discard processing solutions at the end of their working life. Do not attempt to economise by keeping solutions from one working period to the next if there is any risk that the solutions will not perform in the recommended way upon reuse. Mix fresh chemicals if there is doubt about the condition of any processing solution.

In general, it is satisfactory to mix chemicals with ordinary tap water. Care should be taken with bleach baths and the final rinse solution: de-ionised or distilled water is strongly recommended for making up these solutions to prevent the formation of precipitates.

For highest quality holograms, it is important to keep all processing solutions, including the wash water, at about the same temperature ($\pm$2°C or $\pm$5°F). In this way, image distortion due to random shifts in the emulsion layer, as the gelatin alternately swells and shrinks during processing, will be minimised.

While exposure conditions can be varied to achieve good holographic performance over a wide range of development times and temperatures, it is generally advantageous to standardise on processing parameters such as time, temperature and agitation, and thereby minimise the effects of processing variability. In the same way, while it may be tempting to 'develop by inspection' to obtain the required result, for consistently good results, it is always best to process for the standard times. The hologram should then be examined after processing and the appropriate revised exposure or development time determined to produce a satisfactory hologram.

5.1 Stop bath

ILFORD IN-1 stop bath is recommended between the development and bleach stages, to prevent premature exhaustion of the bleach bath. The stop bath solution should be replaced whenever developer is replaced.

5.2 Treatment with potassium iodide

Phase holograms, consisting of silver halide, are inherently susceptible to photo reduction (printout). Amplitude holograms, where the fringes consist exclusively of metallic silver, are not. The light stability of phase holograms can be significantly improved by the use of a bath of potassium iodide. This should be employed after the hologram has been washed following the bleach bath.

Potassium iodide will cause a yellow stain on the hologram, together with some increase in scatter.

Method
Dissolve 2.5g of potassium iodide in 1 litre of tap water. After bleaching and washing, immerse the film in the iodide bath at 30°C (86°F); agitate the film continuously during this time. After two minutes, remove the film allowing the excess liquid to drain off.

Do not rinse or wash film after the treatment in iodide. This will reduce the effectiveness of the iodide bath.

5.3 **Rinse**
As a final rinse after the final wash, immerse SP672 holographic film in distilled water to which ILFORD ILFOTOL wetting agent has been added. A few drops of ILFOTOL to each litre of water is sufficient. It is important to squeegee the film before drying.

5.4 **Drying**
The use of a film drying cabinet that blows warm air, preferably no higher than 40°C (104°F), over vertically hung holograms is recommended. Holograms can be air dried at room temperature with care, although drying marks may be observed when drying holograms in this way. Such marks may be minimised by the addition of ILFORD ILFOTOL wetting agent to the final rinse.

Adherence to the above simple guidelines will help to maintain a high standard of processing quality.