

METHOD AND APPARATUS FOR
PROCESS CONTROL

FIELD OF THE INVENTION

BACKGROUND OF THE INVENTION

5 The present invention relates to the investigation of processes carried out on optical master disks, being master disks for producing e.g. Compact Discs or Laserdiscs. It relates both to an apparatus for investigation of optical master disks
10 and to a method of investigation of optical master disks.

SUMMARY OF THE PRIOR ART

Optical disks, for example Compact Discs or Laserdiscs, are commonly manufactured by carrying out
15 a number of mastering and replication processes which are broadly as follows.

Firstly, a flat, polished glass master disk (typically 240 mm in diameter and 5-6 mm thick) is coated with a thin, uniform layer (typically 130 nm
20 thick) of positive photoresist.

Next, a beam of blue laser light is focused to a small spot on the coated glass surface by passing it through a microscope objective-type lens of high numerical aperture. The laser light is modulated in
25 accordance with an electrical signal which is derived from and representative of the video, audio, or other data signal which is to be recorded. By rotating the

glass disk while at the same time imparting a radial motion between the point of focus of the laser light and the axis of rotation of the disk, the modulated light spot is made to trace out a spiral track on the coated glass surface, starting at a small radius and working outwards. A latent image is thus formed in the photoresist layer, consisting of a series of exposed and unexposed portions of the spiral track. The pitch of the spiral is typically $1.6\text{ }\mu\text{m}$. The edges of the exposed areas are not sharply defined; because the focused light spot is substantially diffraction-limited, it has a rounded intensity profile.

The next step is to develop the latent image. This is done by bringing the coated surface into contact with a developing fluid (e.g. an aqueous developing solution), usually by rotating the glass in a horizontal plane (coated surface uppermost) while a stream of developing fluid is dispensed onto it, so that the fluid spreads out over the surface and is eventually flung off the edge of the disk. The developing fluid dissolves the exposed areas of the photoresist coating while having much less effect on the unexposed areas, so that the exposed areas become pits in the coating. As the developing fluid progressively attacks the photoresist the pits are initially rounded in cross-section until the whole thickness of the photoresist layer has been dissolved in the most highly-exposed area (the centre) of each

pit. From then onwards, the flat central part of the pit bottom (defined by the glass surface) expands while the pit walls recede and become steeper.

The development process does not continue unchecked, but is deliberately curtailed at a point where the pits are of a suitable size. Control of the pit size is important because it affects the playability of the disks eventually made by the process, in particular the magnitude and symmetry of the reproduced signal waveform. A further object of curtailment development in this way is to ensure that the pit walls are not too steep, as otherwise they are difficult to reproduce in the subsequent plating and moulding processes.

Many aspects of the mastering process, including the behaviour of the pit shape during development, are discussed in "Principles of Optical Disc Systems", edited by G. Bouwhuis (Adam Hilger, 1985).

The width of the pits is typically $0.5\mu\text{m}$, while the lengths of the pits and of the spaces between them along the track are variable, the recorded information being contained in these varying lengths.

The last principal stage of the mastering process is to metallise the developed surface of the master disk, usually with silver or nickel. This renders the surface conductive, and allows a substantial (up to 0.3 mm) layer of nickel to be electroplated onto it. This nickel layer can then be separated away from the

glass intact, and forms a metal master or father.

In subsequent electroplating and separating stages, replicas of the metal master can be made. These replicas (known as stampers) are then used as
5 one surface of the mould in an injection (or injection/compression) moulding machine. Alternatively, the metal master itself can be so used. In either case, the moulding machine is used to produce disks of plastics material, the surface of
10 which is a replica of the pitted surface of the developed, coated glass master disk.

Finally, the moulded disks are metallised (usually with aluminium) on the pitted, information-carrying side, the metallised surface is protectively
15 lacquered, and label information is printed onto the lacquer layer.

The moulded disks are played by focusing laser light, via a lens, through the thickness of the plastic onto the inner surface of the metal layer.
20 From the point of view of the light beam, this inner metal surface carries a negative replica of the original pits, i.e. "bumps". The playback signal is derived from the light reflected back into the lens, and the diffractive properties of the bumps are
25 crucial in determining the nature of the signals obtained. The height, width and shape of the bumps are all important.

The bump height is primarily determined by the

thickness of the original photoresist coating. The width and shape of the bumps are less clearly defined, and are influenced by many parameters in the exposure and developing processes, including the laser light
5 intensity, spot size and profile, ambient temperature and humidity, photoresist sensitivity, developing fluid constitution, and developing time.

If all relevant parameters are well controlled, it is possible to obtain stable performance from the
10 process. Fine adjustments may be made retrospectively by observing the signals obtained by playing the metallised glass master disk, or even by waiting till the moulded replica disks are available and playing them.

15 It is, however, desirable to exert direct control at an earlier stage, and this may be done during the developing process. The progress of formation of the pits may be monitored optically as they develop, and the development process can be curtailed (for example,
20 by substituting a flow of rinse water for the flow of developing fluid) once a suitable pit geometry has been detected. Clearly, only one process variable (the developing time) is controlled by this method. It is, however, an important one, affecting the size
25 of the pits and consequently the magnitude and symmetry of the information-carrying signal during the eventual playback of the disks. If the pit size can be controlled at this stage, then the process becomes

much less sensitive to variations in other process parameters.

It is not found necessary to observe the pits microscopically, or to perform an operation equivalent to playing the recording, in order to do this. Sufficient information for practical control is obtained by relatively gross observations. If a collimated beam of light, say up to a few millimeters in diameter, is directed upward through the glass onto the coated surface in a region where pits are present in the coating, the light is diffracted by the pits. The effects of such diffraction are most noticeable in the radial direction, because, owing to the regular spacing of the recorded tracks, much of the diffracted light emerging from the disk is concentrated into discrete beams in the radial plane, representing different diffracted orders. (This radial diffraction behaviour is observed even though the various adjacent turns of the track spiral which pass through the light beam are not identical but have a fine, quasi-random pit structure in the tangential direction.) The emerging beam which would have been seen even in the absence of pits (the ordinary transmitted beam) is referred to as the zero-order beam.

Moreover, another set of diffracted beams can be seen passing back through the glass, in addition to the ordinary reflected beam (known as the zero-order reflected beam). Such diffracted beams may be

reflection", as opposed to "in transmission".

In a known method of observing the photoresist layer, a laser light beam is passed upwards through the glass master disk, and a detector is placed above
5 the disk so as to intercept one of the transmitted diffracted beams, typically a first-order diffracted beam, during development. When the measured intensity passes a preset threshold, development is automatically terminated.

10 This known method does present some significant difficulties. During development a layer of developing fluid is streaming across the surface of the master disk. If this layer is uniform and flat, it does not alter the directions of the various light
15 beams when they eventually emerge into air. However, in practice a fluctuating pattern of ripples is present on the surface of the developing fluid. The emerging light beams are refracted at the uneven liquid surface, and so their directions fluctuate.
20 One consequence of this is that the optical sensor for detecting the first-order beam intensity needs to embrace a larger area than would otherwise be necessary. More important is that the zero-order (direct) beam is also randomly refracted, and this may
25 occasionally cause it to enter the first-order beam sensor. Since the zero-order beam has many times the strength of the diffracted beam, the consistency of the measurement may thereby be seriously impaired.

There is therefore a need to improve on the reliability of the known method.

SUMMARY OF THE PRESENT INVENTION

According to a first aspect of the present invention, when the formation of the pits during the development of an optical disk master is monitored by causing a light beam to be incident on a region of a surface of the optical master disk and sensing at least one diffracted light beam, there is a rigid body in contact with the layer of developing fluid, which rigid body is spaced from the surface of the optical master disk, and is located near at least the region of the surface of the optical master disk where the light beam is incident. That rigid body then prevents ripples or other variations occurring in the thickness of the layer of developing fluid at the region where the light beam is incident, thereby reducing or eliminating the risk of such variations in the layer of developing fluid affecting the investigation of the development of the optical master disk.

Preferably, the rigid body is transparent enabling it to act as a window for either or both of the light beam to the optical master disk and the diffracted light beam from the optical master disk. Since at least part of the optical path from the source of the light beam to the detector of the diffracted light beam then must necessarily pass

through the layer of developing fluid, it can be seen that accurate control of the surfaces thereof is important so that the intensity of the diffracted beam may be measured consistently.

5 However, the present invention may also be applied to arrangements in which the light beams from the source to the optical master disk, and from the optical master disk to the detector do not pass through the layer of developing fluid. At first
10 sight, control of the layer of developing fluid in the way required by the present invention is then no longer necessary. In practice, however, this is not the case since at least some of the light beam from the source will pass into that layer and there will be
15 light reflected from the surface of that layer which is remote from the disk. In particular, there will be a reflection of the direct or zero-order beam which, if that surface is allowed to have ripples or other fluctuations, will fluctuate in direction and may
20 enter the detector and so interfere with the consistency of the measurement. Thus, it is important in this case also that the surfaces of the layer of fluid are controlled.

In the above discussion, the references to a
25 "diffracted" beam cover diffraction both in transmission and reflection. Thus, the source of the beam which is incident on the optical disk may be on the same side of the optical disk as the detector

which detects the diffracted beam, or may be on the opposite side.

There are many different ways in which this aspect of the present invention may be achieved. In the simplest, the rigid body is a transparent window in a housing. The housing is hollow and may then contain the detector for detecting the diffracted beam and/or the source of the beam which is incident on the optical disk. Then, the surface of the window remote from the optical disk remains dry and the space between the window and the optical disk is filled with fluid, thereby preventing disturbance of the light beams. Preferably at least the diffracted beam passes through the window, and more preferably both the incident beam and the diffracted beam, but it is also possible for the incident beam to pass through the window and the diffracted beam be detected on the opposite side of the optical disk.

It is also possible for both the incident and diffracted beams to pass through the optical disk in their path to and from that surface of the disk which is in contact with the fluid. In this case it is not necessary for the rigid body to be transparent.

In order to ensure there is sufficient developing fluid, a suitable means for supplying that fluid is usually provided adjacent the optical master disk. Therefore, it is possible within this aspect of the present invention for the rigid body to be made

integral with the means for supplying the developing fluid. For example, the rigid body may be a wall of that supply means. Alternatively, where the supply means includes a nozzle through which the developing
5 fluid passes to reach the optical master disk, a window may be provided in a wall of that nozzle so that the diffracted and/or incident beam passes through the fluid in the nozzle, and through the window in the wall of the nozzle, to the detector or
10 from the light source (as the case may be).

In each of these arrangements, the diffracted (or incident) beam passes directly from the developing fluid into the rigid transparent body (or vice versa), because the rigid transparent body is in direct
15 contact with the developing fluid, thereby preventing variations due to ripples on the surface of the developing fluid. As mentioned above, it is also possible for the incident light beam to pass through the transparent body even if the detector is on the
20 other side of the optical disk from the transparent body.

According to a second aspect of the invention, which is independent but may be used in conjunction with the first aspect, the formation of the pits
25 during the development of an optical disk master is monitored by sensing the intensity of a diffracted light beam, the diffracted beam being observed on the same side of the master disk from which the incident

beam impinges on the disk, i.e. the diffracted beam is observed in reflection.

Using a reflected rather than a transmitted beam bring certain practical advantages. All optical parts
5 can be located above the disk, the measurement can be made insensitive to the condition of, for example, the under surface of the glass, and the disk master can be mounted on an opaque turntable or spider structure without interfering with the optical measurement.

10 There is also a more fundamental advantage. It is found that the strength of, for example, the first-order diffracted beam is not greatly different whether it is measured in transmission through the pitted master surface or in reflection from it. The zero-
15 order or direct beam, however, is greatly attenuated in reflection compared with transmission. This means that the strength of the first-order beam, measured as a fraction of the zero-order beam, is greater in reflection than it is in transmission. Therefore, the
20 consequences of stray light from the zero-order beam entering the first-order beam detector are less serious if the reflected beam is used.

According to a third aspect of the invention, the light source is periodically modulated in intensity.
25 This enables the at least one diffracted beam to be monitored whilst discriminating against the effects of ambient light. Thus, by passing the output of e.g. the first-order beam detector through a phase-

sensitive detector whose reference input is the same signal which is used to modulate the laser light, and thereby generating a d.c. output proportional to that component of the detected light intensity which varies
5 in synchronism with the said signal, the influence on the d.c. output of detected light other than light originating in the said light source may be substantially eliminated. Preferably the light source is a laser diode, and its light output is modulated
10 electronically. Again, this third aspect may be independent or may be used in conjunction with the first and/or second aspects.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be
15 described in detail, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a pattern of beams diffracted at a surface;

Fig. 2 shows schematically an optical sensing
20 arrangement illustrating the general principles of the present invention;

Fig. 3 shows an optical sensing arrangement in accordance with an embodiment of the present invention;

25 Fig. 4 shows a general view of a developing arrangement incorporating the optical sensor of Fig. 3;

Fig. 5 shows a detail of the optical sensor and

an adjacent dispensing nozzle;

Fig. 6 shows a combined optical sensor and dispensing nozzle in accordance with a second embodiment of the invention;

5 Fig. 7 shows a combined optical sensor and dispensing nozzle in accordance with a third embodiment of the invention;

Fig. 8 shows a block diagram of an electronic system for controlling the developing process in
10 response to the output of the optical sensing arrangement; and

Fig. 9 shows a refinement of the electronic system of Fig. 8 for more accurately controlling the developing process in response to the output of the
15 optical sensing arrangement;

DETAILED DESCRIPTION

Before describing embodiments of the present invention, the general principles underlying the present invention will be discussed.

20 As has previously been mentioned, the present invention makes use of a diffracted beam generated from a beam of light incident on an optical master disk. In the simple case where a light beam is incident normally (i.e. perpendicularly) on a surface
25 100, e.g. a surface of an optical master disk, the angle between the normal and the mth. order diffracted beam is given by

$$\theta_m = \sin^{-1} (m\lambda / nP) \quad \dots \text{ (Equation 1)}$$

where λ is the wavelength of the light in vacuo, P is the track pitch, and n is the refractive index of the medium in which the beam is observed. The light beam need not, however, be at normal incidence. Fig. 1
5 shows a pattern of beams diffracted by the pit structure in the upper (coated) surface 100 of a disk in a case where the incident beam 101 arrives at a slight angle to the normal.

It should be noted that, while Fig. 1 shows the
10 incident beam 101 reaching the surface 100 through the disk, a similar set of diffracted beams is generated when the incident beam 101 reaches the surface 100 from outside the disk.

The strengths of the various diffracted orders
15 depend on the size and shape of the developed pits. Information about the progress of development may thus be obtained by measuring the intensities of the diffracted beams as a fraction of the incident beam intensity (or alternatively as a fraction of the
20 intensity of the emergent zero-order beam).

The wavelength of the light should be long enough that the light does not expose the photoresist. Helium-neon laser light (wavelength 633 nm) is commonly used. In this case, Equation 1 above shows
25 that, at normal incidence with a 1.6 μm track pitch, two diffracted beams will emerge into air on either side of the zero-order beam, at angles of 23° and 52° from the normal.

In practice the most useful information for process control is obtained from the intensity of one of the first-order beams, since this intensity rises smoothly up to and beyond the optimum stage of development, whereas the second-order beam intensity tends to reach a limit and thereafter to decrease with further development.

It is not necessary to enter into detailed theory in order to define the necessary threshold setting; the system may be calibrated for practical use by establishing an empirical relationship between the threshold setting and the playback properties of the final moulded disks. The required setting will be appreciably influenced by changes either of track pitch or of photoresist coating thickness, but the effects of these can also be established empirically and allowed for. Changes of track pitch will alter the direction of the diffracted beam, and the optical sensor must be able to tolerate the range of directions which correspond to the range of track pitches used (nominally 1.5 - 1.7 μm in the case of Compact Disc).

A theoretical treatment of the subject is given by J.H.T. Pasman, J. Audio Eng. Soc., Vol. 41, No. 1/2 (January 1993).

The behaviour of diffracted beams having been discussed, the passage of such diffracted beams through a transparent body adjacent an optical master

disk will now be described in general terms.

Fig. 2 shows an optical master disk 3 with the coating layer 2 thereon, the coating layer 2 being of photoresist material. During the processing of the optical master disk 3, the layer 2 is exposed to modulated laser light, to create a series of exposed and unexposed portions in the layer 2, corresponding to the intended pattern of the pits that are to be formed on the optical master disk 3. In order to develop the layer 2, and so create that pattern of pits, the layer 2 is exposed to developing fluid (developer) 14.

The present invention is concerned with investigating that developing process, and Fig. 2 shows that a housing 1 is brought adjacent the optical master disk 3, that housing having a window 4 therein. The housing 1 is positioned so that the window 4 is in contact with, and is immersed in, the developing fluid 14. Hence, at the window 4, there are no ripples in the surface of the developing fluid 14, although there are ripples 15 in other regions.

In order to investigate the developing process, a beam of light 6 is incident on the coating layer 2 of the optical disk 3 through the window 4. As was discussed with reference to Fig. 1, the presence of wholly or partly developed pits in that region of the coating layer 2 which is illuminated by the beam 6 generates diffracted beams, including a first-order

diffracted beam 8 (diffracted in reflection) and a zero-order reflected beam 10. Not shown in Fig. 2 are additional diffracted beams, diffracted in transmission as well as in reflection, which in general are generated as has been discussed above with reference to Fig. 1.

Then, in order to determine the progress of the development of the coating layer 2 by the developing fluid 14, at least one of the diffracted beams (preferably the first-order diffracted beam 8) is monitored. Since the optical paths of the beam 6 and beam 8 are stable, accurate measurements are made.

An embodiment of the present invention will now be described in detail with reference to Fig. 3. In Fig. 3, components which correspond to the components of Fig. 2 are indicated by the same reference numerals.

In the embodiment shown in Fig. 3, a waterproof metal housing 1 is located during the developing process above the coating layer 2 of a horizontal glass master disk 3. Mounted in the bottom of the housing 1 is a synthetic sapphire window 4. An encapsulated solid-state laser diode forms a light source 5, which emits a collimated light beam 6 of wavelength 670 nm. A circular mask 7 restricts the diameter of the light beam 6 to about 1 mm. The laser diode source 5 is set at a small angle, about 5-10°, to the vertical, in order to avoid reflected light

passing back into it. The housing 1 is oriented radially with respect to the master disk 3, so that (in the presence of developed pits in the coating layer 2) the first-order diffracted beam 8 lies within the plane of the drawing and reaches the photodiode sensor 9. The sensor 9 is large enough to intercept the beam 8 for any allowable value of the track pitch recorded on the disk 3. (A track pitch range of 1.5 - 1.7 μm corresponds to an angular range of 3.5° , or only 3 mm at a detector distance of 50 mm.)

The reflected zero-order beam 10 is intercepted by an internally blackened absorbing cup 11, in order to minimise scattered light which might reach the detector 9. Optionally a zero-order beam detector 16 may be contained within the cup 11, so that the first-order beam may be measured as a fraction of the zero-order reading. However, it is usual for the output of the laser diode 5 to be stabilised by a local feedback loop, so that it will be sufficiently constant for process control purposes without direct measurement of the zero-order beam 10.

Preferably an aperture 12 is positioned close to the window 4, so as to prevent light scattered back from the lower surface 13 of the master disk 3 from reaching the detector 9.

The window 4 should be close enough to the coating layer 2 to ensure that the developing fluid 14 wets the window 4 and fills the space between it and

coating layer 2. A spacing of 0.5 mm is mechanically practicable. To encourage the fluid to fill the space, the sensor should be placed close to and "downstream" (in the direction of disk rotation) from the developer dispensing nozzle. Preferably the sensor is attached to the same arm which supports the nozzle. In the preferred embodiment the nozzle dispenses developer over a range of radii on the disk covering at least the recorded program area of the disk (23-58 mm in the case of Compact Disc), and the optical sensor directs the light beam 6 to a radius on the disk towards the bottom end of this range (perhaps 30 mm), so that valid readings are obtained even on those occasions when, for economy in mastering time, the recorded area ends at a small radius.

The choice of synthetic sapphire for the window 4 is determined both by its resistance to chemical attack and by its scratch resistance. Developing solutions are usually alkaline, and are found to attack and cloud a glass window over a period of use. A window with a good standard of polish should be selected, and its upper surface may advantageously be given an anti-reflection coating, to reduce light scattered back to the detector 9 from the incident beam 6. Owing to the high refractive index of sapphire, a simple quarter-wavelength coating of magnesium fluoride is suitable for this purpose.

Fig. 4 shows a general view in elevation of a

developing arrangement incorporating the sensor of Fig. 3. The master disk 3 rests on a tripod 30 which rotates on a boss 31. Two arms, 32 and 33, are retracted while loading the disk 3 but are in the positions shown during developing. An arm 32 can dispense developer through a fan-shaped nozzle 34. Arm 33 can dispense rinsing water through a similar nozzle 35. The sensor housing 1 is mounted behind the nozzle 34, with its sapphire window 4 close to the coating layer 2 on the upper surface of the disk 3. In the arrangement shown, the sense of rotation of the disk 3 is anti-clockwise when viewed from above, so that the developer tends to be carried from the nozzle 34 towards the sensor unit.

The process sequence may begin with rinsing water from nozzle 35 followed by developing fluid from nozzle 34, and then switching back to rinsing water from nozzle 35. The nozzle 34 is retracted during the final rinse. After a thorough rinse, the disk 3 is spun dry at high speed. The time at which the flow of developing fluid is replaced by a flow of rinsing water is determined electronically on the basis of the output of the first-order light beam detector 9, as described below.

Fig. 5 shows a cross-sectional view of the sensor housing 1 next to the dispense nozzle 34. It can be seen from Fig. 5 that the housing 1 and the nozzle 34 form an integral unit with the unit 34 being shaped so

that the outlet 41 thereof is adjacent the end of the housing 1 containing the window 4. The detector (not shown in Fig. 5) and the source 5 are contained within the housing 1, as has previously been mentioned with reference to Fig. 3.

Fig. 6 shows a second embodiment in which the optical sensor unit is combined with the dispense nozzle 34. The layout of the laser diode 5, the aperture 7, the detector 9 and the absorber 11 are all similar to that shown in Fig. 3, and corresponding parts are indicated by the same reference numerals.

In the second embodiment of Fig. 6, the incident beam 6 from the laser diode 5, the zero-order reflected beam 10 and the first-order diffracted beam 8 all pass through a transparent body 35 forming a wall of the nozzle 34, which is made from acrylic plastics, rather than through air. Instead of a window 4 there is a flat, polished lower face 40 to the nozzle 34. The lower face 40 extends equally on either side of a slot 42 through which developing fluid is dispensed, so that the developing fluid is forced out between the lower face 40 and the coating layer 2, thus forming an optically homogeneous part of the light path to and from the coating layer 2. The clearance between the lower face 40 and the coating layer 2 may be about 2 mm.

The incident beam 6 enters the plastics body 35 from the laser diode 5 and the first-order beam 8

leaves it through further polished faces in the plastics body 35. Preferably an absorber similar to the absorber 11 in Fig. 3 is formed by cutting away material of the body 35 to leave a stub, the rough
5 outside surface of which is painted black.

Fig. 7 shows a further embodiment in which an optical sensor unit is combined with a dispenser nozzle 34. The layout of the laser diode 5, the aperture 7, the detector 9 and the absorber 11 are
10 again similar to that of Fig. 3, but the light beams 6, 10 and 8 pass through developing fluid within the nozzle 34 itself, reaching the disk surface 2 through a slot 43 in the nozzle 34 through which the developing fluid also emerges. The slot 43 is made
15 somewhat wider (perhaps 2 mm) than the slot 42 in the embodiment of Fig. 6, the beam 6 being carefully aligned so as to pass centrally through it. At least one polished windows 50 are provided for the beam 6 to enter and the beam 8 to leave the cavity of the nozzle
20 34. It is possible to provide separate windows 50 for the beams 6 and 8, but a single window 50 may be sufficient. There is a tendency for bubbles to form within the nozzle 34; so the liquid flow must be so directed that bubbles, if any, settle at points which
25 do not interrupt any of the beams 6, 10 or 8.

Any of the sensor arrangements shown in Figs. 3, 5, 6 and 7 may also be employed in a transmissive system. In such a case the laser diode source 5 need

not be within the sensor assembly. Instead, the incident light beam from the laser diode is directed from underneath through the glass disk 3 into the window 4, the face 40, or the aperture 43 as appropriate. If a tripod 30 is used to hold the disk 3, allowance can be made in the detecting electronics for the periodic interruption of the beam by the legs of the tripod 30; alternatively, the tripod may be dispensed with if the disk 3 has an attached centre boss, so that it can be mounted directly onto the boss 31.

Fig. 8 shows a block diagram of an electronic system for generating from the output of detector 9 a signal for terminating development, in accordance with the third aspect of the invention. The laser diode source 5 is equipped with a modulation input which allows the light power to be switched between a high value and a low value in response to an externally applied signal. An oscillator 110 generates a square-wave signal 111, at a frequency in the order of 10 kHz, which is applied both to the said modulation input of the laser diode source 5 and to the reference input of a phase-sensitive detector or multiplier 112. Meanwhile the output of the detector 9 passes through a preamplifier 113, an a.c. coupling 14 and a further amplifier 115 to yield an a.c. coupled signal which is fed to the signal input of the multiplier 112. The output 116 of the multiplier 112 is filtered by a low-

pass filter 117 so as to remove high-frequency components associated with the oscillator signal 111. The filtered output 118 is suitably amplified by an amplifier 119 whose output 120 is applied to one input 5 of a comparator 121, the other input of which is a reference voltage 122 derived from a potentiometer 123. The output 124 of the comparator 121 is a signal which, when the detected first-order beam power at detector 9 exceeds a threshold determined by the set 10 voltage 122, switches so as to terminate development.

A zero-adjusting voltage 125 is also applied by the potentiometer 126 to the amplifier 119; this enables the output 120 to be set to zero in the absence of developed pits in the coating layer 2, thus 15 compensating for any light scattered into the detector 9 within the assembly 1, for example from the surfaces of the window 4.

It is not necessary for the signal 111 to switch the laser diode output on and off completely. A 20 moderate depth of modulation will suffice, so long as it is stable over time.

Fig. 9 shows a refinement of the last part of the electronic system, in which a differentiating circuit 127 lowers the reference voltage applied to comparator 25 121 by an amount proportional to the rate of increase of the voltage 120. By this means the circuit can compensate, to a fair approximation, for delays in the operation of the various valves which terminate

development in response to the signal 124. The faster the voltage 120 is rising, the lower the threshold voltage 128, so that the comparator 121 anticipates by a substantially fixed time interval the time at which

5 voltage 120 would have reached voltage 122. The differentiating behaviour of circuit 127 is determined mainly by C1 and R1; the extra components R2 and C2 serve to limit the high-frequency gain.

CLAIMS

1. A method of investigating an optical master disk
(3) comprising:

providing a layer of developing fluid (14) with
5 a surface of said layer in contact with a surface of
said optical master disk (3) to develop said surface,
causing a light beam to be incident on a region of
said surface of said optical master disk (3), and
investigating at least one diffracted light beam
10 (8,10) generated from said light beam (6) by
diffraction at said region of said surface;

characterised in that:

another surface of the layer of developing fluid
(14) is in contact with a rigid body (4,35,50) spaced
15 from said optical master disk such that the thickness
of said layer of developing fluid (14) at at least
said region of said surface of said optical master
disk (3) is determined by the spacing between said
optical master disk (3) and said rigid body (4,35,50).

20 2. A method according to claim 1, wherein said at
least one diffracted light beam (8,10) comprises a
first-order diffracted light beam (8).

3. A method according to claim 1 wherein said at
least one diffracted light beam (8,10) comprises a
25 first-order diffracted light beam (8) and a zero-order
beam (10).

4. A method according to any one of claims 1 to 3,
wherein said rigid body (4,35,50) is transparent and





at least one of said light beam (6) and said at least one diffracted beam (8,10) passes through said rigid body (4,35,50).

5. A method according to any one of the preceding
5 claims, wherein said at least one diffracted light beam (8,10) is generated from said light beam (6) by reflection at said region of said surface of said optical master disk (3).

6. A method according to any one of claims 1 to 4,
10 wherein said at least one diffracted light beam (8,10) is generated from said light beam (6) by transmission through said surface of optical master disk (3).

7. A method according to any one of the preceding claims, including supplying said developing fluid (14)
15 through a nozzle (34), said rigid body being a window (50) in said nozzle (34).

8. A method according to any one of the preceding claims, wherein said light beam (6) is periodically modulated in intensity.

20 9. A method according to any one of the preceding claims, wherein said optical master disk (3) is coated with photoresist (2) to form said surface of said optical master disk (3) and said photoresist is exposed to modulated light prior to the providing of
25 said layer of said developing fluid (14) on said surface of said optical master disk.

10. A method according to any one of the preceding claims, wherein said optical master disk (3) is



rotated when said layer of said developing fluid (14) is provided thereon.

11. A method of investigating an optical master disk (3) comprising:

5 providing a layer of developing fluid (14) with a surface of said layer in contact with a surface of said optical master disk (3) to develop said surface, causing a light beam (6) to be incident on a region of said surface of said optical master disk (3), and
10 investigating at least one diffracted light beam (8,10) generated from said light beam (6) by refraction at said region of said surface;

characterised in that:

said at least one diffracted light beam (8,10) is
15 generated from said light beam (6) by reflection at said surface of said optical master disk (3).

12. A method according to claim 11, wherein said light beam (8) comprises a first-order diffracted light beam (8).

20 13. A method according to claim 11 or claim 12 wherein said light beam (6) is periodically modulated in intensity.

14. A method of investigating an optical master disk (3) comprising:

25 providing a layer of developing fluid (14) with a surface of said layer in contact with a surface of said optical master disk (3) to develop said surface, causing a light beam to be incident on a region of





said surface of said optical master disk (3), and investigating at least one diffracted light beam (8,10) generated from said light beam (6) by diffraction at said region of said surface;

5 characterised in that:

said light beam (6) is periodically modulated in intensity.

15. An apparatus for investigating an optical master disk (3) comprising:

10 support means (30,31) for supporting said optical master disk (3);

means (34) for supplying a layer of a developing fluid (14) to a surface of said optical master disk (3) when said optical master disk (3) is supported by
15 said support means (30,31);

a light source (5) for generating a light beam (6) to be incident on a region of said surface of said optical master disk (3) when said optical master disk (3) is supported by said support means (30,31); and

20 a light detector (9) for detecting at least one diffracted light beam (8) generated from said light beam (6) when said light beam (6) is incident on said region of said surface of said optical master disk (3);

25 characterised in that:

a rigid body (4, 35, 50) is provided adjacent said support means (30,31) to be contacted by said developing fluid (14) such that the thickness of said





layer of developing fluid (14) at at least said region of said surface of said optical master disk (3) is determined by the spacing between said optical master disk (3) and said rigid body (4,35,50).

5 16. An apparatus according to claim 15, wherein said rigid body (4,35,50) is transparent.

17. An apparatus according to claim 16, wherein said rigid body is a window (4) in a housing (1) containing said detector (9).

10 18. An apparatus according to claim 17, wherein said window is of sapphire.

19. An apparatus according to claim 15, wherein said rigid body (35) forms a wall of said means for supplying said developing fluid (14).

15 20. An apparatus according to claim 15, wherein said means for supplying said developing fluid (14) has a nozzle (34) extending towards said support means (30,31) and said rigid body is a transparent window (50) in a wall of said nozzle (34).

20 21. An apparatus according to any one of claims 15 to 20, wherein said source (5) and said detector (9) are on the same side of said optical master disk (3) when said optical master disk (3) is supported on said support means (30,31).

25 22. An apparatus according to any one of claims 15 to 21, wherein said detector (9) and said means (34) for supplying said developing fluid are integral.

23. An apparatus according to any one of claims 15 to





22, having control means (110-128) for controlling the progress of development of said surface by said developing fluid (14) on the basis of the output of said detector (9), said control means (110-128) being
5 arranged to modulate periodically the intensity of said light beam from said source (5).

24. An apparatus according to any one of claims 15 to 23 wherein said support means (30,31) is rotatable, thereby to rotate said optical master disk (3).

10 25. An apparatus for investigating an optical master disk (3) comprising:

support means (30,31) for supporting said optical master disk (3);

means (34) for supplying a layer of a developing
15 fluid (14) to a surface of said optical master disk (3) when said optical master disk (3) is supported by said support means (30,31);

a light source (5) for generating a light beam (6) to be incident on a region of said surface of said
20 optical master disk (3) when said optical master disk (3) is supported by said support means (30,31); and

a light detector (9) for detecting at least one diffracted light beam (8) generated from said light beam (6) when said light beam (6) is incident on said
25 region of said surface of said optical master disk (3);

characterised in that:

said source (5) and said detector (9) are on the





same side of said optical master disk (3) when said optical master disk (3) is supported on said support means (30,31).

26. An apparatus for investigating an optical master
5 disk (3) comprising:

support means (30,31) for supporting said optical master disk (3);

means (34) for supplying a developing fluid (14) to a surface of said optical master disk (3) when said
10 optical master disk (3) is supported by said support means (30,31);

a light source (5) for generating a light beam (6) to be incident on a region of said optical master disk (3) when said optical master disk (3) is
15 supported by said support means (30,31); and

a light detector (9) for detecting at least one diffracted light beam (8) generated from said light beam (6) when said light beam (6) is incident on said region of said surface of said optical master disk
20 (3);

characterised in that:

said apparatus further includes control means (110-128) for controlling the progress of development of said surface by said developing fluid (14) on the
25 basis of the output of said detector (9), said control means (110-128) being arranged to modulate periodically the intensity of said light beam (6) from said source (5).

This Sheet Has Been Replaced

