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(14)

(54) OPTICALLY READABLE RECORDS AND READING APPARATUS THEREFOR

(71) We, PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED of Abacus House, 33 Gutter Lane, London EC2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The invention relates to a record on which a television (i.e. video) signal is stored in a track structure of constant track width which is readable with optical radiation, which structure is adapted to modulate the phase of a read beam of optical radiation, the recorded television signal comprising a first carrier wave which is frequency modulated with the luminance or brightness information, and one or more further carrier waves which are modulated with additional information, for example chrominance and sound information. The invention also relates to apparatus for reading such a record.

In the case of a colour television signal the said additional information is chrominance and sound information, which sound information may be modulated on one, two (stereo) or even four carrier waves. In the simplest case the television signal is a black-and-white signal and the sound is modulated on one carrier wave.

In "Philips' Technical Review" *33*, No. 7, pages 181–185 a record of disc form is described, in which the luminance information and the chrominance and sound information are stored in each optically readable track in pulse-coded form. The tracks may be the turns of a spiral or a multitude of separate concentric tracks. In a preferred arrangement an information track comprises a multitude of pits which are pressed into the record disc surface. The luminance information is contained in the spatial frequency of the pits, whilst the chrominance and sound information is recorded in the form of a modulation of the lengths of the pits (a so-called "duty cycle" modulation).

When writing the record described above a write beam of radiation is modulated in intensity by, for example, an electro-optic modulator to which is applied a rectangular electrical signal in accordance with the information to be written. When electronically composing said rectangular signal from the luminance information and the chrominance and sound information, limitations are necessary in the signal. This gives rise to mixing products of the first and the second carrier wave during reading. Such mixing products are undesirable. Should a mixing product occur within the frequency band covered by the modulated first carrier wave, said mixing product will give rise to interference (so-called moiré effects) in the luminance signal which is read from the record and reproduced. In a similar way, a mixing product of a frequency within the frequency bands which are occupied by the modulated further carrier waves results in interference e.g. in the chrominance signal which is read from the record and reproduced. When mixing products occur the disturbing effect of said products depends both on the photochemical process and signal processing circuits used during recording and on the choice of the carrier frequencies.

It is an object of the present invention to provide a television record capable of minimizing the occurrence of mixing products of the luminance information and any other information present, for example the chrominance and sound information. In accordance with the invention the track is, for example, a continuous trough rather than a sequence of separated pits and there is an analog (and preferably linear) relationship between one or more parameters of the track structure and the information of the television signal. Herein tracks are defined as continuous in this sense.

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The invention provides a record on which a television signal is stored in the tracks of a track structure of constant track width in a plane of the record, said tracks being separated by lands, which record is readable with optical radiation, and which structure is adapted to modulate the phase of a read beam of optical radiation, the recorded television signal comprising a first carrier wave which is frequency modulated with the luminance or brightness information, and one or more further carrier waves which are modulated with additional information, characterized in that the tracks of the information structure are continuous tracks as defined herein before which in the plane of said structure exhibit an undulation, as defined herein after, transverse to the track length, the variation of said undulation being determined by both the first and the or each further modulated carrier waves, that the maximum undulation amplitude is substantially smaller than the average separation between the centre lines of adjacent tracks, and that the tracks are adapted to cause a difference in optical path-length between the parts of the road beam which fall on the track and on the lands. Preferably said difference in optical path-length is approximately an odd multiple of a quarter of the wavelength of said radiation.

An undulation is defined herein to mean an oscillation which consists of sinusoidal or approximately sinusoidal excursions whose frequency and/or amplitude varies over the record.

It is to be noted that in British Patent Specification 1,133,480 it has already been proposed to provide a record for sound with a wobbling groove, which groove is optically readable. As the wobble of the groove is only determined by the low-frequency sound information and not by a combination of high-frequency luminance information and chrominance and sound information of a lower frequency, the wobble on the known record carrier is completely different from the undulation on the proposed record. Furthermore the groove is very deep relative to the wavelength of the read radiation and the depth of the groove may very by some wavelengths without affecting the read process. For reading this prior art record use is made of the fact that the polarization of the read radiation is modified by reflection at the groove walls. By an imaging system, which is disposed in the path of the radiation which is reflected at the record, a black line is imaged on two radiation-sensitive detectors with the aid of polarizing means, the variation of which line corresponds to that of the groove. The phase properties of the information structure are not utilized whereas they are in the record according to the present invention.

Apparatus for reading a record in accordance with the invention comprises a radiation source for supplying a read beam of optical radiation of a wavelength chosen so that the said difference in optical path length is approximately an odd multiple of a quarter of a wavelength and an objective system for transferring radiation from the radiation source *via* such a record when placed in the apparatus to a radiation-sensitive detection system which converts the read beam which is modulated by the information structure on the record into an electric signal, characterized in that the information detection system comprises two radiation-sensitive detectors which are disposed in the effective exit pupil, as herein defined, of the objective system, the separating line between one detector and the other, if projected on the plane of the recorded information structure, being parallel to the reading direction at the region of such projection, and that the output terminals of the detectors are connected to a differential amplifier at whose output the information signal is available.

The "effective" exit pupil of the objective system is defined herein to mean the actual exit pupil of said system if said pupil is readily accessible. The effective exit pupil may also be constituted by an image of the actual pupil if said actual pupil is substantially inaccessible.

It is to be noted that in German Patent Application 2,342,906 (which has been laid open for public inspection) apparatus is proposed for reading an optical information structure, in which two detectors are used which occupy the same position in the direction of reading and different positions in a direction transverse thereto. In this known apparatus, however, the two detectors are employed for detecting whether the read beam is correctly centred relative to the track, and not for reading the information stored. The high frequency information signal is obtained in the known apparatus by addition of the output signals of the two detectors. In said Patent Application another read apparatus is described, in which apparatus the high-frequency information signal is derived from the difference between the output signals of two detectors. However, the two detectors are then offset relative to each other in the direction of reading and not in a direction transverse thereto. As will be explained hereinafter the position of the detectors and the manner in which the detector signals are combined are determined by the manner in which the information structure is composed. From this it will become evident that the apparatus according to the said German Patent Application employs a read mechanism which differs from that of the present read apparatus.

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

Figure 1 shows a part of a record of disc form which is provided with an information structure in accordance with the invention.

Figure 2 shows a part of a track of the information structure,

Figure 3 shows an embodiment of apparatus for reading a record according to the invention,

Figures 4*a*, 4*b*, 5*a*, 5*b*, 6*a*, 6*b*, 6*c*, 6*d*, 7*a* and 7*b* clarify the reading mechanism,

Figure 8 represents the amplitude of the detected signal as a function of the difference in optical path-length caused by the information tracks, and

Figure 9 shows an acousto-optic modulator for use in apparatus for writing an information structure in accordance with the invention.

Figure 1 shows a part of a record 1 of disc form, on which a television signal is stored. The record is provided with a multitude of concentric or spiral tracks 2 of constant width alternating with lands 3. In accordance with a feature of the invention the tracks undulate transversely to the track length in the plane of the track structure around an average position, the full information of the television signal (for example a colour television signal) being contained in the approximately sinusoidal undulation of the tracks. As can be seen in Figure 2, which shows a small portion a single track, the undulation of a track varies in accordance with two modulated carrier waves. The dotted line 4 represents the average position of the track centre. The track exhibits a first undulation with a short, variable period P_1 and a second undulation with a longer period P_2 which is also variable. The spatial frequency of the first undulation is determinded by the carrier wave which is modulated by the luminance information of the colour television signal, whilst the spatial frequency of the second undulation is determined by a carrier wave which is modulated with the chrominance and sound information.

When the amplitude of the undulation on the record is kept small relative to the track width (said amplitude is for example 1/10 of the track width) the detected electrical signal can be approximately proportional to the recorded signal. In the entire system, from the formation of the electrical drive signal for the optical modulator to the decoding of the detected electrical signal, no abrupt changes or amplitude limitations occur. Substantially no higher harmonics are produced, so that substantially no mixing products occur in the frequency bands of the luminance information and of the chrominance and sound information.

As is shown in Figure 2, both the luminance information and the chrominance and sound information may be recorded as variations in the spatial frequencies of the undulations of the track. However, it is also possible to define said luminance information and chrominance and sound information by amplitude modulation of an undulation having a constant period. Furthermore, it is possible to modulate the undulation of the track both in amplitude and in frequency, the luminance information then being for example contained in the spatial frequency of the undulation and the chrominance and sound information in the amplitude of the undulation.

The information structure of Figure 2 is a phase structure, which means that it modifies the phase of a read beam. The information tracks are for example disposed in the record body on a plane spaced from the plane of the intermediate lands. The record may be radiation reflecting or radiation transmitting. In either case the distance between the plane of the tracks and that of the lands must be such that radiation which has passed through a track or is reflected at a track traverses an optical path-length which is approximately $(2n+1)\,\lambda/4$ shorter or longer than the optical path-length which is traversed by radiation which has passed through or is reflected at a land. In this context the optical path-length is the product of the actual path-length and the refractive index of the medium in which said path is located. λ is the wavelength of the radiation used for reading and n is zero or a whole number. For example, for a record with a reflecting information structure which adjoins air, the distance between the plane of the tracks and that of the lands should be approximately $(2n+1)\,\lambda/8$.

Figure 3 shows apparatus for reading a reflecting record according to the invention. An optical radiation source 11, for example a laser, emits a read beam of radiation 12. Said beam is focussed onto the information plane 5 of the record carrier 1 by an objective system, which in this case is schematically represented by a single lens L_1. The record is shown in radial cross-section. The tracks are again denoted by 2. The beam which is reflected by the record carrier and modulated by the information structure passes the objective L_1 for a second time, and is subsequently reflected to a radiation-sensitive detection system 14 by, for example, a semi-transparent mirror 13.

According to a feature of the invention said detection system is disposed in the plane of the effective exit pupil of the objective system L_1. Said effective exit pupil is an image of the actual exit pupil of the objective system, which image is formed by an

auxiliary lens L_2. For simplicity only the image a' of one point a of the exit pupil is shown in the Figure. If the actual exit pupil of the objective system is suitably accessible it is obvious that imaging is not necessary.

The radiation-sensitive detection system 14 comprises two separate detectors 15 and 16. Said detectors are disposed so that the separating line between one detector and the other, if projected on the plane of the recorded information structure, is parallel to the reading direction at the region of such projection. The detectors thus occupy different radial positions. The electrical signals supplied by the detectors 15 and 16 are applied to a differential amplifier 17. When the record is rotated about an axis 6 and the read system and the record are radially moved relative to each other, a signal S_i is obtained at the output of said amplifier. The information contained in said signal may further be rendered visible and audible in known manner.

The television signal information is stored on the record as track undulations in a direction transverse to the direction in which the tracks are read and during reading the record these transverse undulations are sensed by the read beam. The principle of the invention will now be explained in greater detail with reference to Figures 4*a*, 4*b*, 5*a*, 5*b*, 6*a*, 6*b*, 6*c* and 6*d*.

A lens L, which exhibits no aberrations, can form a faithful image B in the image plane *b* of an object V which is located in the object plane *v* (cf. Figure 4*a*). All information on the object is present in an arbitrary plane through the optical axis 00' and perpendicular to said axis. However, in the plane *u* of the exit pupil of the lens L certain information can be detected which in practice can generally no longer be observed separated from other information in the image plane.

If the object is a grating, a radiation beam *c* is divided by the grating into a zero-order beam c_0, two first-order beams c_{+1} and c_{-1} and a number of higher-order beams, not shown. The zero-order beam then contains no information about the object; said information is divided over the beams of other orders. Provided that the lens pupil is sufficiently large all orders together yield a faithful image of the grating in the image plane. In said image plane the individual orders cannot be distinguished. However, in the plane of the exit pupil the orders are more or less separate. Figure 4*b* shows the situation in said plane. The circle 20 represents the exit pupil, whilst the circles 21 and 22 represent cross-sections at the location of the exit pupil of the +1 order and the −1 order beam respectively. The positions of the circles 21 and 22 in the plane of the exit pupil are determined by the period of the grating. The angle α between the chief rays of the first-order beams and the chief ray of the zero-order beam is given by $\alpha = \lambda/p$, p being the period of the grating and λ the wavelength of the radiation of the beam *c*. With decreasing grating periods the diffraction angle α increases (compare the dotted circles 21' and 22'). With increasing grating periods the overlap of the +1 and −1 order beams with the zero-order beam increases. By arranging a separate detector (23 and 24 in Figure 4*b*) in each of the left and the right halves of the pupil, the +1 and the −1 order beams can be detected separately.

So far it has been assumed that the grating lines are straight lines and that the grating is stationary. If the grating is the information structure of a record according to the invention the situation is modified in that the tracks exhibit undulations, and said structure moves relative to the optical read system.

Figure 5*a* shows a small portion of a track 2 of the information structure. The track is illuminated by a read spot of radiation V. During reading the read spot and the information track move relative to each other in the direction of the arrow 52. A tracking control system ensures that the read spot V and the exit pupil of the objective are always substantially centred on the dotted line 51. Said dotted line represents the average position of the track centre taken over a distance large compared with the undulations. Owing to the undulation of the track the radiation is diffracted *inter alia* in directions such as those denoted by the arrows *p*, *q*, *r* and *s*. The beams diffracted in these directions are of significance in reading the information structure.

In the plane of the exit pupil the situation of Figure 5*b* occurs. The central circle 53 represents the size of the exit pupil. The cross-sections of the beams of the (−1, +1), (+1, −1), (+1, +1) and (−1, −1) orders at the location of the exit pupil, which beams are diffracted in the directions *p*, *q*, *r*, and *s* of Figure 5*a*, are represented by the circles 54, 55, 56 and 57. Said circles, with centres *p'*, *q'*, *r'* and *s'*, have the same radius as the circle 53. The distance *e* in Figure 5*b* is determined by λ/p_t, in which p_t is the period of the information structure in a direction transverse to the direction of reading and is therefore the average distance between the centre lines of adjacent tracks. Said period may be assumed to be constant. The distance *f* is a function of λ/p_l, in which p_l is the period of the information structure in the direction of reading. If the television signal is contained in a modulation of the spatial frequency of the undulation of a track, p_l will vary during reading of the information structure.

Figures 6*a*, 6*b*, 6*c* and 6*d* show the varia-

tions of the phases of the various first-order beams relative to the zero-order beam. The electric field vector $\overline{E_{00}}$ of the zero-order beam, as well as those of the first-order beams, rotate with the velocity of light. For a specific point in a track the (−1, +1) order beam has a phase vector $\bar{p}$ which makes a certain angle with the vector $\overline{E_{00}}$. The (+1, −1) order beam has a phase vector $\bar{q}$ at the same angle to the vector $\overline{E_{00}}$ as the phase vector $\bar{p}$. If the information track moves relative to the read spot, as is shown in Figure 5*a*, the phase angle of the order which is diffracted to the right will increase and that of the order which is diffracted to the left will decrease. When the information track and the read spot V move relative to each other the vectors $\bar{p}$ and $\bar{q}$ consequently rotate in opposite directions. The vectors r and s correspond to the (+1, +1) and (−1, −1)-order beams. These vectors also rotate in opposite directions during reading of the information structure.

Starting from the initial situation of Figure 6*a*, the situation of Figure 6*b* will occur after the read spot has moved over a distance which equals ¼ of the local undulation period in the direction of reading. Figure 6*c* represents the situation after the read spot has moved over a distance equal to ½ of the local undulation period in the direction of reading, and Figure 6*d* the situation after a distance is covered which equals ¾ of the local undulation period. After a movement of the read spot over a distance equal to a full local tangential period the situation of Figure 6*a* obtains again.

The component of the sum of the vectors $\bar{p}$ and $\bar{r}$ in the direction of the vector $\overline{E_{00}}$ decreases from 0 (Figure 6*a*) to a minimum (i.e. maximum negative) value (Figure 6*b*), then becomes zero again (Figure 6*c*) and subsequently becomes a maximum (Figure 6*d*). For the component of the sum of the vectors q and s the variation occurs in the reverse order, namely from 0 to a maximum (Figure 6*b*), then to 0 again (Figure 6*c*) and subsequently to a minimum (Figure 6*d*).

In the areas which are shown hatched in Figure 5*b*, where the first-order beams and the zero-order beam overlap, there is alternately constructive and destructive interference between the zero-order beam and the relevant first-order beam, so that the intensities in said areas increase and decrease alternately. The intensity variations, which are determined by the variation of the undulation and thus by the information which is stored, can be detected with radiation-sensitive detectors 15 and 16 (Figure 5*b*). The intensity variations which are the result of the diffraction in the directions *p* and *r* are mutually in phase and are in phase opposition with the intensity variations resulting from the diffraction in the directions *q* and *s*, said last-mentioned variations also being mutually in phase. By subtracting the output signals of the detectors 15 and 16, as is effected in the apparatus described (see Figures 3 and 5*b*), an electric signal is obtained having an amplitude which is twice the amplitude of the signal supplied by the individual detectors.

As stated previously, the positions of the centres p', q', r' and s' of the circles 54, 55, 56 and 57 of Figure 5*b* are determined by the period in the tangential direction p_t. With increasing spatial frequency of the information on the record, in other words with decreasing local periods of the undulation, the centres p', q', r' and s' will move outwards relative to the central circle 53, so that the overlapping areas (shown hatched) of the circles 54, 55, 56 and 57 with the circle 53 becomes smaller. The extent to which the first-order beams interfere with the zero-order beam then decreases. This means that the magnitude of the signals supplied by the detectors 15 and 16 decreases at higher spatial frequencies of the information on the record.

The electric signal supplied by each of the detectors 15 and 16 varies in time in accordance with the variation of the undulation of the tracks on the record carrier. In the case described above in which the information is contained in the variable period of the undulation, the electric signal has a constant amplitude and a varying frequency. The information may also be contained in an amplitude modulation of the undulation. In that case the period p_t may no longer be considered a constant and the centres p', q', r' and s' in Figure 5*b* will then alternately move up and down during reading of the record carrier. In terms of the vector diagrams of Figures 6*a*, 6*b*, 6*c* and 6*d* this means that the lengths of the vectors vary with the information stored, whilst the velocity with which the vectors rotate relative to the vector $\overline{E_{00}}$ is constant. The electric signal from the detectors 15 and 16 then has a constant frequency and a varying amplitude.

In Figures 6*a*, 6*b*, 6*c* and 6*d* it has been assumed that the tracks of the information structure cause a difference in optical path-length of $\lambda/4$ in the read beam, so that in the initial position (Figure 6*a*) the angle between the vectors $\bar{p}$, $\bar{q}$, $\bar{r}$ and $\bar{s}$ and the vector $\overline{E_{00}}$ is $\pi/2$. For reading by phase changes such a track structure is ideal since the detected signal is then maximum. However, said difference in optical path-length may vary over a fairly wide range around the value $\lambda/4$ without the amplitude of the detected signal becoming too small. Figure 8 represents the amplitude of the detected signal S_i as a function of the difference *w* in optical path-length caused by the tracks. From this it appears that a satisfactory read-

ing of information is possible for path-length differences ranging between $\lambda/8$ and $3\lambda/8$. However, reading by phase changes cannot be employed for records whose tracks cause a difference in optical path-length in the read beam which approximates 0 or $\lambda/2$. To read the transverse undulations it is thus essential that the path length difference caused by the tracks and the lands be approximately $(2n + 1)\lambda/4$, and that the separating line between one and the other detector, if projected on the plane of the recorded information structure, is parallel to the reading direction.

Figures 7*a* and 7*b* show two phase vector diagrams which apply to the last-mentioned case in which the difference in optical path length is approximately 0 or $\lambda/2$. Figure 7*a* shows the initial position which corresponds to Figure 6*a*, whilst Figure 7*b* shows the situation after the read spot has moved along the track over a distance equal to ¼ of the local undulation period. In practice the sum of the vectors $\bar{E}_{00}$, $\bar{p}$ and r will not vary substantially and variation takes place with a frequency which is twice the frequency which corresponds to the spatial frequency of the information on the record. The detectors 15 and 16 then supply a distorted electric signal of a small amplitude.

The situation shown in Figure 5*b* only applies to a radiation transmitting record. When a radiation-reflecting record is to be read, only the hatched parts of the first-order circles are transmitted by the objective.

When describing the read mechanism only first-order beams have been mentioned. It is evident that the track structure will also diffract radiation of higher orders. However, the radiation energy of the higher diffraction orders is fairly low, and the diffraction angles are such that only a small portion of the higher order beams falls inside the lens pupil. The higher order beams may therefore be neglected for the described method of reading.

Furthermore, in describing the method of reading only diffraction in the directions *p*, *q*, *r* and *s* has been assumed. By means of calculations based on the theory of diffraction at a phase grating, it can be demonstrated that the diffraction in the direction of reading and the diffraction in the direction transverse to the direction of reading have no influence on the high-frequency signal supplied by the detectors 15 and 16. It will be readily seen that no diffraction occurs in the direction of reading when it is borne in mind that the track is a continuous track.

The beams of the (0, −1) and (0, +1) orders which are diffracted in directions *x* and *x'* perpendicular to the dotted line 51 in Figure 5*a* do not contain any high-frequency television information. The radiation energy in said beams is low relative to that of the (0,0) order beam and the angle between the phase vectors of said beams and the phase vector E_{00} is 90°. Interference of the (0, −1) and (0, +1) order beams with the (0,0) order beam hardly causes the intensity of said last-mentioned beam to change. The influence of the beams which are diffracted in a direction transverse to the direction of reading on the signals from the detectors 15 and 16 is therefore negligible.

During reading of the record carrier the read spot should remain centred on the average position of the track centre. For the detection of errors in the centring of the read spot the high-frequency undulation of the tracks, which is determined by the television signal, can be modulated with an additional undulation of constant period, which period is an order of magnitude longer than the longest period of the high-frequency undulation. The additional undulation impresses an additional modulation on the detector signals and its phase is a measure of the centring of the read spot relative to the average position of the track centre. From the electric signals supplied by the detectors a low-frequency component may be extracted for correcting the centring of the read spot in known manner. The use of an undulating track for centring purposes has already been proposed in Patent Specification No. 1,489,756.

It is also possible to control the centring of the read spot without an additional undulation. For this use can be made of the fact that centring errors will always have a low frequency relative to the undulation of a track which is determined by the television signal. In a manner similar to that described in the German Patent Application 2,342,906, which has been laid open for public inspection, a control signal for correcting the position of the read spot relative to a track can be obtained by extracting a low-frequency component from the electric signals supplied by the detectors.

An information structure according to the invention may be written in a record body by means of apparatus described in the aforesaid Patent Specification No. 1,489,756. In said apparatus a direction modulator (for example an acousto-optic cell) is disposed in the path of a radiation source which supplies a write beam of radiation to the radiation-sensitive surface of the record body. Such a cell is shown in Figure 9.

The cell 60 is provided with two electromechanical transducers 61 and 62, which are connected to electrical terminals 65 and 66. When an electric signal is applied to terminals 65 and 66 acoustic waves of a certain frequency are produced in the cell medium, for example glass or water. This

results in so-called Bragg diffractions in the cell medium, so that a radiation beam 63 is partly diffracted through an angle β is proportional to the frequency of the electric signal applied to terminals 65 and 66. The angle through which the radiation beam is to be diffracted during writing of a record carrier according to the invention is only small. Therefore, the acousto-optic cell may be driven with high frequencies. For example a basic signal or carrier may be applied to the cell with the order of 100 MHz, which basic signal is modulated with a television signal whose frequency is of the order of 5–10 MHz.

The term "television" has been used in the broad sense of video and includes, for example, a series of still pictures (one per track) which can be individually selected for repetitive display.

Record carriers and apparatus adapted to read them which also utilise detectors placed in the effective exit pupil of the objective system are described and claimed in Patent Applications Numbers 39940/75 and 07415/76.

WHAT WE CLAIM IS:–

1. A record on which a television signal is stored in the tracks of a track structure of constant track width in a plane of the record, said tracks being separated by lands, which record, is readable with optical radiation, and which structure is adapted to modulate the phase of a read beam of optical radiation, the recorded television signal comprising a first carrier wave which is frequency modulated with the luminance or brightness information, and one or more further carrier waves which are modulated with additional information, characterized in that the tracks of the information structure are continuous tracks as defined herein before which in the plane of said structure exhibit an undulation, as herein before defined, transverse to the track length the variation of said undulation being determined by both the first and the or each further modulated carrier waves, that the maximum undulation amplitude is substantially smaller than the average separation between the centre lines of adjacent tracks, and that the tracks are adapted to cause a difference in optical path-length between the parts of the read beam which fall on the track and on the lands.

2. A record as claimed in Claim 1, wherein the carrier wave which is modulated with the luminance information determines the spatial frequency of the undulation of the tracks, whilst the additional information is laid down in the amplitude of the undulation.

3. A record as claimed in Claim 1 or Claim 2, wherein the first-mentioned undulation which is determined by the television signal is modulated with a second undulation of the tracks, which second undulation has a constant spatial period which is an order of magnitude longer than the longest spatial period of the first mentioned undulation.

4. Apparatus for reading a record as claimed in Claim 1, comprising a radiation source for supplying a read beam of optical radiation of a wavelength chosen so that the said difference in optical path length is approximately an odd multiple of a quarter of a wavelength and an objective system for transferring radiation from the radiation source *via* such a record when placed in the apparatus to a radiation-sensitive detection system which converts the read beam which is modulated by the information structure on the record into an electric signal, characterized in that the information detection system comprises two radiation-sensitive detectors which are disposed in the effective exit pupil gas hereinbefore defined, of the objective system, the separating line between one detector and the other, if projected on the plane of the recorded information structure, being parallel to the reading direction at the region of such projection, and that the output terminals of the detectors are connected to a differential amplifier at whose output the information signal is available.

5. A record substantially as hereinbefore described with reference to the accompanying drawings.

6. Play back apparatus substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

7. A record as claimed in any of Claims 1 to 3 in combination with apparatus as claimed in Claim 4.

8. A combination as claimed in Claim 7 wherein the plane of the track structure is at a constant distance from a second plane which contains all the lands.

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results in so-called Bragg diffractions in the cell medium, so that a radiation beam 63 is partly diffracted through an angle β is proportional to the frequency of the electric signal applied to terminals 65 and 66. The angle through which the radiation beam is to be diffracted during writing of a record carrier according to the invention is only small. Therefore, the acousto-optic cell may be driven with high frequencies. For example a basic signal or carrier may be applied to the cell with the order of 100 MHz, which basic signal is modulated with a television signal whose frequency is of the order of 5–10 MHz.

The term "television" has been used in the broad sense of video and includes, for example, a series of still pictures (one per track) which can be individually selected for repetitive display.

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1. A record on which a television signal is stored in the tracks of a track structure of constant track width in a plane of the record, said tracks being separated by lands, which record, is readable with optical radiation, and which structure is adapted to modulate the phase of a read beam of optical radiation, the recorded television signal comprising a first carrier wave which is frequency modulated with the luminance or brightness information, and one or more further carrier waves which are modulated with additional information, characterized in that the tracks of the information structure are continuous tracks as defined herein before which in the plane of said structure exhibit an undulation, as herein before defined, transverse to the track length the variation of said undulation being determined by both the first and the or each further modulated carrier waves, that the maximum undulation amplitude is substantially smaller than the average separation between the centre lines of adjacent tracks, and that the tracks are adapted to cause a difference in optical path-length between the parts of the read beam which fall on the track and on the lands.

2. A record as claimed in Claim 1, wherein the carrier wave which is modulated with the luminance information determines the spatial frequency of the undulation of the tracks, whilst the additional information is laid down in the amplitude of the undulation.

3. A record as claimed in Claim 1 or Claim 2, wherein the first-mentioned undulation which is determined by the television signal is modulated with a second undulation of the tracks, which second undulation has a constant spatial period which is an order of magnitude longer than the longest spatial period of the first mentioned undulation.

4. Apparatus for reading a record as claimed in Claim 1, comprising a radiation source for supplying a read beam of optical radiation of a wavelength chosen so that the said difference in optical path length is approximately an odd multiple of a quarter of a wavelength and an objective system for transferring radiation from the radiation source *via* such a record when placed in the apparatus to a radiation-sensitive detection system which converts the read beam which is modulated by the information structure on the record into an electric signal, characterized in that the information detection system comprises two radiation-sensitive detectors which are disposed in the effective exit pupil gas hereinbefore defined, of the objective system, the separating line between one detector and the other, if projected on the plane of the recorded information structure, being parallel to the reading direction at the region of such projection, and that the output terminals of the detectors are connected to a differential amplifier at whose output the information signal is available.

5. A record substantially as hereinbefore described with reference to the accompanying drawings.

6. Play back apparatus substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

7. A record as claimed in any of Claims 1 to 3 in combination with apparatus as claimed in Claim 4.

8. A combination as claimed in Claim 7 wherein the plane of the track structure is at a constant distance from a second plane which contains all the lands.

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