(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 June 2007 (07.06.2007)

PCT

(10) International Publication Number
WO 2007/063353 A2

(51) International Patent Classification:
G11B 7/0045 (2006.01)

(21) International Application Number:
PCT/IB2005/003628

(22) International Filing Date:
4 December 2005 (04.12.2005)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **NEW MEDIUM ENTERPRISES, INC** [GB/GB]; VMD House, 195, The Vale11219, London, Greater London W3 7QS (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LEVICH, Eugene** [IL/IL]; 43 Yehuda Anassi Str., Apt. 71, Ramat-Aviv, 69391 Tel Aviv (IL). **MAGNITSKII, Sergei** [RU/RU]; 9 Garibaldi Street, Apt. 76, 117313 Moscow (RU).

(74) Agent: **LEVICH, Eugene**; 43 Yehuda Anassi Str., Apt. 71, Ramat-Aviv, 69391 Tel Aviv (IL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 2007/063353 A2

(54) Title: OPTICAL PICK-UP METHOD AND DEVICE FOR MULTILAYER RECORDING MEDIUM

(57) Abstract: An optical pick-up method and device for multilayer recording medium using a source of reading radiation, a detector of reflected signal, an optical system for focusing the reading radiation into information layer and said detector of reflected signal, an arrangement for focusing and tracking control and means for suppression interference of layers reflected signals.

OPTICAL PICK-UP METHOD AND DEVICE FOR MULTILAYER RECORDING MEDIUM

The present invention generally concerns the principles of reading/writing the information from/on multilayer optical media and design of reading device which can realize this function.

BACKGROUND OF THE INVENTION

There is a growing demand in a cheap and reliable storage systems of digital information for computers, video systems, HDTV, multimedia, etc. To improve recording densities of optical disks according to demand for recording long term high definition video data or the like a multiplayer optical disk having two or more information recording layers is under development.

Optical pickup devices and methods use recording/reading of data on a recordable plane of an optical medium having at least two recordable planes inside disk and an input plane of protection substrate of the recording/reading disk. The optical pickup devices usually use a semiconductor laser beam spot focused by an objective. Exact focusing of the spot the recordable plane is assured by special focusing servo system that utilizes focus error signal formed with the help of the said recording/reading laser beam.

The multi-layer optical medium contains a set of recordable or data carrying planes separated by intermediate transparent layers-spacers.

During reading from such multi-layer optical medium, some noise is present due to interference of laser beams reflected from the said recordable/data carrying planes which drastically reduces quality of reading.

Recording/reading involves a reading spot formed by a laser beam focused on the data surface. The mentioned objective and other additional optical elements assist in creating laser beams to form focus and track errors.

Conventional optical pickup devices for focusing and tracking control use so-called discriminating S-curve detection (see Fig. 5). Detection of S-curve signals for controlling of servo systems of the recording/reading device shall hold the focused beam on the data surface and on information track. Since multi-layer disks has several information layers to be distinguished and captured by focusing system, multilayer disc must have several such S-curves each of them is corresponding to own information layer. To this end, dependence of error signal vs objective moving perpendicular to disc plane looks like a few S-curves, as illustrated on Fig. 6

Accordingly, various focusing and tracking methods and systems for multiplayer disks are used. Patent US 5,513,158 discloses the use of a piezo-ceramic deflector to form the signal of 'narrow' focus sensor. The major weakness of this solution is that it requires a powerful high-voltage generator to form pulse for PZLT plate; the former includes transparent electrodes to change the plate's optical phase fast in different areas of objective pupil causing slight flicker of focus point. The PZLT plate is very inefficient and requires a highly powerful generator which will create strong interference too.

Also, active wobbling of micro objective focus to read from multi-layer disks is disclosed in Patent US 5,740,145. Focusing system is modified in such a way that the micro objective wobbles continuously along optical axis at frequency f_0. To form signal of 'narrow' focus, the frequency f_0 must be > 5 kHz.

Since the sensitivity of the mechanism that moves the objective along focus is limited, it becomes practically impossible for this method to assure focusing in layers having spacer thinner than 50 μm and in DVD or other disks of similar density. Another example of optical disk reader focus servo system is disclosed in Patent US 4,695,158.

In this case, the system contains an eight-sector instead of traditional four-sector photo receiver in order to shorten the astigmatic focus sensor. This solution allows substituting the known algorithm of forming a discriminator:

$$F = (A1+A2) - (B1+B2)$$

with a new algorithm:

$$F' = (A1+A2) - (B1+B2) + \beta[(A1+A2) - (B1+B2)].$$

However, this solution shall shorten the focus sensor by 20÷40 % at best, furthermore, signal-to-noise ratio gets significantly worse.

It is known that the aberration of light beam caused by increasing the numerical aperture NA of the objective lens and multiplayer structure of disks makes it difficult to read/write information. An executive unit of beam aberration correction may be introduced into the recording/ reading apparatus in order to correct such beam aberrations. Such unit may be based on liquid-crystal or piezoelectric effect, for example. Patent US 6,628,589 provides a method of correcting aberrations similar to the one described above. A value of data signal amplitude value serves as a sensor for correcting tilt aberrations or spherical aberrations. A device based on liquid crystal cell with transparent electrodes serves as an executive unit or, to be more precise, an adaptive corrector. The cell is divided into several zones with the help of transparent electrodes along the area of an objective input pupil. The type and shape of the electrodes depend on the type of aberration corrected, e.g. radial tilt and spherical aberration.

Under the action of electric field, liquid crystals begin to orient along the electric field line and create a local area of changing refraction index, the shape of this area being determined by the electrode configuration. Degree of the change in refraction index and so the local changes in the phase of beam's wave front depend on electric field strength, i.e. the voltage applied to the transparent electrodes.

The system of automatic compensation of wave front aberrations described in the mention Patent operates in the following manner. If any beam aberration is present, the amplitude of data signal decreases. This change is registered and serves as an error signal generating a control signal for the said liquid crystal compensator.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an optical pick-up method and device capable of accurately reproducing an information signal storage layers of multi-layer optical storage device, e.g. disk.

It is another object of the present invention to provide an optical pick-up method and device capable of conducting a focusing and/or tracking control with desired accuracy for multi-layer optical storage device.

Further, it is an object of present invention to provide an effective aberration compensating for reproducing an information signal from storage layers of multi-layer optical storage device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates laser beam propagation through multilayer disk;

FIG. 2 illustrates dependence of reflected light power **PR** vs. spacer thickness **h**;

FIG. 3 illustrates dependence of semiconductor laser radiation wavelength vs. power of radiation (information is taken from Hitachi HL6323M6 Laser Data sheet);

FIG. 4. illustrates graph of power modulation of laser HL6323M6 that gives $\Delta\lambda = 1.63\,nm$ and average power $P_{cp} = 5mW$;

FIG. 5 shows typical discriminating S-curve; detection

FIG. 6 shows discriminating S-curve for multilayer (three layer) medium;

FIG. 7 shows tracking unit layout, and

FIG. 8 shows graphically the degradation coefficients of frequency-contrast parameter for spherical aberration and comma.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown reflecting signal from multiplayer reflective optical medium, having two layers in the present example. As shown in FIG. 1 there are two reflecting light beams, one reflecting from the layer of interest (layer to be read) I_r and another beam I_c reflected from the adjacent layer (back-reflected beams).

Due to interference, amplitude modulation of read signal arises. This interference disturbs both information channel and servo tracking and focusing systems.

In accordance with one aspect of the present invention a method of suppressing of interference noise is provided. In order to provide suppressing of interference noise coherence of reading light beam should be "destroyed" or at least decreased up to appropriate levels.

Various techniques may be used for that purpose. It is known, for example, that high frequency modulation provides multi-mode laser generation ($\lambda_0 \pm n\Delta\lambda$) instead of single-mode generation (λ_0). This decreases laser length of coherence and thus, interference.

However, the number of modes (n) and the value of wavelength difference (Δλ) between modes do not assure complete suppression of interference from layers, particularly, if the inter-layer distance becomes smaller than 50μm.

It is known replacing laser with a super -luminescent diode, its radiation spectrum being similar to radiation spectrum of LED (λ0 ± 20 nm). Nevertheless, such solution is not optimal for this case: although the radiation spectrum become wide, the power drops fast when the wavelength changes from the central one. The mentioned diodes are characterized by low efficiency, low power, high consumption and expensive price. Thus, these solutions of overcoming interference noise do not provide its complete suppression and thereby assure quality of data recording/reading.

In accordance with one aspect of the present invention, it is to develop a method and an optical device for recording/reading of data with almost complete suppression of noise on the basis of radiation with two wavelengths (2-frequency suppression methods).

The optical pickup device is characterized by use of two lasers with different wavelengths, e.g. λ_1 and λ_2, where preferably $\lambda_2 = \lambda \pm \Delta\lambda$ Value of Δλ is defined by the following expression

$$\Delta\lambda = \frac{\lambda_1^2}{4hn - \lambda_1},$$

where

λ_1 is a wavelength of the first laser;

λ_2 is a wavelength of the second laser;

Δλ is a difference between the first and second laser wavelengths;

h is a thickness of spacer (interlayer distance);

n is a refraction index of spacer (n=1.57 for polycarbonate).

It is important that the difference Δλ remains stable.

As a result of two-wave interference (see "Optical shop testing" edited by D. Malacara. page 311) fluctuations of radiation power (interference noise) will occur along with changes in inter-layer distance not with a period of $\Delta h = \frac{\lambda_1}{4n}$ but rather with an increased period of $\Delta H = \frac{\lambda_{eq}}{4n}$, where $\lambda_{eq} = \frac{\lambda_1 * \lambda_2}{|\lambda_1 - \lambda_2|}$, i.e. the fluctuations of spacer thickness will no longer cause fluctuations of power (interference noise) or the latter will, to some extent, be attenuated.

Numerical calculation for □ = 0,64 □m and ncn = 1,57 (polycarbonate) gives result presented in the table:

h, μm	$\Delta\lambda$, μm
100	0,65
60	1,09
40	1,63
30	2,18
20	3,28

In accordance with additional aspect of the present invention two lasers emitting alternately, rather than simultaneously, depending on the value of thickness of interlayer distances might be used.

Realization of such method will require:

1) an interference sensor, e.g. an information photo receiver with low-pass filter to detect amplitude of interference-caused low frequency noise signal;

2) a system of interference suppression with the help of low frequency switching of lasers (in the spectrum of 0÷100 kHz). To determine the phase of noise signal, it is possible to use a method of power modulation of one of the lasers.

In accordance with still another aspect of the invention single two-mode (multi-mode) laser with two lines of radiation λ_1 and λ_2 with equal intensity.

There are several methods providing two-mode operation of laser with the required value of $\Delta\lambda$ difference.

a) Method with $\Delta\lambda$=const.

i) Distributed reflection laser (DBR-laser) where the first reflector grating is adjusted for λ_1 wave and the second one is adjusted for λ_2 wave.

ii) Laser with a controlled external resonator which allows adjustment for λ_1 and λ_2 of equal intensity.

b). Methods based on dynamically controlled difference of wavelengths $\Delta\lambda$ of a single irradiator are:

i) Using electro optical converters;

ii) Based on Zeeman effect;

iii) Based on dynamic shift of laser generation wavelength caused by injection current changing. This effect is found for closed heterostructure lasers with distributed feedback. (Semiconductor injection Lasers, I. 1985. Volume Editor W.T. Tsang).

If the controlled difference $\Delta\lambda$ of two laser waves is employed, it is possible to suppress interference noise almost to zero immediately in the process of reading.

In this case the sensor of interference noise value and phase is required, for this purpose, one can use the method of changing wavelength λ of laser radiation e.g. using frequency modulation of pumping current of laser with distributed feedback.

In accordance with still another embodiment of the present invention, a for suppressing of interference noise that arises at a time of reproducing information from multilayer disc having multiple semi-transparent information-carrying layers high frequency pulse laser radiation might be used. This method utilizes semiconductor laser and high frequency pulsed laser power source that allows fast switching (turning of/on) of output laser radiation power.

Interference "destroying" in that case is due to various effects. It is known that the wavelength of laser radiation is depending on power of generation, to this end fast switching of laser power provides generating several wavelengths by the laser. Also, transient processes during laser switching leads to unstable parameters of optical resonator causing generation of additional modes with different wavelengths.

The interference noise is suppressed due to superposition of interference patterns produced by radiation with different wavelengths on the photo receiver.

In this invention is proposed method of suppressing of named interference by means of laser radiation wavelength high frequency shift.

Let consider interaction of laser beam with multilayer disc having multiple semi-transparent layers (see FIG. 1). Optical disc comprises several semi-reflective layers with information pits that are separated by plastic spacer having thickness 20…70 μm and refraction coefficient ~ 1,49…1,58.

For phase thickness of spacer h it may derive follow dependence:

$$h = m\left(\frac{\lambda}{4n_{cn}\cos\Theta}\right)$$

Following this expression, power of reflected light $I_r = 0$ by even m (clearing effect) and $I_r = I_0$ by odd m (mirror effect). Due to spacer thickness is varying in real disks, reflected light will be amplitude modulated when disc rotates (see FIG. 2.). Note that clearing and mirror conditions are depending from light wavelength, hence, for single spacer thickness, for one wavelength may be fulfilled clearing condition, but for second one - mirror condition.

It is known, that semiconductor lasers have not so stable light wavelength. Wavelength of semiconductor laser may vary with temperature and actual power of laser generation. So, dependence of wavelength of generated light vs. output light power for laser HITACHI HL6323M6 is illustrated in FIG. 3

It is proposed to suppress interference by sequential generation of laser light pulses with different power and, hence, with shifted wavelength.

Let define how should be difference of wavelength $\Delta\lambda$ for spacer having thickness h and refraction coefficient n_{cn} for to obtain clearing condition for first wavelength, but reflective condition for second wavelength.

$$h = m\frac{\lambda_1}{4n_{cn}} = (m-1)\frac{\lambda_2}{4n_{cn}} = (m-1)\frac{\lambda_1 + \Delta\lambda}{4n_{cn}}$$

hence: $\Delta\lambda = \frac{\lambda_1}{m-1}$ Taking into consideration that $m = \frac{4hn_{cn}}{\lambda_1}$, it may derive follow basic dependence:

$$\Delta\lambda = \frac{\lambda_1^2}{4hn_{cn} - \lambda_1}$$

Example 1. For more clearance, suppose, that we have two information layers separated by polycarbonate spacer having h=40µm. Used laser is HITACHI HL6323M6.

For this laser 5 mW pulse has wavelength λ_1 = 637,6 nm. Following to the above wavelength difference should be $\Delta\lambda$ = 1,63 nm. So, λ_2 = = 639,23 nm. Following FIG. 3, this wavelength corresponds to power 25 mW. In order to obtain average power of reading beam 5 mW energy of 5 mW pulse should be equal to that of 25mW pulse, i.e. duration of 5 mW pulse should be 5 times longer than that of 25mW pulse. Finalized pulse sequence is presented on Fig. 4. The repetition frequency of pulses should be more than highest frequency used for optical disc information transfer. For actual DVD disks (3T pits) this frequency is 36 MHz. So appropriate pulse frequency is ~ 100 MHz. A method of suppressing of interference noise that arises at a time of reproducing information from multilayer disc having multiple semi-transparent information-carrying layers separated by spacers. This method utilizes semiconductor laser and high frequency pulsed laser power source that allows fast switching of output laser radiation power. Said high frequency pulsed power source provides repeated sequence of pulses having different power. Power difference between pulses said repeated sequence consist of, leads to wavelength shift $\Delta\lambda$ of laser radiation generated during of pulse duration. Said wavelength shift preferably should satisfy the above-mentioned expression.

In accordance with still another aspect of the present invention suppressing of interference noise might be performed by using repeated pulse sequence consist of two or more pulses having different power.

A method of suppressing of interference noise wherein energy E of each pulse, namely,

$$E = P \cdot \tau ,$$

where

P - power of pulse

- pulse duration,

is constant for all pulses.

Preferably, the frequency of repeated pulse sequence should be at least two times higher than highest frequency used in channel coding of storage device this method is utilized in.

In accordance with another embodiment of the present invention focusing and tracking control method is proposed. Since multi-layer disks has several information layers to be distinguished and captured by focusing system, multilayer disc must have several S-curves each of them is corresponding to own information layer. In order to provide maximal volume of multiplayer disk, the interlayer spaces should be as small as possible. In that case S-curves corresponding to different information layer may be interlaced and focusing and tracking signal does not provide stable reproducing of information signal. The challenges for reading multi-layer disks are that the servo system sensors, i.e. focus and track sensors receive both laser beams from a specific reading data layer and layers adjacent to it thereby generating significant noise and interference.

An additional challenge for reading is that the discrimination curve working region of the optical focus sensor may be longer than the distance between data layers, so reflected from adjacent layers light distort the tracking and focusing signal. Analysis of the track sensor discovers similar problems which hinder reliable operations of the device. Thus, to assure reliable reading of multi-layer systems, there is a need to develop new methods to form focusing and tracking error signals with more resolving power, i.e. having ability to distinguish information layers spaced by 15...30 μm spacer and information tracks having less track pitch and more resistant against interference.

In accordance with additional aspect of the present invention direct analysis of signals from each quadrant of standard photo receiver is proposed. This provides increasing signal-to-noise and signal-to-interference ratio during multi-layer disk reading. Another aspect of the present invention is to find possibilities significantly shorten the length of focus sensor discrimination parameter.

As a base algorithm of error discrimination is used standard approach using four signals from quadrant photoreceiver, namely:

$$F = (A1+A2) - (B1+B2)$$

In proposed solution is used the following fact: when objective moves across disc layer structure with open feedback loop, (search mode) near the point of coincidence of focal point and information layer arises flash of HF signal caused by pits of information layer. This HF flash is very narrow: it begins at several microns before layer, grooves till maximum value in moment of focus and layer coincidence and disappear at several microns after layer. This HF signal is superimposed on the usual signal on photo-detector quadrant and exists on the all quadrants. So total region of this HF signal existence is

~10..15 micrometers, and this enables to create narrow S-curve much narrower than that based on low frequency signals.

In addition to receiving narrow S-curve, HF method allows suppress influence of adjacent layers on the useful focus servo signalIf multilayer disc is read, all layers reflect incident laser beam, and finally, all reflected beams are captured by photo receiver. It is clear, that beams that are reflected from adjacent to actually read layer cause distortion of useful optical response from layer to be read. But only useful beam (i.e. that reflected from read layer) is amplitude modulated by HF information signal in contrast to all other disturbing beams because of read spot is focused on the actually read layer only, and another layers are illuminated by defocused spots. To this end, pits of adjacent layers cannot be resolved by defocused spot. When disk is rotating, high frequency information signals in the band with $f_{inf} \geq 1$ MHz have greater frequency resolution than tracking and focusing sensor signals $f_{servo} \leq 0,1$ MHz and all disturbing beams that are modulated in the same as tracking and focusing servo signal low frequency range. So, if we single HF information signal out from entire photo receiver electric signals by means of high-pass filter, then this signal will be cleared from disturbing influence of all other layers. Therefore, there will be an immediate improvement of signal-to-noise ratio if we process the detected high frequency signals from focus and track sensor instead of low frequency focus and track signals.

Furthermore, the track sensor based on three spots with high frequency detection will have a better signal-to-noise ratio than the known differential tracking methods, since the amplitude of signals formed will be much greater.

Both tracking and focusing sensors, n_{ifn} utilize HF signal for servo purposes are fully compatible with actual optical heads. The electronic circuit of head signal processing unit only should be upgraded. Example of appropriate electronic circuit is illustrated in FIG. 7.

As shown in FIG. 7, tracking unit includes photo receiver or photo receiver matrix for High Frequency (HF) information signal, and photo receiver or photo receiver matrix for trackingng servo signal **F**, and photo receiver or photo receiver matrix for tracking servo signal **E** circuit for processing of electric signals from photo receivers or photo receiver matrices for tracking servo signals that derives tracking error signals. Tracking unit includes two high pass filters and detectors of high frequency signals. High-pass filters followed by high frequency detectors are placed between photo receiver or photo receiver matrices for tracking servo signals outputs and inputs of circuit for processing of electric signals from photo receivers or photo receiver matrices for tracking servo signals.

An identical layout of signal processing will be used to form high frequency focus signals. Furthermore, the optical methods to form focus error signal can be different, namely: astigmatic, full internal reflection, method of Fresnel bi-prism, method of hologram gratings, etc.

Additionally, cut-off frequency of high pass filters $f_{cut\ off}$ might satisfy the following condition:

$$f_{servo\ high\ limit} \leq f_{cut\ off} \leq f_{inf\ low\ limit}$$

where

$f_{servo\ high\ limit}$ - is upper limit of servo systems spectrum or/and upper limit of spectrum of radial and axial beats of spinning disc

$f_{inf\ low\ limit}$ - is lower limit of read information signal.

In accordance with still another embodiment of the present invention, an optical pickup device for reading data from multi-layer disks is equipped with a beam phase corrector, which allows reducing aberrations of a reading beam to an acceptable level in case of disk tilt or change in distance from an input surface to a reading data layer.

Furthermore, the suggested corrector shall enable correcting both statistical and dynamic phase aberrations of the beam's wave front occurring during reading of the spinning disk.

This embodiment relates to methods of constructing apparatuses for optical recording/ reading of data using optical media (particularly disks) having at least two data surfaces (layers) in the capacity of the medium separated by thin transparent layers of plastic.

During data reading, the laser beam focuses on the data layer, the former being modulated by data marks (pits), and at the same time additional beams are generated for focus and tracking sensors as well as a beam aberration sensor for multiplayer disk aberration correction.

An executive unit of beam aberration correction is introduced into the recording/ reading apparatus in order to correct beam aberrations; the mentioned unit may be based on liquid-crystal or piezoelectric effect, for example.

A data signal amplitude value may be used for correcting tilt aberrations or spherical aberrations. A device based on liquid crystal cell with transparent electrodes serves as an executive unit or, to be more precise, an adaptive corrector. The cell is divided into several zones by transparent electrodes along the area of an objective input pupil. The type and shape of the electrodes depend on the type of aberration corrected, e.g. radial tilt and spherical aberration.

Under the action of electric field, liquid crystals begin to orient along the electric field line and create a local area of changing refraction index, the shape of this area being determined by the electrode configuration. Degree of the change in refraction index and so the local changes in the phase of beam's wave front depend on electric field strength, i.e. the voltage applied to the transparent electrodes.

In accordance with an additional aspect of the present invention a method of generating a dynamic sensor of wave front aberrations for multi-layer optical disks is proposed. It should provide:

- assure generation of signal proportionate to the value of aberration;
- have speed of operation as high as the method of analyzing data signal amplitude;
- approximate in authenticity to the methods based on data signal jitter analysis.

Reduced image contrast due to availability of different aberrations is described by degradation coefficients. The following is a general definition of a degradation coefficient:

$$\delta(\nu)=\frac{C^{aberrated}(\nu)}{C^{Ideal}(\nu)}$$

where

$C^{aberrated}(\nu)$ - image contrast at spatial frequency ν for a wave front with aberrations;

$C^{Ideal}(\nu)$-image contrast at spatial frequency ν for a wave front without aberrations.

Then MTF with aberrations is described by such formula as:

$$C(\nu)=\prod_{i}\delta_i(\nu)\cdot C^{ideal}(\nu)$$

where

δi(ν) - degradation coefficients for different aberrations available in an observed optical system.

According to some sources if aberrations are available, Optical Transfer Function of a system is degraded the most in the sector of medium spatial frequencies. FIG. 8 shows graphically the degradation coefficients of frequency-contrast parameter for spherical aberration and comma.

Example 1.

Let us see how aberration affects an optical signal of DVD disk reading.

Spatial frequency of an edge of Optical Transfer Function equals:

$$\nu_{cutoff} = \frac{2A}{\lambda} = \frac{2*0.6}{0.65*10^{-3}mm} = 1846 lpm.$$

Spatial frequency of the largest pits (14T)

$$\nu_{14T} = 270 lpm \rightarrow \frac{\nu_{14T}}{\nu_{cutoff}} = 0{,}145.$$

Spatial frequency of the smallest pits (3T)

$$\nu_{3T} = 1250 lpm \rightarrow \frac{\nu_{3T}}{\nu_{cutoff}} = 0{,}677.$$

Respective values are given in FIG. 8.

It is seen that the degradation coefficient of Optical Transfer Function at frequency ν_{3T} is 1,5÷2,5 higher than the one at frequency ν_{14T}.

The amplitude of 14T pits is approximately 4 times larger than that of 3T pits due to decreased ideal MTF; hence, it is these pits that generate an aberration sensor when separating averaged data signal amplitude for aberration correction. At the same time, Example 1 shows that the signal of 14T pits is 1,5...2,5 times less sensitive to aberrations than that of 3T pits. Therefore, to increase sensitivity of the aberration sensor, it is necessary that the input of 3T pit signal amplitude in the average amplitude of aberration sensor error signal becomes dominant. It provides:

- Improving aberration compensation
- Broadening a dynamic range of aberration compensation.

In case of spherical aberration due to increased thickness of transparent layer when reading optical disks with several data surfaces, the broadening of dynamic range of compensated spherical aberration makes it possible to increase the number of data layers per one optical medium and retain quality of reading these layers.

The proposed method is such that an error signal of a system of automatic adjustment (compensation) of aberrations of recording and/or reading devices for moving optical media (particularly optical disks) is generated as defined below.

A high frequency data signal from an optical head photo receiver is used as an initial signal. This signal goes to an amplifying correcting device which amplified the electric signal from pits, furthermore, the amplification index of the said device is larger for signals from short pits than for signals from long pits. After the initial signal is processes by such a device, the amplitude of pulse from small pits in the resulting signal shall be amplified to a greater degree than the one from large pits; hence specific power of a signal from small pits in the resulting signal increases compared to specific power of a signal from large pits. Further, the said resulting signal is used to generate an error signal of the system of automatic adjustment (correction) of aberration.

The mentioned amplifying correcting device may be an amplifier, wherein the dependence of amplification coefficient on initial signal frequency is a monotone increasing function for entire working range of initial signal frequencies; e.g. the amplification coefficient may be directly proportional to the frequency of amplified signal.

In accordance with additional aspect o the present invention, a method of generating error signal of a system of automatic adjustment (compensation) of optical aberrations is proposed, wherein an initial signal is a high frequency signal of optical disk reading, high frequency signal being a series of electric pulse at the output of photo receiver under influence of optical radiation modulated by pits of various length located on a moving optical medium. Initial signal proceeds to the input of an amplifying correcting device which amplifies the initial signal in such a way that the amplification index for pulse from short pits is larger than that for pulse from long pits.

Additionally, amplifying correcting device may be an amplifier, wherein the dependence of amplification coefficient on initial signal frequency is a monotone increasing function for entire working range of initial signal frequencies.

Also, a resulting signal of amplifying correcting device proceeds to an amplitude detector, the output signal of which proceeds to a device of generating error signal for the system of automatic aberration control (correction).

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described herein above. For example, An optical pick-up method and device particularly is useful for multilayer recording medium using in low reflective information layers with reflectivity les than 10% per layer and preferably 1-5 %. Rather the scope of the invention is defined by the claims that follow:

CLAIMS:

1. An optical pick-up device for multilayer recording medium comprising a source of reading radiation, a detector of refelected signal, an optical system for focusing the reading radiation into information layer and said detector of reflected signal, an arrangement for focusing and tracking control and means for suppression interference of layers reflected signals.

2. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said means for suppression interference of layers reflected signals provides decreasing of said reading radiation coherence.

3. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said source of reading radiation comprising a laser source emitting radiation having at least two spectral components having different wavelength.

4. The optical pick-up device for multilayer recording medium as claimed in claim 3, wherein said multiplayer recording medium having information layers separated by transparent spacers having thickness **h** and refraction coefficient **n** and wherein wavelength difference of said spectral components $\Delta\lambda$ satisfy follow requirement:

$$\Delta\lambda = \lambda_1 - \lambda_2 = \frac{\lambda_1^2}{4hn - \lambda_1},$$

where

λ_1 is a wavelength of spectral component 1;

λ_2 is a wavelength of spectral component 2;

h is a thickness of spacer (interlayer distance);

n is a refraction index of spacer.

5. The optical pick-up device for multilayer recording medium as claimed in claim 3, wherein said spectral components are generated simultaneously.

6. The optical pick-up device for multilayer recording medium as claimed in claim 3, wherein said spectral components are generated sequentially.

7. The optical pick-up device for multilayer recording medium as claimed in claim 4 wherein said source of reading radiation comprising a distributed reflection laser DBR-laser, having a first reflector grating adjusted for λ_1 wave and a second reflector grating adjusted for λ_2 wave.

8. The optical pick-up device for multilayer recording medium as claimed in claim 4 wherein said source of reading radiation comprising a laser with a controlled external resonator enabling adjustment for λ_1 and λ_2.

9. The optical pick-up device for multilayer recording medium as claimed in claim 4 wherein said source of reading radiation providing substantially equal intensity for λ_1 and λ_2.

10. The optical pick-up device for multilayer recording medium as claimed in claim 7 wherein said source of reading radiation providing substantially equal intensity for λ_1 and λ_2.

11. The optical pick-up device for multilayer recording medium as claimed in claim 8 wherein said source of reading radiation providing substantially equal intensity for λ_1 and λ_2.

12. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said means for suppression interference of layers reflected signals includes an electro optical converters.

13. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said means for suppression interference of layers reflected signals includes an converter based on Zeeman effect.

14. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said source of reading radiation comprising a laser with dynamic shift of generation wavelength caused by injection current changing.

15. The optical pick-up device for multilayer recording medium as claimed in claim 6, wherein frequency of said spectral components sequential wavelength changing is out of frequency range of read channel coded signal.

16. The optical pick-up device for multilayer recording medium as claimed in claim 1, wherein said arrangement for focusing and tracking control includes a photo receiver for High Frequency (HF) information signal;

- a photo receiver for focusing servo signal;
- a photo receiver for tracking servo signal;
- a circuit for processing of electric signals from said photo receivers for tracking and focusing servo signals that derives focus and tracking error signals;
- high pass filters;
- detectors of high frequency signals.

17. The optical pick-up device for multilayer recording medium as claimed in claim 16, wherein arrangement for focusing and tracking control includes wherein cut-off frequency of said high pass filters $f_{cut\ off}$ satisfy follow condition:

$$f_{servo\ high\ limit} \leq f_{cut\ off} \leq f_{inf\ low\ limit}$$

where

$f_{servo\ high\ limit}$ - is upper limit of servo systems spectrum or/and upper limit of spectrum of radial and axial beats of spinning disc

$f_{inf\ low\ limit}$ - is lower limit of read information signal.

18. The optical pick-up device for multilayer recording medium as claimed in claim 1, further comprising a beam phase corrector, which allows reducing aberrations of a reading radiation.

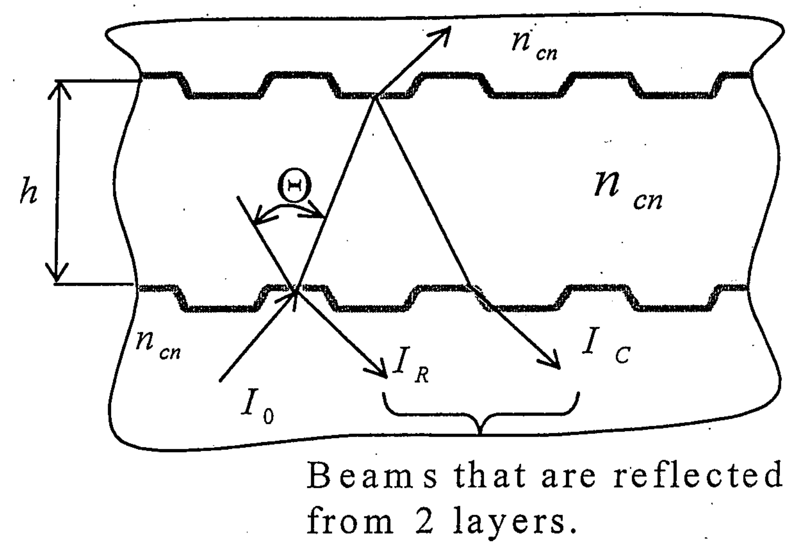
n_{cn}
h
Θ
n_{cn}
n_{cn}
I_R
I_C
I_0
Beams that are reflected from 2 layers.

FIG. 1

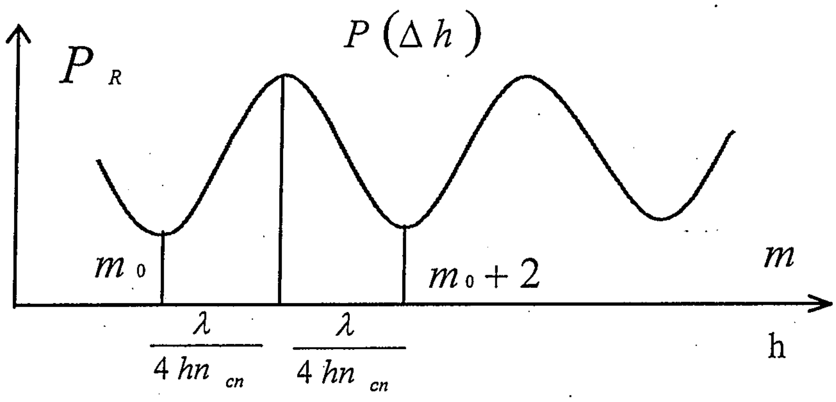
P_R
$P(\Delta h)$
m_0
$m_0 + 2$
m
h
$\frac{\lambda}{4hn_{cn}}$
$\frac{\lambda}{4hn_{cn}}$

FIG. 2

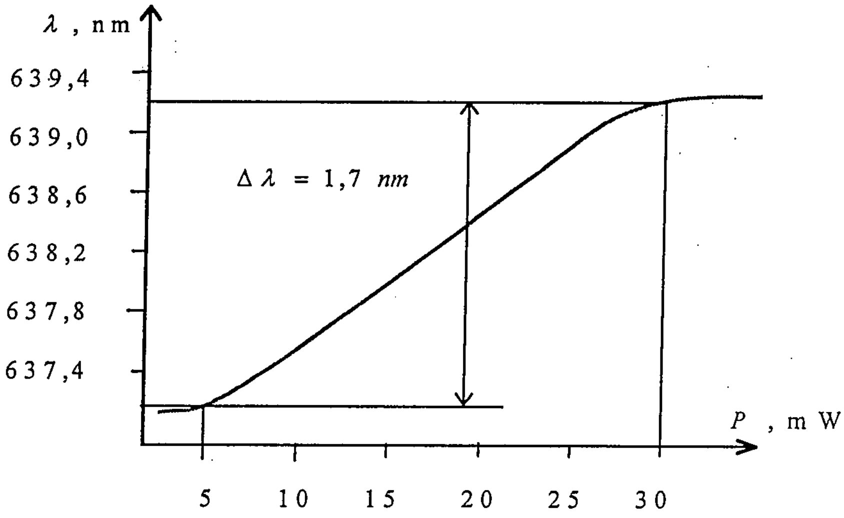
λ , nm
639,4
639,0
638,6
638,2
637,8
637,4
Δ λ = 1,7 nm
P , mW
5
10
15
20
25
30

FIG. 3

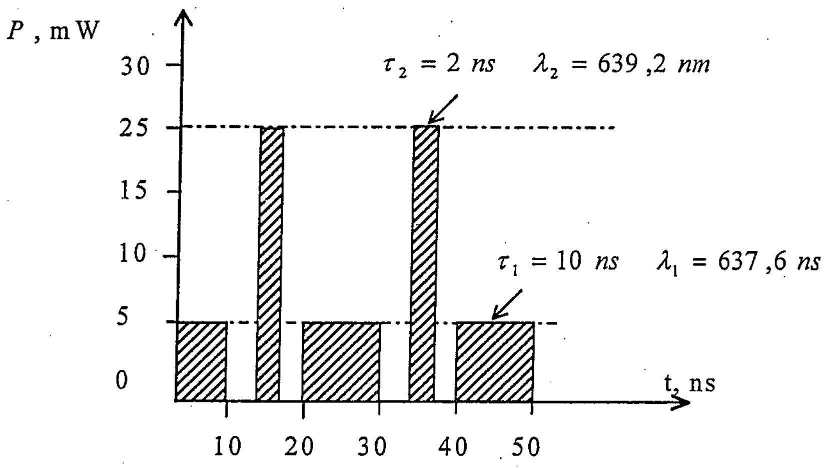
P , mW
30
25
15
10
5
0
τ2 = 2 ns λ2 = 639 ,2 nm
τ1 = 10 ns λ1 = 637 ,6 ns
t, ns
10
20
30
40
50

FIG. 4

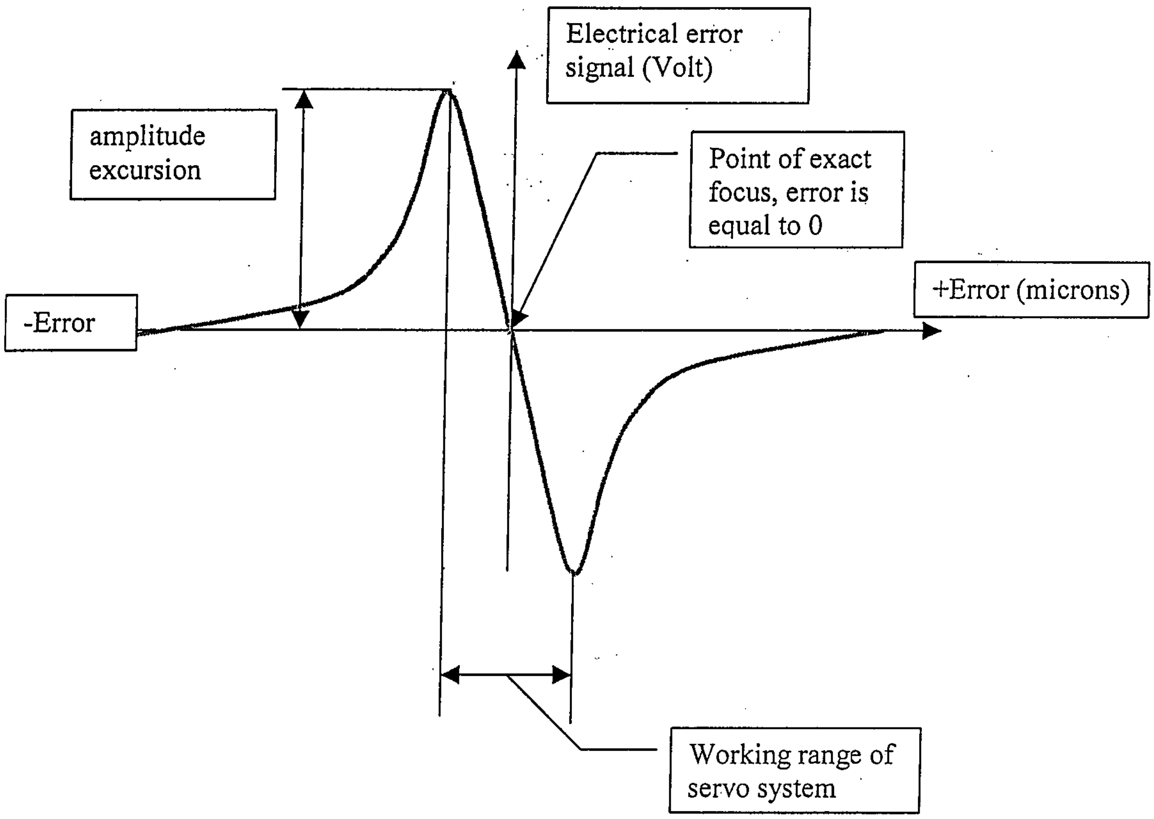
Electrical error signal (Volt)
amplitude excursion
Point of exact focus, error is equal to 0
-Error
+Error (microns)
Working range of servo system

FIG. 5

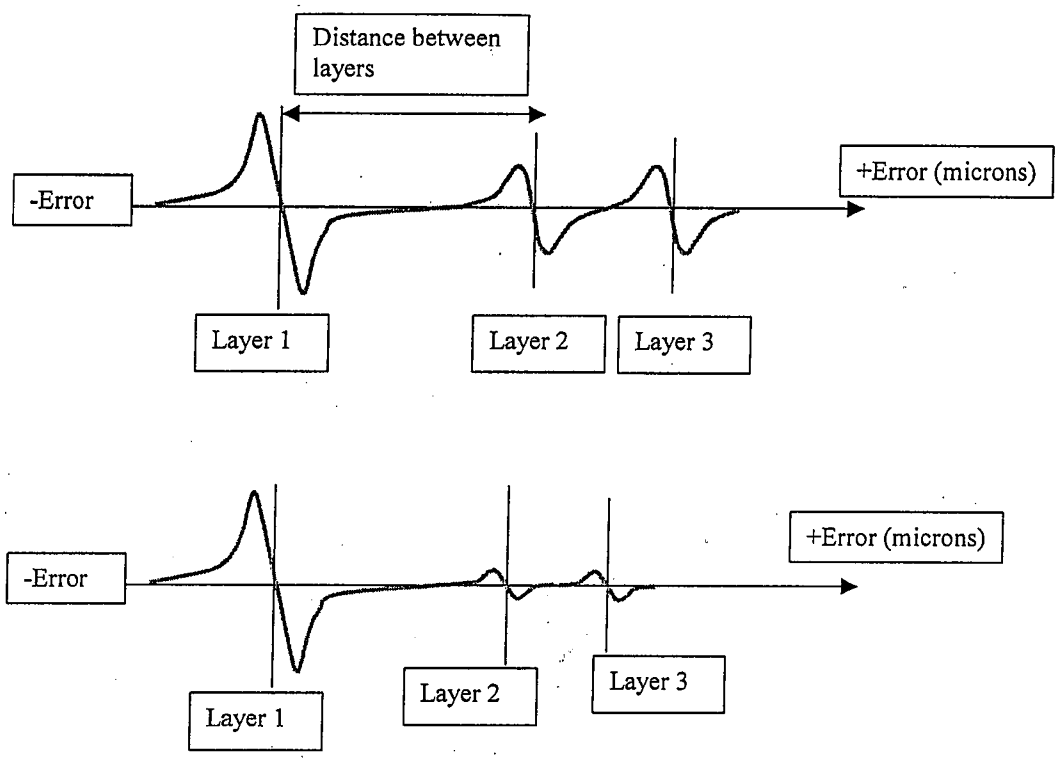
Distance between layers
-Error
+Error (microns)
Layer 1
Layer 2
Layer 3
-Error
+Error (microns)
Layer 1
Layer 2
Layer 3

FIG.6

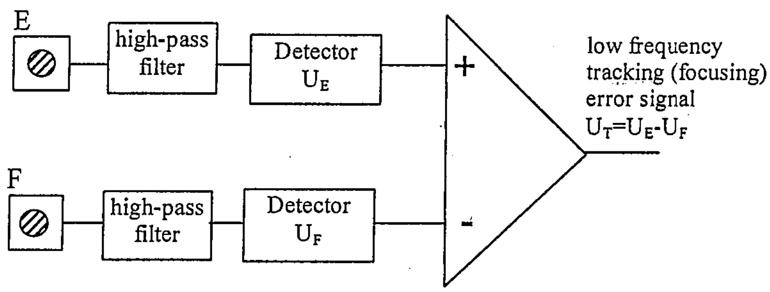
E
high-pass filter
Detector U_E
+
low frequency tracking (focusing) error signal $U_T=U_E-U_F$
F
high-pass filter
Detector U_F
-

FIG. 7

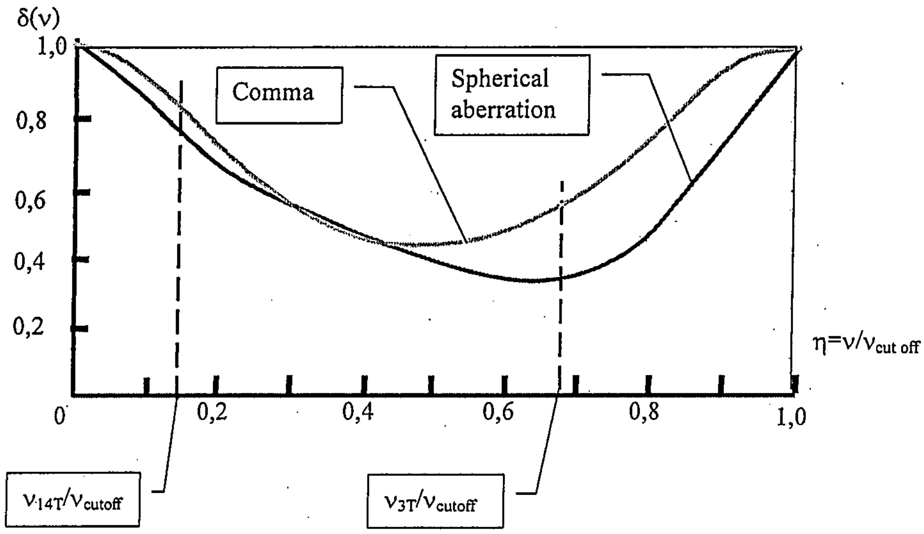
δ(ν)
1,0
0,8
0,6
0,4
0,2
Comma
Spherical aberration
η=ν/ν cut off
0
0,2
0,4
0,6
0,8
1,0
ν14T/νcutoff
ν3T/νcutoff

FIG. 8