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(54) **INTERFACE COMPONENT AND METHOD FOR THE OPERATION THEREOF**

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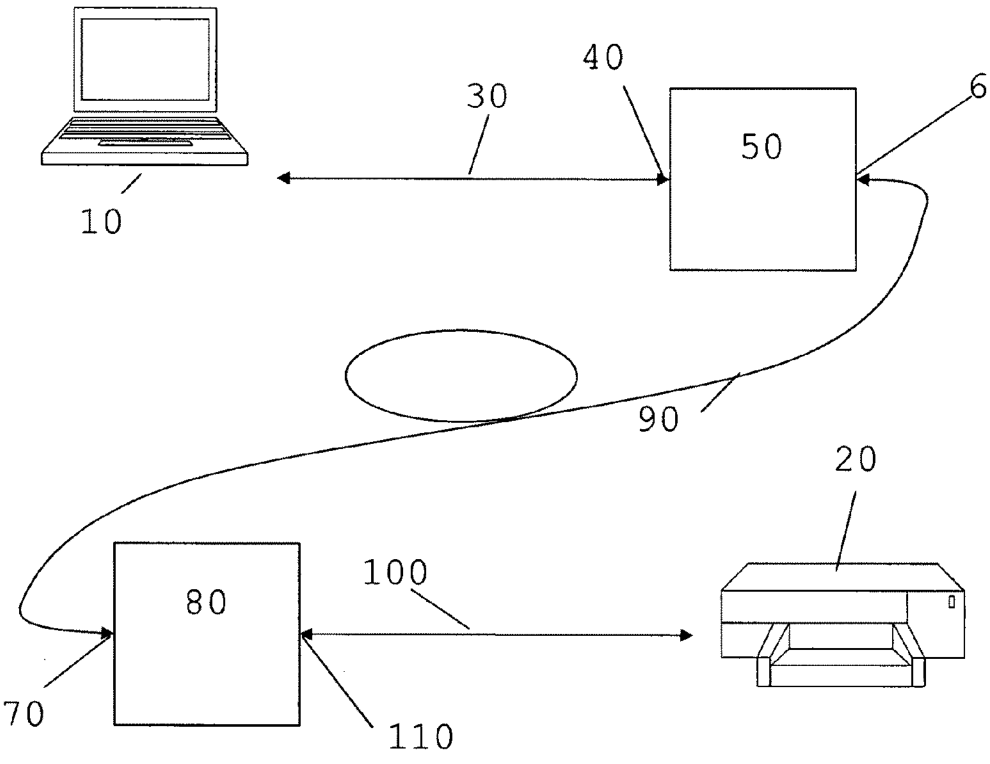
(57) **ABSTRACT**

The invention concerns an interface unit (**50**,**80**) with an electrical interface (**40**, **110**) for connection to an electrical USB cable, an optical interface to connect to at least one optical waveguide for sending and receiving of optical signals, and a conversion unit that is capable of converting the signals D+ and D− at the electrical interface to optical signals for output at the optical interface, and that is capable of converting the optical signals from the optical interface to electrical signals and output these signals as D+ and D− at the electrical interface

According to the invention it is defined that the conversion unit has an analyzing unit (**210**) for separation of the useful signals (NS) and the control signals (SS) that are contained in the D+ and D− signals, and that the analyzing unit is subsequently connected to a recovery unit (**220**, **400**) that generates at least two electrical driver signals for subsequent sending units out of the useful signals (NS) and the control signals (SS), and that the subsequent sending units generate at least two optical signals with at least two different wavelength channels out of the at least two incoming electrical signals and output them at the optical interface.



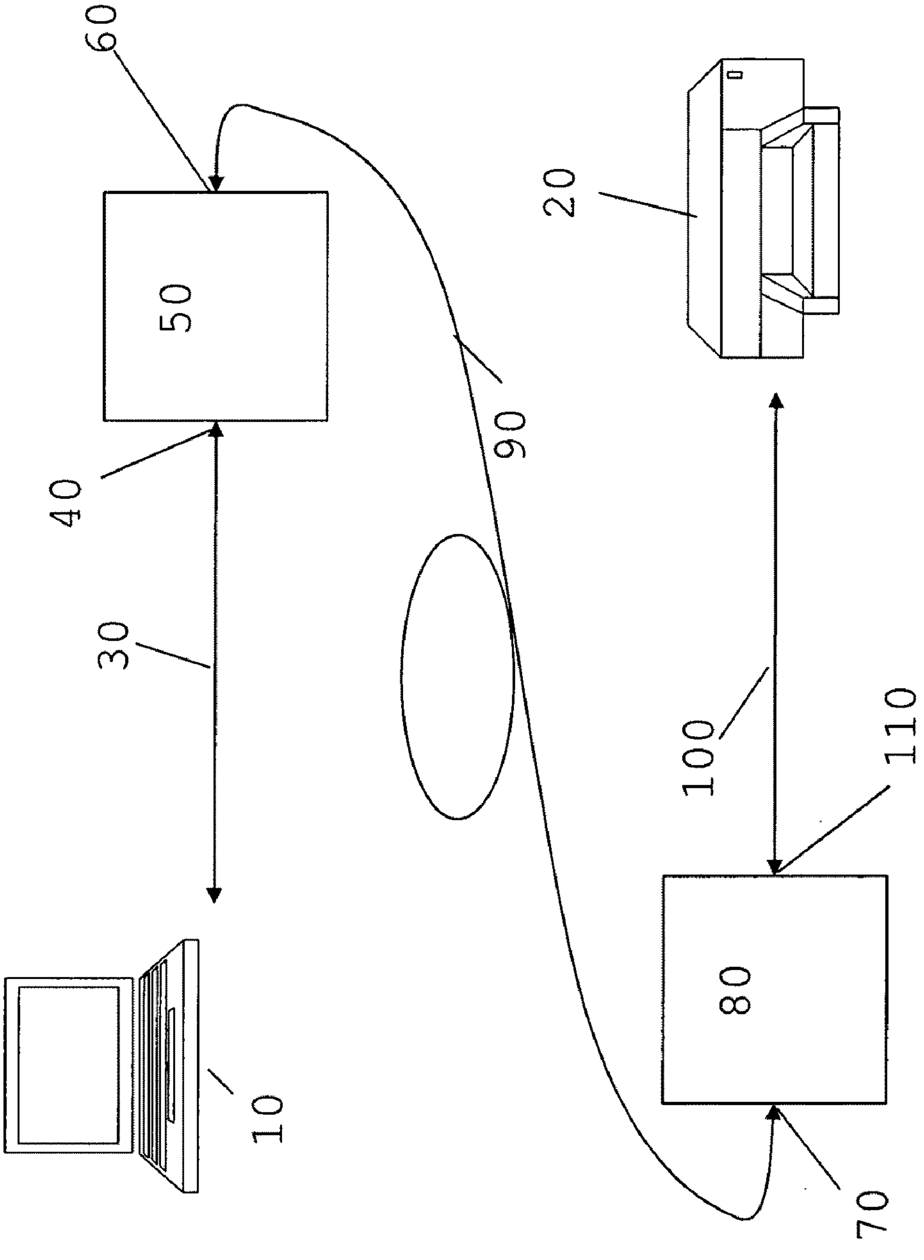


Fig. 1

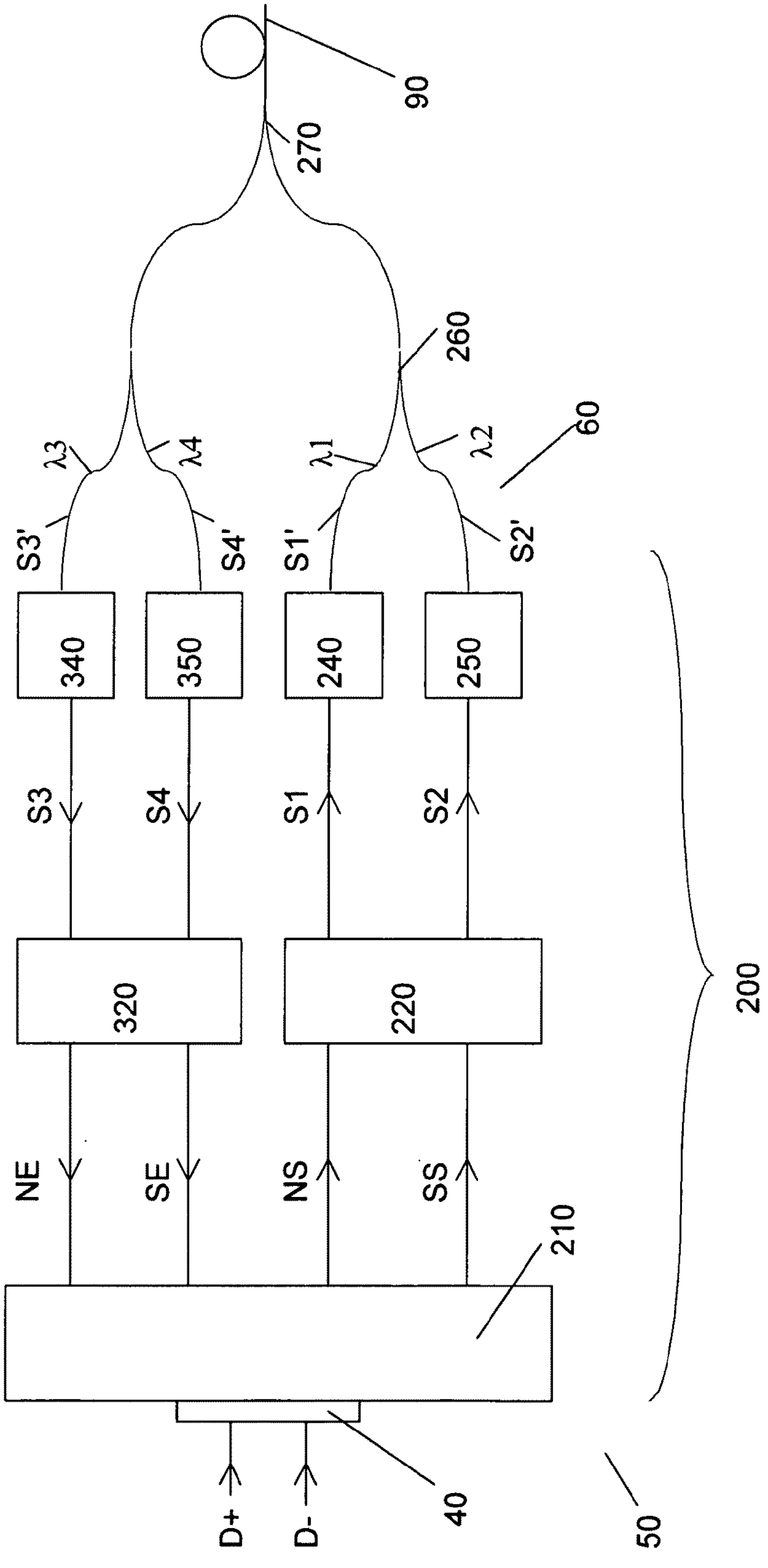

90
270
260
60
λ3
λ4
λ1
λ2
S3'
S4'
S1'
S2'
340
350
240
250
S3
S4
S1
S2
320
220
NE
SE
NS
SS
210
200
40
50
D+
D-

Fig. 2

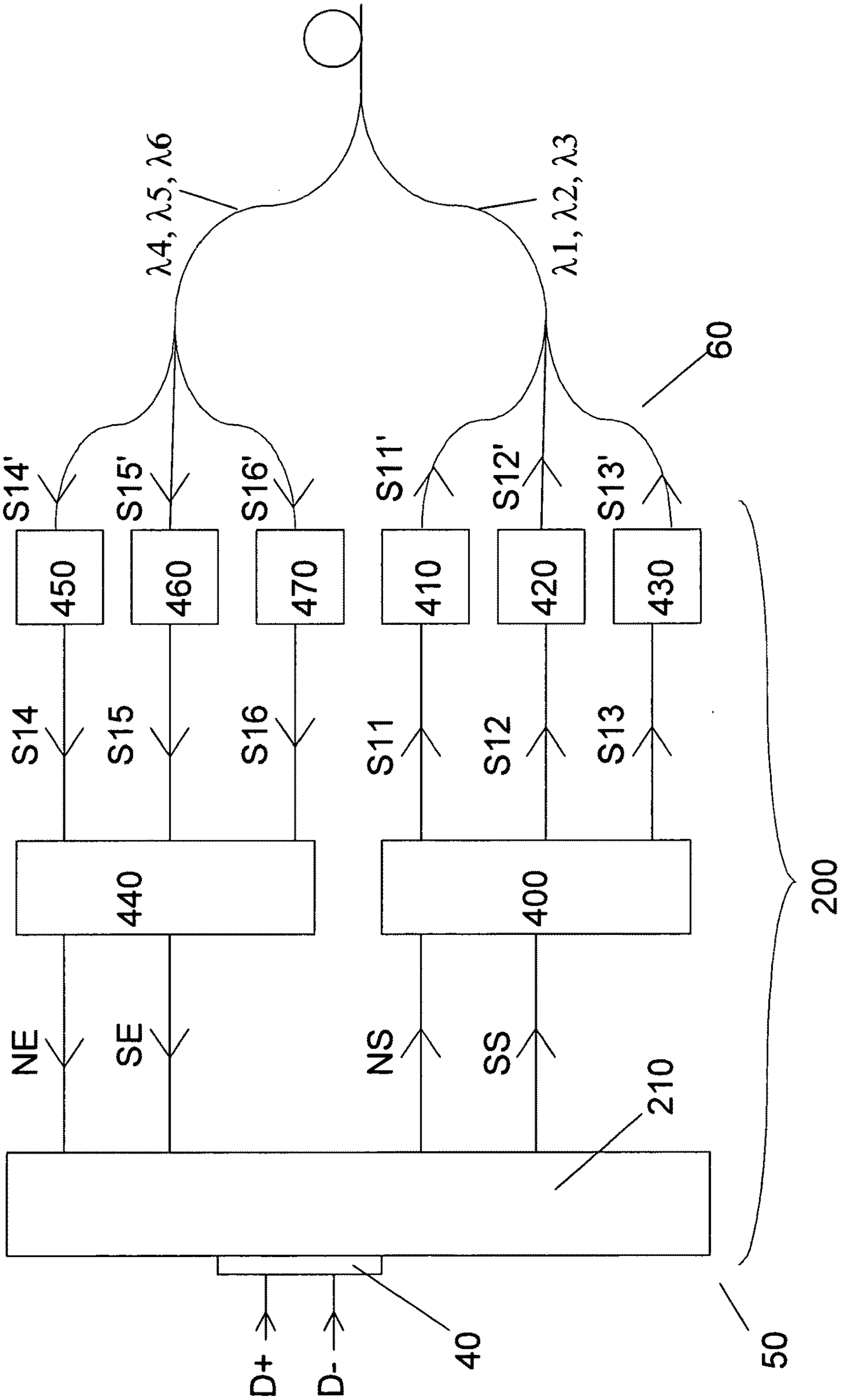

λ4, λ5, λ6
λ1, λ2, λ3
60
S14'
S15'
S16'
S11'
S12'
S13'
450
460
470
410
420
430
S14
S15
S16
S11
S12
S13
440
400
200
NE
SE
NS
SS
210
D+
D-
40
50

Fig. 3

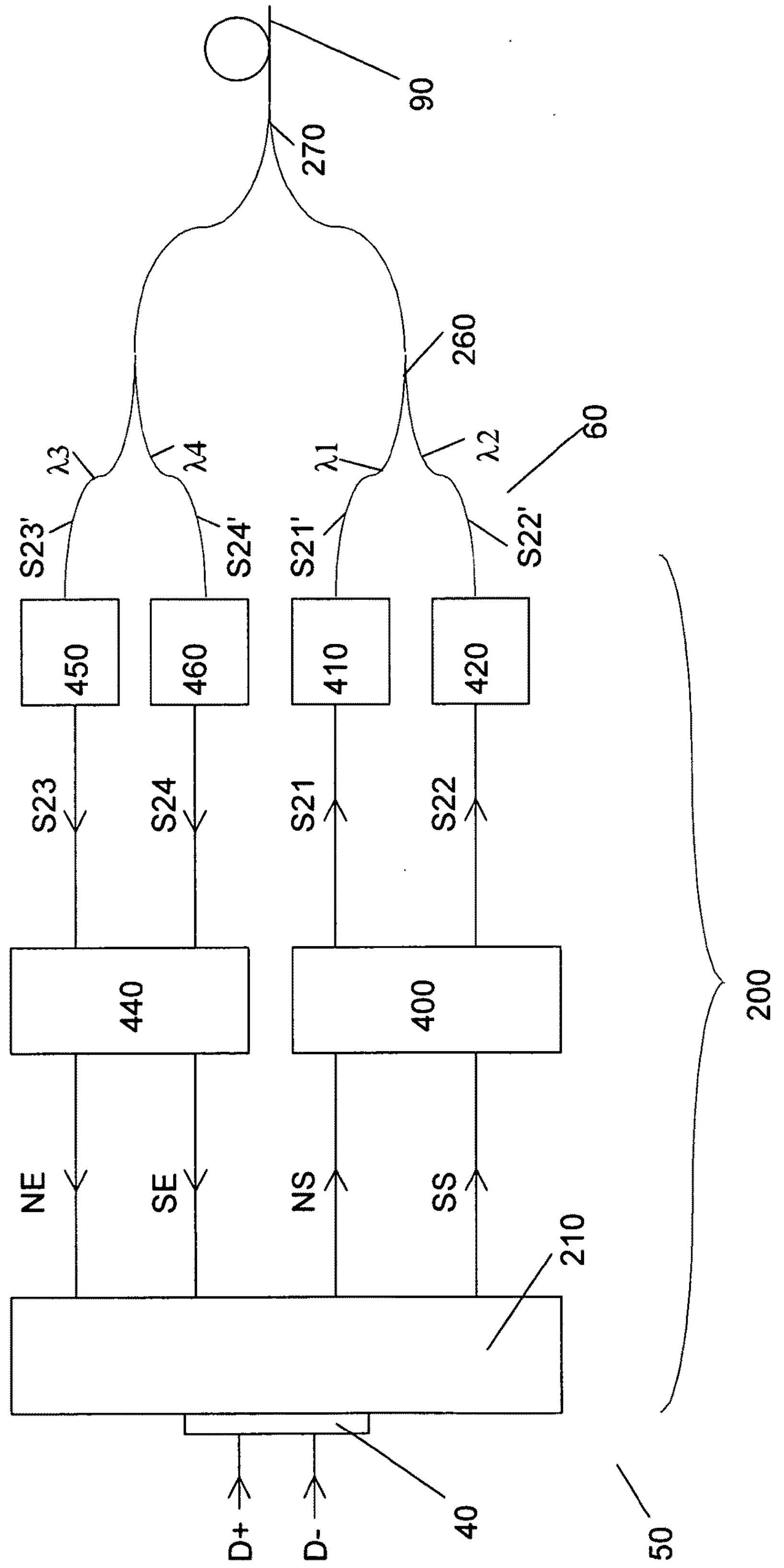

90
270
260
60
λ3
λ4
λ1
λ2
S23'
S24'
S21'
S22'
450
460
410
420
S23
S24
S21
S22
440
400
NE
SE
NS
SS
210
200
D+
D-
40
50

Fig. 4

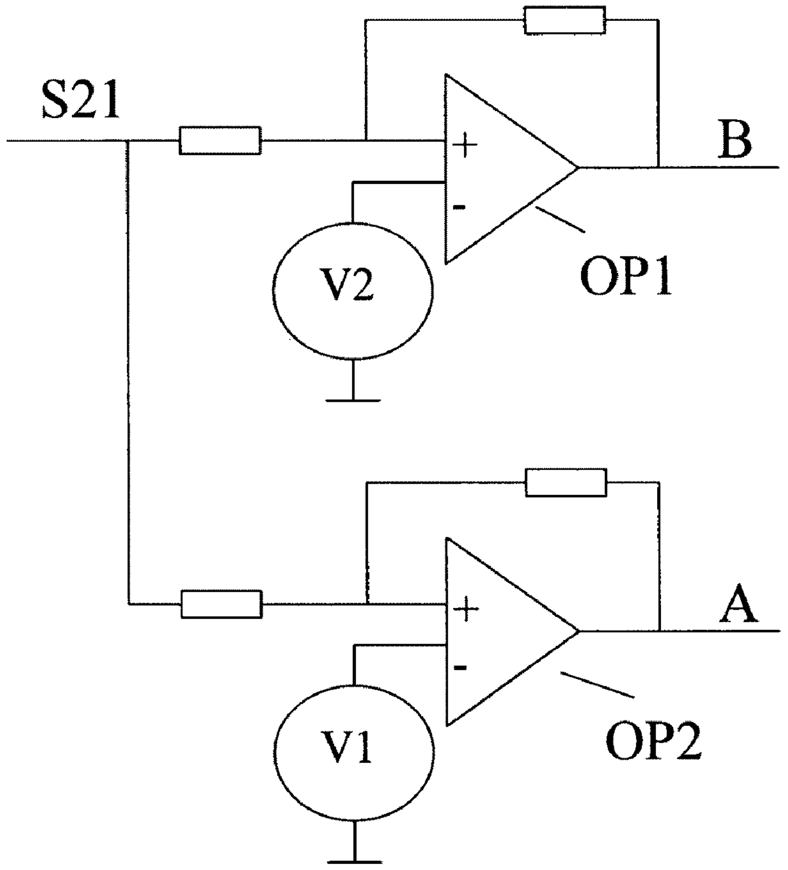


Fig. 5

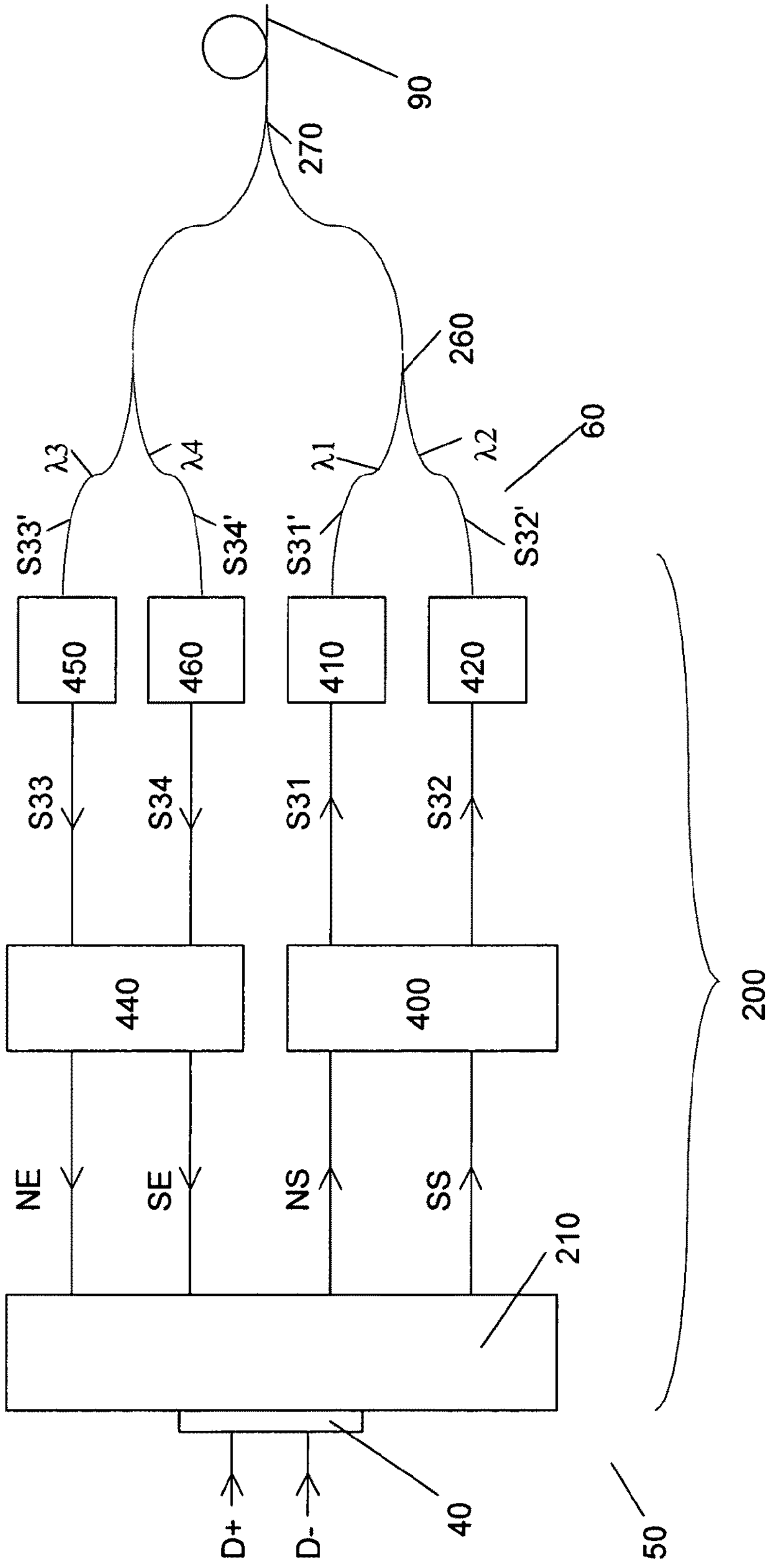

D+
D-
40
50
210
NE
SE
NS
SS
440
400
S33
S34
S31
S32
450
460
410
420
S33'
S34'
S31'
S32'
λ3
λ4
λ1
λ2
60
260
270
90
200

Fig. 6

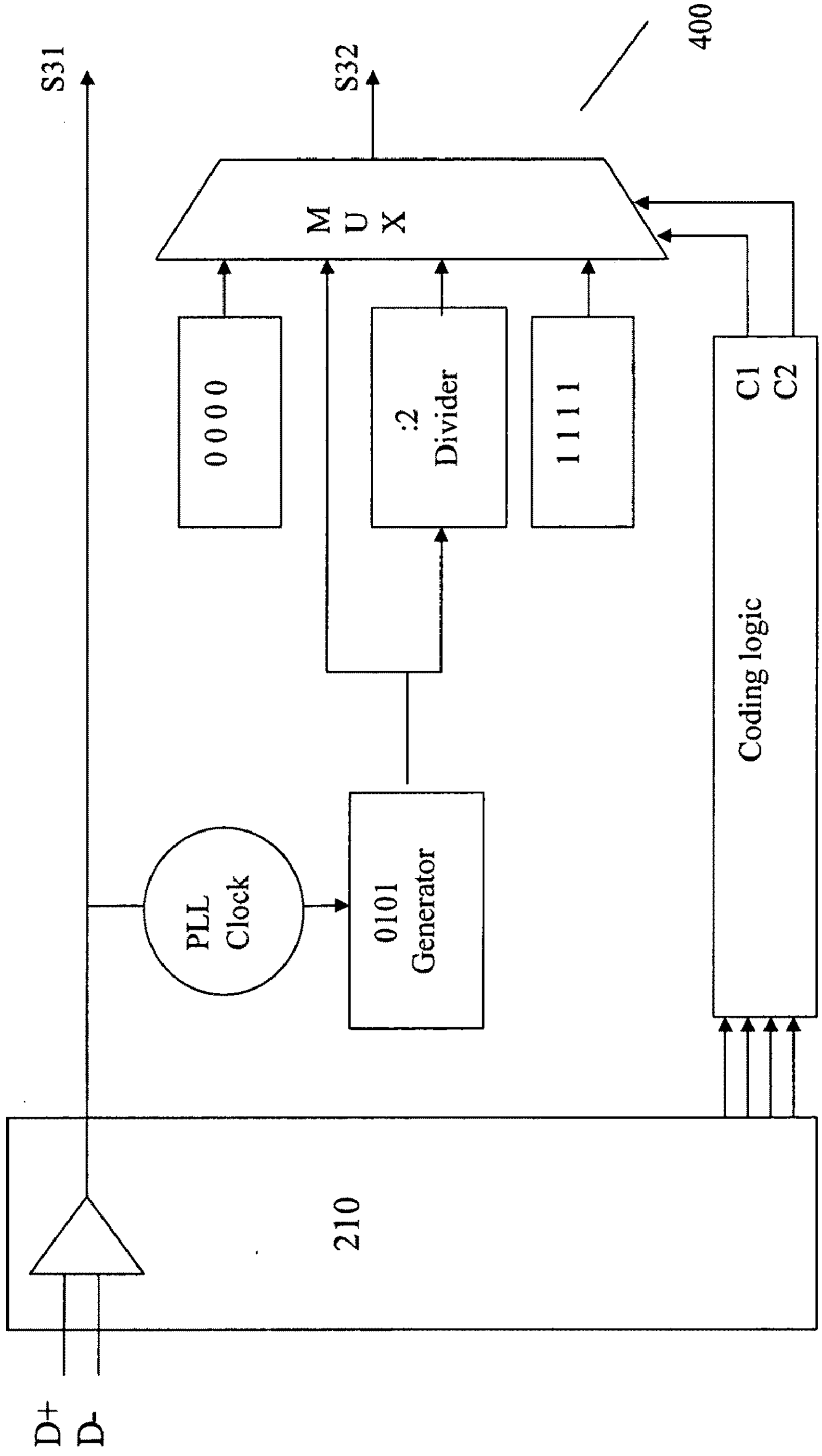

S31
S32
400
MUX
0000
:2
Divider
1111
C1
C2
Coding logic
PLL
Clock
0101
Generator
210
D+
D-

Fig. 7

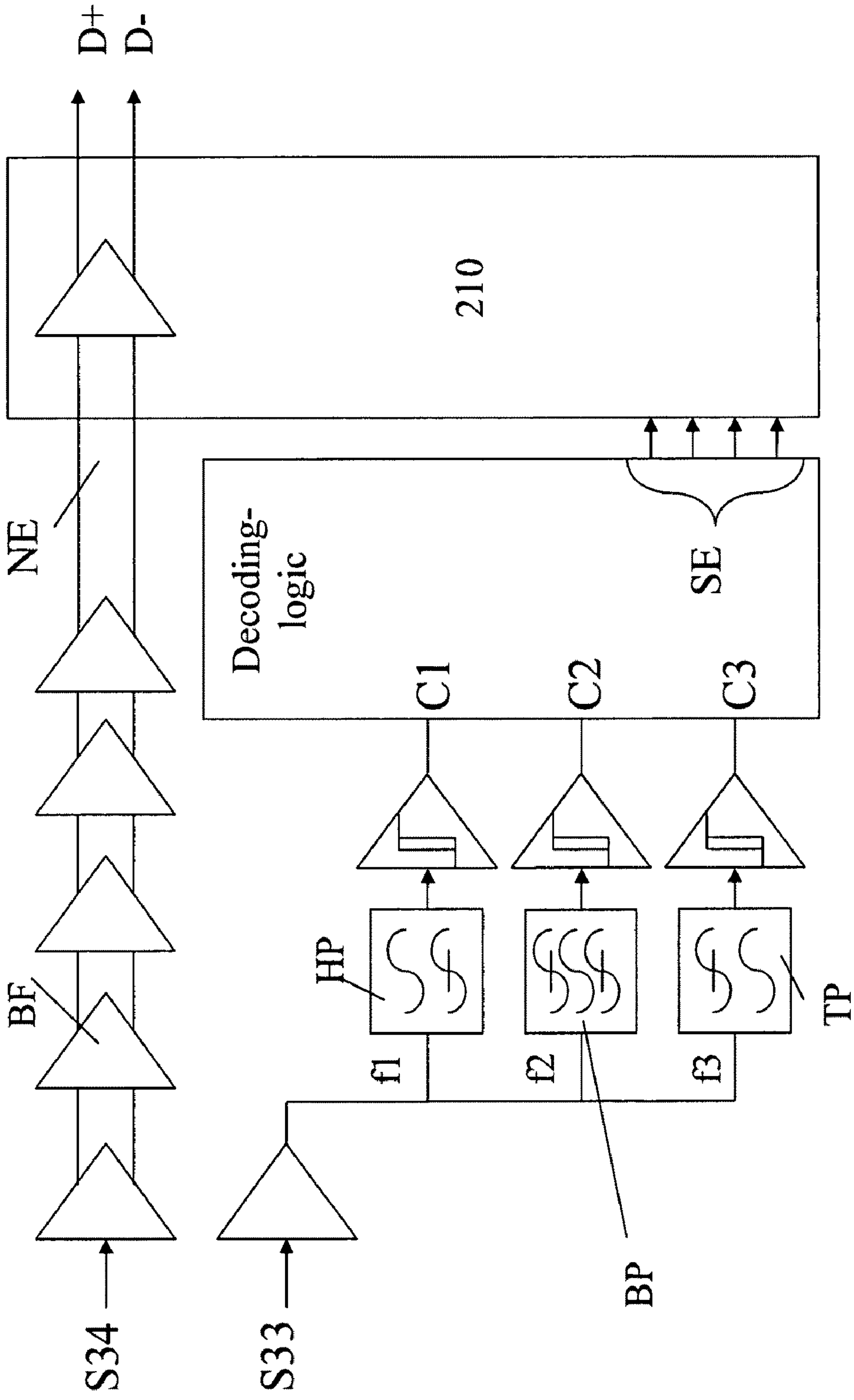


Fig. 8

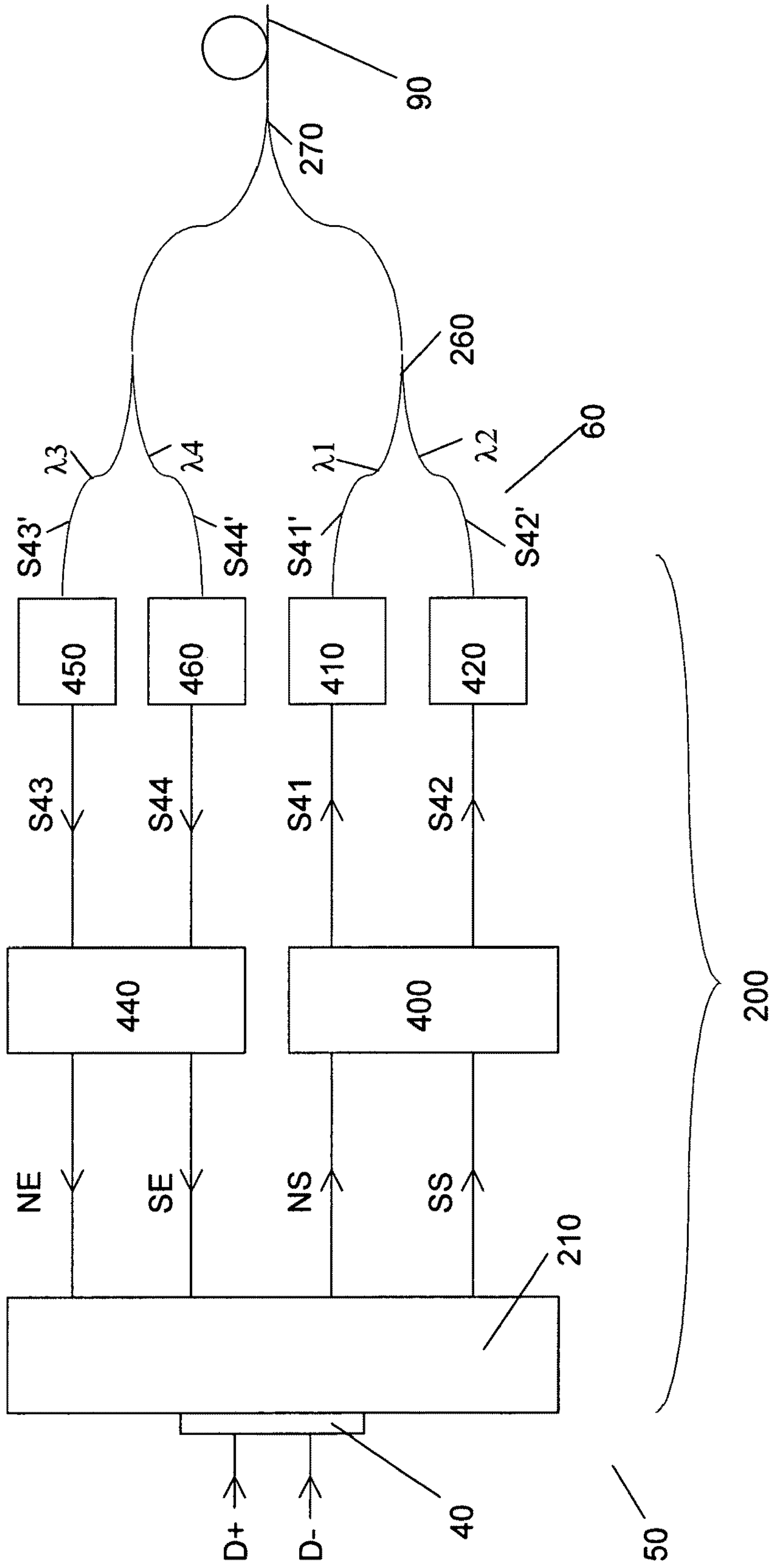

90
270
260
60
λ3
λ4
λ1
λ2
S43'
S44'
S41'
S42'
450
460
410
420
S43
S44
S41
S42
440
400
NE
SE
NS
SS
210
200
D+
D-
40
50

Fig. 9

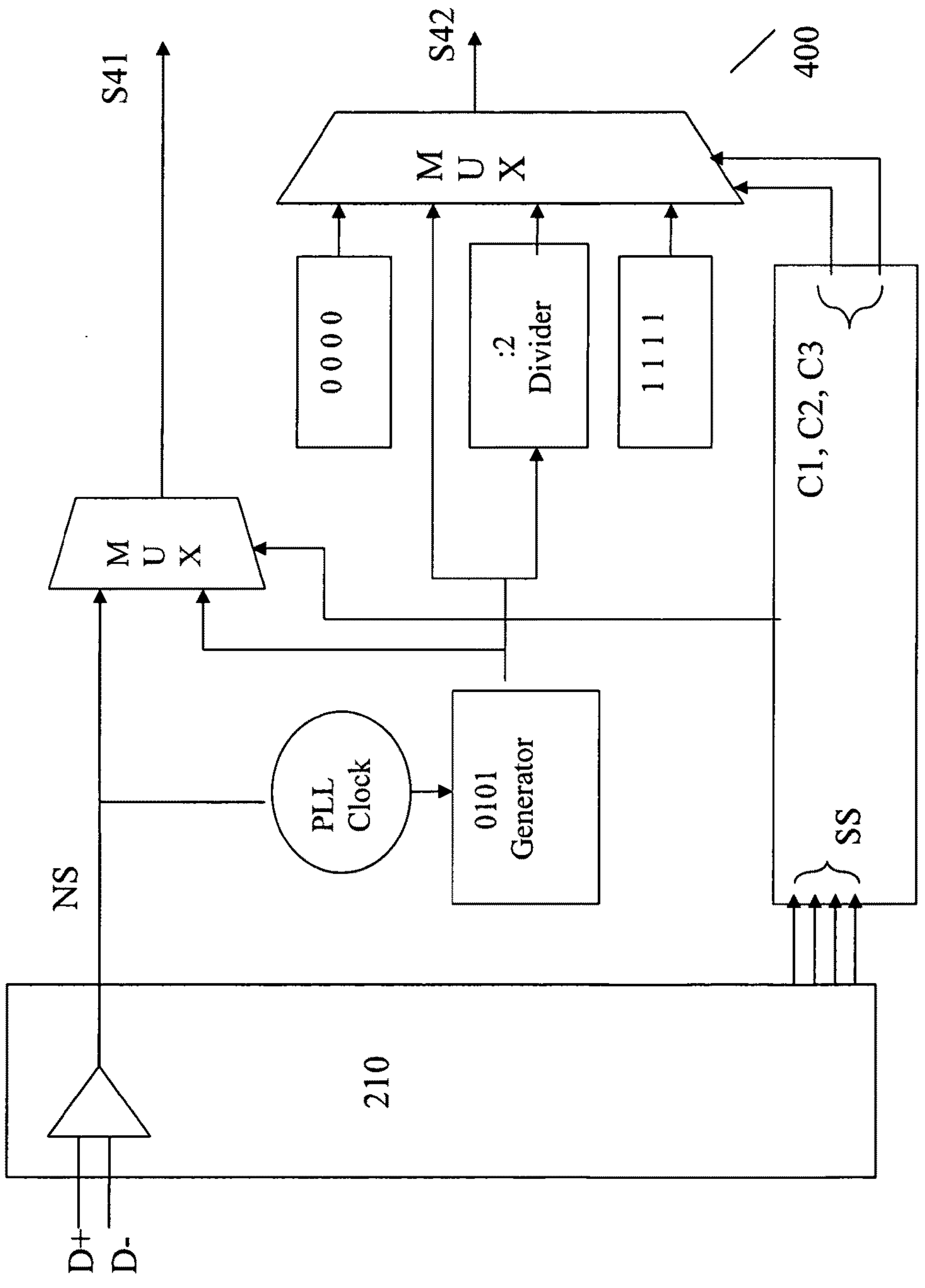

D+
D-
210
NS
PLL Clock
0101 Generator
M U X
S41
0 0 0 0
:2 Divider
1 1 1 1
M U X
S42
400
C1, C2, C3
SS

Fig. 10

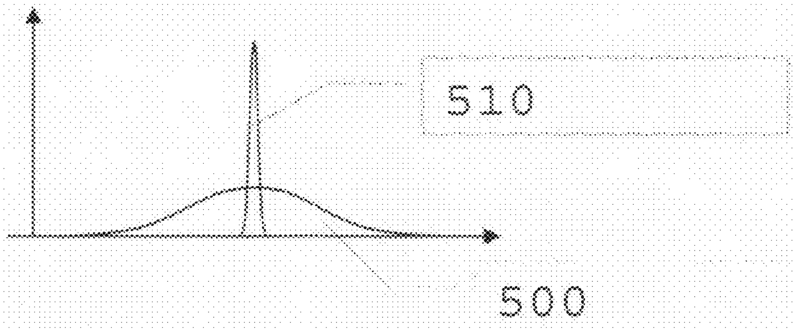


Fig. 11a

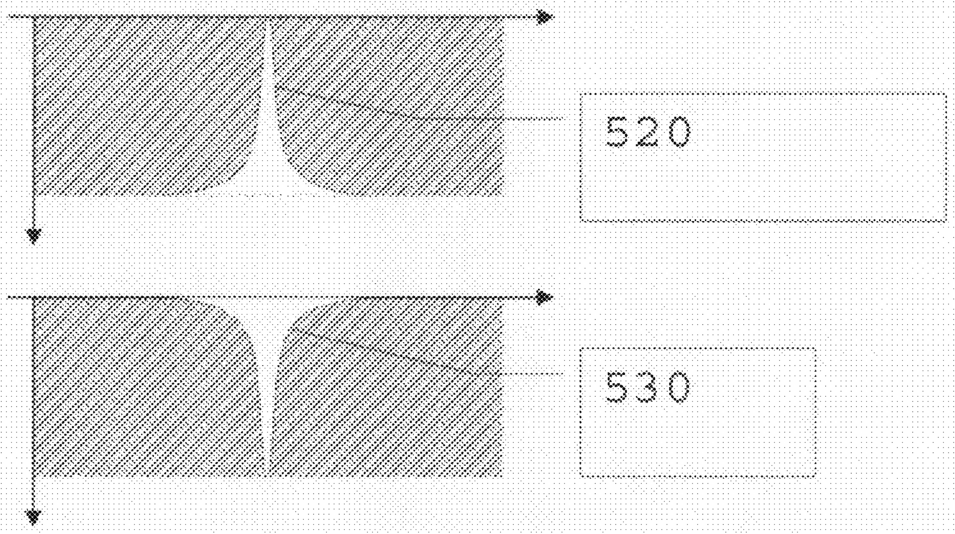


Fig. 11b

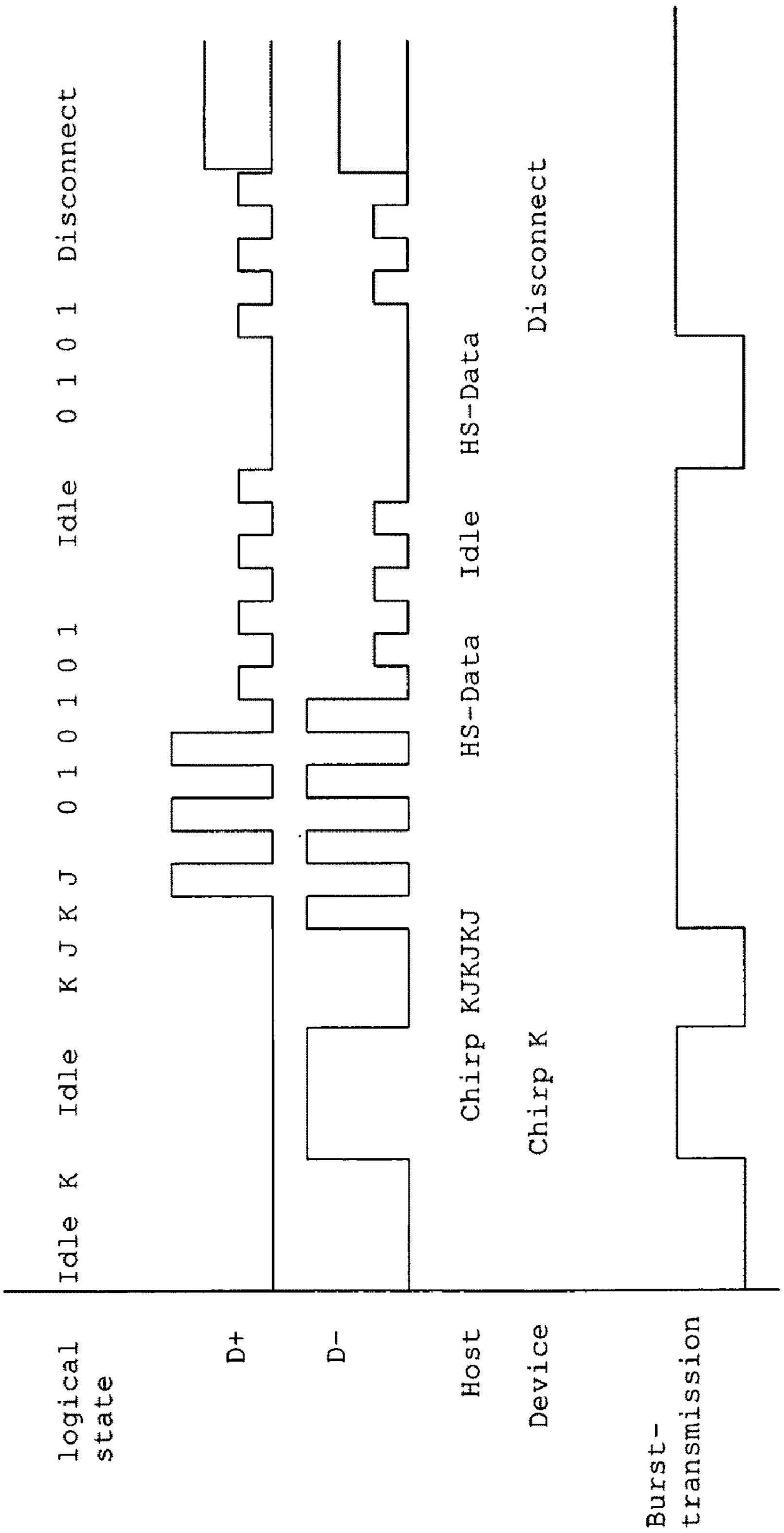

logical state
Idle K
Idle
K J K J
0 1 0 1 0 1
Idle
0 1 0 1
Disconnect
D+
D-
Host
Chirp KJKJKJ
HS-Data
Idle
HS-Data
Device
Chirp K
Disconnect
Burst-transmission

Fig. 12

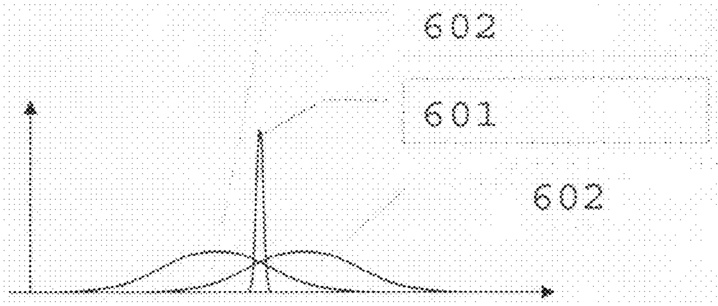


Fig. 13a

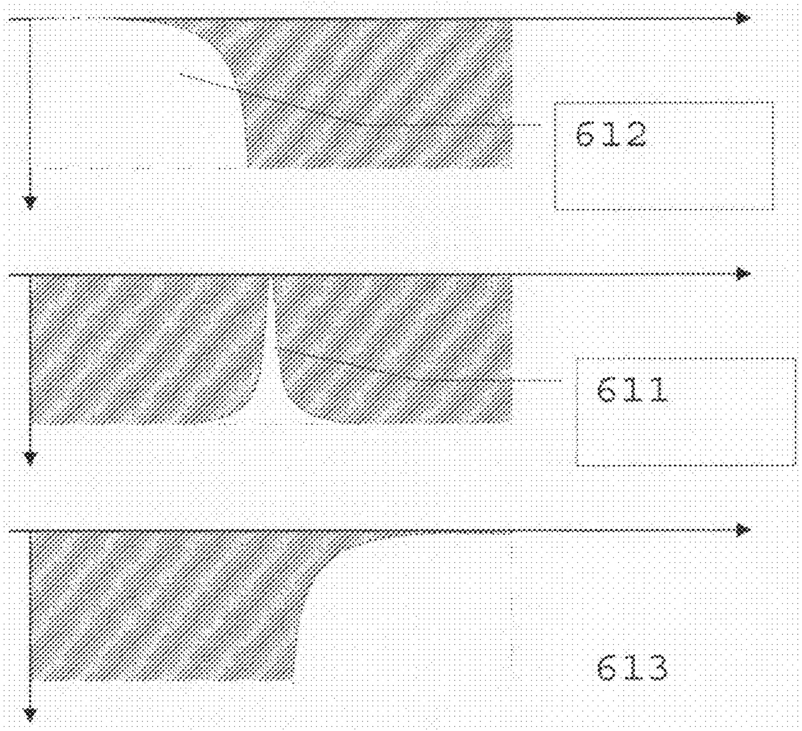


Fig. 13b

INTERFACE COMPONENT AND METHOD FOR THE OPERATION THEREOF

[0001] The invention is related to an interface unit with the characteristics according to the preamble of claim **1**.

[0002] The so called Universal Serial Bus—USB—is an electrical interface for Personal Computers (PC) for connection of peripherals like keyboard, mouse, camera, printer, etc. The specification is published at www.usb.org. USB 2.0 is limited to 5 m cable length. That is a significant limitation for several applications.

[0003] Electrical Bus systems like USB that use a multilevel logic with more than two logical states are not directly adaptable to optical data transmission. Besides pure data transmission USB also has to transfer additional state information about the peripheral devices i.e.

[0004] Peripheral is connected and active

[0005] Selected transmission speed

[0006] Send or receive

[0007] Send or pause

[0008] USB data is transmitted via differential signal lines D+ and D−. Logic “0” stands for D+=0 and D−=1, logic 1 equals D+=1 and D−=0. Furthermore there are the states D+=0 and D−=0 and D+=1 and D−=1. These signal conditions are not static; they occur bitwise i.e. for two bits as an End of Packet (EOP) identifier of Full speed connections, or as Idle for High-Speed.

[0009] The USB connection establishment goes through several stages which are encoded by time and amplitude. The time information will be maintained in the optical transmission and can therefore stay untouched. In FIG. **12** are examples of logical and operational states of a high-speed connection from connection establishment up to the termination.

[0010] In the following table all these logical states are described that are important for complete signaling of all USB operational states for USB 1.x and 2.0:

0	Data logical 0
1	Data logical 1
J	Chirp J
K	Chirp K
Disconnect	Peripheral disconnected
Idle	Connected but no data transfer

[0011] The electrical characteristics are precisely specified in the USB 2.0 standard.

[0012] A USB Interface unit as defined above is known from U.S. Pat. No. 6,950,610. That unit contains an electrical interface for connection to a USB cable and an optical interface for connection to two optical waveguides. A conversion unit translates the data D+ and D− from the electrical interface to optical signals and translates the optical input data to the electrical signal D+ and D− output. The mentioned unit encodes the D+ and D− into a ternary code consisting of a binary signal and an analog coded signal. The result is to be transferred optically. The signal amplitude of the optical signal in the mentioned unit plays a significant role. So usage for USB 1.0 is possible whereas direct usage for USB 2.0 is not possible because USB 2.0, besides other functions, uses a change in the amplitude as an indicator of the data rate. The amplitude is also used to signal IDLE packets. It would be possible to generate more amplitude levels for the additional operating modes, however those levels would change due to attenuation of the optical fiber and connector losses.

[0013] The task of the invention is to define an interface unit that transfers data reliably also at higher data rates, and is inherently compatible to the USB 2.0 standard.

[0014] According to the invention this task will be fulfilled by the attributes in claim **1**. Usable Variants are shown in the claims and subclaims.

[0015] Therefore it is defined by the invention that the conversion unit has an analyzing unit that separates the control signals (USB status signals) contained within the D+ and D− signals, from the useful signal (USB useful signal). The analyzing unit is followed by a signal recovery unit that generates at least two driving signals for driving following transmission units. The following transmission units generate at least two optical signals with at least two different wavelengths driven by at least two electrical signals and output these signals at the optical interface.

[0016] A significant advantage of the interface unit according to the invention is that due to the intended preanalysis of the D+ and D− signals according to the invention, the intended separation of the D+ and D− signals in the USB control signals and USB-useful signal according to the invention, and the intended transmission of data through at least two optical wavelength-channels according to the invention, there are additional degrees of freedom that can be used for a simple way to transfer data in compliance with the USB 2.0 standard. For example this allows for sending the information at the USB2.0 transmission speed whilst maintaining compatibility to earlier versions of the standard. Also since USB 2.0 is block-orientated, handling of empty blocks similar to EOP of the USB1.0 is possible. The differentiation to EOP can for example be done in combination with the speed indication. Furthermore the USB permitted function of anytime plugging and unplugging of the peripherals can be handled by having ( ) dedicated signaling for connected (active) and not connected (inactive) peripheral devices.

[0017] The conversion unit primarily transfers the useful signal on a separate dedicated wavelength channel. In contrast to the low speed or almost static control signals, the high speed or very dynamic signals of the useful signal are primarily generated with a laser. The low speed signals are generated mainly with LEDs.

[0018] An additional benefit results from the recovery unit logically combining at least two of the control signals while generating an electrical driver signal, so that a consecutive transmission unit generates an optical signal at a special wavelength based on the driver signal and output at the optical interface. Such a combination for USB 2.0 is therefore beneficial because some of the USB control signals are redundant in content and can therefore be combined, transferred, or even not sent.

[0019] Also for example, the interface unit can be of the kind that allows the recovery unit to logically combine at least one of the control signals with the useful signal while generating an electrical driver signal, so that a consecutive transmission unit generates a dedicated wavelength channel based on this driver signal and outputs it at the optical interface. This kind of combination with the useful signals is recommended for example for transfer of very low speed control signals that do not disturb or slow down the transfer of the useful signals.

[0020] The wavelength channels can have different frequency rates. Alternatively there could be an overlap of the wavelength of the different channels i.e. when they have different spectral channel widths.

[0021] The interface unit sends exclusively binary coded signals in order to dispense with a multilevel analog transmission as described in the aforementioned interface unit description. A multilevel analog transmission has the disadvantage that the absolute signal level has to be known by the receiver for a proper signal analysis. This level can change due to attenuation caused by for example small bending radiuses or unstable quality of the optical connection. Therefore a multi-level transmission can be faulty.

[0022] Furthermore it is beneficial that the conversion unit contains a recovery unit that is able to simultaneously receive at least two optical wavelength channels at the optical input, and generate a useful signal out of these received signals, and that the recovery unit is connected to an analyzing unit that generates the D+ and D− signals for the electrical output out of the control signals and the useful signals.

[0023] The invention also includes a method for transmission of a USB compatible signal where D+ and D− are converted into optical signals and transmitted through at least one optical waveguide i.e. glass fiber.

[0024] The invention meets the requirement that a reliable data transmission is also achieved at high data rates and the principle procedure allows for compatibility with USB 2.0.

[0025] According to the invention the control signals and useful signals derived from the electrical D+ and D+ signals are transferred through at least two optical wavelength channels over at least one optical transmission media.

[0026] Regarding the advantages of the method and beneficial forms of the method, we refer to the aforementioned description concerning the interface unit according to the invention.

[0027] The invention will be explained subsequently with exemplary embodiments

[0028] FIG. **1** a setup of two electrical devices which are connected via a USB connection, where two USB interface units make an electro-optical conversion on the transmission channel;

[0029] FIG. **2** a first exemplary embodiment for a USB interface unit according to the invention where the USB useful signals and the USB status signals go through two different wavelength channels;

[0030] FIG. **3** a second exemplary embodiment for a USB interface unit according to the invention where the USB useful signal goes through one wavelength channel and the USB status signals are combined and go through two other wavelength channels;

[0031] FIG. **4** a third exemplary embodiment for a USB interface unit according to the invention where the USB useful signal and the USB status signals are combined and go through two wavelength channels;

[0032] FIG. **5** a schematic for a recovery unit of the USB interface unit according to FIG. **4**;

[0033] FIG. **6** a fourth exemplary embodiment for a USB interface unit according to the invention where the USB useful signal and the USB status signals are combined and digitally encoded signals are being transferred;

[0034] FIG. **7** a schematic for a recovery unit of the USB interface unit according to FIG. **6**;

[0035] FIG. **8** another schematic for a recovery unit of the USB interface unit according to FIG. **6**;

[0036] FIG. **9** a fifth exemplary embodiment for a USB interface unit according to the invention where the USB useful signal and the USB status signals are combined and analog-digital encoded and transferred through two wavelength channels;

[0037] FIG. **10** a schematic for a recovery unit of the USB interface unit according to FIG. **9**;

[0038] FIGS. **11***a*, **11***b* optical wavelength channels and filters for filtering the optical signals;

[0039] FIG. **12** exemplarily examples of logical and operational states for a high speed connection according to USB standard from start of connection up to termination of connection; and

[0040] FIGS. **13***a*, **13***b* further optical wavelength channels and filter for filtering of the optical signals;

[0041] In FIGS. **1** to **13***b* the same reference symbols are used for a better overview of comparable or identical components.

[0042] In FIG. **1** is shown a setup of two electrical units **10** and **20** that are communicating with each other. Unit **10** could be a personal computer and unit **20** could be a printer.

[0043] Unit **10** is connected to the electrical interface **40** of the first interface unit **50** via a USB cable **30** which is compliant with USB standard 2.0. The first interface unit **50** is connected to an optical interface **70** of a second interface unit **80** via the optical interface **60** and the optical connection **90**. The optical connection **90** could be implemented as a single waveguide or a multiple waveguide. The device **20** is connected via a second USB cable **100** to an electrical interface **110** of the second interface unit **80**.

[0044] In FIG. **2** an exemplary embodiment of the first interface unit **50** is described. The second interface unit **80** can be of identical or at least similar structure.

[0045] At the electrical interface **40** in FIG. **2**, the D+ and D− of the device **10** are present. The electrical interface **40** is connected to a conversion unit **200** with a analyzing unit **210** that analyzes the D+ and D− signals and creates an optical signal "HS_Differential_Receiver_Output"—subsequently called USB useful signal NS—and optical control signals (USB status signals) SS at the output. The analyzing unit **210** can be implemented with or containing i.e. the USB2.0 ICs USB1T1102 from Fairchild and the IC CY7C68000 from Cypress.

[0046] The signals SS can for example be single or all of the subsequent shown signals according to USB2.0 standard:

[0047] "Rpu_Enable"
[0048] "HS_Current_Source_Enable"
[0049] "HS_Drive_Enable"
[0050] "HS_Data_Driver_Input"
[0051] "LS/FS_Data_Driver_Input"
[0052] "Assert_Single_Ended_Zero"
[0053] "FS_Edge_Mode_Sel"
[0054] "LS/FS_Driver_Output_Enable"
[0055] "Squelch"
[0056] "LS/FS_Differential_Receiver_Output"
[0057] "HS_Disconnect"
[0058] "SE_Data+_Receiver_Output"
[0059] "SE_Data−_Receiver_Output"

[0060] The conversion unit **200** contains a recovery unit **220** which is driven by the analyzing unit **210** and at the output is assigned to two optical transmission units **240** and **250**. The optical transmission units **240** and **250** can for example contain laser diodes or light emitting diodes (LED). For a better overview the LEDs are not shown in FIG. **2**.

[0061] The recovery unit **220** converts the optical useful signal NS of the analyzing unit **210** to an electrical driver signal S1 that is used by the optical transmission unit **240** to generate the optical signal S1' on the wavelength channel λ**1** or with the wavelength λ**1**, respectively.

[0062] In a similar way as described above the recovery unit **220** converts a single or all of the control signals SS of the analyzing unit **210** to an electrical driving signal S2 that is used by the optical transmission unit **250** to generate the optical signal S2' with the wavelength λ**2**. The conversion of the control signals SS of the analyzing unit **210** to the electrical driving signal S2 can for example be implemented with a digital encoding and/or with a time multiplex method.

[0063] The two optical signals S1' and S2' are fed into the optical connection **90** through Y-splitter **260** and **270** according to FIG. **1**. The diagram in FIG. **2** assumes that the optical connection **90** is made with a single waveguide.

[0064] The conversion unit **200** further contains a recovery unit **320** which at the input is connected to two optical receiving units **340** and **350**. The optical receiving units **340** and **350** can for example contain receiver diodes; those diodes are not shown in FIG. **2** for a better overview.

[0065] The optical receiving unit **340** receives the optical signal S3' with the wavelength λ**3** and generates a congruent electrical signal S3 that is used by the recovery unit **320** to generate an electrical useful signal NE at the interface **40**.

[0066] In a similar way as described above the optical receiving unit **350** receives an optical signal S4' with the wavelength λ**4** and generates a congruent electrical signal S4 that is used by the recovery unit **320** to generate electrical control signals SE.

[0067] The analyzing unit **210** which is subsequently connected to the recovery unit **320** generates with the optically received and electrically to be sent control signals SE and with the optically received and electrically to be sent useful signal NE at the output the signals D+ and D− that are fed into the USB cable through the electrical interface **40** of the first interface unit **50** according to FIG. **50**.

[0068] As a conclusion in the exemplary embodiment according to FIG. **2**, the four optical wavelengths λ**1**-λ**4** are used for the bidirectional transmission of a USB2.0 signal, i.e.:

- **[0069]** the wavelength λ**1** for the optical transmission unit for sending the optical useful signals NS (HS_Differential_Receiver_Output"),
- **[0070]** the wavelength λ**2** for the optical sending unit for sending the optical control signals SS,
- **[0071]** the wavelength λ**3** for the optical receiving unit and for receiving the optical useful signal NE ("HS_Data_Driver_Input") and
- **[0072]** the wavelength λ**4** for the optical receiving unit and for receiving the control signals SE.

[0073] In conjunction with FIG. **3** it is now another exemplary embodiment for the first interface unit **50** and therefore also for the second interface unit **80**. In the exemplary embodiment according to FIG. **3**, three wavelengths for each of the directions sending and receiving are used.

[0074] In FIG. **3** is shown the electrical interface **40** into which the electrical D+ and D− signals of the device **10** are fed. The electrical interface **40** is connected to a conversion unit **200** containing an analyzing unit **210** that analyzes the D+ and D− signals and at the output generates the signal "HS_Differential_Receiver_Output"—subsequently called useful signal NS—and the control signals SS.

[0075] The conversion unit **200** contains also at the sending side a recovery unit **400** that is connected to the analyzing unit **210** and that at the output is assigned to three optical sending units **410**, **420** and **430**. The optical sending units can for example contain laser diodes or light emitting diodes.

[0076] The recovery unit **400** is used for generation of the three driving signals S**11**, S**12** and S**13** out of the useful signal NS and the control signals SS from the analyzing unit **210**, for example ( ):

[0077] S11=HS_Differential_Receiver_Output

[0078] S12=((SE_Data+_Receiver_Output)OR (SE_Data−_Receiver_Output)) AND NOT(Squelch)

[0079] S13=NOT(HS_Differential_Receiver) AND NOT (HS_Disconnect)

[0080] The following table shows the coding scheme in a different structure with the assigned USB signal states:

Coding table for sending from device 10 to device 20 (signal states according to USB2.0 standard)	S11	S12	S13
Disconnect	0	0	0
Idle	0	0	1
Idle	1	0	1
K	0	1	1
J	1	1	1
0	0	1	0
1	1	1	0

[0081] The three optical sending units **410**, **420**, and **430** create the optical signals S**11**', S**12**' and S**13**' with the wavelengths λ**1**, λ**2** and λ**3** out of the three driver signals S**11**, S**12** and S**13** and couple these into the optical connection **90**. In case of an interruption of the electrical connection at the interface **40**, no light will be sent. This also has the advantage that the optical connection can be interrupted without the need to disconnect the interface units **50** or **80** from the device.

[0082] The conversion unit **200** also contains at the receiving side a recovery unit **440** that at the input is assigned to three optical receiving units **450**, **460** and **470**. The three optical receiving units **450**, **460** and **470** are receiving optical signals S**14**', S**15**' and S**16**' with the wavelengths λ**4**, λ**5** and λ**6** and at the output generate congruent driver signals S**14**, S**15** and S**16**. These are used by the recovery unit **440** to generate the optically received and electrically (at the interface **40**) to be sent useful signal NE, and the optically received and electrically (from the interface **40**) to be sent control signals SE.

[0083] Control signals SE can for example be generated such as:

Rpu_Enable=S**12** AND S**13**

HS_Current_Source_Enable=S**12** AND NOT(S**13**)AND S**11**

HS_Drive_Enable=S**12** AND NOT(S**13**)

HS_Data_Driver_Input=S**11**

LS/FS_Data_Driver_Input=S**11**

Assert_Single_Ended_Zero=NOT(S**12**) AND S**13**

FS_Edge_Mode_Sel=S**12** AND S**13**

LS/FS_Driver_Output_Enable=S**12** AND S**13**

[0084] The following table shows the decoding scheme in a different structure with the assigned USB signaling states:

S14	S15	S16	Decoding table for receiving optical data from device 20 and for the transmission of electrical data to device 10 (signal states according to USB2.0-Standard)
0	0	0	Disconnect
0	0	1	Idle
1	0	1	Idle
0	1	1	K
1	1	1	J
0	1	0	0
1	1	0	1

[0085] The optical signals with the wavelengths **λ1**, **λ2**, **λ3**, **λ4**, **λ5**, **λ6** can be generated by different types of sending elements. For a data rate of 480 Mb/s laser diodes are recommended for the wavelengths **λ1** and **λ4** because through these wavelengths the useful data NS as the USB signal "HS_Differential_Receiver_Output" is transmitted.

[0086] For the wavelengths **λ2**, **λ3**, **λ5** and **λ6** low speed LEDs could also be used because the signaling of the states with the control signals S**12**, S**13**, S**15** and S**16** is encoded in a manner that allows for a lower bit rate like 120 MBit/s. LEDs are more cost effective and simplify the use of optical filters at the receiver.

[0087] In conjunction with FIG. **4** a third exemplary embodiment for the interface units **50** and **80** according to FIG. **1** is described. In the exemplary embodiment according to FIG. **4** two wavelengths for both the sending and the receiving direction are used.

[0088] In FIG. **4** the electrical signals D+ and D− of device **10** are connected to the electrical interface **40**. It is connected to a conversion unit **200** with an analyzing unit **210** which analyzes the signals D+ and D− and generates the useful signal NS ("HS_Differential_Receiver_Output") and the control signals SS.

[0089] The conversion unit **200** also contains at the transmission side a recovery unit **400** which gets the data from the analyzing unit **210** and which on the sending side is assigned to two optical transmission units **410** and **420**. Those optical sending units could for example contain laser diodes or light emitting diodes.

[0090] The recovery unit **400** has to generate two electrical driver signals S**21** and S**22** based on the useable signal NS and the control signals SS from the analyzing unit **210**. Examples are:

S**21**=HS_Differential_Receiver_Output OR NOT((SE_Data+_Receiver_Output)OR(SE_Data−_Receiver_Output))

S**22**=NOT(Squelch) AND LS/FS_Differential_Receiver_Output)+NOT(HS_Disconnect)

[0091] The logical "+" stands for the addition of the signal amplitudes.

[0092] The following table shows the encoding scheme in a different structure and regarding the USB signal states:

Encoding table for sending from device 10 to device 20 (signal states according to USB2.0 standard)	S22	S21
Disconnect	0	0
Idle	0	1
K	2	0
J	2	1
0	1	0
1	1	1

[0093] The two optical sending units **410** and **420** generate the optical signals S**21'** and S**22'** with the wavelengths **λ1** and **λ2** based on the incoming signals S**21** and S**22** and couple these into the optical connection **90**.

[0094] The conversion unit **200** contains additionally a recovery unit **440** at the receiving side which is driven by two optical receiving units **450** and **460**. The two receiving units **450** and **460** receive the optical signals S**23'** and S**24'** of the device **20** with the wavelengths **λ3** and **λ4** and generate at the output the signals S**23** and S**24**. These are used by the recovery unit **440** to generate an optically received and electrically (at the interface **40**) to be sent useful signal NE and optically received and electrically (at the interface **40**) to be sent control signals SE.

[0095] The control signals SE will for example be formed according to:

Rpu_Enable=A AND B

HS_Current_Source_Enable=S**24** AND A AND NOT(B)

HS_Drive_Enable=A AND NOT(B)

HS_Data_Driver_Input=S**24**

LS/FS_Data_Driver_Input=S**24**

Assert_Single_Ended_Zero=NOT(A) AND NOT(B)

FS_Edge_Mode_Sel=A AND B

LS/FS_Driver_Output_Enable=A AND B

[0096] Whereas the values for A and B are defined in the following table which also contains the decoding scheme in a different structure according to the USB signal states:

S22	S21	A	B	Decoding table for optical receiving from device 20 and electrical sending to device 10 (signal states according to USB2.0 standard)
0	0	0	0	Disconnect
0	1	0	0	Idle
2	0	1	1	K
2	1	1	1	J
1	0	1	0	0
1	1	1	0	1

[0097] The generation of the binary intermediate states from the ternary code of signal S**21** is given as an example in FIG. **5**. The operational Amplifiers OP**1** and OP**2** have different reference voltages V**1** and V**2**. Those allow for reliable switching of the OP AMPs, for example V**1**=0.5 V and V**2**=1.5 V, when the maximum amplitude of signal S**21** equals 2V.

[0098] For the assignment of the logical intermediate states, alternatives are also possible. The described coding scheme is however beneficial because it has the following attributes:

[0099] The optical connection may be interrupted because in that case the proper value for HS_Disconnect will be coded if all channels are off, and

[0100] S**21** can be generated by a simple LED because only slow signals have to be transferred.

[0101] In FIG. **6** the fourth exemplary embodiment for the first interface unit **50** and the second interface unit **80** according to FIG. **1** is described. In the exemplary embodiment in FIG. **6** two wavelengths are used both in the send and receive direction.

[0102] The electrical interface **40** in FIG. **6** receives electrical data D+ and D− from the device **10**.

[0103] The electrical interface **40** is connected to a conversion unit **200** with an analyzing unit **210** which analyzes the D+ and D− signals and outputs the signal "HS_Differential_Receiver_Output" as a useful signal NS, and the control signals SS.

[0104] The conversion unit **200** also contains on the sending side a recovery unit **400** that takes over the signals from the analyzing unit **210** and which are assigned at the output to two optical sending units **410** and **420**. These sending units can for example contain laserd diodes or light emitting diodes. The purpose of the recovery unit **400** is to generate two electrical driver signals S**31** and S**32** based on the useful signal NS and the control signals SS of the analyzing unit **210**.

S**31**=HS_Differential_Receiver_Output

[0105] The signal S**32** is generated with the intermediate values C**1** and C**2** according to the following equations and table:

$C1$=NOT(Squelch) OR NOT(HS_Disconnect)

$C2$=NOT(Squelch) AND HS_Disconnect

Code-Folge für S32	C1	C2
0000	0	0
0101	0	1
1111	1	1
1111	1	1
0011	1	0
0011	1	0

[0106] The following table shows the encoding scheme in a different structure with respect to the USB signal states.

Encoding table for sending from device 10 to device 20 (signal states according to USB2.0-Standard)	S31	Code pattern for S32	C1	C2
Disconnect	0	0000	0	0
Idle	0	0101	0	1
K	0	1111	1	1
J	1	1111	1	1
0	0	0011	1	0
1	1	0011	1	0

[0107] The two optical sending units **410** and **420** generate the optical signals S**31**' and S**32**' with the wavelengths λ**1** and λ**2** based on the electrical driver signals S**31** and S**32** and couple these into the optical connection **90**.

[0108] The code pattern of the driver signal S**31** can be generated in the recovery unit **400** at the sending side for example with a schematic according to the diagram in FIG. **7**.

[0109] The conversion unit **200** also contains at the receive side a recovery unit **440** which takes the signal from the optical receiving units **450** and **460**. These units **450** and **460** receive optical signals S**33**' and S**34**' with the wavelengths λ**3** and λ**4** and generate at the output related electrical driver signals S**33** and S**34** that are used by the recovery unit **440** to generate an optical received and electrically to be sent (through interface **40**) useful signal NE and optically received and electrically (through the interface **40**) to be sent control signals SE.

[0110] The control signals SE can for example be generated with the intermediate values C**1**, C**2** and C**3** as follows:

S34	S33	C1	C2	C3	Decoding table for optical receiving from device 20 and for electrical sending to device 10 (signal states according to USB2.0-Standard)
0	0000	0	0	1	Disconnect
0	0101	1	0	0	Idle
0	1111	0	0	1	K
1	1111	0	0	1	J
0	0011	0	1	0	0
1	0011	0	1	0	1

[0111] The intermediate values C**1**, C**2** and C**3** will be used to generate the optical received and electrical to be sent control signals SE:

Rpu_Enable=C**3**

HS_Current_Source_Enable=C**1** OR C**2**

HS_Drive_Enable=C**1** OR C**2**

HS_Data_Driver_Input=S**34**

LS/FS_Data_Driver_Input=S**34**

Assert_Single_Ended_Zero=C**1**

FS_Edge_Mode_Sel=C**3**

LS/FS_Driver_Output_Enable=C**3**

[0112] The generation of the intermediate values C**1**, C**2** and C**3** is given as an example in FIG. **8**. The filter frequency f**1** of the high pass HP, the transit frequency f**2** of the band pass BP and the filter frequency f**3** of the low pass TP are selected primarily to be at least similar in relation to the bit rate B of the useful signal NS as follows:

$$f1 \geqq B/2 = 240 \text{ MHz (for B=480 Mbit/s)}$$

$$f2 \approx B/4 = 120 \text{ MHz (for B=480 Mbit/s)}$$

$$f3 \leqq B/4 = 120 \text{ MHz (for B=480 Mbit/s)}$$

[0113] So the bit pattern "0101" is detectable with the high pass HP, the pattern "0011" is detectable with the band pass BP and static patterns (longer than 4 bit) are detectable with the low pass TP. The four buffers BF are for proper delay time of the four bits so that the right states of the USB sending interface are available in time.

[0114] Many optical transducers have a problem to transfer so called burst signals. In case the optical sender and receiver are not capable of burst signals, a constant change of amplitude of the signals in the send and receive directions must be assured. That can for example be achieved with an additional clocked code generator in the wavelength multiplex method. A possible chip can be the ADF4110 from Analog Devices that operates as a Phase lock loop (PLL) for 480 MHz. The code table is primarily defined in such a way that in a high speed USB transmission there is always activity on the optical channels, and also in cases where gaps in the data stream still occur, the synchronization to the PLL on the other side of the channels is maintained. A related exemplary embodiment for the interface units **50** and **80** is shown in FIGS. **9** and **10**.

[0115] In the exemplary embodiment according to FIG. **9** there are two wavelengths per send and per receive direction. The setup of the sending side recovery unit **400** which takes the signals from the analyzing unit **210** and which at output drives two optical sending units **410** and **420** is given as an example in FIG. **10**.

[0116] The purpose of the recovery unit **400** is to generate two electrical driver signals S**41** and S**42** based on the useful signal NS and the control signals SS. As an example the logic states in the signal S**41** are encoded by code patterns.

[0117] The signal **42** is generated by a multiplexer (MUX) and the intermediate value C**3**.

S41	HS_Differential_Receiver_Output	C3
0	0	0
1	1	0
Code pattern 0101	0	1
Code pattern 0101	1	1

[0118] The signal S**41** is created with the help of the intermediate signals C**1**, C**2** and C**3** according to the following equations and the following table:

$$C1 = \text{NOT(Squelch) OR NOT(HS\_Disconnect)}$$

$$C2 = \text{NOT(Squelch) AND HS\_Disconnect}$$

$$C3 = \text{NOT (SE\_Data+\_Receiver\_Output) AND NOT (SE\_Data−\_Receiver\_Output)}$$

S41	Code-pattern für S42	C1	C2	C3
0	0000	0	0	0
0101	0101	0	1	1
0	1111	1	1	0
1	1111	1	1	0
0	0011	1	0	0
1	0011	1	0	0

[0119] The following table shows the coding scheme in a different structure in relation to the USB signal states:

Coding table for sending from device 10 to device 20 (signal states according to USB2.0-Standard)	S41	Code-pattern for S42	C1	C2	C3
Disconnect	0	0000	0	0	0
Idle	0101	0101	0	1	1
K	0	1111	1	1	0
J	1	1111	1	1	0
0	0	0011	1	0	0
1	1	0011	1	0	0

[0120] The aforementioned exemplary embodiments are based on the assumption that the different wavelength channels have different wavelengths. Alternatively it is also possible that optical spectrums are overlapping partly or completely as shown in FIG. **11***a* through another exemplary embodiment that uses an LED with spectrum **500** and a laser with the spectrum **510**. The spectrum **510** lies within the spectrum **500**.

[0121] In case of overlapping spectrums, the receiver side filter functions look like the example given in FIG. **11***b*. The curve **520** shows as an example a filter characteristic (transmission characteristic) that lets through the spectrum **510** of the laser, and the curve **530** shows as an example the filter characteristic to get the signals of the LED or the spectrum **500** of the LED.

[0122] The different wavelength channels can be transferred over a single waveguide or over multiple waveguides. I.e. two optical fibers can be used where one fiber is for receiving and the other for sending.

[0123] If only one optical fiber is used for both sending and receiving than the separation of the two directions can be achieved with i.e. an optical circulator or dedicated wavelengths are used for sending and receiving, i.e. λ**1**, λ**2**, λ**3** for sending and λ**4**, λ**5**, λ**6** for receiving.

[0124] A related exemplary embodiment is shown in FIGS. **13***a* and **13***b*. In **13***a* curve **601** is the laser sending spectrum and the curves **602** the sending spectrums of two LEDs. The filter characteristic **611** to filter out the laser spectrum and the filter characteristics **612** and **613** to filter out the signals of the LEDs are shown in FIG. **13***b*.

1. Interface unit (**50**, **80**) with
an electrical interface (**40**, **110**) for connection to a USB cable (**30**, **100**),
an optical interface (**60**, **70**) for connection to at least one optical waveguide (**90**) for sending and receiving of optical signals (S**1**', S**2**', S**3**', S**4**') and

a conversion unit (**21**), that is capable of converting the signals D+ and D− at the electrical interface to optical signals for output at the optical interface, and that is capable of converting the optical signals from the optical interface to electrical signals and output these signals as D+ and D− at the electrical interface

wherein the conversion unit has an analyzing unit (**210**) that separates the useful data (NS) and the control data (SS) contained in the signals D+ and D−,

wherein the analyzing units feeds the data to a recovery unit (**220**, **400**) that generates at least two electrical driver signals (S**1**, S**2**, S**11**, S**12**, S**13**) based on the useful signal (NS) and single or all of the control signals (SS) for driving subsequent sending units (**240**, **250**, **410**, **420**, **430**), and

wherein subsequent sending units with at least two electrical driving signals generates at least two optical signals (S**1**', S**2**', S**11**', S**12**', S**13**') with at least two different wavelengths channels (λ**1**, λ**2**, λ**3**) and outputs these at the optical interface.

2. Interface unit according to claim **1**, wherein the conversion unit (**200**) transfers the useful signal (NS) on a separate and dedicated wavelength channel (S**1**').

3. Interface unit according to claim **1**, wherein the recovery unit (**400**) logically combines at least two of the control signals to an electrical driver signal (S**12**, S**13**, S**22**) and

wherein a subsequent sending unit (**420**, **430**) generates an optical signal (S**12**', S**13**', S**22**') with a dedicated wavelength channel (λ**2**, λ**3**) based on the driver signal and outputs it at the optical interface.

4. Interface unit according to claim **1**,

wherein the recovery unit (**400**) logically combines at least one of the control signals with the useful signal (NS) to an electrical driving signal (S**21**), and

wherein a subsequent sending unit generates an optical signal (S**21**') with a dedicated wavelength channel (λ**1**) based on the driver signal and outputs it at the optical interface.

5. Interface unit according to claim **1**, wherein the wavelength channels (λ**1**, λ**2**, λ**3**) have different wavelength ranges.

6. Interface unit according to claim **1**, wherein the wavelength ranges of the wavelength channels (λ**1**, λ**2**, λ**3**) overlap but still have different spectral widths.

7. Interface unit **50**, **80**) with

an electrical interface (**40**, **110**) for connection to a USB cable (**30**,**100**),

an optical interface (**60**, **70**) for connection to at least one optical waveguide (**90**) for sending and receiving optical signals (S**1**', S**2**', S**3**', S**4**'), and

a conversion unit (**21**) that is capable of outputting the D+ and D− signal from the electrical interface as optical signals at the optical interface and is capable of outputting the optical signals from the optical interface as electrical signals D+ and D− at the electrical interface

wherein

the conversion unit (**200**) contains a recovery unit (**320**, **440**) that is capable of simultaneously receiving at least two optical wavelength channels at the optical interface and converting these at least two optical wavelength channels to a useful signal (NS) and control signals (SS), and

the recovery unit (**320**, **440**) is connected to an analyzing unit (**210**) that generates the signal D+ and D− out of the control signals (SS) and the useful signal (NS) for output at the electrical interface

8. Method for transmission of a USB compatible signal where the signals D+ and D− after electro-optical conversion are transferred as optical signals over at least one optical waveguide (**90**) wherein a useful signal (NS) and control signals (SS) are derived from the electrical D+ and D− signals and are transferred on at least two different wavelength channels on at least one optical waveguide (**90**)

9. Method according to claim **7**, wherein the useful signal (NS) is transferred on a separate and dedicated wavelength channel (S**1**')

10. Method according to claim **7**, wherein at least two control signals are logically combined and that the combined signal (S**12**, S**13**, S**22**) is then transferred on a separate and dedicated wavelength channel (S**12**', S**13**', S**22**).

11. Method according to claim **7** wherein at least one of the control signals is logically combined with the useful signal (NS) and that the combined signal (S**21**) then is transferred on a separate and dedicated wavelength channel (S**21**').

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