

DESCRIPTION

The invention concerns a method for the measurement of the distance between a target and a transmitter-receiver for optical pulse signals by the emission of optical pulse signals, reception of the signals reflected by the target, conversion of the received optical signals into digital electrical signals and subsequent signal processing for the derivation of a measurement criterion for the distance information from a sum signal which is formed by summation of N successive reflected signals. The invention furthermore concerns a device for the performance of this method.

Distance-measuring methods are known, which use pulsed electromagnetic signals on the RADAR principle as aids in order to ascertain the distance through measurement of the signal ratio between the target and the transmitter-receiver in the knowledge of certain boundary conditions.

More highly sensitive distance-measuring methods, which operate in the optical frequency spectrum, use solid body lasers (for example YAG, Ruby or the like) as transmitters. These lasers are pumped optically, wherein the distance is ascertained through measurement of the behaviour of a single laser pulse of correspondingly high energy. The electrical efficiency of an optically pumped solid body laser is generally very poor because of the discharge lamps used for the pumping. Beyond that, the frequently required battery change is disadvantageous in practical operation. In order that an individual reflected pulse displays sufficient energy in order to be able to be detected at all, the energy of the individual emitted pulses must be very high. Pulses, the energy of which exceeds a certain limit value, however endanger the eyes in so far as special safety measures are not taken. Semiconductor lasers, which indeed permit higher pulse rates, for example 10 to 100 kilohertz for GaAs, have hitherto not been taken into consideration for distance-measuring methods in the free terrain, thus at least over some hundreds of metres, because of their relatively low peak output power which may not be exceeded for thermal reasons.

A LIDAR, which is suitable for solid body lasers of increased pulse frequency and operates with photo-multipliers as detectors, wherein value is attached to the amplitude measurement of great dynamic range, is known from "Optical and quantum electronics", Volume 7, Number 3, May 1975,

Pages 179-185. The received signals are amplified, digitalised at a clock frequency of 10 megahertz, intermediately stored and after conclusion of the measurements added in a summation storage device. The amplitude and the distance is derived from the resultant signal.

A cloud height measuring device, in which the difference between two signal integrals from two time windows is formed for noise suppression, wherein only noise is picked up in one time window, is known from the FR-A-2 393 321. Shift registers and adders are used.

It is the task of the present invention to improve a method and a device for the distance measurement of the initially named kind in the sense that, on the one hand, higher pulse rates than hitherto can be used for the distance measurement and that, on the other hand, the signal strength of the received signals is strong enough to make an unobjectionable signal processing and thereby the distance measurement over the aimed-at distance range possible at all with sufficient reliability.

This problem is solved according to the invention by the features defined in the patent claims 1 and 4.

The advantage of this solution consists in that, contrary to original expectations, the relatively cheap laser diodes, which are to be managed easily in terms of circuit technique, let themselves be used for the distance measurement over at least a few hundreds of metres in spite of their low peak output powers, wherein high improvements in the sensitivity of the measurement method by at least one power of 10, typically however by several powers of 10, for example by the factor 100, even let themselves be achieved surprisingly. Beyond that, instruments operating with this method can be built up to be particularly small and light. The energy supply and the driving of the laser diodes as well as the subsequent signal processing also let themselves be realised in particularly simple manner with far-reaching use of standard components. Furthermore of advantage is the higher electrical efficiency of a semiconductor laser by comparison with the hitherto used solid body lasers as well as the possibility of operating with higher pulse rates.

In spite of smaller peak power, with measurements safe to the eye are possible by the measures according to the invention than on the use of individual pulse lasers. Because of the strong focussing of the laser beam, target distances let themselves be measured by this method with extraordinarily high accuracy even without reflectors, i.e. without previous mounting of reflecting elements at the target.

Whilst scanning or sampling methods were used hitherto in signal-processing methods for improvement in the resolution of the received signals, thus for their better direct recognition, the present method or the present device aims at the use of the sampling method for improvement in the sensitivity of the receiver and thereby for improvement of the signal-to-noise ratio S/N.

The invention is explained more closely in the following with the aid of the drawings by reference to preferred examples of embodiment.

There show:

- Figure 1 the block schematic diagram of a preferred example of embodiment for an explanation of the method,
- Figure 2 a time diagram for explanation of the method and
- Figure 3 the block schematic diagram of a simplified example of embodiment.

The principle of the method according to the invention consists substantially in the application of the recognition that the sensitivity of the measurement method can be improved by the factor $\sqrt{N}$ through the use of N pulses according to the rules of the information theory. It has proved that not only the disadvantages of the relatively small permissible peak power outputs for laser diodes can be overcome through an optimum utilisation of high pulse rates according to such information theory rules, but the measurement sensitivity can also be improved quite substantially, for example by the factor 100, by comparison with conventional methods.

Through application of the scanning or sampling method to the received pulse signal groups, an extremely precise decision criterion lets itself be derived for the return arrival of the pulses reflected from the target and thereby for the transit time of the pulses between the instant of the emission and the return arrival. In spite of low transmitted energy, relatively large distances let themselves be measured with high precision with a very good S/N ratio.

As Figure 1 shows schematically, the pulse sequence emitted by a laser diode arrangement 1 is reflected by a target 2 and subsequently received by a light-sensitive cell, for example by an avalanche diode 3, preferably arranged in the transmitter-receiver. The selected pulse repetition frequency for example lies in the range between 10 and 100 kilohertz. The pulse delivery is controlled, preferably program-controlled, by a microprocessor 5.

The signals detected by the avalanche diode 3 are amplified in an amplifier 4 to an extent adequate for the following processing. In a following analog-to-digital converter 6, the received pulses are digitalised at a scanning frequency preset by the microprocessor 5. The rate of the scanning operation in the example amounts to 100 nanoseconds. The digitalised data are transferred, for example as 4-bit or 6-bit parallel signals, to a parallel adder 7 and there added on directly at the rate of the aforementioned scanning operation to the corresponding value for each individual pulse within a scanning interval. This adding-on of the scanning values, which are respectively related to corresponding scanning instants, of the periodically emitted pulse sequences leads to a superelevation of the evaluated received signals and thereby to the mentioned increase in the sensitivity for the overall arrangement.

For achieving this effect, a 4-bit line coming from the analog-to-digital converter 6 is fed in the shown example as first sum term input to the parallel adder 7. The second sum term input of the parallel adder 7 is designed at 5-bit input. The output of the adder also displays a 5-bit line. That one of the parallelly conducted lines, which corresponds to the lowest place of the parallelly transmitted signal, is denoted by LSB. The line associated with the highest place is named MSB.

A sensor 11, which is connected by way of an MSB indicator line 10 with an input of the microprocessor 5, is provided for ascertaining a bit signal appearing at the output of the parallel adder 7 on the line MSB. It is ascertained by the microprocessor 5 in program-controlled manner whether a bit appearing on the line MSB is present during a complete scanning cycle between two pulses emitted by the laser diode arrangement 1.

The output of the parallel adder 7 is connected with the input of a shift register 9. A continuous intermediate storage of the values supplied by the parallel adder 7 for a scanning cycle takes place in the shift register 9.

Preferably, a change-over switch 8, which is controlled by the microprocessor 5 and connected at the output by way of a 5-bit parallel line to the second sum term input of the parallel adder 7, is connected by way of a 4-bit parallel line at the output of the shift register 9. Compared with its input, the change-over switch 8 thus displays an additional bit line at its output leading to the adder.

In the connection between the shift register 9 and the change-over switch 8, the lines for the lowest and the highest place are again denoted respectively by LSB and by MSB, according to Figure 1. The output bit lines of the change-over switch 8 are switched over each time by a bit position upwardly or downwardly according to a criterion which is described in the following and supplied by the microprocessor 5, whereby the association of incoming and outgoing bit lines is each time displaced through one place.

When an overflow signal from the parallel adder 7 is ascertained on the MSB indicator line 10 by the microprocessor 5 and this remains maintained over a complete scanning period, a change-over signal is given to the change-over switch by the microprocessor 5. Thereupon, this change-over switch switches all its input lines over each time to an output line lower by one place and remains in this setting during the entire next scanning period. Thereby, the previous MSB is now fed during this time as second-highest bit to the parallel adder 7, the second highest as third highest and so forth and the information of the lowest place is not taken into consideration during this time. All bits arriving during this scanning period are thus displaced downwardly through one place through this measure.

The effect of the described signal processing on the received pulse signals I is illustrated schematically in Figure 2. Whilst the signal train A shows the actual course of the received signal sequence, the result of the signal processing with the clearly superelevated scanning pulses is to be recognised in line B. Such a signal permits the target recognition and thereby the reliable distance measurement with a sensitivity better by about 100 times on the use of 10,000 pulses by comparison with a known method

which applies a threshold value detection within a preset pulse window.

Through the chosen completely parallel signal processing, a very high processing speed results for the pulses received by the avalanche diode. The resolution or the sensitivity of the equipment itself turns out to be correspondingly high even for the relatively weak pulse signals, received over a greater distance, of the laser diodes.

In modification of the aforescribed example of embodiment, the parallel adder 7, which is illustrated as discrete component in Figure 1, can be integrated in the microprocessor 5 itself. With the use of a correspondingly fast microprocessor 5, it is even possible to dispense with the use of a discrete shift register 9. Its function is then taken over by the microprocessor itself.

Figure 3 shows such an example in a simplified execution, in which a microprocessor 20 with parallel adder integrated therein is provided for direct signal processing. Very rapid signal processors, the operating frequency of which lies in the nanosecond range, preferably let themselves be used for this purpose. In that case, the functions described for the first example according to Figure 1 are realised through appropriate programming of the processor 20. Since the principle of the processing has already been described, details of a corresponding programme are not explained more closely here. As in the first example of embodiment according to Figure 1, an amplification-regulating signal AGC for the amplifier 4 can be derived from the microprocessor 20 also in this case.

Apart from the mentioned examples, other solutions are also possible, which differ in terms of circuitry or realised through programming and which make use of the same aforescribed method features in order to obtain a usable criterion for the ascertaining of the distance from the relatively weak received signals.



Claims

1. Method for the measurement of the distance between a target and a transmitter-receiver for optical pulse signals by the emission of optical pulse signals, reception of the signals reflected by the target, conversion of the received optical signals into digital electrical signals and subsequent signal processing for the derivation of a measurement criterion for the distance information from a sum signal which is formed by summation of N successive reflected signals, characterised thereby,
 - a) that a semiconductor laser, which directs pulses at a pulse repetition frequency in the range between about 10 kilohertz and about 150 kilohertz onto the target, is used as transmitter,
 - b) that the received signal sequence reflected by the target is scanned and digitalised at a scanning frequency dependent on the transmitted pulse repetition frequency, for which the scanning interval is started anew for each pulse emission,
 - c) that the obtained digitalised scanning values within a scanning interval are read into a parallel adder at the rate of the scanning frequency and stored during the first scanning interval,
 - d) that the scanning values of the second scanning interval are added continuously to the already present corresponding scanning values at the rate of the scanning frequency, wherein the respectively obtained sum value is stored in place of the respective previous scanning values at each scanning instant,
 - e) that the scanning values of each further scanning interval are added continuously to the already present corresponding scanning values at the rate of the scanning frequency, wherein the sum value newly obtained at each scanning instant of the scanning interval is stored in place of the preceding sum value and
 - f) that the distance information is derived from the resultant sum signal after adding on N scanning values for each scanning instant.



2. Method according to claim 1, characterised thereby, that the scanning of the received signal sequence is undertaken at a scanning frequency with a rate in the nanosecond range.

3. Method according to claim 2, characterised thereby, that the scanning of the received signals is undertaken at a scanning frequency with a rate of about 100 nanoseconds.

4. Device for the performance of the method according to claim 1 with an optical pulse transmitter directed towards the target, a photo-electric receiver for the signals reflected by the target and a signal-processing circuit for the derivation of a measurement criterion for the distance information from a sum signal which is formed by summation of N successive reflected signals, characterised thereby, that

- a) a semiconductor laser (1) is provided as optical pulse transmitter,
- b) an analog-to-digital converter (6), the scanning operation of which is controllable by a processor (5) in dependence on the pulse repetition frequency of the transmitted signal, is connected behind the photo-electric receiver (3) and
- c) a parallel adder (7) with a first and a second sum term input and an output is connected by way of a parallel line behind the analog-to-digital converter (6) in such a manner that its output is connected by way of an intermediate storage device with the second sum term input, wherein the scanning values delivered to the first sum term input by the analog-to-digital converter (6) on the parallel line during a first scanning interval are conducted by way of the output into the intermediate storage device and delivered by this to the second sum term input of the parallel adder (7) at the same rate as the scanning values delivered to the first sum term input by the analog-to-digital converter (6) during the following scanning interval so that the respectively resultant sum signal from the actual and the previously added-on scanning value is conducted by way of the output of the parallel adder (7) into the intermediate storage device and stands at disposal as measurement criterion for the distance information.



5. Device according to claim 4, characterised thereby, that a shift register (9) is provided as intermediate storage device.

6. Device according to claim 5, characterised thereby, that a sensor (11) for reporting an overflow bit (MSB) to the processor (5) is provided in the output line of the parallel adder (7) and that a change-over switch (8), which is controlled by the processor (5) and on a report of an overflow bit (MSB) by the sensor (11) displaces the parallel signal lines from the shift register to the parallel adder (7) each downwardly by one place, is provided in the parallel connection between the shift register (9) and the second sum term input at the parallel adder (7).

7. Device according to claim 4, characterised thereby, that a microprocessor (20), which operates in the nanosecond range and in which the function of the parallel adder (7) with intermediate storage is contained, is provided as processor.