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(54) Process and apparatus for making a numerical determination of the colour, or of a colour change of an object

(57) A coaxial optical fibre bundle assembly 6, carrying emitted light from a light source and receiving light which has been returned by an object illuminated from said light source, is moved towards the object 7 to cause the intensity of the received light, as detected by a photo transistor in light emitter-receiver unit 1, to attain maximum value which is amplified and held as a display on digital voltmeter 11. Comparison of the held value with the corresponding held maximum value resulting from a similar determination made of either a different object or the same object after a colour change can thus be made on a numerical basis.

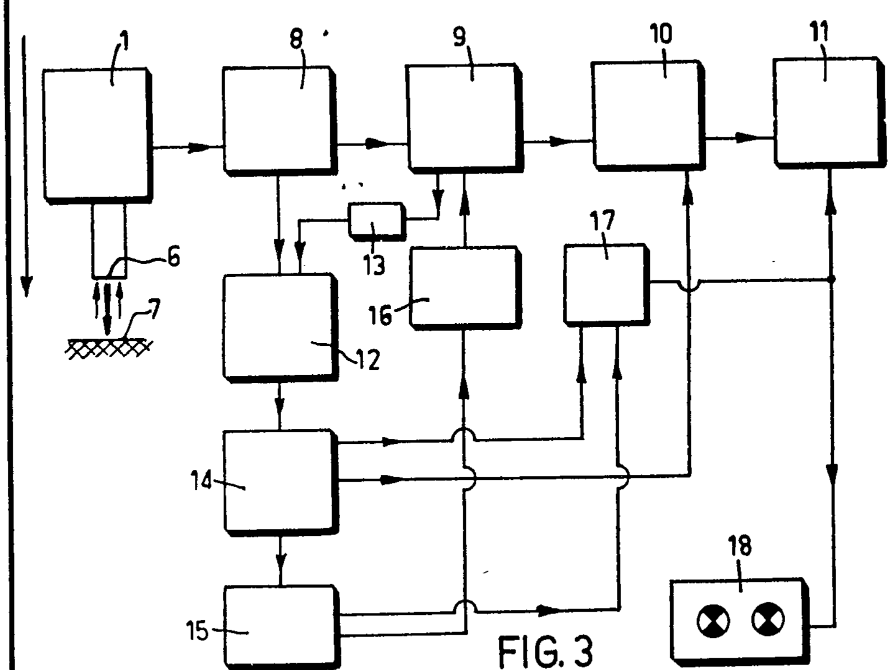

FIG. 3

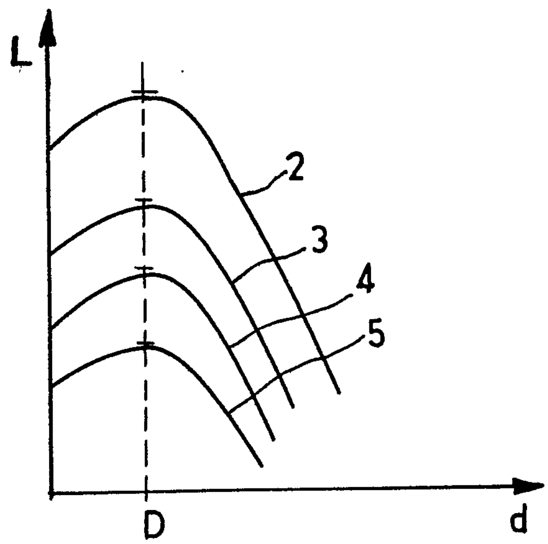

FIG.1

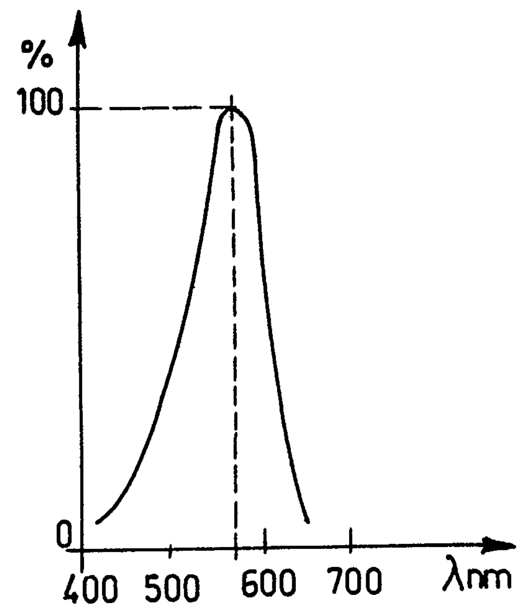

FIG. 2

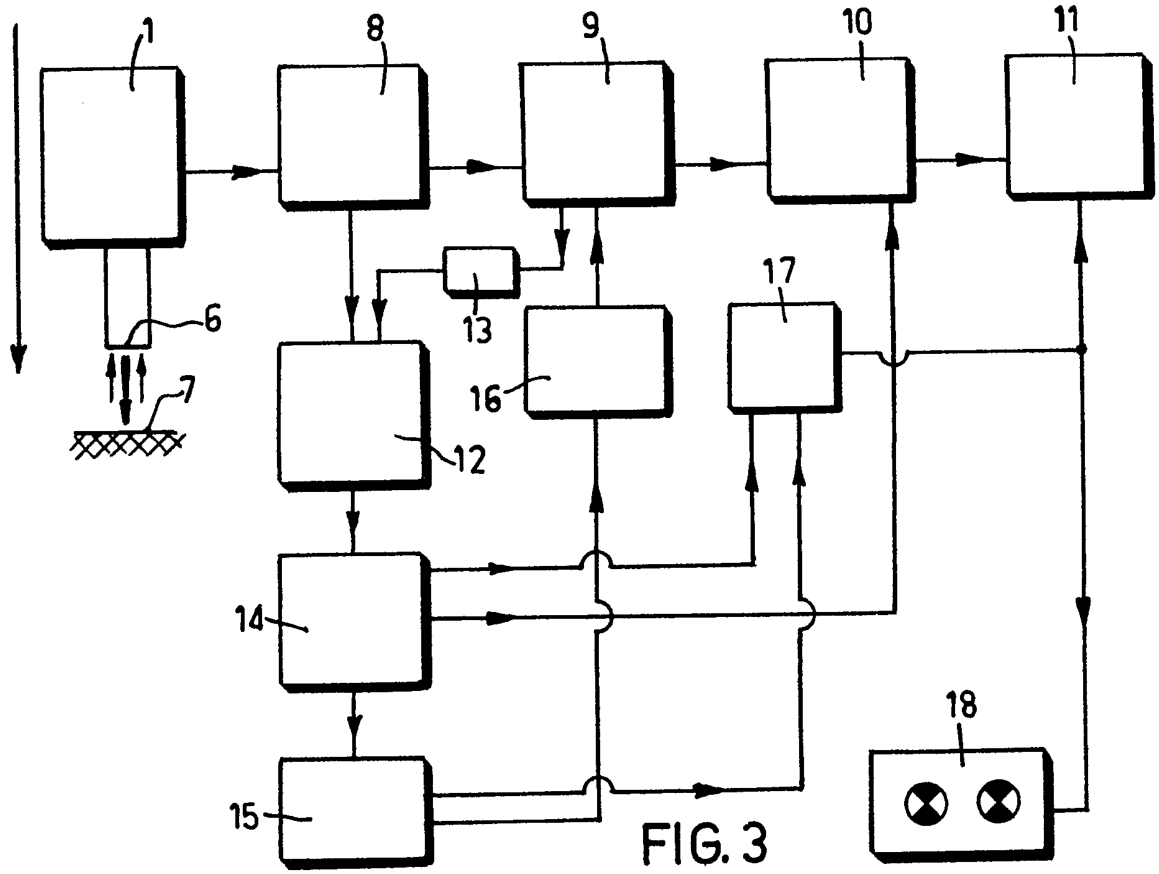

FIG. 3

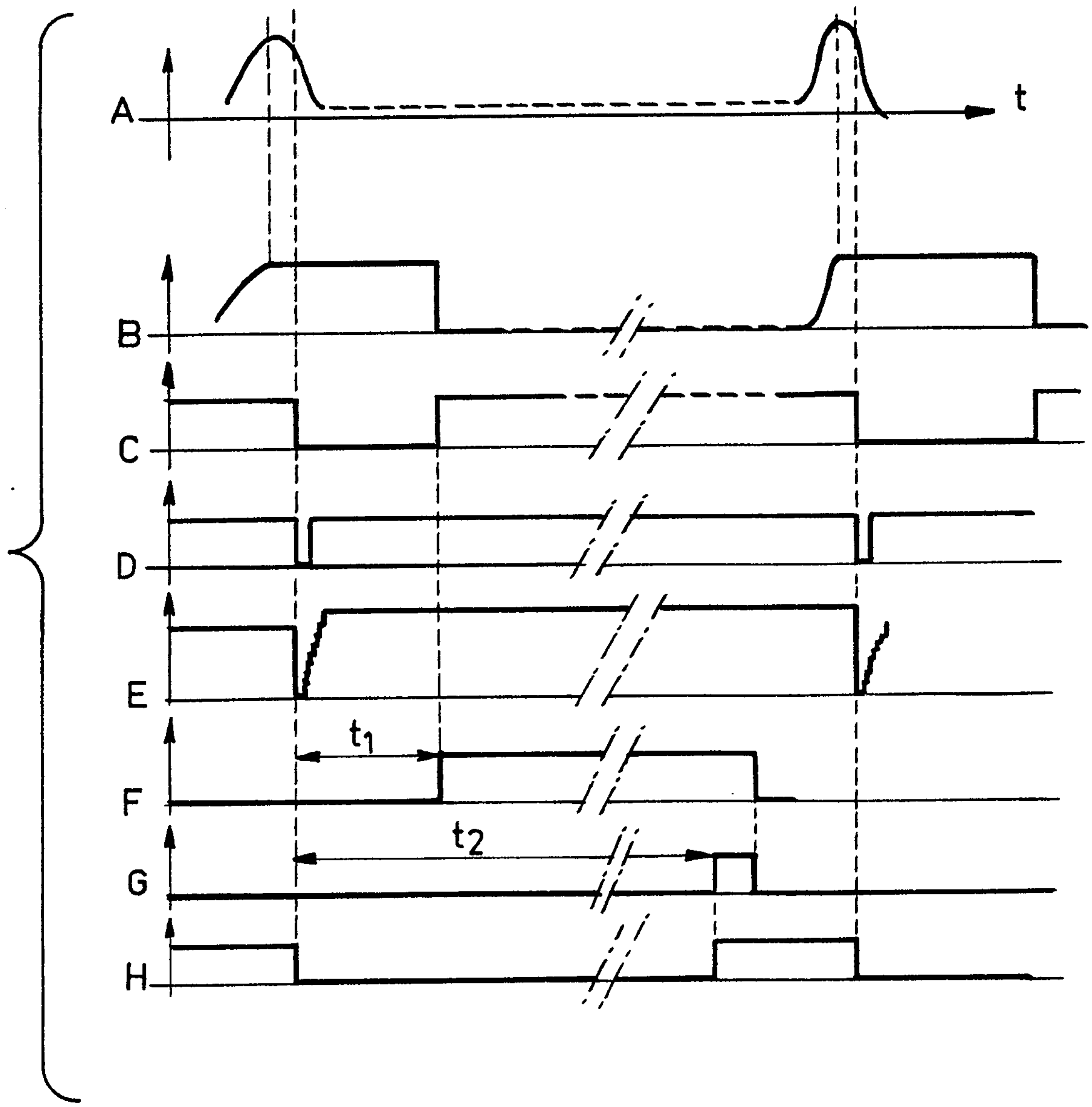

FIG. 4

SPECIFICATION

Process and apparatus for making a numerical determination of the colour, or of a colour change, of an object

The present invention relates to an apparatus and a process for carrying out a numerical determination of the colour, or of a colour change, of an object. More particularly the process and apparatus of the present invention do not require any contact with the object being investigated.

It is known that it is often desirable to allocate a numerical value to the colour, or the colour change of an object. Usually, the observation of an object by the human eye makes it possible to give qualitative information but this has two drawbacks. On the one hand, if the qualitative information is converted into quantitative data by an observer, the numerical value depends considerably on the judgement of the particular observer and may vary from one observer to another. Moreover, the human eye has difficulties in observation to allocate an indication corresponding strictly to the state of a restricted zone without taking into account the colour impression supplied by the surroundings of the observed zone; the surroundings are always taken into consideration so that the results of the qualitative observation of a zone depend largely on the contrasts supplied by the surrounding zones. This phenomenon is particularly evident when one is examining, for instance, the state of redness of human skin, particularly following solar radiation. The observation is affected not only by the intensity of the lighting but also by the background colour of the irradiated skin and by the extent of the contrast between the normal skin and the reddened skin.

It is, moreover, known that any apparatus permitting the numerical determination of an object's colour should be able to function without having to contact the object in the zone investigated. In fact, certain objects to be observed may be moving, or hot, or radioactive, and therefore they must not come into contact with the apparatus. Other objects may change their colour if they are subjected to pressure as is for instance, the case, with irradiated skin where contact pressure produces whitening due to closing of the capillaries. This colour change is also the case with liquid crystals which change colour according to the pressure to which they are subjected.

Now, in the present state of technology, a numerical determination of a colour is obtained by successively illuminating the object by luminous emissions corresponding to different wave lengths and measuring in each case the light returned by the object by way of reflection and diffusion towards a receiver. This technique essentially requires the maintenance of a strictly determined distance between the measuring apparatus and the object subjected to observation, so in the case of soft materials it is necessary to bring the materials into contact with a glass plate or slide. It follows that a pressure which, even though of small magnitude, is not zero, is exerted on the objects to be observed and that this method is not suitable in the case of materials which change colour according to pressure or of those which are moving, hot, or radioactive. Moreover, in this known state of technology, the result of the measurement depends on the surrounding lighting and, in order to become independent thereof, it is not possible to use a pulsed source since in order to obtain a sufficient quantity of light reflected and diffused by the object it is necessary to use a powerful source. It will thus be seen that the present state of technology does not provide an apparatus which is capable of numerically recording a colour or a colour modification of an object in a simple and reproducible manner without contact with the said object.

The object of the present invention is to provide a process and an apparatus facilitating the numeral determination of a colour, or a colour change, of an object which do not require contact with the said object. Strictly speaking, the apparatus does not make it possible to obtain an absolute numerical measurement corresponding to a colour, but it makes it possible to make a numerical determination of a colour or a colour change which determination can be compared with determinations made by using other similar apparatus. With such an apparatus, it is for instance possible to study the effects of vasconstrictors by examining the whitening of a human skin; it is also possible to study the extent of an erythema affecting a skin zone by comparing the measurement obtained on the said zone with a corresponding measurement obtained on a normal skin zone. One may, moreover, exert pressure on a reddened skin to close the capillaries and to whiten the skin zone concerned, then release the applied pressure and study the kinetics of the return of the skin to its original colour. The apparatus according to the invention thus finds a great number of applications and this all the more so, since its operation is extremely simple.

Accordingly one aspect of the present invention provides apparatus for making a numerical determination of the colour, or of a colour change, of an object, the apparatus comprising: a source of light to irradiate the object; a photo transducer to pick up the light returned by the object; optical fibre receiver means to direct the light returned by the object to the said photo transducer, the said optical fibre receiver means having an end displaceable substantially perpendicularly to the object being investigated to obtain the desired determination; optical fibre emitter means to direct the emission of said light source to a said object being investigated; said optical fibre emitter means and optical fibre receiver means being fixed together for conjoint movement towards and away from a said object being investigated; a detection circuit for determining the value of the maximum of the signal supplied by the photo receiver during the displacement of the said end of the optical fibre receiver means; and a display unit responsive to said detection circuit for displaying information according to the determination made.

Another aspect of the invention provides a process for making a numerical determination of the colour, or of a change in colour, of an object comprising taking an apparatus according to the first aspect, moving said coaxial ends of said first and second optical fibre bundles towards said object while receiving the light from said light source returned from the said object, processing the output signal of said photo receiver using said detector circuit, and displaying the output of said detector circuit using said display unit.

The principle of the invention lies in sending a luminous emission on to the object to be investigated, receiving the light returned by the object and determining the maximum value of the reception as the receiving surface of the object subjected to the luminous emission is approached. When the emitting and receiving surfaces are the ends of optical fibre bundles, the intensity of the light retransmitted by the object generally passes through a maximum value if the two surfaces of the object are simultaneously brought near each other. The distance corresponding to the attainment of this maximum value only depends on the geometry of the receiver system and therefore if it is the said maximum value itself which is determined, the measurement of the retransmitted light is always effected at the same distance from the object. The result is thus independent of any constraint imposed by the apparatuses of present-day technology.

The measurement assembly may have a spectral sensitivity corresponding to the sensitivity of the human eye; it is possible to effect correlations between the measurements effected and direct visual observations. If the filter used allows a light to be emitted having a wave length corresponding to the object's colour, the object will return a maximum quantity of light to the receiver. On the other hand, the greater the difference of the object's colour from the medium wave length of the light emission used, the more the quantity of light returned to the receiver by the object will be reduced. It will thus be seen that the intensity of the maximum value of the output signal from the photo transducer essentially depends on the colour of the object for a luminous emission having any given spectral characteristics. If one examines, with the same light emission, two differently coloured zones of the same object or the same zone of the object after its colour has been modified and if the results of the two measurements are compared, one obtains a numerical indication of the colour modification of the object which is practically independent of the light emission used.

In a preferred embodiment of the apparatus, the said first and second optical fibre bundles have their ends coaxial and in the same plane substantially parallel to the object, it being possible to cause the said ends to approach the object substantially perpendicularly to the object in order to effect the required determination; the receiver picks up from the object reflected light filtered through an optical filter whose wave lengths are distributed around a medium wave length approximating to the wave length corresponding to the object's normal unmodified colour; provision may also be made for the light emitter to comprise an optical filter emitting a light whose spectral distribution approximates to that corresponding to the sensitivity of the human eye; the signal processing detector circuit comprises a peak detector comprising an analogue memory; the peak detector is connected to the input of an analogue/digital and digitial/analogue converter whose output feeds the display unit; the display unit comprises a volt meter; a signal proportional to the output signal of the peak detector (the proportionality coefficient being less than 1) is compared in a comparator with the output signal of the photo transducer and the comparator initiates, at the moment the two compared signals are equal, resetting to zero of the said converter as well as the start of a first timed period at the end of which, the peak detector is reset to zero and a second timed period is started, at the end of which, the display unit is reset to zero.

The apparatus according to the invention has the advantage of being extremely simple to handle since it suffices to bring the optical emitter-receiver fibre bundles near the object to be investigated until they are in contact with the object or in the immediate proximity of this contact if such contact must be avoided. In any case, whether contact with the object is established or not, the measurement is effected before the said contact takes place so that the measurement is not disturbed by any possible disturbing effect of the contact of the optical fibres on the object.

The result of the measurement is numerically displayed on a digital voltmeter which is automatically reset to zero after a certain display period so that it is possible to effect a great number of measurements in an extremely short time. Moreover, it should be observed that the measurement effected only concerns an extremely limited zone of the object investigated and that it is completely independent of the colouration of the object's surrounding zones: thus one is no longer dependent on the ability of the human eye to take into account the colourimetric data of the surroundings of the zone subjected to observation. The apparatus supplies a colour determination for a given filtering of the returned luminous emission but of course, the numerical value obtained is modified if the spectral characteristics of the light emission or of the filtering are changed. On the other hand, the results which can be obtained by the apparatus are much more independent of the luminous emission if a colour modification is studied, that is to say if one effects a measurement on a zone of the object and compares it with a similar measurement made on the same object with the same luminous emission, either at the same point or at a different point after the colour of the observed zone has been modified.

In the special case where the apparatus is used for an investigation of the skin, it is preferable to use an optical filter giving a maximum intensity in yellow and whose total range is in the visible spectrum. In these conditions, the maximum response of the apparatus is obtained by examining a yellow object and the examination of a normal skin allows approximately 70% to 80% of the maximum response to be obtained. If erythemas of the skin are studied, it will be seen that the redder the skin the lower the numerical value obtained, and for a pronounced erythema, the reception value of the sensor is approximately 10 to 20% of the maximum response of the said sensor.

In order that the present invention may more readily be understood, an embodiment represented on the accompanying drawing will now be described, by way of a purely illustrative and non-restrictive example. In these drawings:

Figure 1 represents the curves giving luminous intensity L returned by the object (and picked up by the photo receiver) for a given luminous emission in relation to distance d between the object and the end of the optical fibres of the emitter-receiver assembly used in the apparatus according to the invention, each one of these curves corresponding to a different colour of the object subjected to examination;

Figure 2 represents the distribution of the spectrum obtained by means of the optical filter which is interposed ahead of the photo receiver of the preferred embodiment of apparatus;

Figure 3 is a block diagram of the electronic circuit processing the output signal of the photo receiver of the apparatus according to the invention; and

Figure 4 represents the formation, with respect to time, of the signal at various points of the block diagram of Fig. 3.

Referring to the drawings, there will be seen the emitter-receiver unit 1 of the apparatus according to the invention. Unit 1 comprises a light bulb which emits a white light, and an optical filter whose spectral characteristics are represented by the curve of Fig. 2. The luminous beam is sent into an emitter optical fibre bundle which constitutes at its end surface 6 the sheath of a second optical fibre bundle coaxial with the first. The two coaxial, optical fibre bundles have a common end surface 6, the second bundle serving as a receiver intended to receive the luminous flux returned by the object which is subjected to the incident flux originating from the emitter optical fibre bundle. The second optical fibre bundle or receiver bundle is connected to a photo transistor which constitutes the photo transducer of the apparatus according to the invention. The emitter-receiver unit 1 is not described in greater detail because it is marketed by the Company "SKAN-A-MATIC" of the United States of America under reference number "S 35203", with the optical filter.

In view of the geometry of the optical fibre bundles, the light emitted by the peripheral emitter fibre bundle and returned by the object only enters the optical receiver fibre bundle under certain angular pre-conditions so that the light intensity detected by the photo transistor which is connected to the receiver fibre bundle passes through a maximum when the common ends of the emitter and receiver fibre bundles are located at a distance D (Fig. 1) from the object being investigated.

Fig. 1 shows the shape of the curve indicating light intensity L determined by the photo receiver in relation to distance d from the front end surface 6 of the optical fibre bundles in relation to the object. Distance D corresponding to the maximum value of the light reception is always the same for a given emitter-receiver unit 1.

The different curves represented on Fig. 2 show the light intensities received by the photo transistor, according to the colour of the object which is presented in front of the end surface 6 of the emitter-receiver bundle assembly. If this object has a colour whose wave length corresponds to the maximum of the spectral distribution of the particular filter selected, the light intensity detected by the photo transistor is the maximum one which corresponds to curve 2 of Fig. 1. On the other hand, the more the object's colour differs from the dominant colour of the filter the lower is the light intensity detected by the photo transistor; curves 3, 4 and 5 show the light reception levels for orange, orange-red and red objects whilst curve 2 corresponds to a yellow object. As will be clear from the wave lengths indicated in Fig. 2, the filter is centred on yellow.

The values of the maxima of curves 2, 3, 4 and 5 therefore constitute a determination of the colour of the object which is presented opposite the end surface 6 of the coaxial optical fibre bundles. Of course, the numerical values corresponding to these maxima depend essentially on the nature of the filter which has been used for their determination. On the other hand, if a given object changes its colour and if the same apparatus is used to effect measurements both before and after the colour modification, comparison of the results of the two measurements will give a determination of the colour modification which colour modification determination depends to a far lesser degree on the nature of the light emission used.

To effect the measurement, it is sufficient to bring the end surface 6 of the coaxial optical fibres near to the object, either right up to contact with the object if there is nothing prohibiting contact or up to a proximity of a few millimetres if contact with the object must be avoided. In the course of this approach, the photo transistor output signal passes through a maximum at the moment when the end of the optical fibres is at a distance D from the object. As will be described in detail below, the apparatus allows the measurement to be effected at the precise moment when the distance d passes the distance value D.

This technique is particularly worthwhile if it is intended to study erythemas of the skin, because in that case it is possible to bring the end surfaces of the optical fibres right up to contact with the skin although this contact will cause the skin to whiten and will therefore modify the colour of the observed zone since the measurement is taken at a moment before the contact has been effected and when, therefore, the skin still retains its unmodified colour.

In Fig. 3, there has been shown the block diagram of the electronic circuit which allows the measurement to be obtained at the moment when end surface 6 of the optical fibre bundles is located at distance D from object 7 being investigated. The output signal of the photo transistor of the emitter-receiver unit 1 is sent to an amplifier 8 whose output is applied as input to a peak detector 9. In the conventional manner, the peak detector 9 comprises a capacitor having a sizable time constant, about 10 seconds for instance, since this capacitor only discharges very slowly.

The output signal of amplifier 8 is represented on line A of Fig. 4 for the part which corresponds to the passage of the photo transducer output through the maximum, i.e. at a moment when end surface 6 of the optical fibre bundle is at a distance D from object 7. The signal supplied at the output of peak detector 9 is represented on line B of Fig. 4.

This signal is directed to an analogue/digital and digital/analogue converter 10. When reset to zero, the converter 10 charges a memory at the frequency of its internal timer and converts the memory content into an analogue output voltage and it compares the output voltage with the input voltage; the charging of the digital memory continues until the output voltage is equal to the input voltage; at this moment, converter 10 is blocked until it receives a reset pulse to cause it to reset to zero. The output voltage supplied by converter 10 is applied to a digital voltmeter 11 which constitutes the display unit.

The output from amplifier 8 is also applied to a comparator 12 whose second input receives the voltage corresponding to the output of peak detector 9 reduced by a proportionality coefficient of less than 1 derived from a divider bridge 13. In this embodiment, the proportionality coefficient selected is 0.75. The output of comparator 12 is thus a binary signal which is at the higher level while the output voltage of amplifier 8 is higher than that supplied by divider bridge 13 and which changes over to a lower level as soon as the opposite occurs.

This binary signal from comparator 12 is represented on line C of Fig. 4. The descending front of the signal on line C therefore indicates that the maximum of the output signal of the photo transistor of unit 1 has been passed and one may therefore charge the converter 10 with the value stored in peak detector 9. The use of a proportionality coefficient of 0.75 by virtue of the divider bridge 13, makes it possible to avoid any possible interference effects.

The output of comparator 12 controls a monostable device 14 whose output signal is represented in line D of Fig. 4. The output signal of the monostable device 14 is applied to the converter 10 and constitutes the reset signal, resetting the converter to zero to allow the digital memory of the converter to be charged at its internal timer frequency, which charge is produced in 150 nano-seconds at most. As explained above, when the output voltage of converter 10 is equal to the input voltage, converter 10 becomes blocked so that the display on voltmeter 11 remains constant, this display having changed during the charging time of converter 10. The output signal of converter 10 has been represented on line E of Fig. 4 but in this representation, the charging time of the converter has been greatly exaggerated to make it visible in the drawing.

The monostable device 14 releases a timing circuit 15 which supplies two timed periods.

The first timed period is determined by a signal represented on line F of Fig. 4. At a time t_1 after the descending front of the pulse from the monostable device 14, the signal of the first timed period has a rising front which is directed to a transistor 16 arranged in parallel with the capacitor of peak detector 9. The first timed period signal thus produces the resetting to zero of the peak detector output which does not affect the output of converter 10 since the converter has been blocked after completing its charging. The resetting to zero of the output of peak detector 9 also prompts change to the higher level of the output of comparator 12. In the example described, time t_1 is approximately 20 ms.

The second timed period signal is represented on line G of Fig. 4. This signal has a rising front at time t_2 after the descending front of the pulse produced by the monostable device 14. This rising front initiates by way of interface 17, the resetting to zero of the digital voltmeter 11, the output signal of interface 17 being represented on line H of Fig. 4. The second timed period signal constitutes a rectangular pulse and its descending front entails the resetting to zero of the signal relating to the first timed period. The signal supplied by interface 17 is reset to zero at the time of the descending front of the pulse supplied by monostable device 14. The signal supplied by interface 17 is therefore at its lower level during a timed period t_2, and t_2 is chosen at the order of 20 seconds which allows the user of the apparatus to have the display of the measurement on digital voltmeter 11 at his disposal for 20 seconds. After these 20 seconds, the display of digital voltmeter 11 is reset to zero. An indicator device 18 is provided to indicate by one illuminated sign that the apparatus is in the measurement or reading off phase and by a different illuminated sign that the apparatus is on standby which makes it possible to effect a new measurement.

It will be seen that the apparatus which has just been described is simple to make so that its cost price is relatively limited. Moreover, it is very simple to use and the measurements effected can be taken very rapidly. The rapidity of these measurements makes it possible to study the kinetics of a change in colour which may for example extend over several minutes.

CLAIMS

1. Apparatus for making a numerical determination of the colour, or of a colour change, of an object, the apparatus comprising: a source of light to irradiate the object; a photo transducer to pick up the light returned by the object; optical fibre receiver means to direct the light returned by the object to the said photo transducer, the said optical fibre receiver means having an end displaceable substantially perpendicularly to the object being investigated to obtain the desired determination; optical fibre emitter means to direct the emission of said light source to said object being investigated; said optical fibre emitter means and optical fibre receiver means being fixed together for conjoint movement towards and away from a said object being investigated; a detection circuit for determining the value of the maximum of the signal supplied by the photo receiver during the displacement of the said end of the optical fibre receiver means; and a display unit responsive to said detection circuit for displaying information according to the determination made.

2. Apparatus according to Claim 1, wherein said optical fibre emitter means and optical fibre receiver means comprise first and second optical fibre bundles having coaxial ends in the same plane substantially parallel to the object, the said ends being displaceable together substantially perpendicularly to the object to effect the desired determination.

3. Apparatus according to Claim 1 or 2, wherein the said photo transducer further comprises an optical filter.

4. Apparatus according to Claim 3, wherein said optical filter has a spectral distribution which approximates to that which corresponds to the sensitivity of the human eye.

5. Apparatus according to any one of Claims 1 to 4, wherein said detection circuit comprises a peak detector and an analogue memory.

6. Apparatus according to Claim 5, wherein said peak detector is connected to the input of an analogue/digital and digital/analogue converter whose output feeds said display unit.

7. Apparatus according to Claim 6, wherein said display unit comprises a voltmeter.

8. Apparatus according to Claim 7, wherein said voltmeter is a digital voltmeter.

9. Apparatus according to Claim 6, 7, or 8, including: means to obtain a signal proportional to the output signal of said peak detector, the proportionality coefficient being less than 1; and a comparator comparing the said proportional signal and the output signal of said photo transducer, wherein, as soon as the two compared signals are equal, said comparator initiates the resetting to zero of the converter as well as the start of a first timed period at the end of which there is produced both a resetting to zero of said peak detector and the commencement of a second timed period at the end of which said display unit is reset to zero.

10. Apparatus according to any one of Claims 1 to 9, which is usable for examining the skin, wherein the light emission is effected practically completely in the visible spectrum with a maximum in yellow.

11. Apparatus for making a numerical determination of the colour, or of a colour change, of an object, said apparatus being constructed and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

12. A process for making a numerical determination of the colour, or of a change in colour, of an object, comprising taking an apparatus according to claim 1, moving said

coaxial ends of said first and second optical fibre bundles towards said object while receiving the light from said light source returned from the said object, processing the output signal of said photo receiver using said detector circuit, and displaying the output of said detector circuit using said display unit.

13. A process for making a numerical determination of the colour, or of a change in colour, of an object without contact with the object, comprising illuminating an object, moving a mobile light receiver means towards the illuminated object while picking up the light returned by said object, to cause the output signal of the light receiver means to rise up to a maximum value, and processing said maximum value of the output signal to derive a numerical value proportional to said maximum value.

14. A process according to Claim 12 or 13, when carried out using an optical filter in the path of the said returned light picked up from the illuminated object, said optical filter having a medium wave length which approximates to the wave length corresponding to the normal unmodified colour of the object being investigated.

15. A process for making a numerical determination of the colour, or of a change in colour, of an object without contacting said object, such method being substantially as hereinbefore described with reference to the accompanying drawings.

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