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On-line: WPI, EPODOC, PAJ

(54) Abstract Title
Signal signature analysis

(57) Apparatus (10) comprises a collimated light beam (15) arranged to illuminate an optical modulator (13). The beam (15) is modulated by an input signal (16) to form a modulated light beam (17) which passes through a lens (18) to form a characteristic signature (19). The signature (19) is replicated into an array of signatures (21) which are relayed to a correlator (22) for correlation with each of a plurality of reference signatures (24) located in a reference mask (25).

Resultant light (26) from a match between the signatures (19 and 24) is allowed to pass through the mask (25) and is then modified by a lens (27) to form a correlation signal (28) for detection by a detector (29) which produces and electrical signal (30) in proportion to the signal (28).

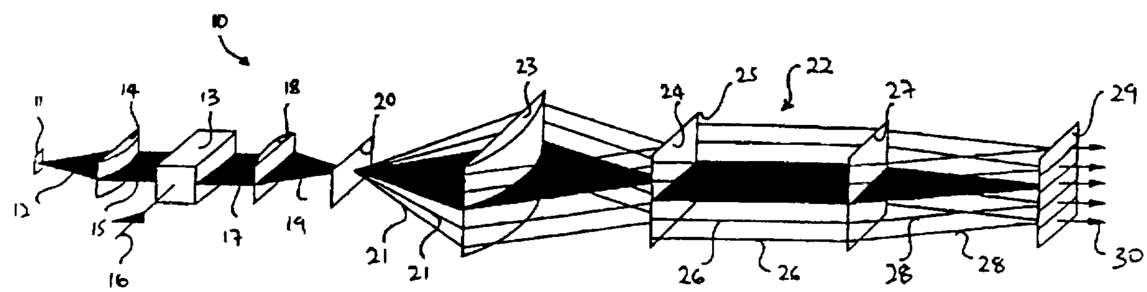

fig.1.

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SIGNAL SIGNATURE ANALYSIS

This invention relates to an apparatus and method, for signal signature analysis. The invention is suitable for processing radar returns corresponding to at least one target and correlating the returns with known reference signatures of targets to provide a means of identification of each target. The invention is also suitable for identifying any pattern of electronic signals in, for example, telecommunications and sensor applications.

At present, there is a lot of interest in target recognition using infrared information. It is usual in such an infrared type system that a target is identified by analysis of wavelength information of infrared energy emitted from the target and matching the information with stored wavelength information of known targets. Uses of the present invention may be for a similar target recognition system to provide a scale invariant partner to current infrared techniques or as an independent source of target recognition.

The invention seeks to provide an improved apparatus for signal signature analysis.

According to a first aspect of the present invention there is provided an apparatus, for signal signature analysis, comprising at least one collimated light beam to illuminate an optical modulator arranged to form a characteristic signature by diffraction of the collimated light beam as a function of a modulation signal applied to the modulator, a correlator which has a reference mask having at least one reference signature and the correlator being arranged to correlate each characteristic signature with the reference signature and to form a resultant correlation signal, and at least one detector to provide an electrical signal proportional to the magnitude of the correlation signal.

Preferably, the reference mask may contain a plurality of reference signatures and may be a holographic filter arranged to retain each reference signature or alternatively may be a programmable device arranged to generate each reference signature in optical form. Such a programmable device may be an optical modulator which is capable of receiving control signals from a control device, such as a computer, and generating the reference signatures. The optical modulator may be an acousto-optic cell. The correlator may further comprise a Fourier Transform lens which may be arranged to form each correlation signal.

A collimated light beam may be formed by a laser device that emits light which is collimated by a collimator lens. The optical modulator may further comprise a Fourier Transform lens which may be arranged to co-act with the diffracted light beam to form a characteristic signature and a micro-optic component may replicate the characteristic signature into an array of substantially equal characteristic signatures which may be relayed to the correlator, for correlation with each reference signature, by a relay lens. Alternatively each collimated light beam may be formed by an array of vertical cavity surface emitting lasers that emit light which may be collimated by a collimator lens. As a further alternative, each collimated light beam may be formed by a laser that emits light which may be arranged to co-act with a lenslet array and may be collimated by a collimator lens thereby providing a multiplicity of collimated light beams. The optical modulator may further comprise a Fourier Transform lens which is arranged to co-act with each diffracted light beam to form an array of characteristic signatures.

Preferably, the optical modulator may be an acousto-optics cell.

Each light beam may comprise coherent light for phase modulation.

Preferably, each detector may be a photo detecting diode and an electrical signal formed by each detector may be fed into a neural network for automatic identification or an electrical signal formed by each detector may be fed into a look up table for identification.

Preferably, a grating may be provided in front of each detector to expose the detector to the correlator signal for predetermined periods of time thereby providing an enhanced amplitude modulated electrical signal from the detector.

According to a further aspect of the present invention there is provided a method, of signal signature analysis, comprising forming at least one characteristic signature by diffraction of light as a function of a modulating signal, correlating each characteristic signature with a reference signature and representing the magnitude of correlation between each characteristic signature and the reference signature as an electrical signal.

The bandwidth, parallelism and analogue nature of acousto-optic devices make them suited for real-time radar signature analysis. The maturity of acousto-optic devices, such as Bragg cell technology, coupled with the reliability of solid state lasers, lead to the possibility of low power, ultra compact, high performance systems. Of interest to the apparatus of the present invention is the use of techniques to correlate radar returns with stored reference signatures in order to extract target identities in real time, and to deploy such an apparatus in equipment where weight, power consumption and volume are critical considerations. A potential application of the apparatus could be use in a seeker head or smart munitions sensor where in-target range profiling could be used for target identification and prioritisation.

The invention is further described, by way of example only, with reference to accompanying drawings, in which:-

Figure 1 illustrates a first embodiment of the present invention which uses a single laser and a micro-optic replicator;

Figure 2 illustrates the motion of the characteristic signature through a correlator with respect to a reference signature for the present invention;

Figure 3 illustrates two types of electrical signals formed by a detector incorporated in the invention;

Figure 4 illustrates a second embodiment of the present invention which uses a vertical cavity surface emitting laser array;

Figure 5 illustrates a portion of a third embodiment of the present invention which uses a lenslet array, this figure only illustrates a system up to and including an optical modulator as the reminding portion operates in the same manner as that of the second embodiment;

Figure 6 illustrates the addition of a grating device in front of a detector to enhance detection;

Figure 7a illustrates a correlation signal and 7b illustrates an electrical signal formed by a detector using the grating illustrated in Figure 6 for the signal in Figure 7a, and

Figure 8a illustrates a correlation signal and 7b illustrates an electrical signal formed by a detector using the grating illustrated in Figure 6 for the signal in Figure 8a.

In Figure 1 there is illustrated a schematic system diagram of a first embodiment of an apparatus 10 for signal signature analysis, and particularly for radar return signature analysis. The apparatus 10 comprises a laser 11 arranged to emit light in the form of a light beam 12 which is collimated by a collimator lens 14 to form a collimated light beam 15 that illuminates an optical modulator 13, for example an acousto-optic modulator such as a Bragg Cell. Laser 11 can be substituted by any light source capable of producing a narrow line width such that the acousto-optic modulator can operate in a preferred, more efficient Bragg Mode. A laser 11 is preferably used as it produces spatially coherent light which improves the efficience of acousto-optic diffraction.

A modulation signal 16, for example a radio frequency signal such as return bursts from a target reflecting energy created by a radar signal generator, is applied to the modulator 13 so as to cause the modulator 13 to diffract the collimated light beam 15 from its path thereby creating a modulated light beam 17 which is a function of the modulation signal 16 applied to the modulator 13. The modulated light beam 17 is modulated in amplitude and, if a coherent light source is used, in phase by the applied modulation signal 16.

By passing the modulated light beam 17 through a first Fourier Transform lens 18, a characteristic signature 19 of the diffracted light at the modulator 13 is formed. The characteristic signature 19 is then replicated by a replicator 20, for example a micro-optic device, into an array of equal characteristic signatures 21.

The array of characteristic signatures 21 are relayed to a correlator 22 by a relay lens 23, for correlation of each characteristic signature 21 within the array with each of a plurality of reference signatures 24 located in a reference mask 25 of the correlator 22.

The reference mask 25 may comprise an array of reference signatures 24, for example holographic matched spacial filters, laid longitudinally side by side or may be a plurality of reference signatures 24 integrated into a single reference mask 25.

If a characteristic signature 21 matches with a reference signature 24 then resultant light 26 from the characteristic signature 21 is allowed to pass through the reference mask 25. However, if a characteristic signature 21 is a poor match for a reference signature 24, or a characteristic signature 21 does not match with a reference signature 24, then substantially very little or none of the resultant light 26 from the characteristic signature 21 will pass through the reference mask 25. The spatial carrier frequency of the reference mask 25 allows complex reference signatures 24 to be encoded and used.

The resultant light 26 which does pass through the reference mask 25 is modified by a second Fourier Transform lens 27 to form a correlation signal 28 for detection by a detector 29, for example a photo detecting diode such as a silicon photodiode. Each reference signature 24 of the reference mask 25 is allocated a detector 29 which produces an electrical signal 30 proportional to the correlation signal 28 for that reference signature 24 with each characteristic signature 21.

Figure 2 schematically illustrates the line of sight of a detector 29, along axis D, through the correlator 22. By the action of the acousto-optic modulator 13 the image of the characteristic signature 21 is caused to transverse with respect to the reference signature 24 over time. As the characteristic signature 21 passes the reference signature 24 a number of points may emerge where the light of the characteristic signature 21 correlates with the reference signature 24 to allow resultant light 26 to pass through the reference mask 25 for detection by the detector 29. The better the match between a characteristic signature 21 and a reference signature 24 the greater the resultant light 26 that passes through the reference mask 25. It should be noted that regions 31 are opaque and that although the reference signature 24 is illustrated as a solid line it is in fact an area transparent to light and that the characteristic signature 21, illustrated also as a solid line, represents an area of light and that regions 32 are areas where no light is present for the characteristic signature 21.

Figure 3 is a graph showing the amplitude of resultant light signal 33, 34 which passes through a reference mask 25 and passes in front of a detector 29 for first and second characteristic signatures. Amplitude is given as A along the ordinate and time is given as t along the abscissa. The first resultant light signal 33 corresponds to a first characteristic signature which is a poor match for the reference mask 25 and the amplitude A of the signal remains relatively low over the time t that the first characteristic signature is present. However, the second resultant light signal 34 corresponds to a second characteristic signature which is a good match for the reference mask 25 and the amplitude A of the signal peaks at point 35 as the characteristic signature 34 comes into alignment with the reference mask 25.

The amplitude of resultant light 33, 34 detected by the detector 29 represents the extent of the match between the characteristic signatures and the reference mask 25.

In Figure 4 there is illustrated a schematic system diagram of a second embodiment of the present invention. An apparatus 40 comprises an array of lasers 41 arranged to emit light in the form of light beams 42 and arrange to illuminate an optical modulator 43, as in the first embodiment of the present invention. The beams 42 are formed by a vertical cavity surface emitting laser device. Each beam 42 is collimated by a collimator lens 44 to form an array of collimated light beams 45 prior to the illumination of the modulator 43.

In Figure 5, there is illustrated a portion of a schematic diagram of a third embodiment of the present invention. Like references correspond to those used in Figure 4, as the reminder of the system, not shown, operates in substantially the same way as that described with reference to Figure 4. Therefore apparatus 40 comprises a laser 41A and lenslet array 41B arranged to emit light in the form of light beams 42 and arranged to illuminate an optical modulator 43, as in the first and second embodiments of the present invention. The beams 42 are formed by collimating a laser beam 41C with a collimating lens 41D to form a beam 41E and passing the beam 41E through the lenslet array 41C to form the light beams 42. Each beam 42 is collimated by a collimator lens 44 to form an array of collimated light beams 45 prior to illumination of the modulator 43.

Referring now to Figure 4 a modulation signal 46, is in the first embodiment, is applied to the modulator 43 so as to cause the modulator 43 to diffract the collimated light beams 45 from their paths thereby creating modulated light beams 47 which are each a function of the modulation signal 46 applied to the modulator 43.

By passing the modulated light beams 47 through a first Fourier Transform Lens 48, an array of substantially equal characteristic signatures 49 corresponding to the diffracted light at the modulator 43 are formed. The array of characteristic signatures 49 pass on to a correlator 50 for correlation of each characteristic signature 49 within the array with each of a plurality of reference signatures 51 located in a reference mask 52 of the correlator 50.

The reference mask 52 and the correlator 50 are constructed and function in the same way as the reference mask 25 and the correlator 22 of the first embodiment of the present invention described above.

If the characteristic signature 49 matches with a reference signature 51 then resultant light 53 from the characteristic signature 49 is allowed to pass through the reference mask 52. However, if the characteristic signature 49 is a poor match or does not match with the reference signature 51, then substantially very little or none of the resultant light 53 from the characteristic signature 49 will pass through the reference mask 52.

The resultant light 53 which does pass through the reference mask 52 is modified by a second Fourier Transform lens 54 to form a correlation signal 55 for detection by a detector 56.

Each reference signature 51 of the reference mask 52 is allocated a detector 56 and the detector 56 produces an electrical signal 57 proportional to the correlation signal 55 for that reference signature 51 with each characteristic signature 49.

The operation of the detector 56 corresponds to the operation of the detector 29 of the first embodiment of the present invention described above.

Figure 6 illustrates a modification of the previously described embodiments of the present invention. A correlator 60 has the same construction as the correlators 22, 50 described in the apparatus 10, 40 respectively. A Fourier Transform lens 61 modifies resultant light 62 from the correlation of each characteristic signature with each reference signature to form a correlation signal 63 for detection by a detector 64.

The detector 64 produces an electrical signal 65 proportion to the correlation signal 63. However, a grating mask 66 is positioned between the detector 64 and the correlator 60 to exposed to the correlation signal 63 to the detector 64 for predetermined periods of time. The periods that this signal 63 is detected is set to enhance only good correlation peaks to be detected by the detector.

This is achieved by designing the spacing of the grating of mask 66 to match the width of the expected "good" correlation signal 63. As such a signal 63 transverses the mask 66, the amplitude of the light reaching the detector 64 is substantially modulated and the electrical signal 65 for a good correlation signal 63 will possess a relatively large a.c. component. If, on the other hand, the match is poor, the a.c. component of the electrical signal 63 would be relatively small, even if the original correlation signal 63 was relatively large. Therefore, by monitoring the output of the detector 64 at a particular frequency, which is determined by the acoustic velocity in the acousto-optic modulator and the grating period, discrimination between good and poor matches can be enhanced.

For example, in Figure 7a, the grating mask 66 having a spacing P as defined in accordance with an expected "good" correlation signal 70 and Figure 7b gives the output signal 71 from the detector 64 for the signal 70. The amplitude A of the signals 70, 71 is given along the ordinate and time t is given along the abscissa. As the correlation signal 70 transverses the mask 66 the signal 70 registered by the detector 64 will be substantially modulated and the output signal 71 will possess a.c. characteristics.

However, from Figures 8a, a correlation signal 72 encountering the grating mask 66 having the same design as that described with reference to Figure 7a will provide an output signal 73 in Figure 8b. The amplitude A of the signals 72, 73 is given along the ordinate and time t is given along the abscissa. As the correlation signal 72 transverses the mask 66 the signal 72 registered by the detector 64 will not be substantially modulated as the signal 72 is relatively flat and the output signal 73 will possess relatively little a.c. characteristics.

The electrical signal output of each detector can be fed to a neural network or look up table for further processing and identification. The use of vertical cavity surface emitting laser devices finds particular application in use with neural networks as the light beams can be weighted by adjustment of the device thereby creating weighted correlation signals for training of the neural network for recognition.

The holographic filter of a reference mask can be replaced by a programmable device which receives control signals from a control device. The control signals cause the programmable device to set up reference signatures which are then used in a reference mask to filter characteristic signatures. Such a programmable device can be an optical modulator, for example an acousto-optic cell and a control device can be a suitable computer.

CLAIMS

1. An apparatus, for signal signature analysis, comprising at least one collimated light beam to illuminate an optical modulator arranged to form a characteristic signature by diffraction of the collimated light beam as a function of a modulation signal applied to the modulator, a correlator which has a reference mask having at least one reference signature and the correlator being arranged to correlate each characteristic signature with the reference signature and to form a resultant correlation signal, and at least one detector to provide an electrical signal proportional to the magnitude of the correlation signal.

2. An apparatus, as claimed in Claim 1, and wherein the reference mask contains a plurality of reference signatures.

3. An apparatus, as claimed in Claims 1 or 2, wherein the reference mask is a holographic filter arranged to retain each reference signature.

4. An apparatus, as claimed in Claims 1 or 2, wherein the reference mask is a programmable device which is arranged to generate each reference signature in optical form.

5. An apparatus, as claimed in any preceding claim, wherein the correlator further comprises a Fourier Transform lens that is arranged to form each correlation signal.

6. An apparatus, as claimed in any preceding claim, wherein a collimated light beam

is formed by a laser device that emits light which is collimated by a collimator lens.

7. An apparatus, as claimed in Claim 6, wherein the optical modulator further comprises a Fourier Transform lens which is arranged to co-act with the diffracted light beam to form a characteristic signature.

8. An apparatus, as claimed in Claim 7, wherein a micro-optic component replicates the characteristic signature into an array of substantially equal characteristic signatures which are relayed to the correlator, for correlation with each reference signature, by a relay lens.

9. An apparatus, as claimed in Claims 1 to 5, wherein each collimated light beam is formed by an array of vertical cavity surface emitting lasers that emit light which is collimated by a collimator lens.

10. An apparatus, as claimed in Claims 1 to 5, wherein each collimated light beam is formed by a laser that emits light which is arranged to co-act with a lenslet array and collimated by a collimator lens.

11. An apparatus, as claimed in Claims 9 or 10, wherein the optical modulator further comprises a Fourier Transform lens which is arranged to co-act with each diffracted light beam to form an array of characteristic signatures.

12. An apparatus, as claimed in any preceding claim, wherein the optical modulator is an acousto-optics cell.

13. An apparatus, as claimed in any preceding claim, wherein each light beam comprises coherent light.

14. An apparatus, as claimed in any preceding claim, wherein each detector is a photo detecting diode.

15. An apparatus, as claimed in any preceding claim, wherein an electrical signal formed by each detector is fed into a neural network for automatic identification.

16. An apparatus, as claimed in Claims 1 to 14, wherein an electrical signal formed by each detector is fed into a look up table for identification.

17. An apparatus, as claimed in any preceding claim, wherein a grating is provided in front of each detector to expose the detector to the correlator signal for predetermined periods of time.

18. An apparatus substantially as illustrated in and/or described with reference to the accompanying drawings.

19. A method, of signal signature analysis, comprising forming at least one

characteristic signature by diffraction of light as a function of a modulating signal, correlating each characteristic signature with a reference signature and representing the magnitude of correlation between each characteristic signature and the reference signature as an electrical signal.

20. A method substantially as illustrated in and/or described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9726694.4
Claims searched: 1-20

Examiner: John Betts
Date of search: 29 May 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G4R (RRQ, RRH) G4G (G900) H4D (DSPJ, DRPK, DLSB, DLFX) F3A (A10A)

Int Cl (Ed.6): G06E 3/00 G06K 9/74 9/76 9//78 9/80 9/82 G01S 7/41 7/539 3/786 17/88 17/89 F41G 7/22

Other: On-line: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2270586 A	(Mytec) see Fig. 1	1, 4--7 12-14, 19
X	GB2258780 A	(Sec. State. Defence) see fig. 1	1, 5-7 12-14, 19
X	GB2130039 A	(Br. Aer.) Whole document	1, 5-7 12-14, 19
X	GB2149257 A	(GEC) whole document	1, 5-7 12-14, 19
X	GB2040036 A	(EMI) whole document	1, 5-7 12-14, 19
X	US4958376	(Grumman) whole document	1, 5-7 12-14, 19

X Document indicating lack of novelty or inventive step
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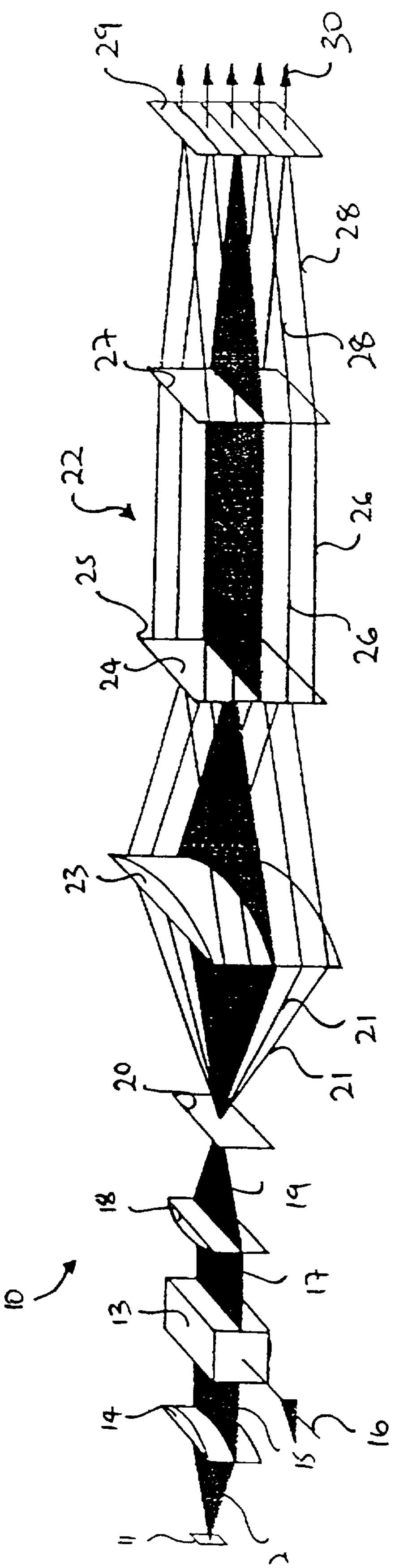
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fig.1.

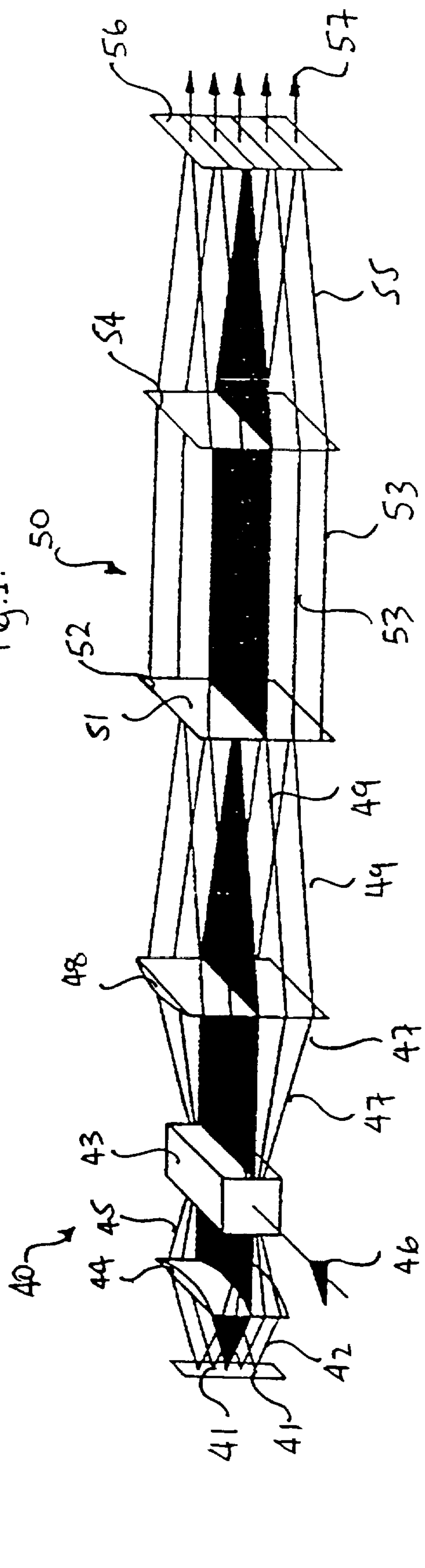
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fig.4.

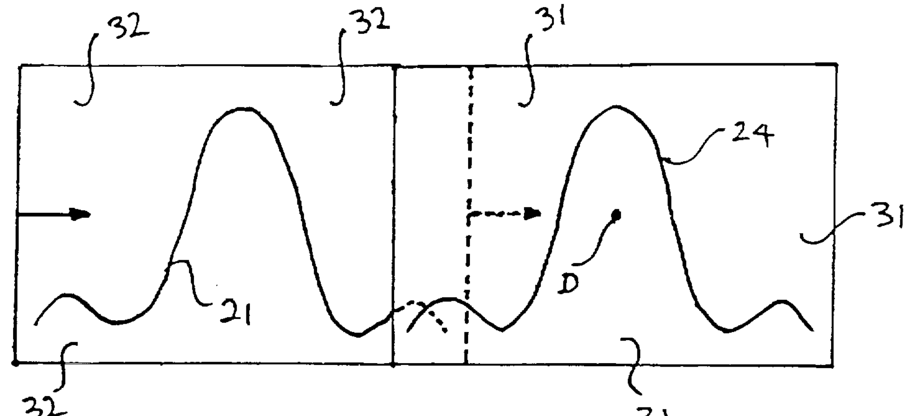

fig. 2

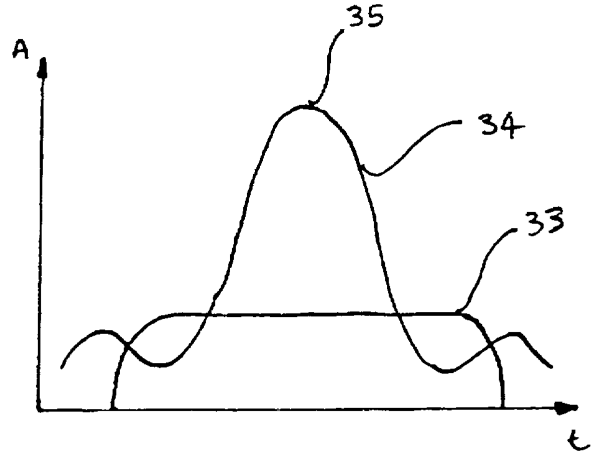

fig. 3

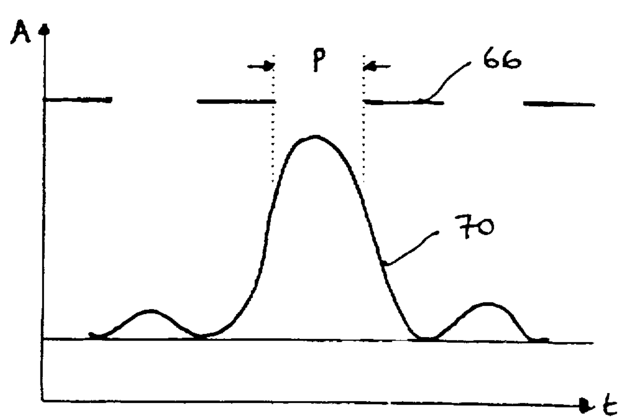

fig. 7a

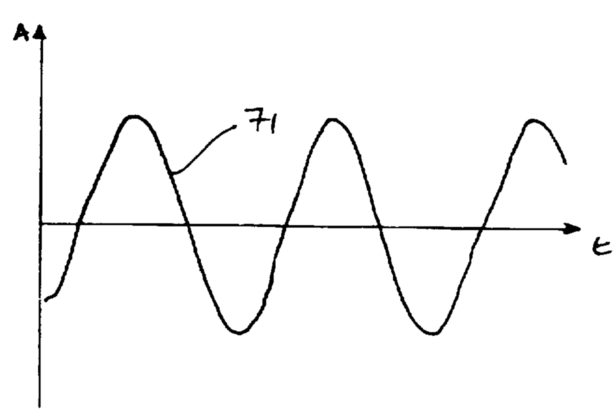

fig. 7b

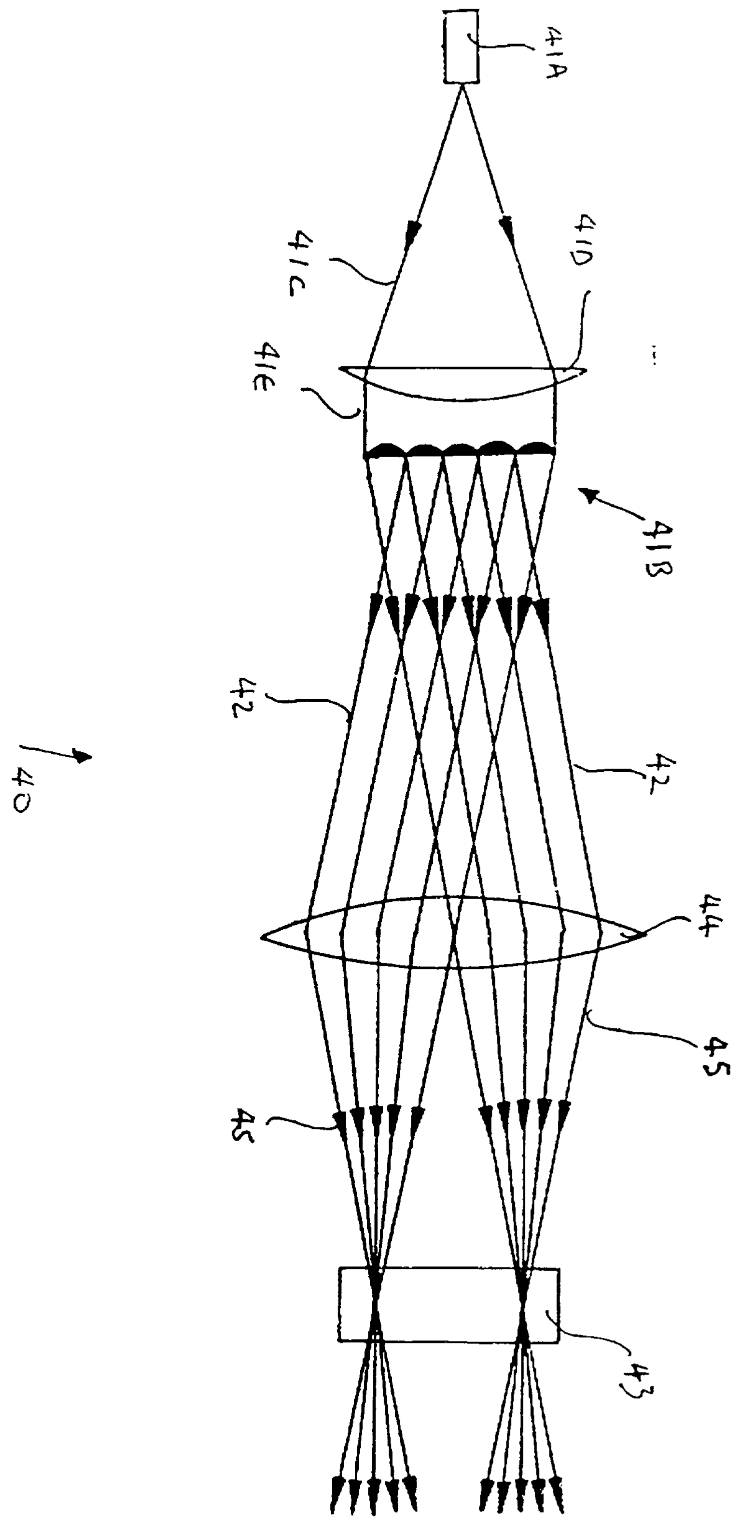

Fig. 5.

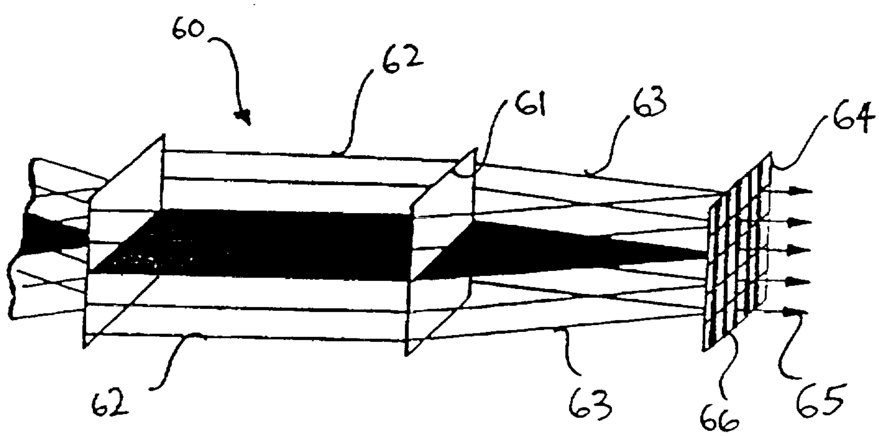

fig. 6.

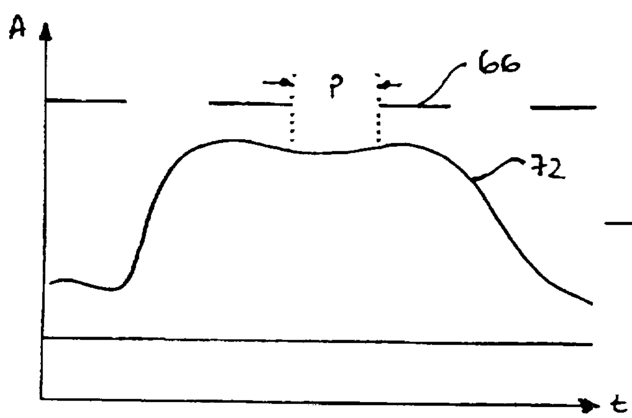

fig. 8a

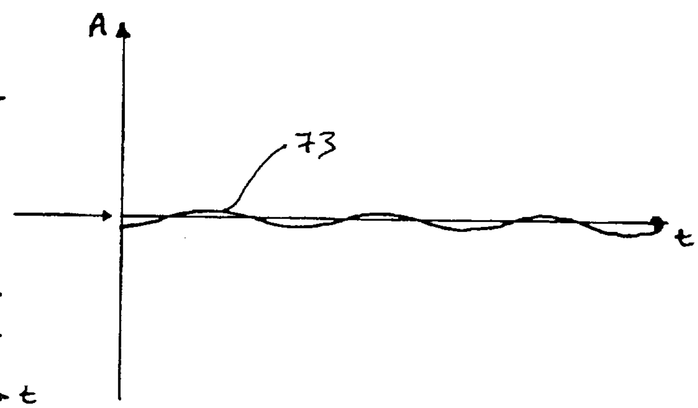

fig. 8b