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Soutar et al.

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[45] **Date of Patent: Apr. 25, 2000**

[54] **METHOD AND APPARATUS FOR IMPROVED SPATIAL LIGHT MODULATION**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics and Space Administration**, Washington, D.C.

[21] Appl. No.: **09/123,016**

[22] Filed: **Jul. 27, 1998**

Related U.S. Application Data

[62] Division of application No. 08/327,762, Oct. 24, 1994, Pat. No. 5,859,728.

[51] **Int. Cl.**[7] **G02F 1/03**; G02F 1/13

[52] **U.S. Cl.** **359/246**; 359/256; 359/276; 359/277; 359/561; 349/18; 349/74; 349/117; 349/118; 349/130

[58] **Field of Search** 359/246, 256, 359/277, 276, 561; 349/18, 74, 117, 118, 130

[56] **References Cited**

U.S. PATENT DOCUMENTS

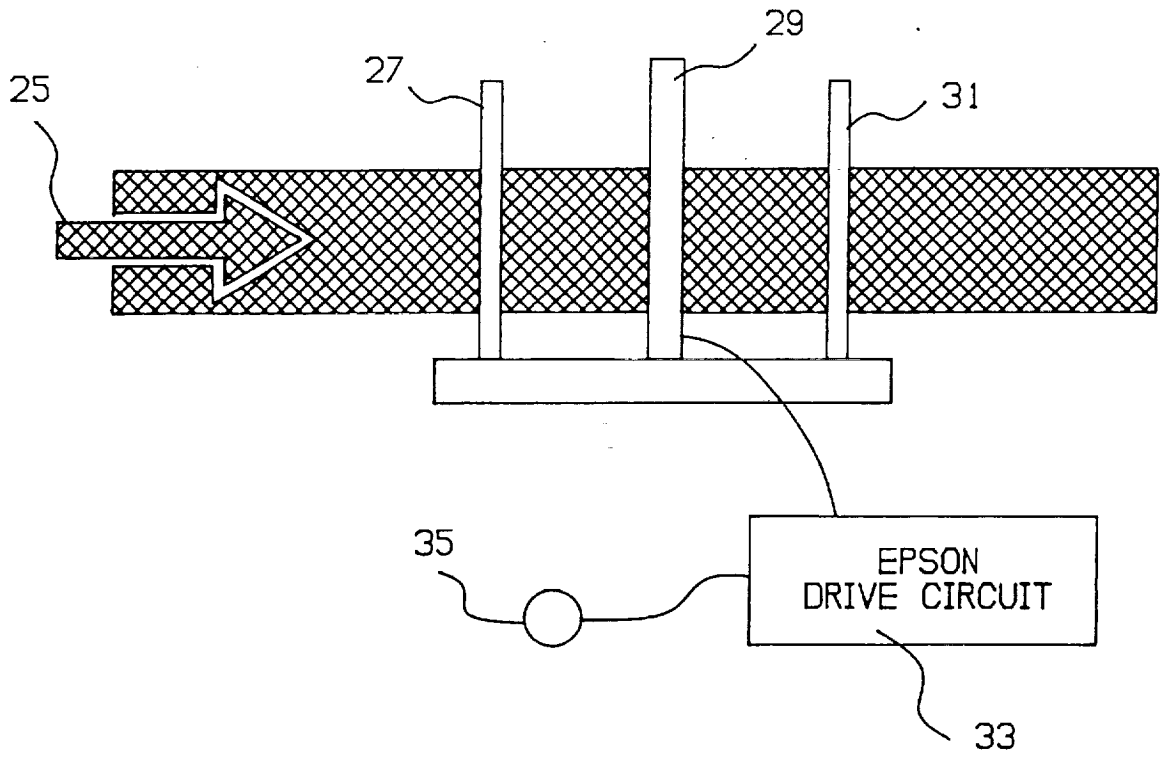
5,412,500 5/1995 Fergason 359/246

Primary Examiner—Georgia Epps
Assistant Examiner—Evelyn A. Lester
Attorney, Agent, or Firm—James M. Cate

[57] **ABSTRACT**

A method and apparatus for modulating a light beam in an optical processing system is described. Preferably, an electrically-controlled polarizer unit and/or an analyzer unit are utilized in combination with a spatial light modulator and a controller. Preferably, the spatial light modulator comprises a pixelated birefringent medium such as a liquid crystal video display. The combination of the electrically controlled polarizer unit and analyzer unit make it simple and fast to reconfigure the modulation described by the Jones matrix of the spatial light modulator. A particular optical processing objective is provided to the controller. The controller performs calculations and supplies control signals to the polarizer unit, the analyzer unit, and the spatial light modulator in order to obtain the optical processing objective.

4 Claims, 14 Drawing Sheets



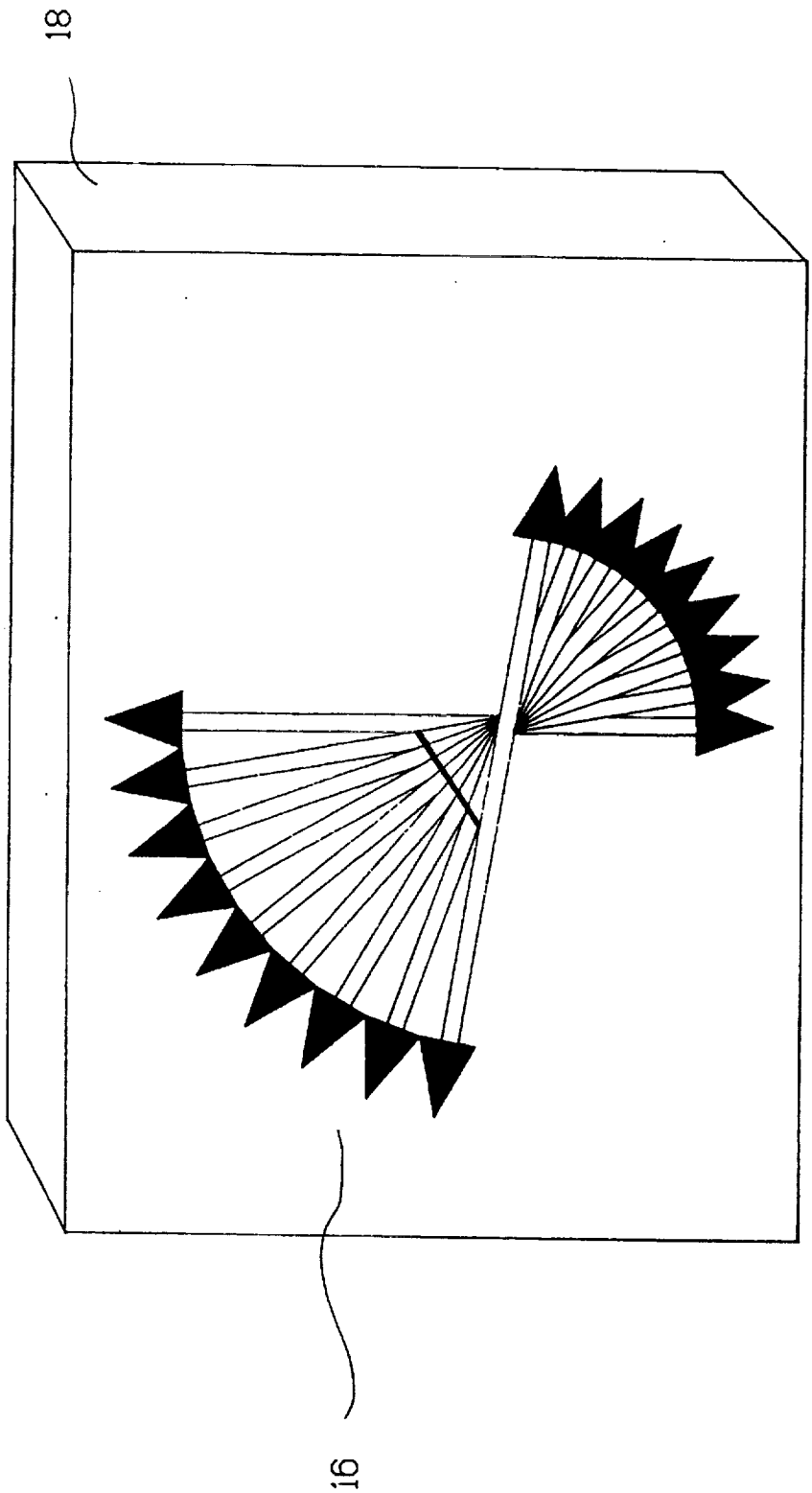


FIG. 1A

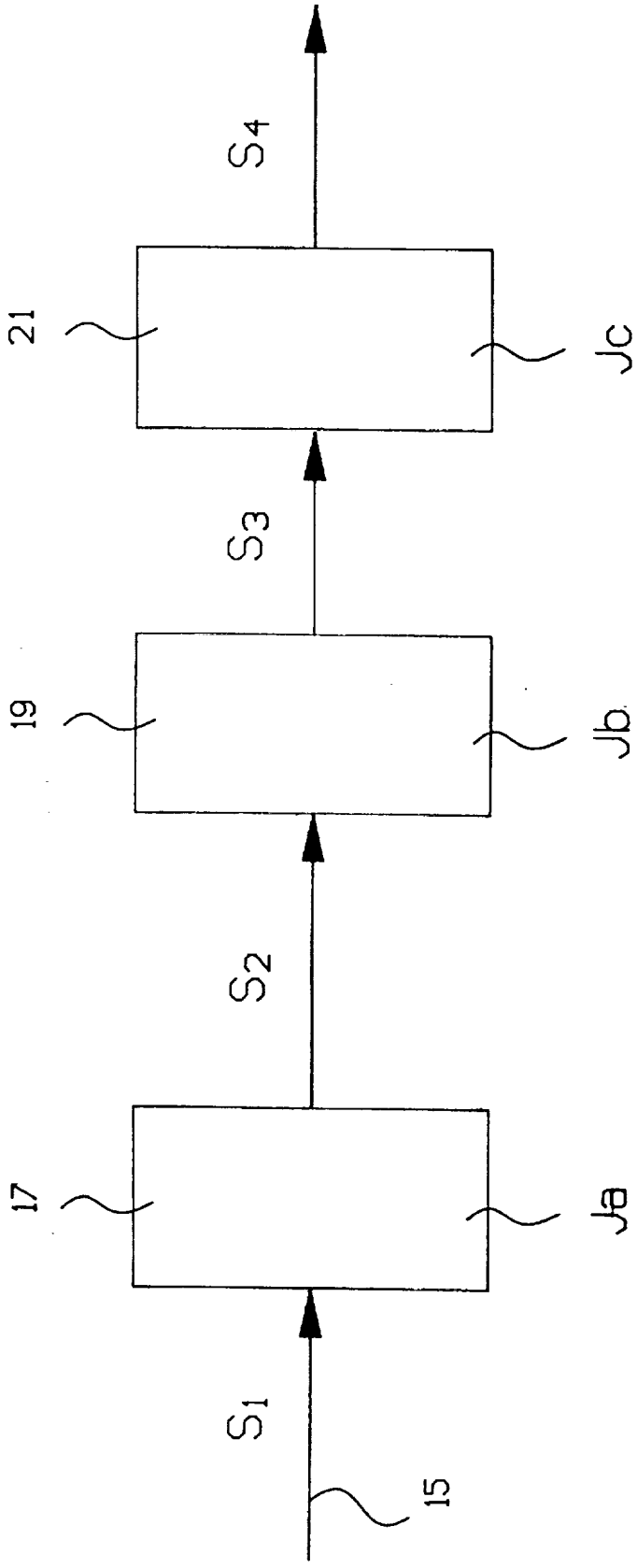


FIG. 1B

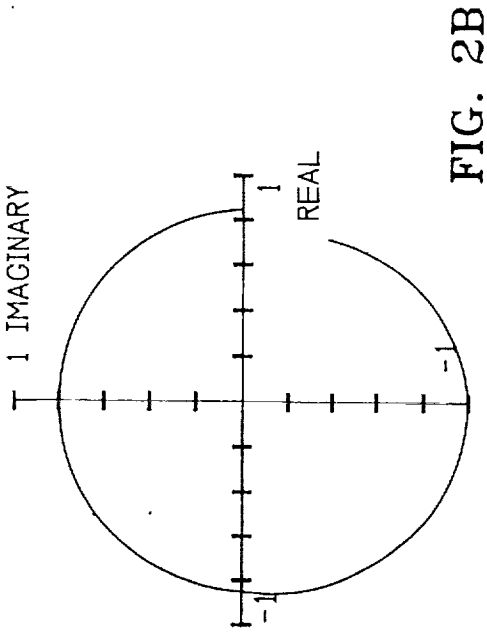


FIG. 2B

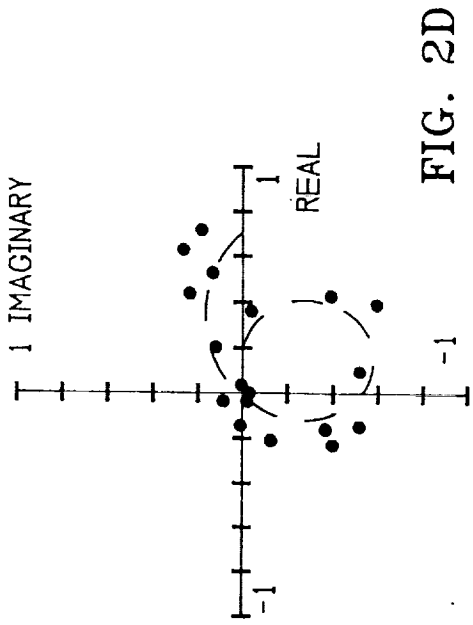


FIG. 2D

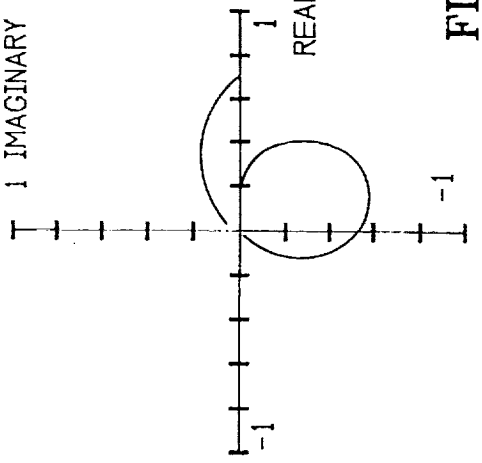


FIG. 2A

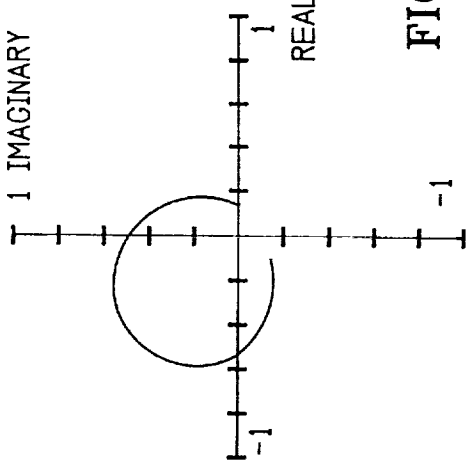


FIG. 2C

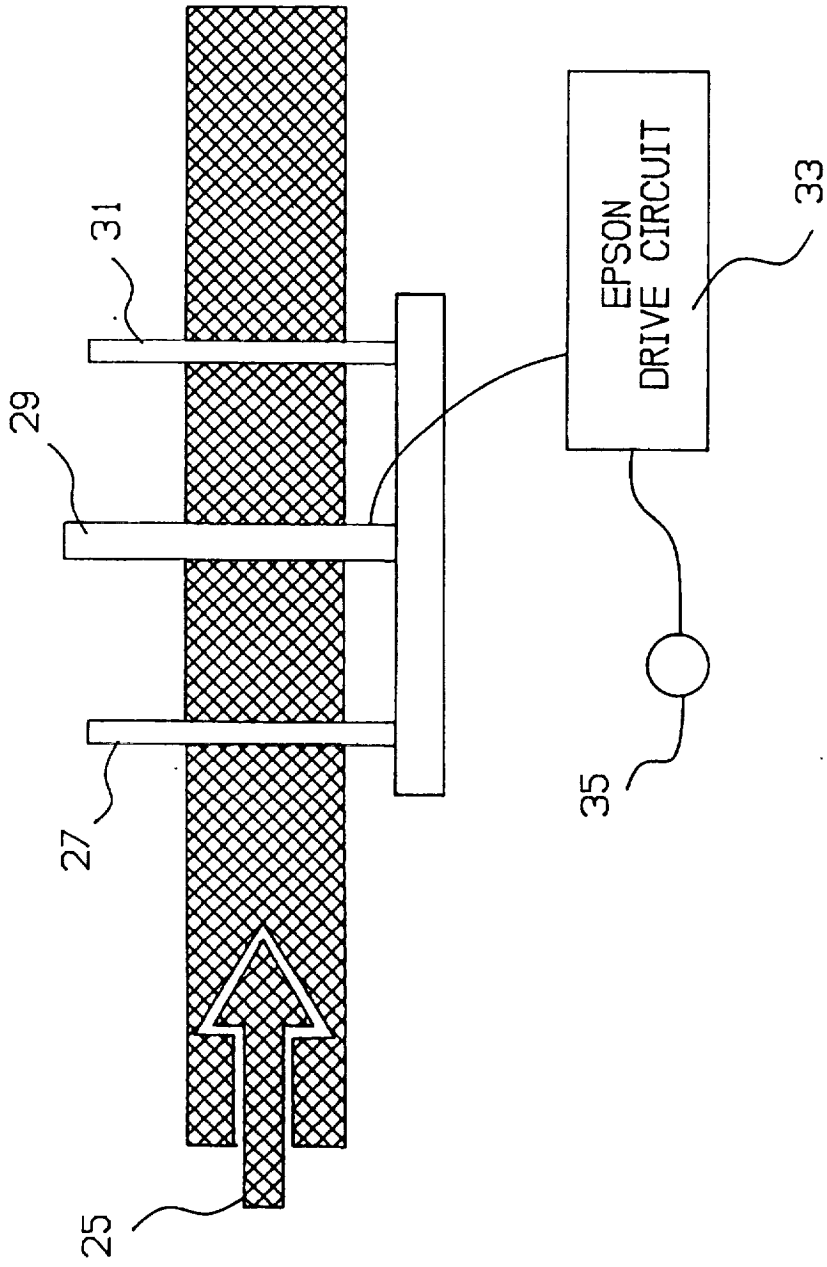


FIG. 3

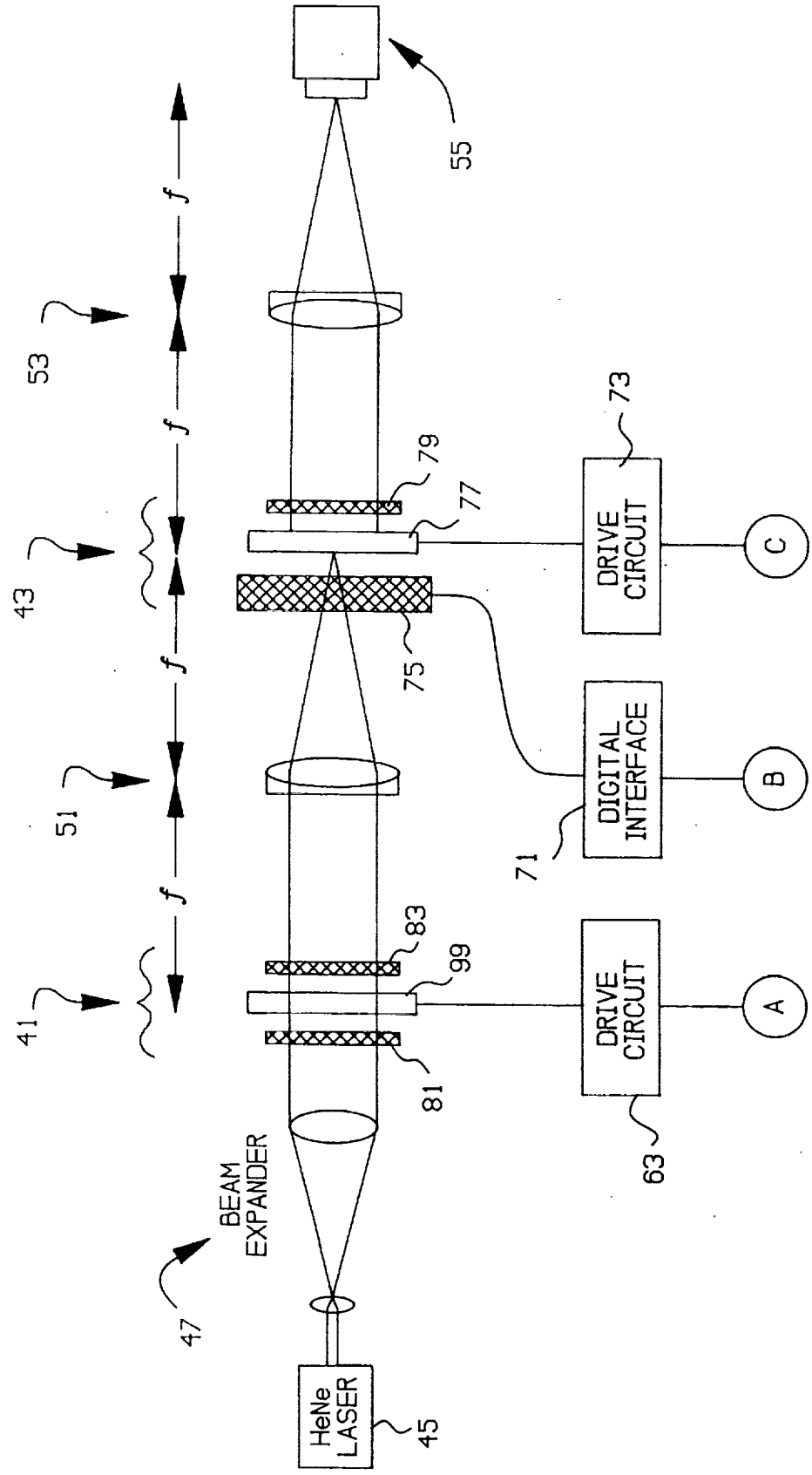
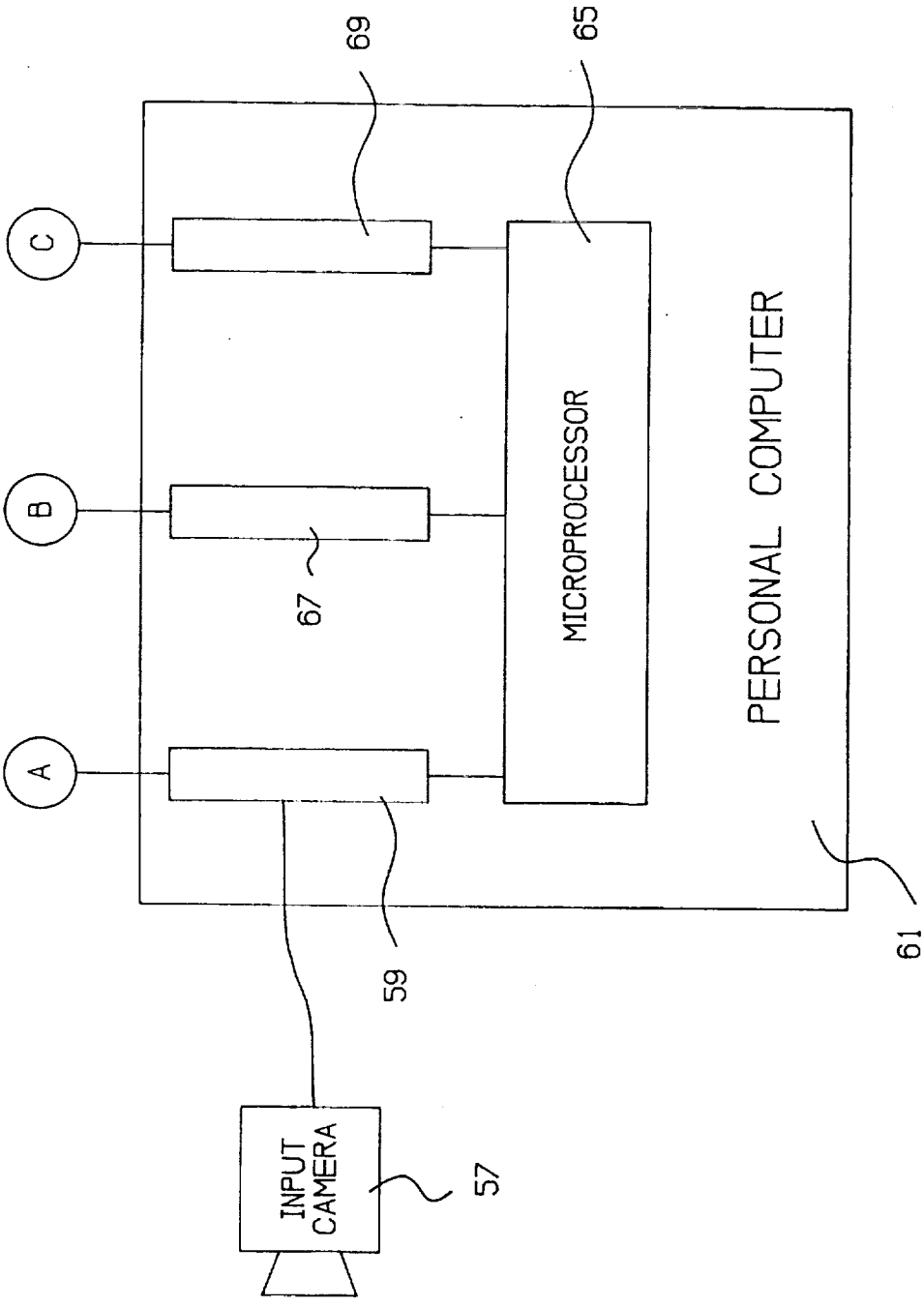

55
53
43
51
41
f
f
f
f
79
77
75
73
DRIVE CIRCUIT
C
DIGITAL INTERFACE
B
71
83
99
81
DRIVE CIRCUIT
A
63
BEAM EXPANDER
47
HeNe LASER
45

FIG. 4A

FIG. 4B


69
65
C
B
A
67
MICROPROCESSOR
PERSONAL COMPUTER
59
61
INPUT CAMERA
57

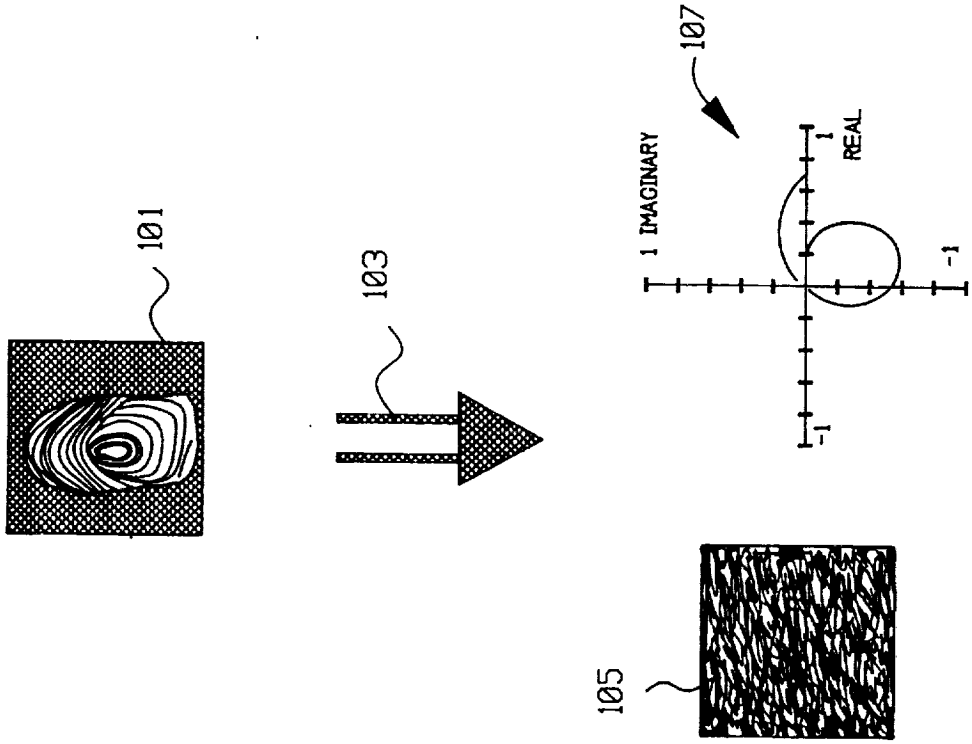

101
103
107
1 IMAGINARY
1
REAL
-1
-1
105

FIG. 5B

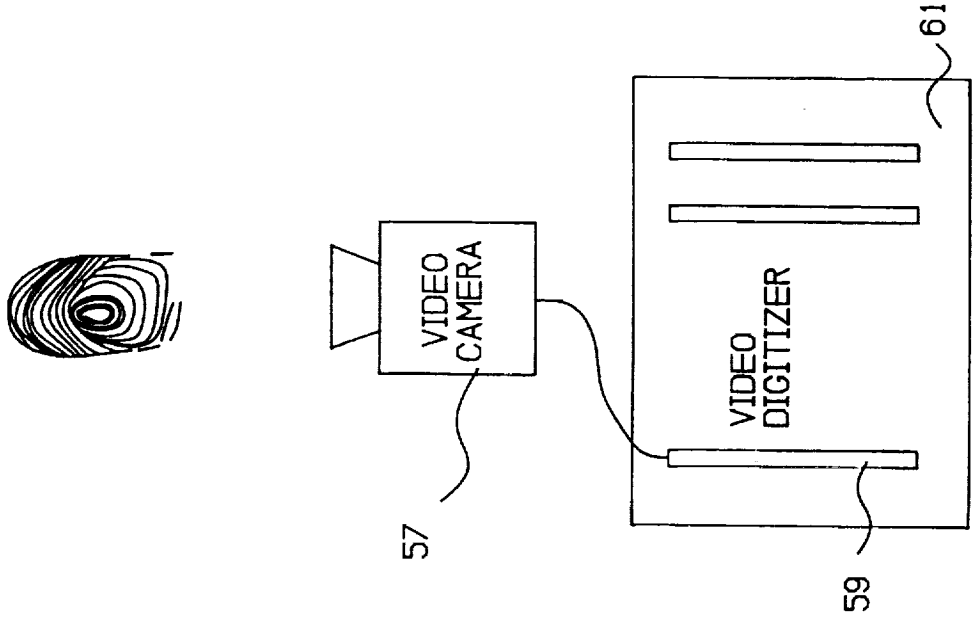

1
VIDEO CAMERA
57
VIDEO DIGITIZER
61
59

FIG. 5A

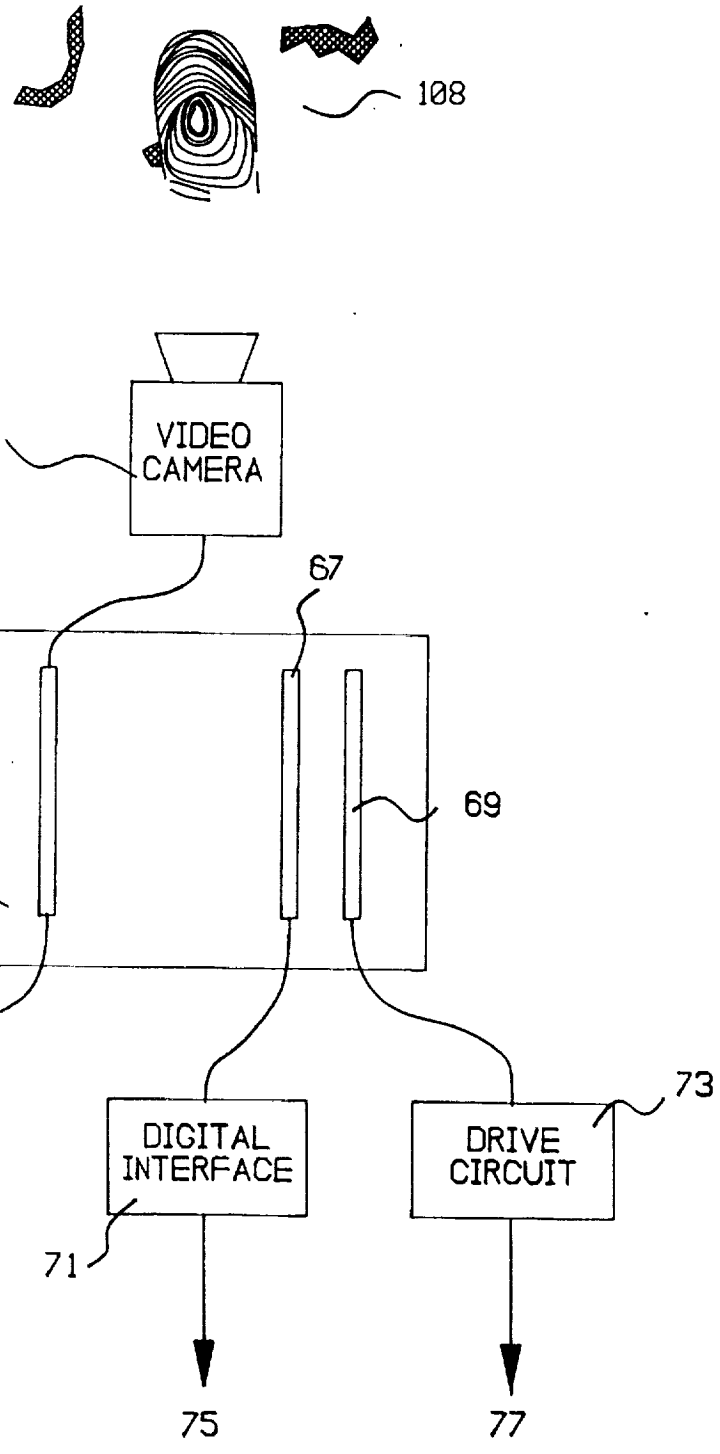

108
57
VIDEO CAMERA
67
69
61
63
DRIVE CIRCUIT
DIGITAL INTERFACE
71
DRIVE CIRCUIT
73
41
75
77

FIG. 5C

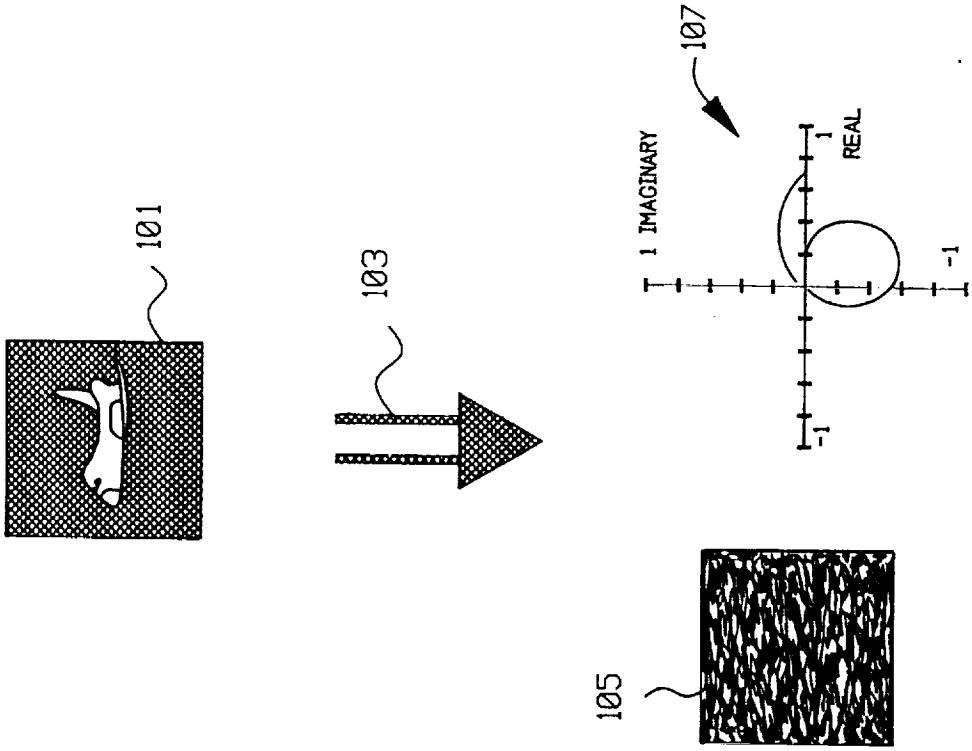

101
103
107
1 IMAGINARY
1
REAL
-1
-1
105

FIG. 5E

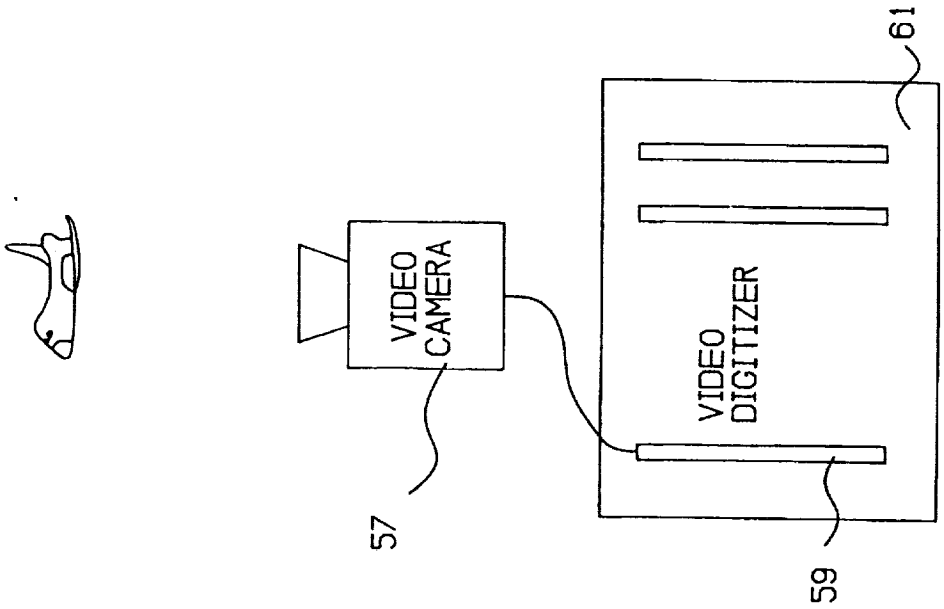

VIDEO CAMERA
VIDEO DIGITIZER
61
57
59

FIG. 5D

109

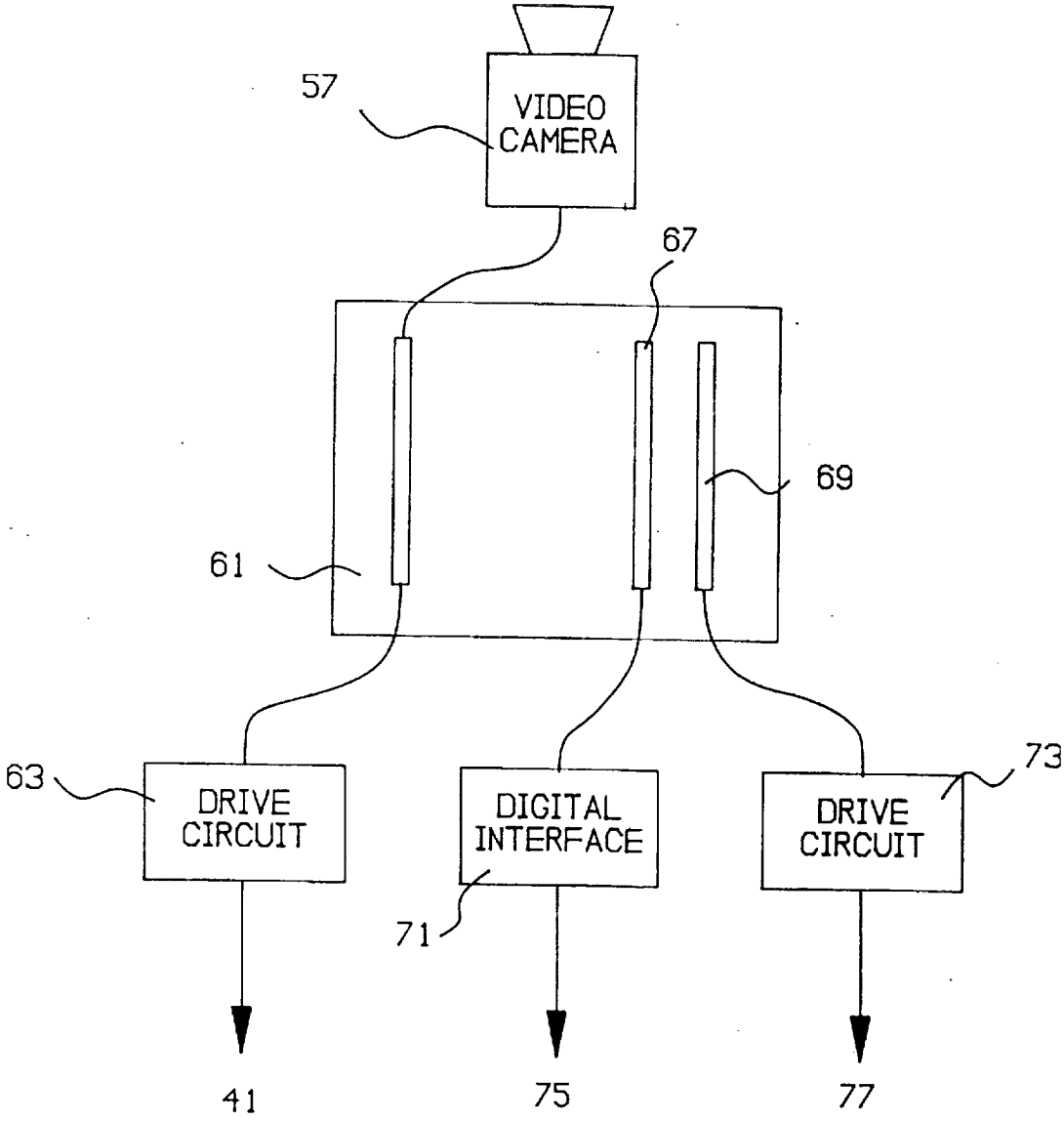

57
VIDEO CAMERA
67
69
61
63
DRIVE CIRCUIT
DIGITAL INTERFACE
71
DRIVE CIRCUIT
73
41
75
77

FIG. 5F

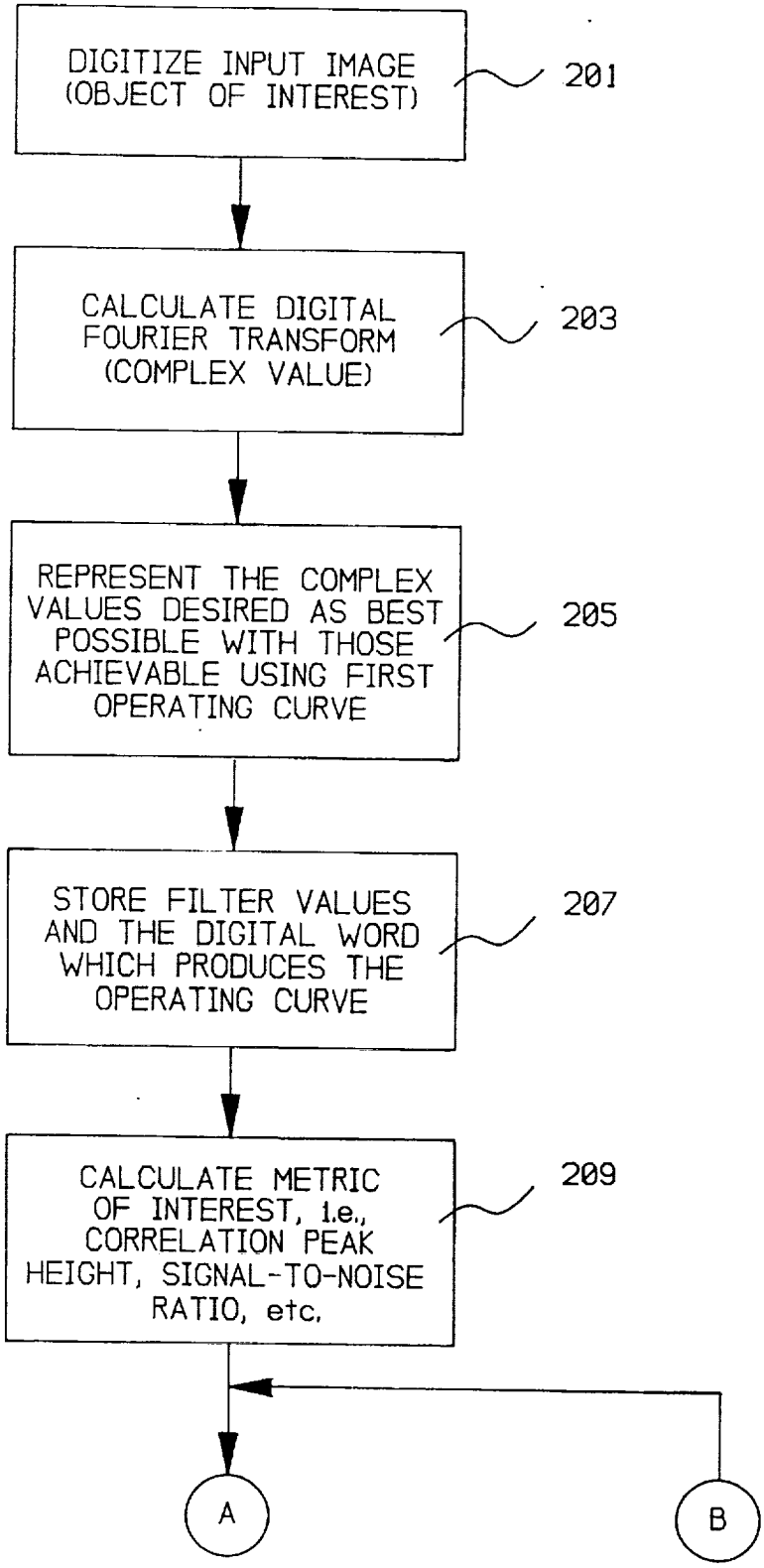

DIGITIZE INPUT IMAGE (OBJECT OF INTEREST)
201
CALCULATE DIGITAL FOURIER TRANSFORM (COMPLEX VALUE)
203
REPRESENT THE COMPLEX VALUES DESIRED AS BEST POSSIBLE WITH THOSE ACHIEVABLE USING FIRST OPERATING CURVE
205
STORE FILTER VALUES AND THE DIGITAL WORD WHICH PRODUCES THE OPERATING CURVE
207
CALCULATE METRIC OF INTEREST, i.e., CORRELATION PEAK HEIGHT, SIGNAL-TO-NOISE RATIO, etc.
209
A
B

FIG. 6A

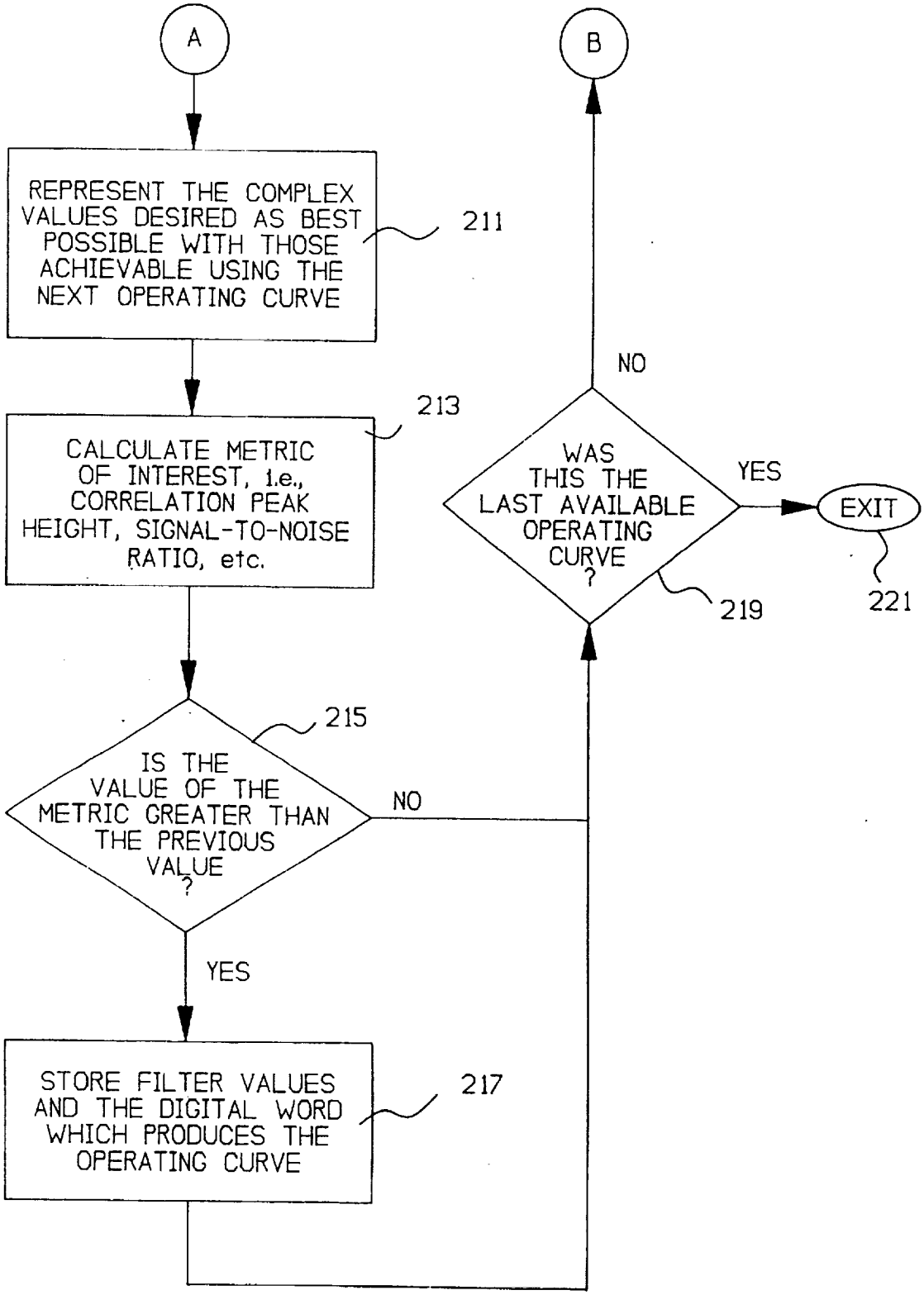

A
B
REPRESENT THE COMPLEX VALUES DESIRED AS BEST POSSIBLE WITH THOSE ACHIEVABLE USING THE NEXT OPERATING CURVE
211
CALCULATE METRIC OF INTEREST, i.e., CORRELATION PEAK HEIGHT, SIGNAL-TO-NOISE RATIO, etc.
213
IS THE VALUE OF THE METRIC GREATER THAN THE PREVIOUS VALUE ?
215
NO
YES
STORE FILTER VALUES AND THE DIGITAL WORD WHICH PRODUCES THE OPERATING CURVE
217
WAS THIS THE LAST AVAILABLE OPERATING CURVE ?
219
NO
YES
EXIT
221

FIG. 6B

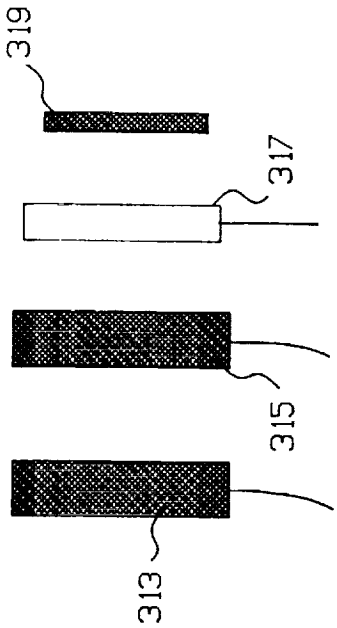


FIG. 7C

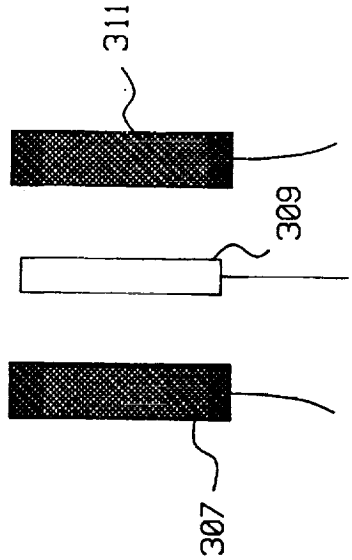


FIG. 7B

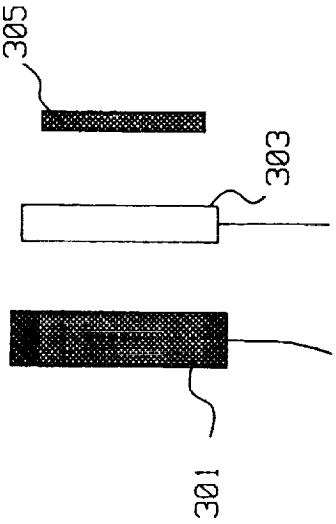


FIG. 7A

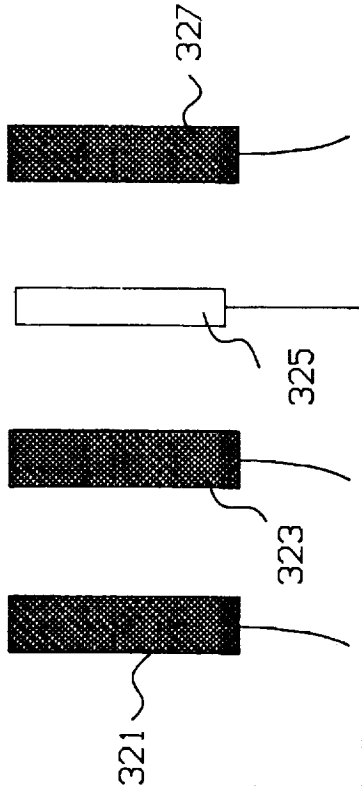


FIG. 7D

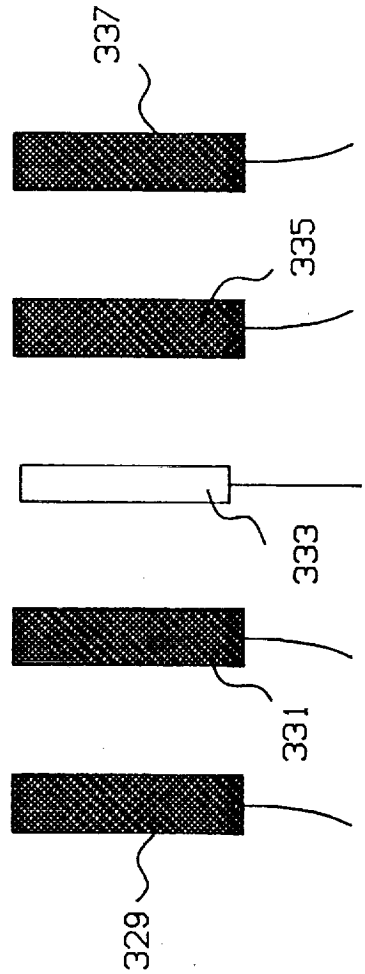


FIG. 7E

METHOD AND APPARATUS FOR IMPROVED SPATIAL LIGHT MODULATION

This is a division of application Ser. No. 08/327,762, filed Oct. 24, 1994, now U.S. Pat. No. 5,859,728.

ORIGIN OF THE INVENTION

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates in general to optical processing systems, and in particular to an improved method and apparatus for modulating a light beam in an optical processing system.

2. Description of the Prior Art

Many optical processing systems utilize spatial light modulators to encode and/or filter information onto or from a light beam, typically a coherent laser beam. These spatial light modulators operate by modulating a light beam in two dimensions by changing the intensity and/or phase of the light wave in a controllable manner. Thus, they can be used to introduce spatial patterns onto a light beam. The commercially available spatial light modulators however tend to be expensive. As a consequence, many optical processing systems utilize liquid crystal video displays as an inexpensive and readily available alternative to spatial light modulators. They may be obtained from commercially-available color video projector units, such as the Crystal Image Video Projector unit Model No. E1020, manufactured by Epson. Such projector units have a reasonable optical quality insofar as they are spatially uniform. Furthermore, each liquid crystal display is individually electrically addressable. The displays are typically driven utilizing a specialized electronic drive circuit which is supplied with the projector unit. The drive circuit acts as an interface between an analog video signal and the two dimensional matrix of pixels which make up the liquid crystal video display at that particular pixel. The voltage across each pixel of the liquid crystal video display is proportional to the gray scale level at the corresponding location in the video display. Typically, the liquid crystal video displays are twisted-nematic liquid crystal devices, which means that the optical birefringent axes, caused by the anisotropy of the liquid crystal molecules, rotate throughout the thickness of the cell, in a manner similar to that depicted in FIG. 1A. The birefringence is altered or modulated by the application of the drive voltage (which is derived from the video signal) across a pixel. This change in the birefringence causes a change in the polarization state of any light beams which pass through the liquid crystal video display. If the liquid crystal video display is disposed between two polarizing optical instruments, the polarization modulation is converted to amplitude or phase modulation of the light beam. It is the amplitude and/or phase modulation of a light beam which allows for the processing of images. More specifically, the amplitude and/or phase modulation can be utilized for either encoding information onto the light beam, or for filtering or otherwise manipulating information on the light beam. Since the interaction between the light beam and the liquid crystal video display is fairly complicated, a simple amplitude-only modulation or phase-only modulation is not possible.

The liquid crystal video displays are merely one type of "complex spatial light modulator" which are utilized in optical processing systems. A complex spatial light modulator can be characterized as an optical processing device whose action on a light beam may be expressed as affecting the phase and amplitude (or alternately, the real and imaginary parts) of an incident light beam. Typically, spatial light modulators, such as the liquid crystal video display, are useful for optical processing of images as a function of position over the active area of the optical processing device. While liquid crystal displays may be electrically addressed on a pixel-by-pixel basis, other types of complex spatial light modulators are addressable as a continuous function of position. For purposes of the present application, the terms "complex spatial light modulator" and "spatial light modulator" will define all optical devices which affect the phase and amplitude of an incident light beam; however, the preferred embodiment discussed herein will specifically refer to a liquid crystal video display, which is merely one type of complex spatial light modulator.

The prior art devices used for generating and analyzing specific polarization states include one device developed by J. L. Pezzaniti and R. A. Chipman which permits the automated measurement of the Meuller matrix of a spatial light modulator. This device is described in detail in the following publications:

J. L. Pezzaniti and R. A. Chipman, "Phase-only Modulation Of A Twisted Nematic Liquid-Crystal TV By Use Of The Eigenpolarization States", Optics Letters vol. 18, pp. 1567–1569 (September 1993); and

J. L. Pezzaniti, R. A. Chipman, and D. A. Gregory, "Polarization Characterization Of A LCTV With A Meuller Matrix Imaging Polarimeter", in Optical Pattern Recognition IV, D. Casasent, ed., Proc. SPIE vol. 1959, pp. 266–281 (1993).

J. L. Pezzaniti, Meuller Matrix Imaging Polarimetry, PhD Thesis, University of Alabama in Huntsville (1993).

A major distinction of the present invention from the Pezzaniti and Chipman device is that the Pezzaniti and Chipman device requires gross physical motion (rotation) of polarizers and retarders in order to generate and analyze its set of polarization states. Another distinction of the present invention is its preferred embodiment as a laboratory bench tool to characterize the polarization properties of spatial light modulators, as opposed to the present invention's major operational intent of providing immediate access to any of a plurality of different polarization behaviors. Accordingly, itis slower, more accurate, more stable, bulkier, heavier, more complicated, and more precise that the present invention.

SUMMARY OF THE INVENTION

It is one objective of the present invention to utilize the rather large number of different operating characteristics which are possible with complex spatial light modulators in order to achieve particular optical processing objectives.

Still more particularly, itis another objective of the present invention to utilize a complex spatial light modulator in combination with at least one of (1) a polarizer unit, and (2) an analyzer unit, which has an optical effect on the light beam, which either is incident to the complex spatial light modulator or emergent from the complex spatial light modulator, in a manner which is determined by one or more electrical control signals provided by a controller.

It is a still more particular objective of the present invention to utilize the controller in order to respond to a provided optical processing objective by examining a predetermined number of optical transform options available

through the control parameters which may be provided to one or more of the complex spatial light modulator, a polarizer unit, and an analyzer unit.

These and other objectives are achieved as is now described. The present invention may be characterized as either a method or apparatus for processing a light beam. At least one of a polarizer unit and an analyzer unit are provided. The polarizer unit polarizes an incident light beam in a selected one of a plurality of available polarization states in response to receipt of at least a selected one of a plurality of available electrical command signals. The analyzer unit selects from an incident light beam one of a plurality of available polarization states in response to receipt of at least a selected one of a plurality of available electrical command signals. A spatial light modulator is provided for receiving an incident light beam and modulating the incident light beam by converting one polarization state into another in accordance with an optical polarization transform associated with an operating range of at least one drive parameter for the spatial light modulator. Additionally, a controller member is provided for supplying control signals to at least one of the polarizer unit and the analyzer unit. The controller member also supplies at least one drive parameter value to the spatial light modulator. A light beam is passed through the spatial light modulator and at least one of the polarizer unit and the analyzer unit. A particular optical processing objective is provided to the controller member, and the controller member is utilized to supply the control signals to at least one of the polarizer unit and the analyzer unit, and to supply at least one drive parameter value to the spatial light modulator, in a manner which obtains or achieves the optical processing objective.

Additional objectives, features and advantages will be apparent in the written description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. **1**A depicts the changing direction of the extraordinary birefringent axis of light through the thickness of an LCD screen;

FIG. **1**B is a block diagram of light propagating through linear optical elements including their Jones matrices;

FIGS. **2**A–**2**C each is a graph of selectable operating curves according to the present invention;

FIG. **2**D is a graph of hypothetical ideal complex filter values according to the present invention, in which it is seen that the ideal values (dots) conform more closely to the curve of FIG. **2**A than to either of the others;

FIG. **3** depicts a block diagram of a spatial light modulator according to the present invention;

FIGS. **4**A and **4**B depict a block diagram of an optical correlator system according to the present invention;

FIG. **5**A depicts the first stage of operation of the optical correlator as depicted in FIGS. **4**A and **4**B for use in fingerprint identification;

FIG. **5**B further depicts the operation of the optical correlator according to FIGS. **4**A and **4**B used in fingerprint identification;

FIG. **5**C depicts the final stage of operating optical correlator of FIGS. **4**A and **4**B as used in FIGS. **5**A–**5**B;

FIGS. **5**D, **5**E, and **5**F depict the use of the optical correlator of FIGS. **4**A and **4**B in aircraft and spacecraft tracking operations;

FIGS. **6**A and **6**B depict a flowchart for computing the optimal use of the spatial light modulation method according to the present invention; and

FIGS. **7**A–**7**E depict different embodiments which may be used in the optical correlator system of FIGS. **4**A and **4**B.

DETAILED DESCRIPTION OF THE INVENTION

Before discussing the particular details of the present invention, a brief overview of optical processing components and the related Jones calculus will be provided. Linear polarizers are devices which transmit a component of an incident electromagnetic electric field in the direction of its "transmission axis", and which block the component of the electromagnetic electrical field which is orthogonal to its "transmission axis". This preferential passing of components of an electric field can be achieved by selective absorption, selective reflection from an isotropic medium, or selective reflection/refraction at the boundary of an anisotropic medium. "Wave retarders" are characterized by a retardation amount, and the orientation of a "fast axis" and a "slow axis". Upon transmission through a retarder, a relative phase shift between the orthogonal components of the electric field in the light beam occurs. "Polarization rotators" are utilized to rotate the plane of rotation of linearly polarized light by a fixed angle, while maintaining its linearly polarized nature. Optical "analyzers" are utilized to selectively transmit light which is polarized in only one orientation, thus acting as a valve or filter. A "spatial light modulator" is a device that modulates light at different positions by predefined factors. Typically, it is a planar optical element of controllable intensity transmittance and/or relative phase shift. The emergent light at each location can be characterized by the product of the Jones matrix describing the optical properties of the spatial light modulator times the Jones vector describing the polarization state of the light input to the modulator. When a pixelated liquid crystal video display is utilized as a spatial light modulator, each pixel of the liquid crystal video display may be described in terms of an optical transform, typically in terms of the Jones matrix for the pixel. Commercially available liquid crystal video displays typically utilize twisted-nematic liquid crystal cells placed between two parallel glass plates and rubbed so that the molecular orientation rotates about a helix normal to the plates, which is defined as the "axis of twist". When an electric field (which is created by one or more drive voltages applied to the pixel) is applied in the direction of the axis of twist, the molecules tilt toward the field. When the molecules are tilted at ninety degrees, the polarizing effect of the liquid crystal cells is eliminated. If the electric field is removed, the orientation of the crystal layers near the glass dominate, thereby causing the molecules to return to their original upright state, causing the polarization effect to be regained. FIG. **1**A graphically depicts changing direction of the extraordinary birefringent axis **16** of light through the thickness of a liquid crystal video display **18**.

An optical processing component may be characterized mathematically in the terms of a Jones matrix. Jones matrices describe the effects of mathematically linear optical polarizing elements. Table I which is appended hereto provides Jones matrices for a variety of rather simple and conventional optical devices, including linear polarizers,

quarter-wave retarders, half-wave retarders, isotropic retarders, relative phase changers, and circular polarizers. In the table, where applicable, a plurality of different "orientations" are defined for each type of optical device. The table also includes a Jones matrix which defines the effect of the optical device at the particular defined orientation. When light is propagated through mathematically linear optical polarizing elements, the light wave's polarization state is sequentially multiplied by the optical elements' Jones matrices. This can best be described with reference to FIG. **1B**. The polarization state of light beam **15** is defined by polarization states S_1, S_2, S_3, and S_4, wherein S_1 represents the polarization state of light which is incident to optical processing device **17** which has a Jones matrix of J_a. The light which emerges from optical processing device **17** has a polarization state of S_2 which is the vector product of the polarization state S_1 and the Jones matrix J_a. The polarization state of the light incident to optical processing device **19** is S_2. The optical effect of optical processing device **19** is represented by Jones matrix J_b. The light emergent from optical processing device **19** has a polarization state of S_3 which is the vector product of the polarization state S_2 and the Jones matrix J_b. The polarization state of light incident to optical processing device **21** is S_3. The Jones matrix associated with optical processing device **21** is represented by Jones matrix J_c. The polarization state of the light emerging from optical processing device **21** is S_4 which is the vector product of the polarization state of the incident light S_3 and the Jones matrix J_c. Since these optical processing devices **17**, **19**, **21** are mathematically linear, the composite optical effect of optical devices **17**, **19**, **21** is the matrix product of Jones matrices J_c, J_b, and J_a, vector multiplied with the polarization state of the incident light S_1. Therefore: the emergent light S_4 equals $J_c \cdot J_b \cdot J_a \cdot S_1$.

In the context of the preferred embodiment of the present invention, optical processing device **17** comprises a compound polarizer, optical processing device **19** comprises a pixelated spatial light modulator, and optical processing device **21** comprises a compound analyzer. The compound polarizer and compound analyzer may be defined by rather simple Jones matrices such as those set forth in Table 1 (and the Jones vectors for some types of polarization on which the matrix operates can be described as set forth in Table 2); however, the operation of a pixelated spatial light modulator, such a optical processing device **19**, is rather more complicated, with each pixel of the spatial light modulator defining a different optical transform which affects the polarization state of the light incident to the spatial light modulator in a manner which is dependent upon one or more control voltages which are applied to the spatial light modulator to effect a pixel-by-pixel spatial modulation of light beam **15**. Also, typically with analog polarization spatial light modulator devices, the Jones matrix for each pixel represents a range of the available optical transforms, dependent upon the drive voltage or voltages which are available.

In the preferred embodiment of the present invention, the compound polarizer preferably comprises a linear polarizer, a polarization rotator, and a retarder, as will be discussed in further detail herebelow. Additionally, in the preferred embodiment of the present invention, the compound analyzer comprises a retarder, a polarization rotator, and a linear polarizer. In various alternative embodiments of the present invention, certain elements of the compound polarizer and compound analyzer may be omitted. Additionally, in still other embodiments, either the compound polarizer or compound analyzer may be omitted in its entirety. Also, preferably, in the present invention, the compound polarizer and compound analyzer are uniform over their active areas, which stands in contrast with the preferred spatial light modulator which is preferably a pixelated spatial light modulator with independent action at each pixel. However, in alternative embodiments, non-pixelated spatial light modulators may be utilized.

In the preferred embodiment of the present invention, the combined controller-implemented selection of Jones matrices optical transforms for the pixels of the spatial light modulator, the polarization effect of the compound polarizer, and the selection effect of the compound analyzer are utilized to obtain a particular one of a plurality of available transform operating curves, in order to obtain some optical processing objective.

In the preferred embodiment of the present invention, the improved spatial light modulator comprises in sequence a compound polarizer, the spatial light modulator itself, and a compound analyzer. It uses the pixellation of the Jones matrix spatial light modulator to provide spatial variation in the optical processing. The combination of the compound polarizer and the compound analyzer may be used to obtain a desired member of a family of operating curves in order to achieve a particular data processing objective.

Ordinarily a spatial light modulator may modulate light by varying its Jones matrix J_b at each pixel. Ordinarily, the Jones matrix will be controlled by a single control parameter, such as voltage across the liquid crystal cell, so the set of input polarization states S_2 in Cartesian product with the resultant output polarization states S_3 is accordingly limited. The purpose of the present invention is to allow a wide latitude in selecting from the family of possible input/output combinations, and also to make such selection easily, efficiently, and rapidly accomplished.

Again, with reference to FIG. **1B**, the polarization state S_2 is determined by the first compound element. Not just any input state S_1 will pass through the first compound element without losing energy to the compound element. The matrix J_a describes the selection of part of the state S_1 that passes through the compound polarizer and appears as S_2. Similarly, the component state of S_3 that will pass the second compound element without being blocked, thus appearing as S_4, is determined by the compound analyzer, which is described by matrix J_c. The action of J_b of the Jones matrix modulator is to connect the polarization states S_2 and S_3, with further aspects of the S_1 to S_4 modulation being determined by J_a and J_c. Thus, if we can easily change J_a and J_c, we can easily change the overall effective Jones matrix J. Typically, with analog spatial light modulators of the Jones-matrix type, there is a family of curves available. More particularly, the Jones matrix at each pixel is a function of one or more drive voltages applied to that pixel.

If we consider the case where S_1 and S_4 are similar polarization states, as determined by the values of the component elements of the compound polarizer and the compound analyzer, then the action of J may clearly be seen to be expressed as a complex scalar, so its behavior is immediately plotted in the complex plane. If S_1 and S_4 are different polarization states, even though J is a complex matrix, its voltage-controlled action will change the phase and amplitude of the light in the analyzed state S_4, and thus the combination of compound analyzer, spatial light modulator and compound polarizer may be regarded as affecting both the amplitude and phase of S_4 so again the assembly may be regarded as a complex spatial light modulator.

In optical information processing, it is important to have spatially localized control of the light. For example, in

optical correlator pattern recognition operations, a spatial light modulator is used to encode the signal pattern into the light beam at the input location, and similarly a spatial varying effect is implemented at the filter location. Spatially distributed control of the pixelated modulator is one key to having a spatial light modulator. Since J_b may have differing values at different locations on the modulator, so also may J vary across its face. A significant point of the present invention is that the compound spatial light modulator may be used in any location where light is to be modulated as a function of spatial position. In a serial correlator architecture, sometimes known (slightly erroneously) as a VanderLugt architecture, one might place a compound spatial light modulator in accordance with the present invention in both the input plane and the filter plane, or in either one.

As was stated above, the mode of operation of a twisted-nematic liquid crystal video display produces many interesting characteristics, which modulate both intensity and phase. Graphically, the optical effect of a particular pixel in a liquid crystal video display can be represented as a curve traced out in the complex plane. This is so because the modulation is complex, modulating both amplitude and phase together, but is restrained to a single path in the complex plane. We may call this path the "operating curve" of the device. These operating curves are determined by measuring the amplitude and phase modulation as a function of a particular drive parameter: the parameter that is varied to change the voltage across each pixel. In the preferred liquid crystal video displays utilized in the present invention, this voltage is representative of a gray scale value for the pixel which extend from a gray scale value of 0 to a gray scale value of 255. The plot produced is of the function:

$$(T)^{1/2}*\sin(S)\text{versus}(T)^{1/2}\cos(\delta);$$

where T represents the intensity transmission, and delta represents the phase-shift produced at each gray scale level. An example of such a plot is shown in FIG. **2**A. To produce the appropriate amount of complex modulation, the relevant gray scale level is configured in a digitizer board and the liquid crystal video display produces one of the points on the curve, which we may consider to be points which are "realizable". It is important to note that only points on the operating curve can be represented exactly in this operating mode of the liquid crystal video display. Any of the complex values of modulation can be approximated using only those values which are "realizable".

FIG. **3** is a representation of the preferred embodiment of the present invention, with laser beam **25** providing a coherent light which is passed first through polarizer unit **27**, the liquid crystal television **29**, and finally through analyzer **31**. A video signal **35** is provided to a drive circuit **33** for liquid crystal television **29** in order to provide a spatial pattern which is modulated on laser beam **25**. Polarizer unit **27** determines the state of the linear polarization of the light that is incident to liquid crystal television **29**. This polarization is then modified to a certain degree by the voltage-sensitive birefringence caused by changing the voltage across the pixels of the liquid crystal television **29**. Then, the analyzer unit **31** selects a component polarization state of the emergent beam. Thus, the properties of modulation are dependent upon both the settings of the polarizer unit **27** and the analyzer unit **31**, relative to liquid crystal television **29**. Of course, it is also dependent on the voltage bias that is usually added to the video signal. The setting of the polarizer unit **27** is particularly critical in determining the operating curve of liquid crystal television **29**. The term "spatial light modulator" is now being used to refer to the complete unit which comprises the polarizer unit **27**, the liquid crystal television **29**, and the analyzer unit **31**. FIGS. **2**A through **2**C show some examples of operating curves of a spatial light modulator. It is worth noting that these three curves were all obtained with the same orientation of analyzer unit **31**; all that was changed between the three curves (other than the bias added to the video voltage) was the setting of polarizer unit **27**.

One particular application of the present invention is in an optical correlator system, such as that depicted in FIGS. **4**A and **4**B. In this system, two spatial light modulators are utilized: one as an input-modulator **41**, and the other as a filter-modulator **43**. In prior art systems, spatial light modulators are utilized in optical correlators. Typically, they are configured to operate in a particular manner by fixing the polarizer unit and analyzer unit to specific orientations, which cause the resulting action to approximate amplitude-only modulation or phase-only modulation, for example. In the prior art, any change between the different operating modes of a modulator would have to be made by mechanically rotating either the polarizer unit or the analyzer unit or both. This mechanical adjustment requires a certain degree of skill, physical access to the equipment, and assurance of repeatability. The calibration problems associated with manual adjustments can be formidable. In the present invention, in lieu of manually-adjusted polarizer units and analyzer units, an electrically-addressable device is utilized to alter the polarization, so the overall operating characteristics of the filter modulator **43** may be changed without requiring manual or mechanical interaction with the equipment. In the preferred embodiment of the present invention, an electrically-controlled polarization rotator is utilized, such as the Model No. SPR0.7.633 polarization rotator which is manufactured by Meadowlark Optics of Longmont, Colo. Also in the preferred embodiment of the present invention, a liquid crystal variable retarder is utilized, such as the model number LVR0.7.633 liquid crystal variable retarder manufactured and sold by Meadowlark Optics of Longmont, Colo., which provides a predefined amount of differential retardance in response to a control voltage.

With reference now to FIGS. **4**A and **4**B, Helium-Neon laser **45** is used as a source of coherent light. The laser beam diameter is expanded using a two lens system which define beam expander **47**. This produces a beam which is large enough to illuminate input modulator **41**. The beam expansion also ensures that the intensity and phase do not vary greatly across the central portion of the beam that is used. The expanded laser beam then passes through input modulator **41**, and "picks-up" the information displayed on liquid crystal television **49** of input modulator **41**, owing to the amplitude and/or phase modulation. This image information on the laser beam is subject to the process of diffraction, and is accordingly decomposed into its spatial frequency components. The complete decomposition of the image into the spatial frequency components occurs at the far-field diffraction pattern (infinity); however, Fourier transform lens **51** is used to bring this far-field pattern into a more reasonable distance, such as the back focal plane of the lens which is defined as the plane which is located a distance of one focal length behind the lens. The input data are placed at the front focal plane (one focal length) away from Fourier transform lens **51**. The result is that an optical Fourier transform is formed at the plane of filter modulator **43**. The Fourier transform is important to the operation of a correlation system because of its well known properties in signal processing. Among these properties is its "shift-invariance"

which allows the system to be used for shift-invariant pattern recognition or object tracking.

The image that is displayed on the filter modulator **43** is a previously calculated version of the complex-conjugate of the Fourier transform of the object being tracked. If the input scene, which is derived from live video, is identical to the object of interest then the phase-structure of a laser beam will be to a greater or lesser degree "canceled-out" at the filter modulator **43**, and a flat wavefront will emerge. This beam is again Fourier transformed by Fourier transform lens **53** to produce a bright spot, which is identified as the "correlation peak", at the correlation plane. This bright spot of light is formed at the center of the object of interest, and will move if the object moves. In other words, the bright spot of light formed one focal length from Fourier transform lens **53** will provide a tracking indicator. Typically, a charged coupled device, such as CCD camera **55** is located at the correlation plane to record the position of the bright spot to allow replay and storage of the tracking operations.

As is shown in one embodiment in FIGS. **4**A and **4**B, the input image is captured by input camera **57** which provides an analog signal to personal computer **61** which includes microprocessor **65**. Microprocessor **65** controls the operation of video digitizer **59** which digitizes the analog input from input camera **57**, and provides it through drive circuit **63** to the spatial light modulator (preferably a liquid crystal video display) of input modulator **41**.

As was stated above, the filter modulator **43** is utilized to apply the complex-conjugate of the Fourier transform of the object being tracked to the light beam. This is accomplished by utilizing microprocessor **65**, video digitizer **69** and drive circuit **73** to provide for spatial light modulation by liquid crystal spatial light modulator **77**. Additionally, an electrically-actuable polarization rotation device **75** is provided and controlled by the microprocessor through digital input/output card **67** and digital interface **71** (which is preferably an interface which is provided with the polarization rotation device). Electrical control signals are provided by personal computer **61** through digital interface **71** to polarization rotation device **75** to influence the cumulative optical transform of filter modulator **43** in a manner which optimizes a provided optical processing objective which is provided to or derived by personal computer **61**, as will be discussed further herebelow.

In the embodiment of FIGS. **4**A and **4**B, input modulator is shown as including polarizer **81** and analyzer **83** which substantially uniformly polarize and filter the light beam. Additionally, filter modulator **43** is depicted as including analyzer **79**.

The operation of the optical correlator of FIGS. **4**A and **4**B winnow be described with reference to FIGS. **5**A, SB, and SC in the context of fingerprint identification. First, a digital version of the object of interest (the fingerprint) is acquired using the combination of video camera **57** and video digitizer board **59** which is resident in personal computer **61**. This digital image is then read into a computer program which will be used to create the filter. The classical matched-filter is usually used as the starting point for filter generation. This filter is the complex conjugate of the Fourier transform of the object of interest. However, as mentioned previously, current available spatial light modulators cannot attain arbitrary complex values of modulation. Instead, they are constrained to the set of "realizable values" specified by the drive parameter, as is shown in FIGS. **2**A through **2**C. Thus, the best that can be done is to approximate the ideal filter by making the best use of what is "realizable" with filter modulator **43** of FIGS. **4**A and **4**B. There are many procedures used to implement this approximation, but the methods described in the following references are favored, which are incorporated herein by reference as if fully set forth:

Reference 1: Richard D. Juday, "Optimal Realizable Filters and The Minimum Euclidean Distance Principle", Applied Optics, Vol. 32, No. 26, pages 5001–5111, Sep. 10, 1993;

Reference 2: Richard D. Juday, R. Shane Barton, Jason Kinser, and Jennifer Lacroix Alvarez, "Efficient Code for Optimal Realizable Filter Calculation", Proc. SPIE, 262–268 (1993);

Reference 3: "MEDOF: Minimum Euclidean Distance Optical Filter", Computer code available under NT control number MSC-22380 from Cosmic (Computer Software Management Information Center), University of Georgia, 382 East Broad Street, Athens, Ga. 30602-4272.

This algorithm is utilized in Reference **3** which is the computer program called MEDOF which is available through COSMIC. This algorithm produces a filter which accounts for the actual modulation characteristics of the modulators used in the correlator. This is in contrast with previous techniques which assume ideal behavior of the modulator. The filter control produced by these techniques is sent to the filter modulator **43** of FIGS. **4**A and **4**B, and will produce a correlation spot if the object of interest is present in the live scene under examination. Therefore, as is depicted graphically in FIG. **5**B, the digitally acquired image **101** is subjected to a filter generation software **103** to generate the set of filter drive signals **105** which, when applied to filter modulator **77** through drive circuitry **73**, cause the correlator to recognize the reference object. The set of filter drive signals **105** will optimally depend on several factors, explicitly including the set of filter values **107** from which to choose and the pattern recognition metric being optimized.

In the present invention, the operating curve of filter modulator **43** (of FIGS. **4**A and **4**B) is not restricted to one specific configuration, such as encountered in the prior art when a pre-set operating curve is provided for the filter modulator. Instead, the range of available operating curves is expanded, by providing a means for changing the operating curves, which is under the control of personal computer **61** (of FIGS. **4**A and **4**B). This is accomplished in a preferred embodiment by substituting an electrically-addressable polarization modifying device in lieu of a conventional polarizer, as a component of filter modulator **43** (of FIGS. **4**A and **4**B). This is equivalent to changing the polarization state with a prior art device which can be adjusted simply by changing the voltage applied across polarization rotation device **75**, rather than by mechanical manipulation of the polarization rotation device. As stated above, such devices are commercially available. One example is a Meadowlark Optics liquid crystal Sénarmont polarization rotator. Such a device can be controlled by a computer which supplies a digital word via a digital input/output card to a digital interface unit for the polarization rotator. In FIG. **5**B we indicate that a specific digital word has resulted in the selection of operating curve **107**. In the digital interface **71**, the digital word is then converted to an analog voltage suitable for driving the polarization rotator **75** (of FIG. **5**C), which will produce a certain rotation of the light polarization. This will change the linear polarization state which is incident on liquid crystal video display **77** in filter modulator **43**. As is seen in FIGS. **2**A through **2**C, this dramatically affects the operating curve of filter modulator **43**. Therefore, each of the operating curves shown in FIGS.

2A through 2C can have associated with it a digital word which, if supplied to the digital interface **71** for polarization rotator **75**, will cause its associated operating curve to be present in filter modulator **43**. Liquid crystal video display **77** is updated at video frame rates. Polarization rotator **75** can be changed during the "dead-time" of the liquid crystal video display addressing, such as during vertical retrace operations. Thus, a different operating curve could be used for each filter displayed on filter modulator **43**. Once the system has been calibrated, each operating curve need be known only by its digital word identifier.

So, in broad overview and with reference to FIG. 5C, input image **108** is captured by video camera **57** and routed to video digitizer **61** which provides through drive circuit **63** a video image which is impressed upon a light beam. Additionally, video digitizer **69** of personal computer **61** provides a signal to drive circuit **73** which is provided to a spatial light modulator (preferably a liquid crystal video display **77**) of filter modulator **43**. Additionally, digital input/output card **67** of personal computer **61** provides a digital word to digital interface **71** which converts the digital word into an analog signal which alters the polarization effect of polarization rotation device **75**.

The reason for wanting to reconfigure the filter modulator **43** (of FIGS. 4A and 4B) to operate with different operating curves is that each curve can trace out only a restricted path in the complex plane. The filter is calculated so that the best approximation to the ideal filter is obtained. This involves comparing the ideal filter values (which desire arbitrary complex transmittances of the filter modulator **43**) with the realizable values (which constitute the values traced out by the operating curve). Thus, for each operating curve a different solution may be obtained. Furthermore, it is anticipated that certain operating curves will produce a better approximation to the ideal filter than others. The hypothetical example of this effect is represented graphically in FIG. 2D. The black points in this complex plot represent ideal complex filter values. Itis seen that of the three operating curves shown in FIGS. 2A through 2C, FIG. 2A would give a much better approximation to the ideal filter values than the other two operating curves. While this example is exaggerated to demonstrate the concept, there will be instances where an operating curve such as that shown in FIG. 2A would give a far superior performance in a correlator than the other two operating curves of FIGS. 2B and 2C. Specifically, this could be when some optical system noise is present in the live input scene. If this noise is spectrally characterized, then the regions in the filter at which this noise appears will be well defined. If the operating curve has on it some regions which produce very low transmittance (such as seen in FIG. 2A but not in FIGS. 2B and 2C), then the noise can be filtered out of the system. Thus, the curve shown in FIG. 2A would perform well in situations where input noise was to be suppressed, while still providing a useful correlation. The signal-to-noise ratio is a metric that is fairly well established in the optical processing community. Other metrics include the height of the correlation peak produced by the correlator. It is intended that the user of the filter generation algorithm would select a particular metric that he is interested in, and an example of the object of interest. The filter generation algorithm would then select the best operating curve from the set available, for that particular task (an optical processing objective), and would produce a filter suitable for implementation on it. A flowchart is shown in FIGS. 6A and 6B which describes the intended procedure. The data supplied to the correlator device would be the filter and the digital word.

Turning now to FIGS. 6A and 6B, the process begins at step **201** wherein the input image of the object scene, or pattern of interest is digitized. Then, in accordance with step **203** a discrete Fourier transform is calculated for the input image of the object of interest. Then, the complex values which are desired are represented as best possible with those values which are "achievable" or "realizable" using the first of a plurality of operating curves. Next, in accordance with step **207**, the filter values are stored along with the digital word which produces the operating curve. Then in accordance with step **209** the metric of interest is calculated, such as the correlation peak height, or the signal-to-noise ratio. Next, in accordance with step **211** the complex values which are desired are represented as is best possible with the "achievable" or "realizable" values which are in the next operating curve. Then in accordance with step **213**, the metric of interest is calculated, such as the correlation peak height, or the signal-to-noise ratio, or any other suitable metric. In step **215**, the software determines whether the value of the metric for the present operating curve is greater than the previous value; if not, the process continues at software block **219**; if so, the process continues at software block **217**. In step **219**, it is determined whether all of the available operating curves have been examined; if they have all been examined, the process continues at step **221** by exiting from this routine; however, if it is determined in step **219** that not all of operating curves have beeh examined, the process returns to step **211** where another operating curve is examined. If in step **213** it is determined that the value of the present metric is greater than the previous value, the process continues at step **217**, wherein the filter values and associated digital word are stored in memory. In this manner, each of the available operating curves (from a finite set of operating curves such as six to ten curves) is successively examined to determine its suitability in terms of the metric selected by the operator. The operating curve which best achieves the metric goal established by the operator is recorded in memory along with the digital word which is used to realize this operating curve.

In order to understand References 1, 2, and 3 and their relationship to the flowchart of FIGS. 6A and 6B of the present invention, suppose one has the following fixed set: bias voltage V_b, drive voltage for the polarization rotation cell V_p and angles of polarizer Ψ_p, and analyzer Ψ_a. Then the set of complex values traced as a pixel's video drive voltage varies through its range and is known as the operating curve.

Reference 1 describes a theory of how to use a given operating curve, and References 2 and 3 relate to a practical code that implements the theory of Reference 1. However, none of these References tell how to evaluate the utility of that curve and thus select the best curve for a particular application. The following material supplements these References.

Reference 1 describes that, given an operating curve, we search over a pair of numbers G and ζ performing the computations given below. (In Reference No. 1, see section 3 in the vicinity of Eq. 15, and also Section 4. See also the Cookbook Summary in Appendix C). We have selected a metric T, for example one of those given in Eqs 7 through 11 of Reference 1. For each frequency m in the set of all frequencies at the filter plane, one then:

1. Computes H^+ as in Eq. 15 (It is a function of G and β); and
2. Determines the value H° on the curve that is closest by Euclidean measure in the complex plane to H^+.

The Cookbook summary of Appendix C of Reference 1 is repeated below since it provides a detailed and practical summary of the technique disclosed in Reference 1:

(1) Decide on a metric T. The general form is in Eq. (12) and some particular forms are in Table 1.

(2) For the metric, determine the partial derivative in the denominator of Eq. (15) even if the modulator is discrete. Obtain the necessary signal and noise quantities. (See the discussion of normalization in Appendix B). They are as follows: δ[hence S=A exp(jφ)], the as-encoded signal and its transform; $P_{\prime\prime}$, the input noise power spectral density assuming additive wide-sense-stationary colored noise; σ^2_d correlation detector noise.

(3) Understand the realizable values of the modulator H=M exp(jφ) in appropriate physical terms. See Appendix B.

(4) Achieve an algorithm that finds the Euclidean-closest realizable filter value, given an arbitrary location in the complex plane.

(5) From the histograms of signal's amplitude A and the filter's magnitude M, determine a search range of gain, G_{min} to G_{max}. For example, if SNR is the metric, Eq. (15) indicates $G_{min}[A/P]_{max}=M_{min}$ and vice versa.

(6) The search range for output phase β is [0, 2π) unless it can be restricted by other knowledge.

(7) Execute a two-dimensional search over G and β;

(a) For each frequency m, calculate H^+ from Eq. (15) and set H_m equal to the closest realizable filter value.

(b) From the set $[H_m](G,\beta)$, calculate T(G,β).

(8) Determine G* and β* that maximize T.

(9) Select $[H_m](G^*, \beta^*)$ as the filter.

In that manner one computes the optimal filter for the given pair (G,β), and one may evaluate the metric T(G,β) for that filter. The search over G and β is a finite search, and we select G* and β* that produce the largest value of T. This is describe in flowchart form in FIGS. **6**A and **6**B. Box **205** represents the search over G and β and items 1 and 2 above. Box **209** represents an evaluation of T(G,β) for the present operating curve. The loop represents the trial of all the operating curves, and the selection of the best of all of them.

One can generalize that procedure to include optimizing a filter over the other parameters that determine its operating curves. In the present case, one would ordinarily choose a parameter that is easily modified, the two simplest such being V_b and V_p. In accordance with the present invention, we select operating curves by motorized control of Ψ_p and Ψ_a, but the voltage control of polarization rotation devices either singly as in FIGS. **4**A and **4**B and **5**C, or in the more complicated architectures of FIG. **7**, could supplant the motor drive. Changing the other parameters from filter to filter does not consume a lot of data storage; typically there are between 128^2=16,384 and 512^2=262,144 filter values to store, and we are talking about adding another 1 to 4 stored values to select the operating curve.

So far only discrete operating curves have been considered: that is, those at specific orientations for the polarizer and analyzer. However, it can be shown that all of the available operating curves can be expressed in an analytic form by using the Jones calculus. This produces a two-by-two matrix which describes the polarizing nature of an optical element, in this case a liquid crystal video display. The Jones matrix can be evaluated by a series of empirical measurements, or by determining the values of some physical parameters to construct a physical model, as is set forth in the following articles which are incorporated herein by reference as if fully set forth:

Reference 4: R. Clark Jones, "A New Calculus for the Treatment of Optical Systems VI. Experimental Determination of the Matrix",J. of the Opt. Soc. of Am. Vol. 37, pages 110–112 (1947);

Reference 5: Khangua Lu and Bahaa E. A. Saleh, "Theory and Design of The Liquid Crystal TV and An Optical Spatial Phase Modulator", Opt. Eng., vol. 29, pages 240–246 (1990).

Once the Jones matrix has been determined for the filter modulator, further sets of operating curves for the liquid crystal video display can be investigated by the filter generation algorithm, thus extending the possibilities of modulation.

FIGS. **5**D, **5**E, and **5**F depict the utilization of the present invention in the tracking of aircraft of spacecraft. As is shown in FIG. **5**D, video camera **57** is utilized to acquire an image of the craft. Then, in accordance with FIG. **5**E the digitally acquired image **101** is subjected to a filter generation software **103** to generate a set of filter drive signals **105** which, when implied to filter modulator **77** through drive circuitry **73**, cause the correlator to "recognize" the craft. Next, as is depicted in FIG. **5**F, the input image **108** of the craft is captured by video camera **57** and routed to video digitizer **61** which provides through drive circuit **63** of video image which is impressed upon a light beam. Additionally, a video digitizer **67** of personal computer **61** provides a signal to drive circuit **73** which is provided to a spatial light modulator (preferably a liquid crystal display **77**) of filter modulator **43**. Additionally, digital input/output card **67** of personal computer **61** provides a digital word to digital interface **71** which converts the digital word into an analog signal which alters the polarization affect of polarization rotation device **75**.

The different sets of operating curves can be selected in an optical correlator system by using further embodiments of the invention. The first embodiment of the invention which has been discussed so far is depicted in FIG. **7**A, and includes polarization rotation device **301**, liquid crystal television **303**, and analyzer **305**. In a second embodiment of the invention, which is depicted in FIG. **7**B, the spatial light modulator consists of an electrically-actuable polarization rotation device **307**, a liquid crystal television **309**, and an electrically-actuable polarization rotation device **311**. This device provides significant commercial advantage in that both the polarizer and analyzer are replaced with electrically-actuable polarization rotation devices. This configuration can access all of the operating curves which are possible with different orientations of linear polarization at the input and output of liquid crystal television **309**. Note that polarization rotation device **311** is placed in the optical system facing the direction opposite from that of polarization rotation device **307**; this is because the polarization rotation device has a linearly polarizing element on the input face of the polarization rotation device **307** itself. When such a rotator is substituted for an analyzer, this linearly polarizing element is required to be on the exit face of the device. The third embodiment of FIG. **7**C includes an electrically-actuable polarization rotation device **313**, electrically-actuable variable retarder **315**, liquid crystal television **317**, and analyzer **319**. Preferably, a variable retarder such as those available from Meadowlark Optics is utilized and will utilize the same addressing mechanism as polarization rotation device **313**. Thus, a digital word supplied to the interface unit of variable retarder **315** causes a specified differential wavefront retardance. The combination of the rotator **313** and the retarder **315** is capable of producing any arbitrary (elliptical, circular, or linear) polarization state of light. Thus, this configuration can produce operating curves

which are a result of arbitrary input states of polarization. Note that the set of operating curves produced by this configuration would be different from those obtained with a system shown in FIGS. 7A and 7B.

Still another embodiment of the present invention is depicted in FIG. 7D, which includes an electrically-actuable polarization rotation device **321**, an electrically-actuable variable retarder **323**, a liquid crystal television **325**, and a polarization rotation device **327**.

A final embodiment of the present invention is depicted in FIG. 7E, and includes electrically-actuable polarization rotation device **329**, electrically-actuable variable retarder **331**, liquid crystal video display **333**, electrically-actuable variable retarder **335**, and electrically-actuable polarization rotation device **337**. This configuration could be used as an electrically controlled polarimeter, which is a device that produces a full polarization characterization of an optical specimen, but which is not necessarily a liquid crystal video display. Such a polarimeter could be used for the calibration of optical components, or could be used to calculate the Jones matrix of an optical device. An electrically-controlled polarimeter would be much faster and potentially much cheaper than those prior art devices currently in use. This configuration could be used to maximize the light throughput of a filter modulator system, by permitting arbitrary states of polarization input to the liquid crystal video display and allowing the analysis for arbitrary polarization states leaving the liquid crystal video display **333**. Although the configuration shown in FIG. 7E provides the full capability to control the input polarization and analyze the output polarization, it is also the most complicated of all these systems presented, as it requires four elements of polarization control. In practice, it will often be more advantageous to accept less flexibility in the control of the input and output polarization states and thus decrease the number of control parameters required. A wide selection of potential operating curves will still be possible using the simpler configurations presented to FIGS. 7A through 7D, and others that are not pictured here for example: (rotator, modulator, retarder, rotator); (rotator, modulator, retarder); or (polarizer, modulator, retarder, rotator).

A further advantage of the present invention is that of "tuning" a filter modulator's operating curve to one which previously specified. This is accomplished by adjusting the digital word sent to the two digital interface boards for the polarization rotators (in the case of the configuration shown in FIG. 7D), and then adjusting them until a "standard" performance of the correlator is achieved. In other words, a particular filter control is calculated for the correlator that gives a very specific response in the correlation output (for example, a dark spot at the center of the correlation plane). This filter control is written for the standard operating curve of the filter modulator, so that any deviation from this operating curve would produce a well characterized change in the output, such as a non-zero intensity at the center of the correlation plane. The polarization rotators are then be adjusted to reproduce the original response. This procedure helps to ensure reliable uniformity in the day-to-day operation of a correlator apparatus.

While the invention has been shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit thereof.

TABLE 1

Optical Device	Orientation	Jones Matrix
Linear Polarizer	Horizontal Transmission	$\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$
Linear Polarizer	Veritical Transmission	$\begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$
Linear Polarizer	Transmission at 45° angle	$\begin{bmatrix} 1 & \pm 1 \\ 1 & 1 \end{bmatrix}$
Quarter-Wave Retarder	Fast Axis at Vertical	$\begin{bmatrix} 1 & 0 \\ 0 & -j \end{bmatrix}$
Quarter-Wave Retarder	Fast Axis at Horizontal	$\begin{bmatrix} 1 & 0 \\ 0 & -j \end{bmatrix}$
Quarter-Wave Retarder	Fast Axis at 45° angle	$\begin{bmatrix} 1 & \pm j \\ \pm j & 1 \end{bmatrix}$
Half-Wave Retarder	Fast Axis at either Horizontal or Vertical	$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$
Isotropic Retarder		$\begin{bmatrix} e^{j\phi} & 0 \\ 0 & e^{j\phi} \end{bmatrix}$
Relative Phase Changer		$\begin{bmatrix} e^{j\phi x} & 0 \\ 0 & e^{j\phi y} \end{bmatrix}$
Circular Polarizer	Right	$\frac{1}{2}\begin{bmatrix} 1 & j \\ -j & 1 \end{bmatrix}$
Circular Polarizer	Left	$\frac{1}{2}\begin{bmatrix} 1 & -j \\ j & 1 \end{bmatrix}$

What is claimed is:

1. A method in an optical correlation system of correlating an input image with an optical filter, comprising:

providing a filter modulator which includes (a) a spatial light modulator, and (b) an electrically-actuated polarization apparatus;

defining a preselected number of optical transforms available from said filter modulator for a plurality of differing polarization states of said electrically-actuated polarization apparatus;

impressing said input image upon a light beam utilizing an input modulator;

decomposing said input image into its frequency components;

supplying said frequency components to an input plane of said filter modulator;

providing a processor for operation of said filter modulator;

providing an optical processing objective to said processor;

utilizing said processor to successively examine said preselected number of optical transforms and select a particular one of said preselected number of optical transforms which best satisfies said optical processing objective;

utilizing said processor to provide commands to said electrically-actuated polarization apparatus in order to cause said filter modulator to provide said particular one of said preselected number of optical transforms;

filtering said light beam with said filter modulator; and detecting and monitoring a correlation indicator.

2. A method in an optical correlation system of correlating an input image with an optical filter, according to claim 1:

wherein, during said step of utilizing said processor to successively examine, said processor is utilized to successively analyze each of said preselected number of optical transforms with respect to a particular provided metric, in order to determine which particular one of said preselected number of optical transforms best satisfies said optical processing objective.

3. A method in an optical correlation system of correlating an input image with an optical filter, according to claim 1:

wherein said electrically-actuated polarization apparatus of said filter modulator functions as a polarizer which polarizes said light beam into a desired polarization state prior to communication of said light beam to said spatial light modulator.

4. A method in an optical correlation system of correlating an input image with an optical filter, according to claim 1:

wherein said electrically-actuated polarization apparatus of said filter modulator functions as an analyzer which selects a polarization state from said light beam subsequent to communication of said light beam to said spatial light modulator.

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