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[54] **OPTICAL DATA TRANSDUCER**

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[73] Assignee: **The United States of America as represented by the Secretary of the Air Force,** Washington, D.C.

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[51] **Int. Cl.**[5] **G01J 1/00**

[52] **U.S. Cl.** **250/352;** 250/330; 250/332; 250/349

[58] **Field of Search** 250/352, 332, 349, 330

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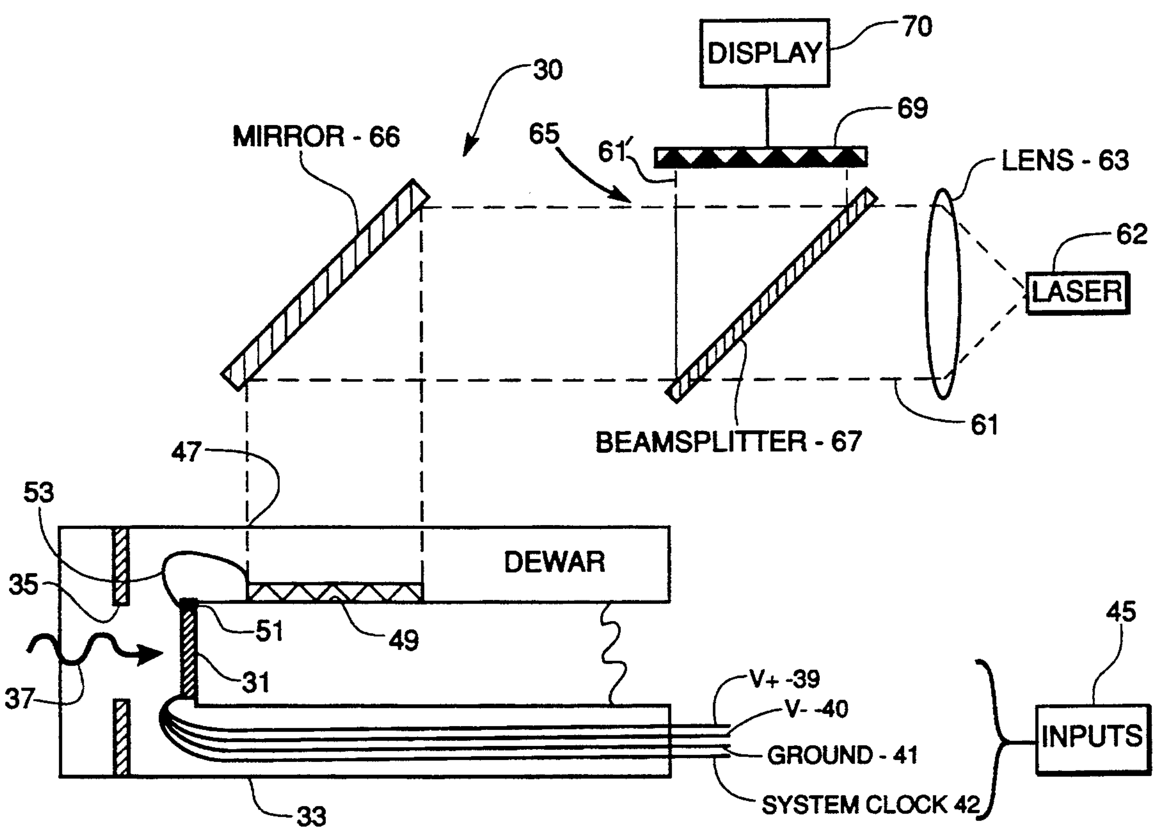
[57] **ABSTRACT**

An optical data transducer system is described which comprises a cryogenic dewar for containing an infrared focal plane array at low temperature and an optical spatial light modulator, collimated laser beam and associated optical train and detector for efficient extraction of information from the array.

8 Claims, 3 Drawing Sheets



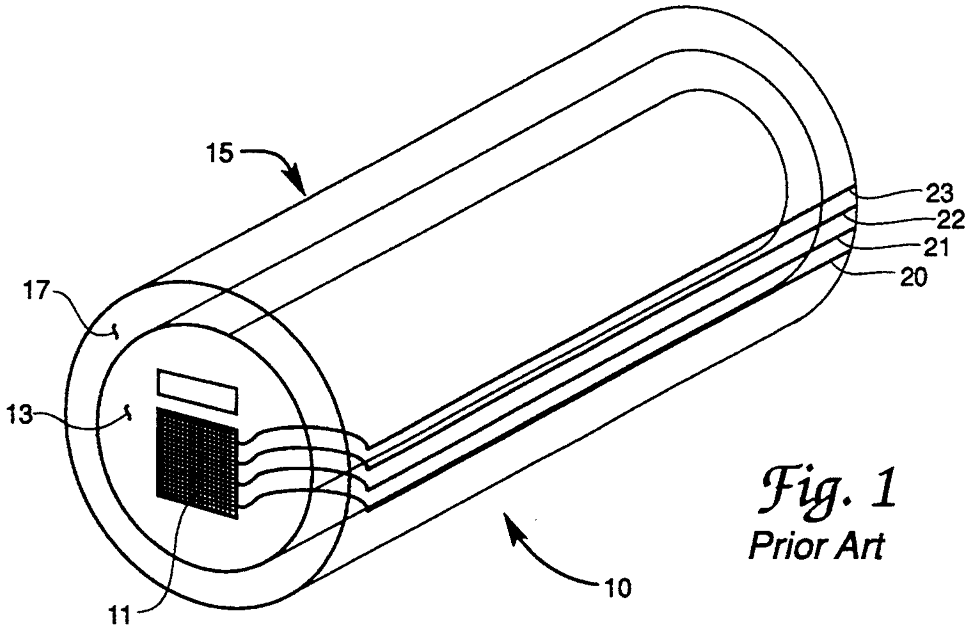


Fig. 1
Prior Art

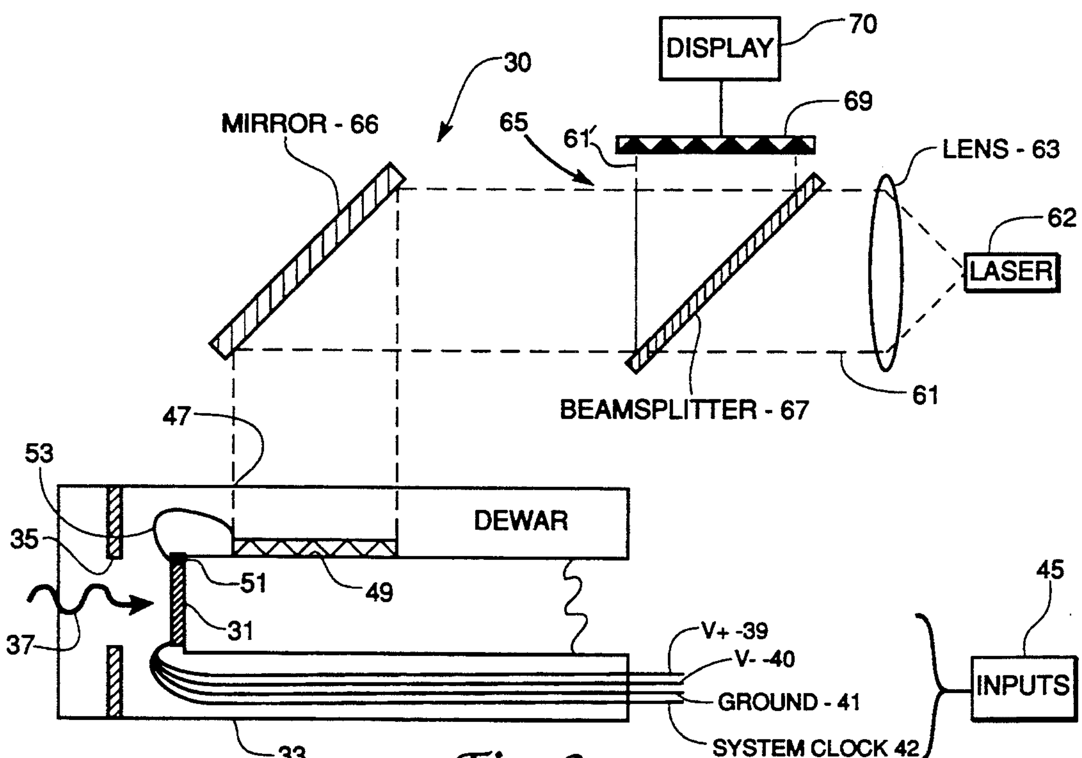


Fig. 2

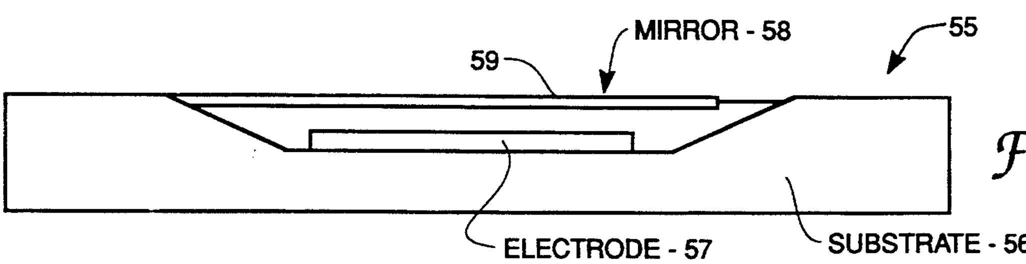


Fig. 3

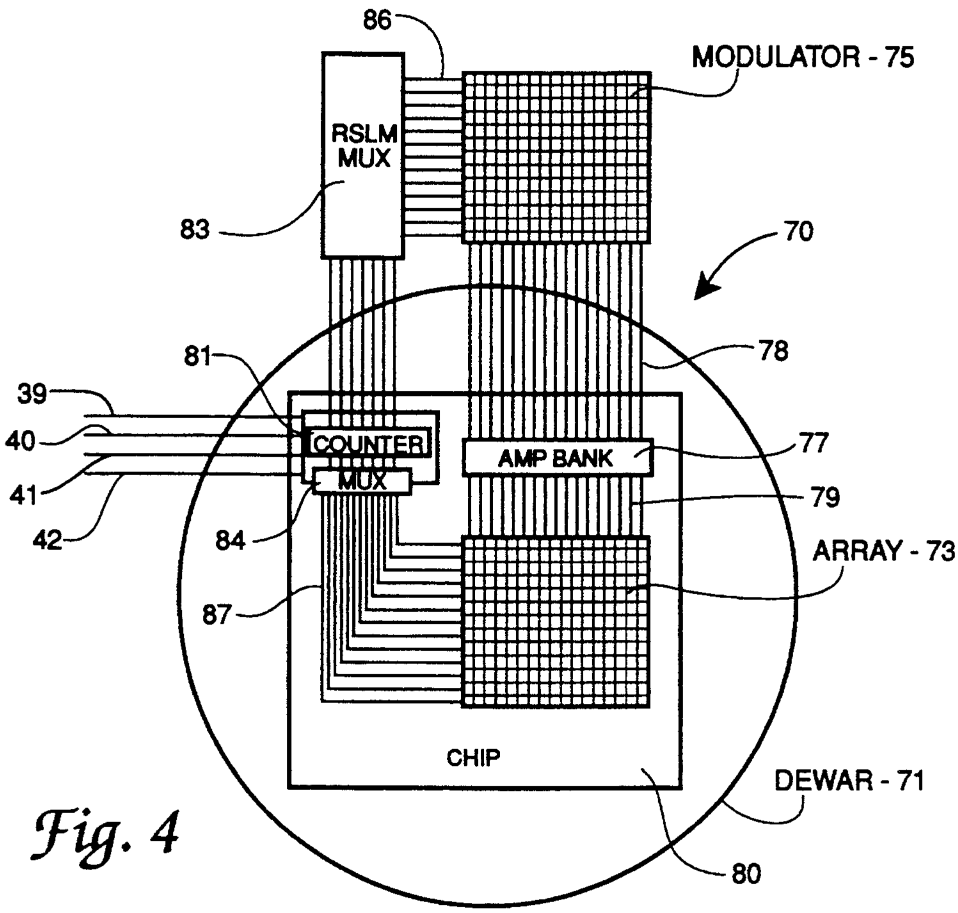
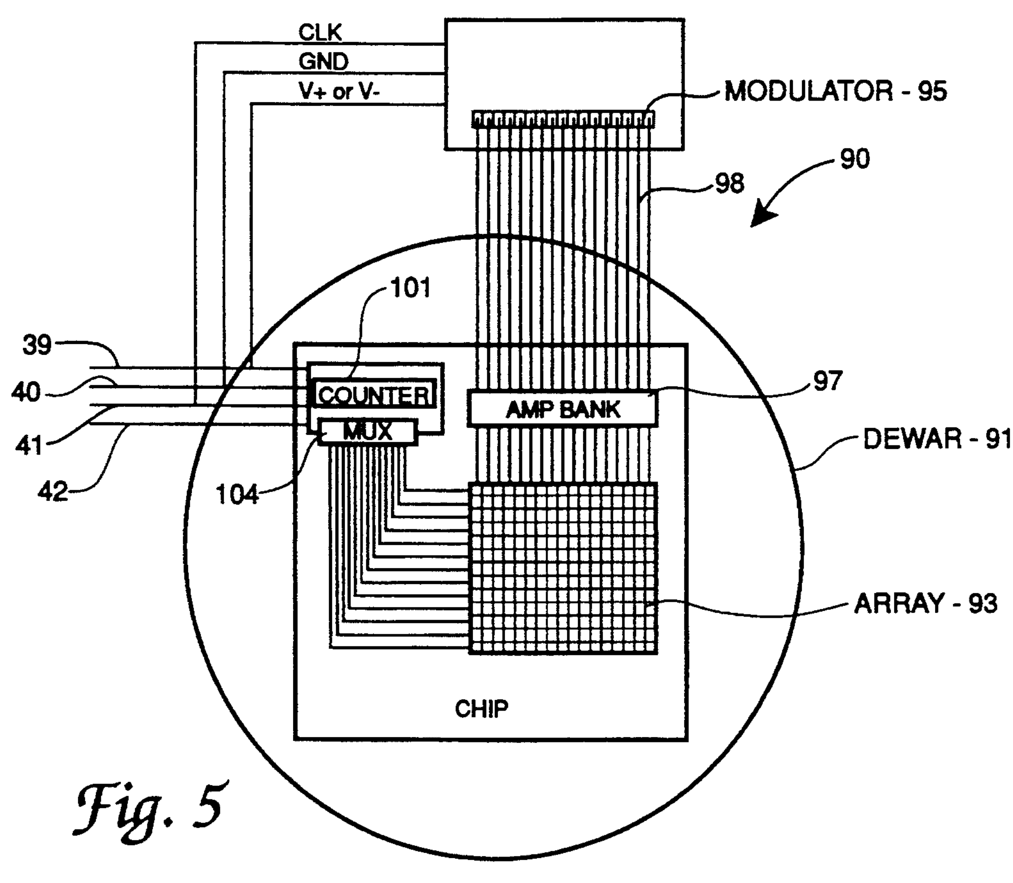

86
MODULATOR - 75
RSLM
MUX
83
70
81
78
39
40
COUNTER
AMP BANK
77
MUX
41
79
42
84
ARRAY - 73
87
CHIP
DEWAR - 71
80

Fig. 4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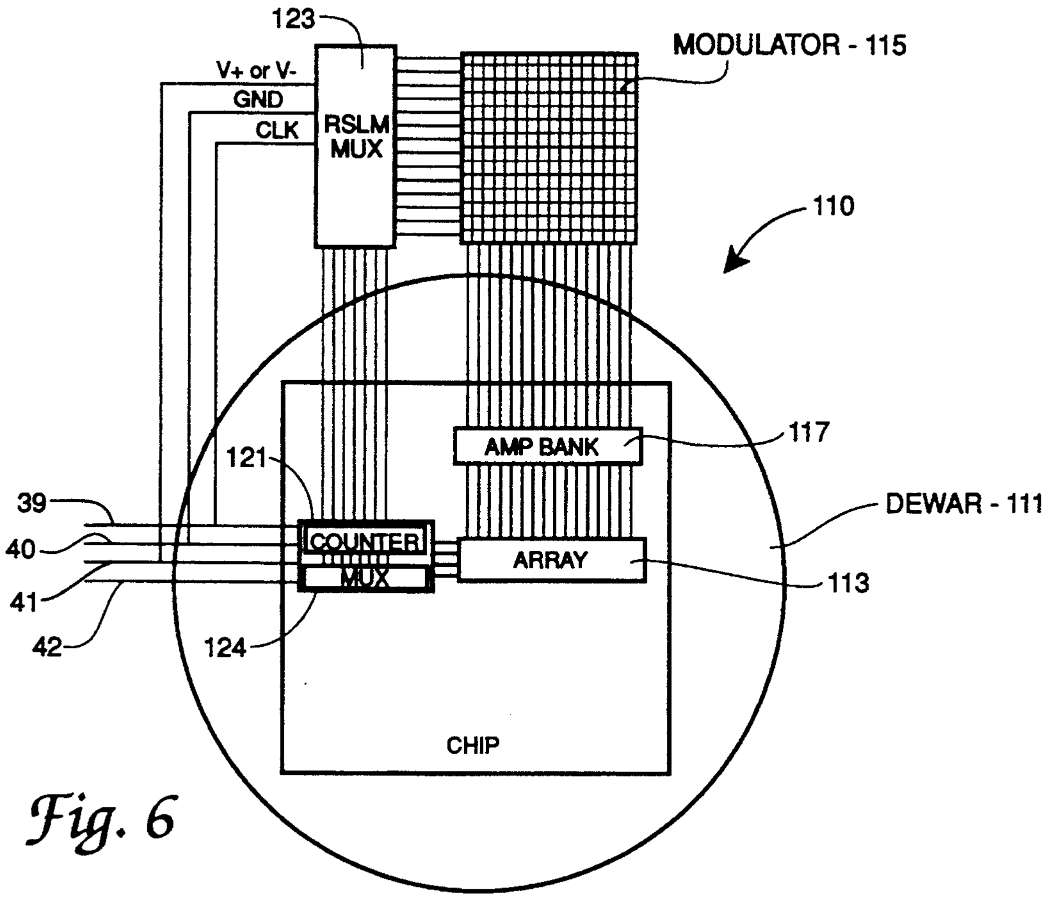
V+ or V-
MODULATOR - 95
90
98
101
39
40
COUNTER
AMP BANK
97
MUX
41
DEWAR - 91
42
104
ARRAY - 93
CHIP

Fig. 5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GND
CLK
RSLM MUX
MODULATOR - 115
110
AMP BANK
117
121
39
40
41
42
COUNTER
MUX
ARRAY
DEWAR - 111
113
124
CHIP

Fig. 6

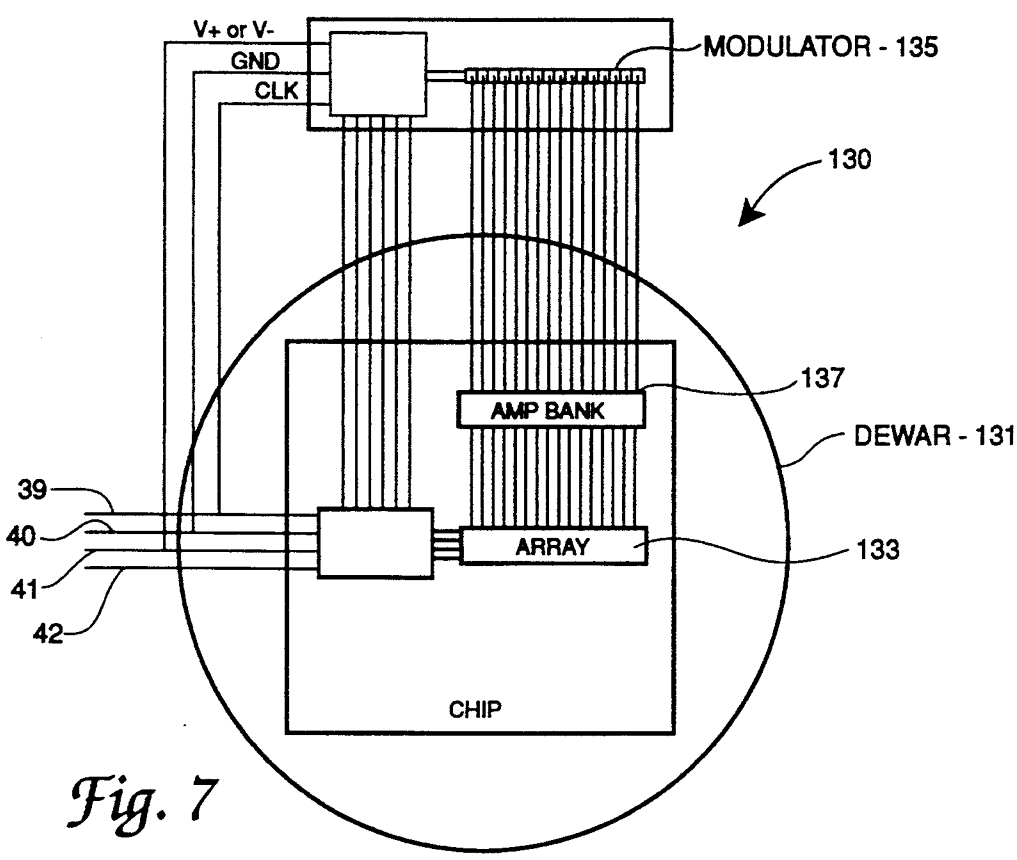
V+ or V-
GND
CLK
MODULATOR - 135
130
AMP BANK
137
DEWAR - 131
39
40
41
42
ARRAY
133
CHIP

Fig. 7

OPTICAL DATA TRANSDUCER

RIGHTS OF THE GOVERNMENT

The invention described herein may be manufactured and used by or for the Government of the United States for all governmental purposes without the payment of any royalty.

BACKGROUND OF THE INVENTION

The present invention relates generally to optical data transducer devices, and more particularly to an improved cryogenic dewar and optical data transducer system configured to efficiently extract information from within the dewar using a spatially modulated low power laser beam.

Sensitive infrared focal plane arrays (IRFPA) normally must be disposed within a cryogenic dewar for operation at low temperature. In the operation of an IRFPA, high data rates are necessary in order to efficiently extract information from the dewar to an externally located detection system. In conventional systems, high data extraction rates carry a corresponding penalty of a need for a large number of electrical leads from the dewar. As a result, severe vacuum loss and heat leak problems arise.

The invention solves or substantially reduces in critical importance problems with prior art systems as just described by providing a cryogenic dewar and optical transducer system comprising an optical spatial light modulator in conjunction with a collimated laser probe beam and an IRFPA for efficient extraction of information from the IRFPA using a maximum of four electrical leads (system clock, ground, and two power leads) to the dewar. The invention has substantial application in systems using cryogenically cooled infrared detectors, such as infrared search and track sets, guidance systems and imaging systems.

It is therefore a principal object of the invention to provide an improved optical transducer system.

It is another object of the invention to provide a cryogenic dewar improved with an optical data transducer to extract information from the dewar.

It is yet another object of the invention to provide a cryogenic dewar and optical spatial light modulator and collimated laser beam system for efficient extraction of information from a cryogenically cooled IRFPA using a minimum of electrical leads.

It is yet another object of the invention to provide a combined reflective spatial light modulator and IRFPA.

These and other objects of the invention will become apparent as a detailed description of representative embodiments proceeds.

SUMMARY OF THE INVENTION

In accordance with the foregoing principles and objects of the invention, an optical data transducer system is described which comprises a cryogenic dewar for containing an infrared focal plane array at low temperature and an optical spatial light modulator, collimated laser beam and associated optical train and detector for efficient extraction of information from the array.

DESCRIPTION OF THE DRAWINGS

The invention will be more clearly understood from the following detailed description of representative

embodiments thereof read in conjunction with the accompanying drawings wherein:

FIG. **1** is a schematic perspective view of a conventional dewar system for cooling a sensitive infrared focal plane array;

FIG. **2** is a schematic layout of an optical transducer system and modified dewar according to the invention including associated external optics and electronics;

FIG. **3** is a schematic cross-sectional view of a micro mirror which the deformable mirror array of the invention may comprise;

FIG. **4** is a schematic of a basic transducer layout within a dewar for illustrating the general operation of the invention;

FIG. **5** is a schematic of an alternative transducer system within a dewar using a two dimensional infrared focal plane array and a one dimensional spatial light modulator;

FIG. **6** is a schematic of another transducer system within a dewar using a one dimensional infrared focal plane array and a two dimensional spatial light modulator according to a further aspect of the invention; and

FIG. **7** is a schematic of yet another transducer system within a dewar using a one dimensional infrared focal plane array and a one dimensional modulator.

DETAILED DESCRIPTION

Referring now to the drawings, FIG. **1** shows a schematically a perspective view of a conventional dewar system **10** for cooling a sensitive infrared focal plane array **11**. In conventional designs as represented by system **10**, array **11** is immersed in a cryogen **13** such as liquid argon, liquid nitrogen or liquid helium within a heat conduction to array **11**. Array **11** normally operates within a dewar cooled below about −200° C. Data, control and power lines **20–23** interconnect array **11** and electronics (not shown) external of container **15** and may be disposed within container **15** or etched on a wall thereof. In the operation of array **11**, high data rates may be necessary to extract information from array **11** to a data processor external of system **10**, and may dictate the need for an undesirably great number of electrical leads (well in excess of the four suggested in FIG. **1**) for data extraction purposes. The greater number of leads may result in substantial vacuum loss and heat leak problems for system **10**.

Referring now to FIG. **2**, shown therein is a schematic layout of an optical transducer system **30** constructed according to the invention, including associated external optics and electronics. Infrared focal plane array **31** may, in substantially conventional fashion, be mounted within dewar **33** near an optical window **35** through a wall of dewar **33** for receiving an external signal in the form of infrared radiation **37**. No more than four electronic leads **39–42** interconnect array **31** and input electronics **45** disposed external of dewar **33**, providing input for a system clock, power (−V and +V) and ground.

In accordance with a principal feature of the invention, an optical window **47** is defined in a wall of dewar **33** through which data may be extracted from system **30**. A reflective spatial light modulator **49** (such as a deformable mirror array) is disposed on the cold finger of dewar **33** confronting window **47** as suggested in FIG. **2**. Modulator **49** is operatively connected through amplifier bank **51** to array **31** via bus **53** comprising any suitable number of electrical leads.

A deformable mirror array may be preferred for use in system **30** because spatial light modulators based on liquid crystals may be inoperative at the cryogenic temperatures contemplated for operation of system **30**. FIG. **3** schematically illustrates in section typical construction of a micro mirror segment **55** of which the deformable mirror array is comprised. Each mirror segment **55** is about 6×10^{-7} to 4×10^{-5} square inch in area, and comprises a substrate **56** of p or n type semiconductor material, such as silicon or gallium arsenide. A driving electrode **57** of aluminum, gold or silver is deposited on substrate **56** and is operatively connected to an electrical lead (not shown) included in bus **53**. Mirror **58** supporting a mirrored surface **59** is deposited or otherwise disposed on substrate **56** over electrode **57** as suggested in FIG. **3**. Mirrored surface **59** may comprise aluminum, silver or other suitable metallic. Each mirror **58** of each mirror segment **55** may be fabricated by microscopic machine construction techniques or other method occurring to one skilled in the applicable art. Each mirror **58** is structured as a cantilevered plate which is deformed to a degree corresponding to the amount of electrical current applied to energize the corresponding electrode **57**. A laser probe beam **61** is projected from a source **62** thereof and may be collimated by collimating lens **63** (FIG. **2**). Probe beam **61** is incident onto modulator **49** comprising such as an array of mirror segments **55**. Each mirror segment **55** in the array cooperates with other segments **55** to shift the phase and/or amplitude of beam **61** in proportion to the current applied to the segment. Beam **61** is therefore modulated by signals from array **31** to modulator **49** (represented by the array of mirror segments **55**). An optical train **65** including any required number of optical elements such as mirror **66** and beamsplitter **67** direct the incident beam **61** to modulator **49** and direct the modulated beam **61'** to a detector system such as charged couple device (CCD) photodiode array **69** and display **70**, digital processor or other detector system.

Referring now to FIG. **4**, shown therein is a schematic of a basic transducer layout **70** contained within dewar **71** in accordance with a principal teaching of the invention. As suggested in the foregoing paragraphs, an N×N infrared focal plane array **73** and N×N reflective spatial light modulator **75** may be disposed within dewar **71** and interconnected by amplifier bank **77** and buses **78,79**. Array **73** and amplifier bank **77** may be carried on IC chip or ceramic carrier **80** as would occur to the skilled artisan practicing the invention. Counter **81** interconnects inputs **39–42** and multiplexers **83,84** connected by buses **86,87** to modulator **75** and array **73**.

In the operation of the arrangement suggested in FIG. **4**, at the application of power, counter **81** is initially reset to mark the beginning of a frame period and increases in value at the occurrence of each following cycle of the system clock. The value impressed upon counter **81** is decoded by multiplexers **83,84** which allows a single line for data from a row or column (depending on read-out structure) to be applied to a row of electrodes within array **73**. The set of column or row data is then presented to amplifier bank **77** which amplifies the signals for transmission over bus **78** to modulator **75** and applied to the corresponding row or column of reflective elements on modulator **75**. The value on counter **81** is then increased on the next cycle of the system clock to enable the set of row or column data for transfer to modulator **75**. The foregoing process following initial reset of counter **81** is then repeated for the rest of the rows or columns during the frame period until modulator **75** contains the image transferred from array **73**. Modulator **75** is then illuminated from outside dewar **71** by a low power laser (**61** of FIG. **2**). The laser light reflected by modulator **75** (beam **61'** of FIG. **2**) is encoded with an image from array **73** and is directed a detector system as suggested above. The process described within this paragraph defines one frame period, and counter **81** is again reset and the entire sequence is repeated for each following frame period. Since data from array **73** is transferred outside dewar **71** using no data lines, the number of operating leads (**39–42**) is but four.

FIG. **5** illustrates an alternative transducer system **90** within dewar **91** using two dimensional infrared focal plane array **93** and one dimensional modulator **95** for two dimensional to one dimensional data transfer according to an aspect of the invention. In operation of system **90**, at the application of power, counter **101** is initially reset to mark the beginning of a frame period and increases in value at the occurrence of each following cycle of the system clock. The value impressed on counter **101** is decoded by multiplexer **104** which enables a single line for data from a row or column (depending on read-out structure) to be applied to a row of electrodes within array **93**. The set of column or row data is then presented to amplifier bank **97** which amplifies the signals for transmission over bus **98** to linear modulator **95**. Modulator **95** is then illuminated by a low power laser (**61** of FIG **2**), the reflected beam (beam **61'** of FIG. **2**) being encoded with an image of a single row of array **93** and directed a detector system. The value on counter **101** is then increased on the next cycle of the system clock to enable the next row or column for transfer to modulator **95**. The process is then repeated for the remaining rows during the frame period until the entire image from array **93** is transferred to the digital or optical processor external of dewar **91**. Counter **101** is then reset to the first row of array **93** and the sequence repeated for each following frame period.

FIG. **6** illustrates yet another transducer system **110** within dewar **111** using one dimensional infrared focal plane array **113** and two dimensional modulator **115** for one dimensional to two dimensional data transfer according to yet another aspect of the invention. No counter is needed for array **113** since but a single line of information exists therein. The clock cycle may be used to cycle array **113**. Counter **121** records the image gathered by array **113** on modulator **115**. In the operation of system **110**, the clock signal activates transfer of data to the row electrodes of array **113** and counter **121** of modulator **115** is set to a value corresponding to the first row of the image to be scanned. The row data from array **113** is then transferred to the amplifier bank **117** for transmission to modulator **115** and applied to the row of modulator **115** corresponding to the row in the image being scanned. The value on counter **121** is then increased to coincide with the next row of imagery from (linear) array **113**, and the foregoing process is repeated until modulator **115** contains the entire image scanned by array **113**. Modulator **115** is then illuminated by a low power laser as above to encode the reflected beam with the image stored in modulator **115** and to direct the encoded beam to a detector, which marks the end of a frame period. Counter **121** is then reset to the top row of modulator **115** and the sequence repeated for each following frame period.

FIG. 7 illustrates another transducer system **130** within dewar **131** using one dimensional infrared focal plane array **133** and one dimensional modulator **135** for one dimensional to one dimensional data transfer according to the invention. No counter is needed in system **130** since there is only a single line of information. The clock cycle is used to cycle array **133** and modulator **135**. In operation of system **130**, the clock signal activates data transfer to the row electrodes of array **133**. The row data is amplified by amplifier bank **137** and transmitted to modulator **135**. Modulator **135** is then illuminated by a low power laser as above to encode the reflected beam with the image stored in modulator **135** and to direct the encoded beam to a detector.

The invention therefore provides an improved cryogenic dewar and optical data transducer system configured with a minimum number of electrical input leads and wherein data is efficiently extracted from the dewar optically and in parallel allowing high frame rates without corruption of the data during transmission. It is understood that modifications to the invention may be made as might occur to one with skill in the field of the invention within the scope of the appended claims. All embodiments contemplated hereunder which achieve the objects of the invention have therefore not been shown in complete detail. Other embodiments may be developed without departing from the spirit of the invention or from the scope of the appended claims.

I claim:

1. A cryogenic data transducer system, comprising:

(a) a cryogenic dewar having optical window means therein for admitting an optical signal and a probe beam;

(b) an infrared focal plane array disposed within said dewar near said optical window means for receiving an optical signal from external of said dewar;

(c) a spatial light modulator disposed within said dewar near said optical window means, said spatial light modulator being operatively connected to said infrared focal plane array;

(d) a source of a collimated laser beam source and optical means for directing a probe beam from said source onto said spatial light modulator through said optical window means and directing a reflected beam external of said dewar from said spatial light modulator; and

(e) detection means for detecting and analyzing said reflected beam.

2. The system of claim **1** further comprising a cryogen within said dewar for maintaining the temperature of said infrared focal plane array below about −200°C.

3. The system of claim **2** wherein said cryogen is selected from the group consisting of liquid argon, liquid nitrogen and liquid helium.

4. The system of claim **1** wherein said spatial light modulator comprises a deformable mirror array operatively connected to said infrared focal plane array and responsive thereto.

5. In a cryogenic data transducer system including a cryogenic dewar and an infrared sensor array disposed within the dewar for receiving an optical signal external of the dewar, an improvement comprising:

(a) optical window means on said dewar for admitting a probe beam;

(b) a spatial light modulator disposed within said dewar near said optical window means, said spatial light modulator being operatively connected to and responsive to said infrared sensor array;

(c) a source of a collimated laser beam source and optical means for directing a probe beam from said source onto said spatial light modulator through said optical window means and directing a reflected beam external of said dewar from said spatial light modulator; and

(d) detection means for detecting and analyzing said reflected beam.

6. The improvement of claim **5** further comprising a cryogen within said dewar for maintaining the temperature of said infrared focal plane array below about −200° C.

7. The improvement of claim **6** wherein said cryogen is selected from the group consisting of liquid argon, liquid nitrogen and liquid helium.

8. The improvement of claim **5** wherein said spatial light modulator comprises a deformable mirror array operatively connected to said infrared focal plane array and responsive thereto.

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