

- [54] **DEVICE FOR TRANSMITTING
WAVELENGTHS OF THE
ELECTROMAGNETIC SPECTRUM**
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- [51] Int. Cl. **G02b 5/14**, G06k 7/10
- [58] Field of Search **340/347 P**; 350/96 B

[56] **References Cited**
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Attorney, Agent, or Firm—Johnson, Dienner, Emrich,
Verbeck & Wagner

[57] **ABSTRACT**

A device for transmitting wavelengths of the electromagnetic spectrum from one or more sources to detector means, comprising one or more channel plates each having channels therein into which are disposed conduction elements of a material having a higher index of refraction than the material of the associated plates. The channels and associated conduction elements selectively intersect exterior surfaces of the channel plates such that wavelengths from sources positioned generally adjacent selected end portions of the conduction elements are guided to the opposite ends of the channels. The device finds application in optical encoder systems, card and punched tape illuminators and readers, and alphanumeric devices and the like.

9 Claims, 12 Drawing Figures

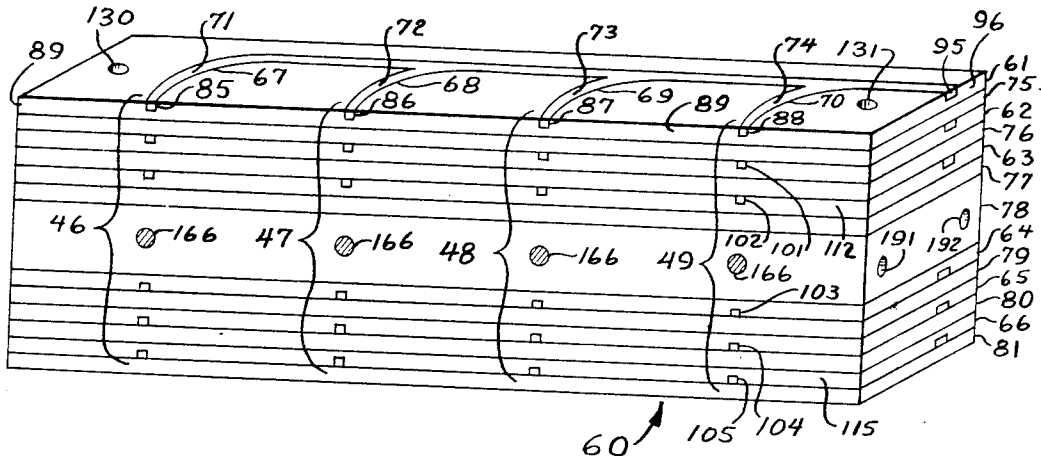


Fig. 1

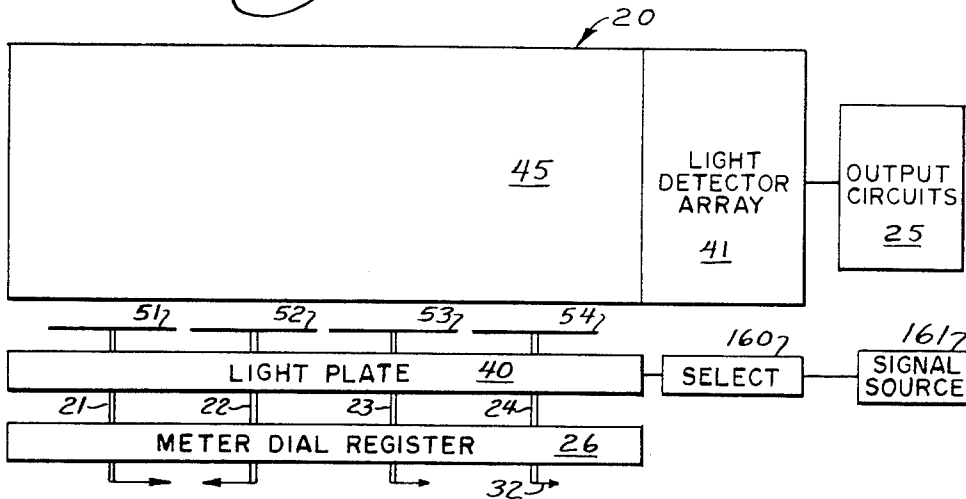
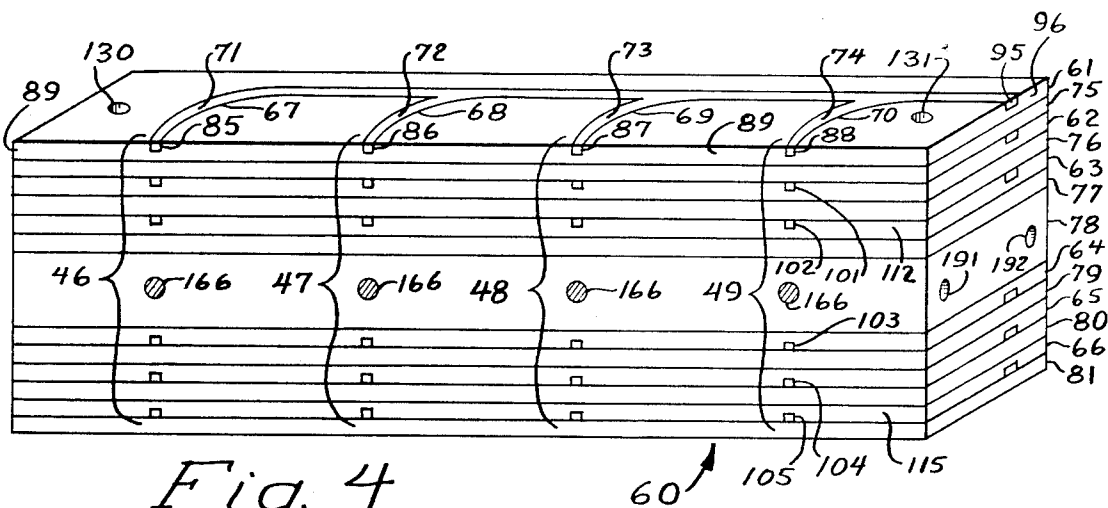
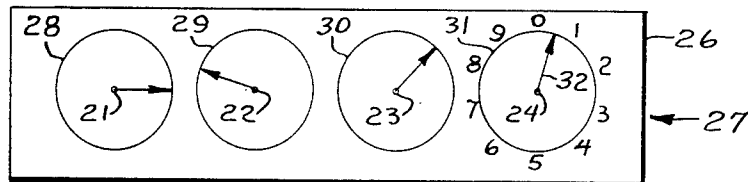
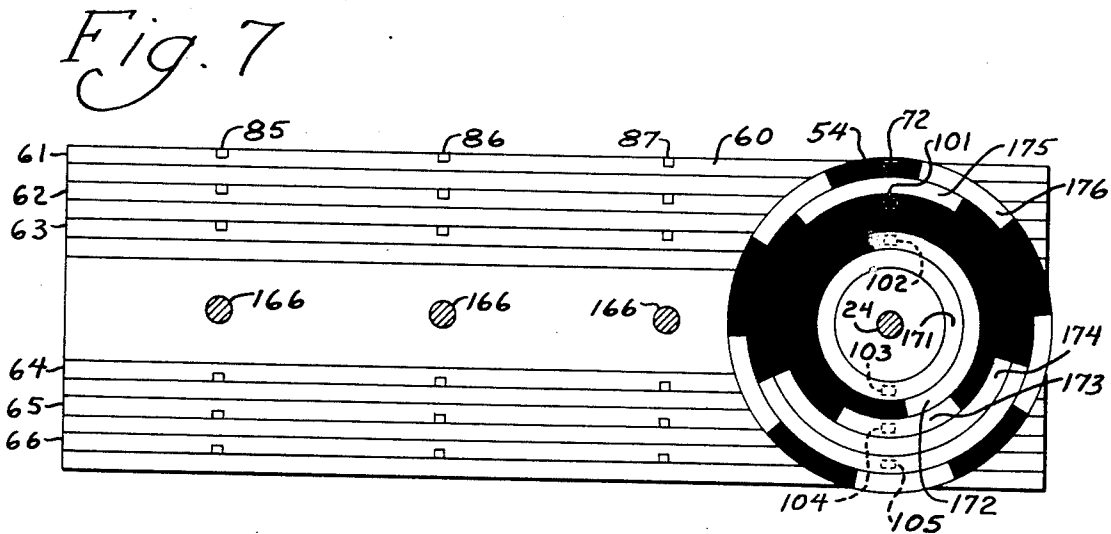
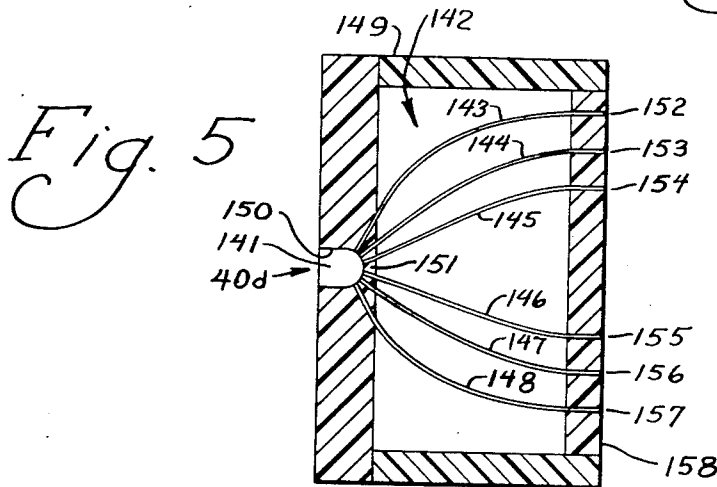
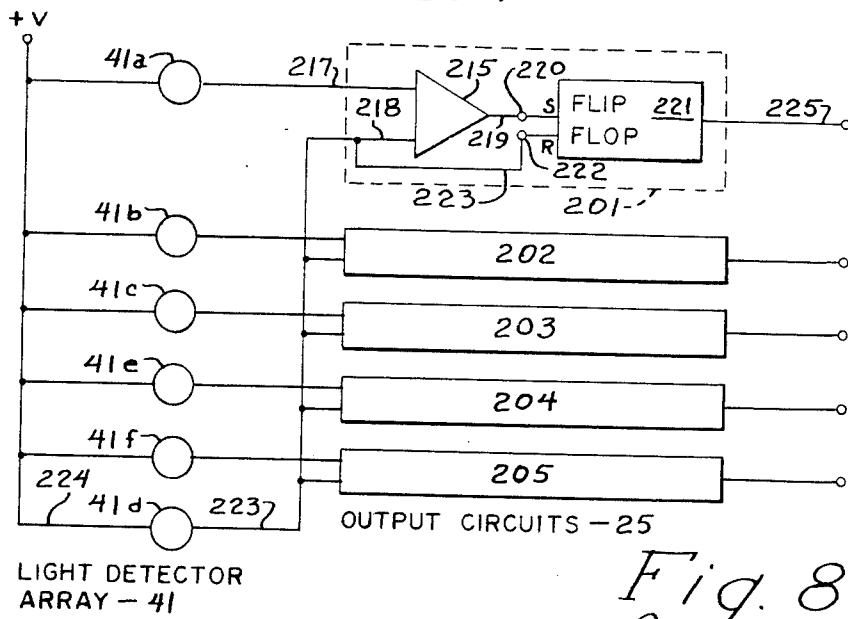


Fig. 2





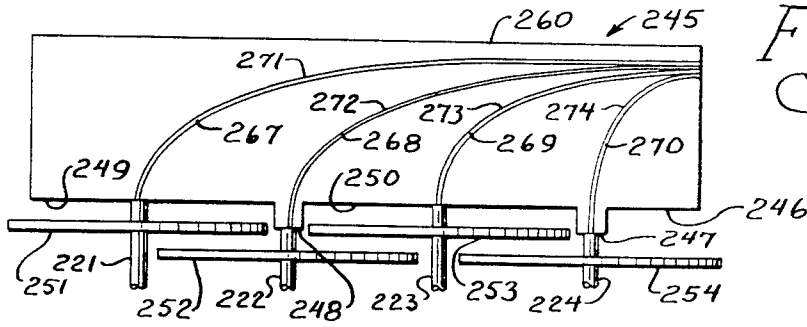


Fig. 9

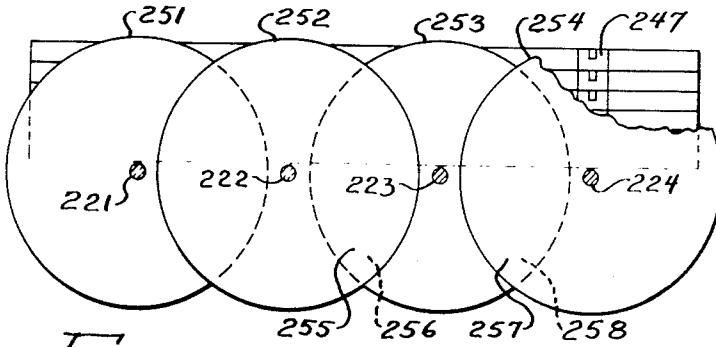


Fig. 10

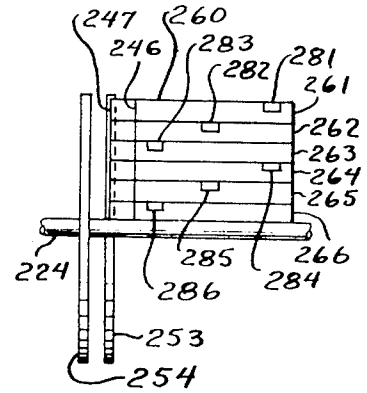


Fig. 11

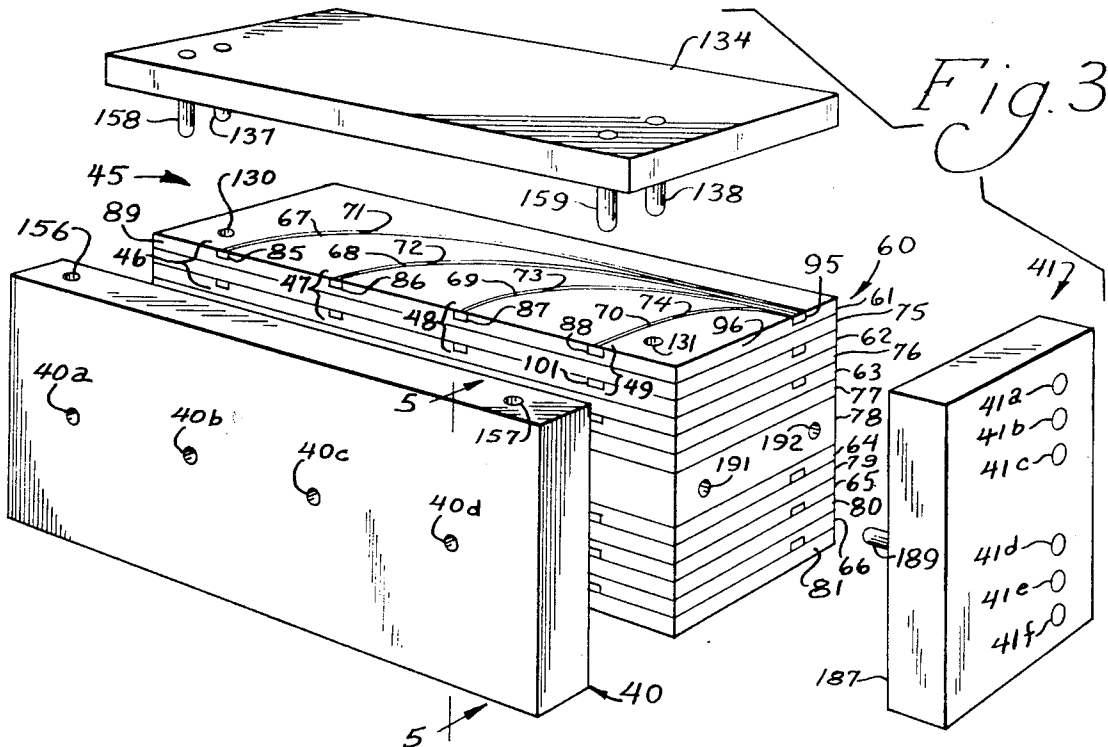
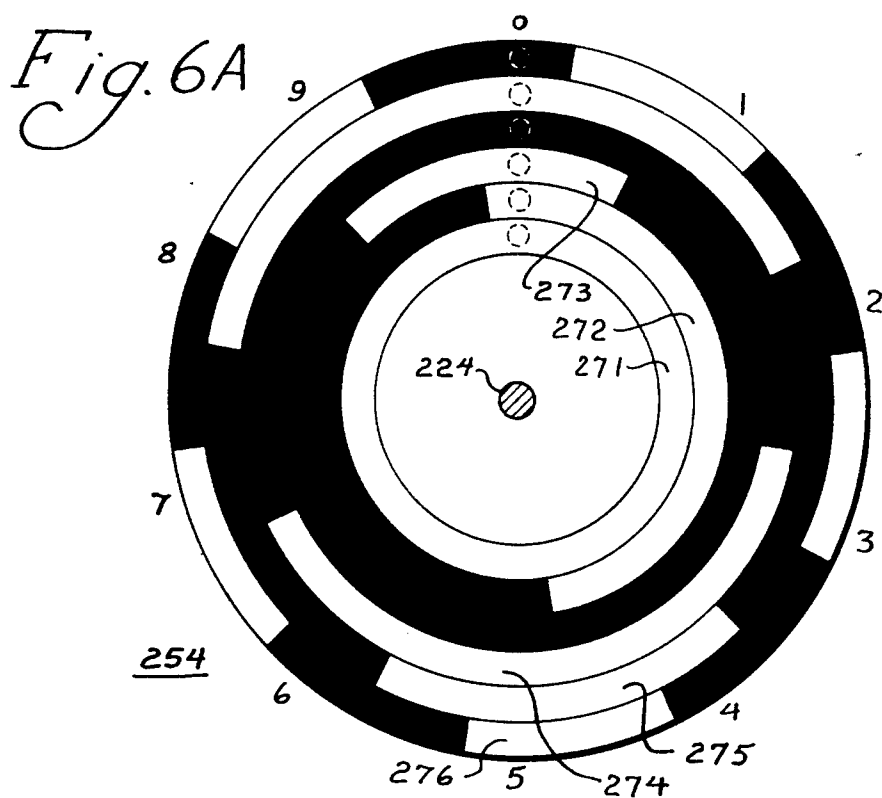
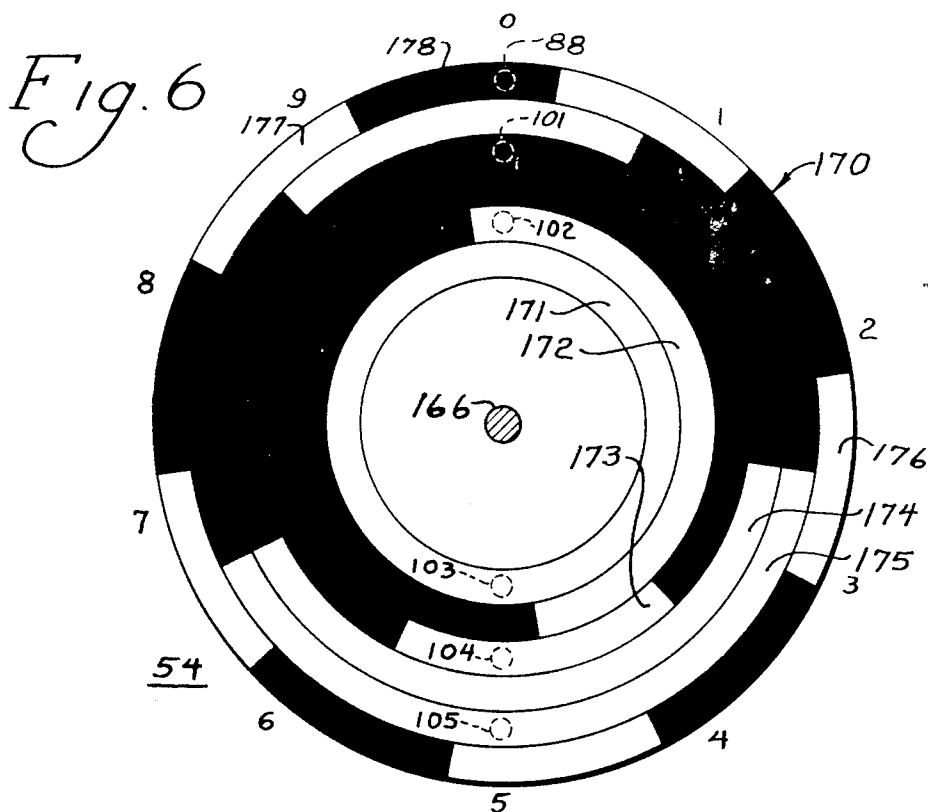


Fig. 3



DEVICE FOR TRANSMITTING WAVELENGTHS OF THE ELECTROMAGNETIC SPECTRUM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to wave transmitting devices and more particularly to a novel transmitting device employing one or more channel plates having transmitting channels adapted to transmit wavelengths of the electromagnetic spectrum through a plurality of predetermined paths from one or more light sources to detection means.

2. Description of the Prior Art

It is generally known to use optical transmitting means for guiding light waves from a light source to detection means. For example, fiber optic bundles comprising lengths of fiber optic rods have been employed in optical encoders to transmit light waves from a light source over both linear and non-linear paths to light detection means. Analog-to-digital computers such as disclosed in U.S. Pat. No. 3,247,506 to E. O. Grim, Jr. employ optical encoders wherein optical bundles transmit light from a light source onto one side of a code disc that is coded with clear and opaque areas. Light passing through clear areas of the code disc selectively energize photosensors which are positioned on the opposite side of the code disc.

The known fiber optic bundles include a plurality of fiber optic rods each having one end supported in a plate which is positioned adjacent the light source and another end supported in a plate which is positioned adjacent the code disc so that light from the source is conducted over the fiber optic rods and directed toward the code disc. The intermediate portions of the fiber optic rods are encapsulated in epoxy. The fiber optic bundles enable optimum positioning of the photosensors relative to the light source by permitting bends and twists in the light paths over which light is conducted from the light source to the code disc and thence to the photosensors.

A shortcoming of encapsulated fiber optic rod assemblies of the type disclosed in the references patent to E. O. Grim, Jr. is that after encapsulation, the individual fiber optic rods cannot be removed from the assembly and replaced in the event that a rod is damaged or broken during assembly. Moreover, since the fiber optic rods are generally of a small diameter, which may be on the order of 1/32 inch, the fabrication of the fiber optic assemblies requires insertion of the ends of the fiber optic rods into apertures in the support plates which can be difficult and time consuming, particularly where a large number of fiber rods must be positioned to provide a plurality of individual optical paths.

SUMMARY OF THE INVENTION

One of the primary objects of the present invention is to provide novel means for transmitting wavelengths of the electromagnetic spectrum from a source to detection means through the physical mechanism of total internal reflection.

Another object of the present invention is to provide a novel channel plate arrangement employing one or more channel plate members having channel means formed therein into which are disposed conduction path means adapted to transmit wavelengths of the

electromagnetic spectrum through the mechanism of total internal reflection.

Another object of the present invention is to provide a channel plate arrangement as described wherein a plurality of channels are provided in each of the channel plate members, the channels of each plate intersecting a common surface of the plate and converging to a common point of intersection on another surface of the plate, the conduction path means disposed within each of the channel plates being adapted to transmit wavelengths from either a common source to a multiplicity of outlets or from a plurality of sources to a single detector means.

Another object of the present invention is to provide a novel wavelength transmitting device as described wherein each of the wavelength conduction path means is defined by a channel material having a higher index of refraction than the material of the plate defining the channels into which the conduction medium is disposed.

Another object of the present invention is to provide a wavelength transmitting device comprising a plurality of stacked channel plates each of which lends itself to low fabrication cost, exact duplication, simple assembly, and a production process which is considerably less complex than required by the prior art devices for transmitting wavelengths of the electromagnetic spectrum.

A feature of the transmitting device in accordance with the present invention is that it may be used economically and efficiently in optical encoder systems, card and punched tape illuminators and readers, and alphanumeric devices and the like.

In carrying out the objects and advantages of the present invention, there is provided a channel plate arrangement comprising one or more generally planar channel plate members each having a plurality of channels formed in one surface thereof. In one embodiment of the present invention, a plurality of channel plates are assembled in stacked relation and the channels of each plate have first end portions intersecting a common edge surface of the plate and extend to a common point of intersection at a second edge surface of the plate. Conduction path means are disposed in the channels and extend the full lengths thereof. The conduction path means comprises channel material adapted to transmit wavelengths of the electromagnetic spectrum, the channel material having a higher index of refraction than the material comprising the associated plate member.

In one method of manufacture of the channel plate assembly, each channel plate having channels therein is formed by injection molding from acrylic plastic having an index of refraction of 1.49. A second mold is used to inject plastic such as polystyrene having a higher index of refraction than the acrylic plastic of the plate body into the channels, the plates being thereafter assembled into stacked relation to establish the desired unit size.

An alternate method of manufacture of the channel plate assembly in accordance with the present invention is to fabricate polystyrene channel elements and position them accurately in sandwich fashion between plate members made from a transparent material having a lower index of refraction than the channel elements. The channel elements constitute guide paths for wavelengths of the electromagnetic spectrum and are

bounded on two sides by air, the channels being of substantially any desired cross-sectional configuration such as circular or square.

In a described application of the channel plate assembly in accordance with the present invention, the channel plate assembly is employed as an optical encoder in an analog-to-digital converter.

The analog-to-digital converter provides sets of output signals representing the angular positions of four shafts and employs a single optical channel plate assembly which provides separate sets of light-conducting paths from the code discs associated with the shafts to a light detector array. Each set of light paths is defined by a plurality of light transmitting channel elements which individually intersect a common edge surface of the plate and converge to form a single light output for the channel plate. In this manner, only one light detector is required for each optical channel plate thereby minimizing the number of light detectors required for the optical encoder and simplifying the output circuits required to convert the outputs of the light detectors to digital signals.

The optical encoder employing the optical channel plate assembly in accordance with the present invention provides encoding of four shafts using a common optical array and is more compact and economical in manufacture than prior art optical encoders employing fiber optic light conducting rod elements.

Further objects and advantages of the present invention, together with the organization and manner of operation thereof, will become apparent from the following detailed description of the invention when taken in conjunction with the accompanying drawings wherein like reference numerals designate like elements throughout the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a channel plate assembly transmitting device in accordance with the present invention embodied in an analog-to-digital converter;

FIG. 2 is a front elevational view schematically illustrating the meter portion of FIG. 1;

FIG. 3 is an exploded perspective view showing the channel plate assembly of FIG. 1 with associated elements which cooperate to define an optical encoder;

FIG. 4 is an isometric view of the channel plate assembly of the optical encoder shown in FIG. 3;

FIG. 5 is a sectional view taken along lines 5-5 of the light plate shown in FIG. 3;

FIGS. 6 and 6a are schematic plan views of the two embodiments for the code discs of the optical encoder shown in FIG. 1;

FIG. 7 is a front elevational view of the channel plate assembly and a code disc to show the relationship between the light channels and the code tracks of the code disc;

FIG. 8 is a schematic circuit diagram of the output circuits of the encoder shown in FIG. 1;

FIG. 9 is a schematic top plan view of a channel plate assembly and associated code discs in accordance with a second embodiment of the invention;

FIG. 10 is a front elevational view of the assembly shown in FIG. 9; and

FIG. 11 is an end view of the assembly shown in FIG. 10.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and in particular to FIG. 1, a device for transmitting wavelengths of the electromagnetic spectrum in accordance with one embodiment of the present invention is schematically illustrated as being incorporated in an optical analog-to-digital converter indicated generally at 20. By way of example, the optical encoder 20 is described relative to an application for converting angular positions of four shafts 21-24 into sets of binary coded output signals which are provided over output circuits 25. While the transmitting device in accordance with the present invention will be described as being employed for transmitting light, it will be understood that the broad concept of the present invention finds application in transmitting substantially any selected wavelengths of the electromagnetic spectrum. In addition, while the transmitting device of the instant invention is illustrated in use as an optical encoder, the transmitting device can also be used in various other applications. For example, the channel plate assembly to be hereinafter described can be used in card and punched tape illuminators and readers to conduct light from a common light source to a plurality of light detector elements, or in segmented numeric readouts.

The four shafts 21-24 may, for example, be part of a register 26 of a utility meter 27 shown in FIG. 2. The register 26 has four clock-type dials 28-31 associated with the shafts 21-24, respectively, for indicating a reading of measured amount of a commodity used. The register 26 provides a four digit reading with dials 28-31 representing thousandths, hundredths, tens and units digits of the reading respectively.

Each dial, such as dial 31, has ten digits 0-9 circumferentially spaced about the dial 31 and a pointer 32 carried by the associated shaft 24 for indicating one of the ten positions 0-9 of the shaft 24.

Input drive for the register 26 is provided by measuring means (not shown) of the meter 27 which effects rotation of shaft 24 of the units dial 28 in accordance with quanta of a commodity measured by the measuring means. Shafts 21-24 are interconnected by a gear train (not shown) of the type which is conventional in the art of meter registers. Accordingly, shaft 24, driven by the measuring means effects rotation of shafts 21-23 whereby shafts 23 rotates one revolution for each ten revolutions of shaft 24, shaft 22 rotates once for each 100 revolutions of shaft 24, and shaft 21 rotates once for each 1000 revolutions of shaft 24.

The angular positions of each of the shafts 21-24 are converted into digital signals by the optical shaft encoder 20 which provides a different set of binary coded output signals over output circuits 25 for each of a plurality of predetermined positions for the shafts 21-24. The encoder provides a separate set of output signals to represent the angular position of each shaft 21-24, and correspondingly, the reading of the meter dials 28-31 associated with the shaft.

The encoder 20 includes a light plate assembly 40 which directs light through code discs 51-54 toward an optical channel plate assembly or array 45. As will be described hereinafter, the optical channel plate assembly 45 provides four separate sets of light paths which conduct light directed toward the stack from the light plate 40 to a light detector assembly 41. The code discs 51-54 are mounted for rotation by shafts 21-24, re-

spectively, and are interposed between the light plate 40 and the channel plate assembly 45 to permit selective transmission of light over the channel plate assembly from the light plate 40 to the light detector array 41 as a function of the angular positions of the shafts 21-24 which carry the code discs 51-54.

In the view of the encoder 20 shown in FIG. 3, the light plate assembly 40 and the light detector assembly 41 are shown spaced apart from the optical channel plate array 45. The code discs 51-54 are not shown in FIG. 3 for purposes of clarity. As can best be seen in FIG. 4, the optical channel plate array 45 includes a stack 60 of light channel plates 61-66. Each channel plate, such as channel plate 61, comprises a base or plate body sheet having four generally arcuate channels 67-70 formed in the upper surface of the plate body. Each channel has conductive path means disposed therein comprising a conductive element, such as indicated at 71-74, which extends the full length of the associated channel and is adapted to conduct wave-lengths of the electromagnetic spectrum.

Each of the plate bodies or base sheets 61 is made of an acrylic plastic material which is one embodiment is approximately one-sixteenth inch in thickness, one-half inch in width, and $3\frac{1}{2}$ inches in length. The channels 67-70 in the exemplary illustration have a square cross-section of approximately 1/32 inch by 1/32 inch. The channels 67-70 are defined by smooth wall surfaces and may be formed in the plastic sheets 61a by molding or casting the sheet to the desired configuration.

The conductive elements 71-74, which are disposed in the channels 67-70 of channel plate 61, may comprise elongated bodies made of polystyrene formed to be readily received within the associated channels. The optic elements 71-74 may, in one method of manufacture, be drawn and cut to the desired lengths. The ends of the conductive elements are then trimmed and finished by heating or chemical polishing so that the ends are smooth. In this manner, light directed toward the ends of the conductive channel elements will be conducted over the full lengths and will not be reflected away from the conductive elements.

In one method of manufacture, the conductive channel elements 71-74 are formed to have square cross-sectional configurations and are pressed into the square shaped channels 67-70 in the base sheet 61 using an optically smooth die which will maintain the surfaces of the channel elements optically smooth when they are embedded in the acrylic plastic base sheet 61. Such precaution is taken to assure that the surfaces of the conductive elements will remain optically smooth so as to minimize light scattering. Alternatively, the conductive channel elements may be formed with circular cross-sectional configurations and heated and pressed into the square channels 67-70 in the base sheet 61 to conform to the shape of the channels. It is also possible to employ channels and conductive channel elements having circular or semi-circular cross-sections.

The four channels 67-70 and their associated conductive elements 71-74 have input ends 85-88, respectively, which intersect an edge surface 89 of the channel plate 61. The channels 67-70 and their associated conductive elements 71-74 converge together so as to form a single output channel 95 which terminates at a second edge surface 96 of the light channel plate 61. Since sharp bends in the conductive elements are undesirable from the standpoint of reflection losses, the ra-

dius of curvature of the conductive elements is maximized for a given width of the base sheet.

The conductive channel elements, such as channel elements 71-74 of channel plate 61, serve as "light paths" to conduct light from the light plate 40 which impinges on the input ends 85-88 of the conductive elements to the output end 95 adjacent the light detector array 41 as shown in FIG. 3. The conductive channel elements in the respective plate bodies 61-66 conduct light by total internal reflection. Accordingly, the material of the conductive elements is selected to have a higher index of refraction than the material of the plate body sheets. For example, the conductive elements may be made of polystyrene having an index of refraction of 1.59 and the base plate sheets may be made of acrylic plastic having an index of refraction of 1.49. Consequently, as light is conducted through the channel plate assembly 45 over the conductive elements, light rays incident on the walls of the conductive elements 71-74 will be reflected back into the conductive elements rather than passing to the adjacent base sheet, and thus, the light will be conducted along the full lengths of the conductive elements from their input ends to their output ends.

Alternatively, the present invention contemplates manufacture of the polystyrene conductive channel elements by the technique of drawing the elements through a die and cladding them along their peripheral surfaces with a cladding material such as an epoxy or acrylic plastic having a lower index of refraction than that of the conductive elements. The cladded conductive elements would then be inserted into the respective channels. In this fashion, any suitable material can be used for the base sheets.

The channel plates assembly 45 may also be made by first forming the channel plates and associated channels through injection molding techniques, injecting a liquid polystyrene plastic into the channels which have a higher index of refraction than that of the channel plate material. The plastic channel material will find the channels in the channel plate and conform to the shape of the channels. When the plastic cools, the material will solidify to form the desired optical paths through the channel plate with the output ends of the path being integrally combined at 95.

A further technique for manufacturing the channel plates includes the steps of forming the polystyrene conductive elements, and then positioning the conductive elements accurately in sandwich fashion between a pair of base plates of a material such as acrylic plastic. In this embodiment, the base sheets do not have pre-formed channels. Rather, the conductive elements will be bound on two sides by air which has an index of refraction of unity. Light will be transmitted through the conductive paths provided by the conductive elements. The spaces between the conductive elements and the base plates may be filled with a suitable material to assure that the conductive elements remain in position. In such case, the index of refraction of the material provided between the rods will be less than the index of refraction of polystyrene material from which the conductive elements are made.

Referring again to FIG. 4, the channel plates 62-66 are substantially identical to channel plate 61 with each having four conductive elements disposed in channels formed so that the conductive elements have input ends terminating at one edge surface of the associated

base sheet and a common output end terminating at a second edge surface of the base sheet. For example, channel plates 62-66 have light conductive elements 101-105, respectively, which have input ends intersecting edge surfaces corresponding to edge surface 89 of plate 61. The light conductive elements of each of the channel plates similarly converge to establish a common output for the associated channel plate similar to the common output 95 of the conductive elements of channel plate 61.

The channel plates 61-66 and their associated conductive elements are secured together in aligned stacked relation so that the input ends of the conductive elements of the respective channel plates overlie one another in a common edge surface of the stack. The channel plate stack also preferably includes spacing plates 75-81 which are interposed between the light channel plates 61-66 to separate them from each other and thereby establish a desired spacing between the conductive elements which overlie one another in the channel plate stack. The spacer 78 has a greater vertical thickness than the other spacers and serves to support the shafts of code discs 51-54 as will be more fully described hereinbelow. The spacing plates 75-81 also increase the rigidity of the stack. Alternatively, the spacing plates 75-81 may be eliminated and the thickness of each channel plate 61-66 may be increased. In the latter case, the thickness of the channel plates 61-66 should be selected to sufficiently provide the desired isolation between the vertically aligned conductive elements in the stack.

Referring to the FIG. 3, each of the channel plates 61-66 and spacer plates 75-81 includes a pair of alignment apertures, such as apertures 130 and 131 in sheet 61, which are formed in the channel plates for vertical alignment when the channel plates are assembled in stacked relation. The encoder assembly 20 includes an alignment plate 134 which has a pair of spaced parallel alignment pegs 137 and 138 which are received through the alignment apertures 130, 131, respectively, in the channel plates 61-66 and spacers 75-81 to assure that the input and output ends of the conductive channel elements will be vertically aligned.

As has been described, each of the six channel plates 61-66 includes four conductive channel elements each of which provides an individual light path over the corresponding channel plate. With the input ends of the conductive channel elements being vertically aligned as shown in FIG. 4, it can be seen that four separate sets of conductive light paths 46-49 are provided through the channel plate assembly 45.

Noting FIG. 3, the light plate 40 includes a separate light source 40a-40d for each set of light paths 46-49 for directing light toward the conductive channel elements of the associated sets of light paths. The light plate 40 includes alignment apertures 156, 157 which receive spaced parallel alignment pegs 158, 159 on the alignment plate 134 to align the light sources 40a-40d relative to the channel plate stack 60. Referring to FIG. 5, which is taken along line 5-5 of FIG. 3, each light source, such as source 40d, includes a light emitting diode 141 and a light guide 142 comprising six polystyrene fiber optic rods 143-148 for directing light emitted by the diode 141 toward the conductive channel elements comprising each light path set 46-49 in the channel plate assembly 45. The light plate 40 includes a hollow support housing 149 having an aperture 150

for receiving the diodes 141. The fiber optic rods 143-148 are supported by the housing 149 and are merged at one end 151 adjacent the diode 141. The individual fiber optic rods 143-148 extend through the housing 149 to openings 152-157 in a wall 158 of the housing which is adjacent the channel plate stack 60 to permit light from the diode to impinge on the input ends of the conductive channel elements in the channel plates.

The light emitting diode 141 may be a gallium arsenide phosphide diode which, when energized, emits light at a peak wavelength of 650 angstroms. A suitable light emitting diode commercially available is the MV50-light Emitting Diode manufactured by Monsanto Corp. The polystyrene chosen for the fiber optic rods 143-148 is adapted to conduct wavelengths of the electromagnetic spectrum.

Referring to FIG. 1, the light emitting diodes, such as diode 141, are energized by signals extended to the diodes over a select circuit 160 from an energizing source 161. The select circuit 160 may comprise a gating arrangement for sequentially connecting the output of the energizing source 161 to the leads of the diodes which comprise the light sources 40a-40d of light plate 40.

Light sources 40a-40d are associated with dials 28-31, respectively. Thus, to read out the meter reading, the diode of source 40a is energized first, then the diode of source 40b, etc., so that the angular positions of the shafts 21-24 associated with the four diodes 28-31, respectively.

To avoid erroneous readings and to permit the use of AC amplifiers in the output circuits 25, the energizing source 161 provides a DC signal modulated by an AC signal at 100 HZ rate.

As can be seen in FIG. 1, each of the shafts 21-24 carries a code disc member 51-54, such as code disc 54 shown in detail in FIG. 6. The code discs 51-54 are interposed between the light plate 40 and the optical channel stack 45 to permit selective transmission of light from the six light outputs of the light sources 40a-40d comprising the light plate 40 to the six input ends of the conductive channel elements comprising each of the four input areas 46-49 of the channel plate stack 60.

Code member 54 comprises a disc 170 having a code pattern comprising six concentric rings 171-176. Each ring or track, such as track 176, bears coded information in the form of a number of alternating radiation permeable and opaque angular segments, such as segments 177, 178. In the present example, where the radiation employed is visible light, the disc 170 may be formed of a light transparent material, such as plastic, the opaque sections 178 being formed as a coating of an opaque material selectively disposed on a surface of the disc 170.

The code discs 51-54 are mounted for rotation by associated shafts 21-24, respectively. The shafts 21-24 pass through apertures 166, shown in FIG. 4, formed in the spacer sheet 78. The apertures 166 serve to align the code tracks of the discs 51-54, such as tracks 171-176 of disc 54, relative to the input ends of the conductive channel elements in the stacked channel plates.

The locations of the input ends of the conductive channel elements 74 and 101-105 relative to the code tracks 171-176 are indicated by the circles shown in

the code tracks in FIG. 6. Thus, for example, code tracks 176, 174 and 172 are aligned with conductive elements 74, 101 and 102, respectively, while code tracks 171, 173 and 175 are aligned with conductive elements 103-105, respectively. In the present example, the innermost track 171 comprises a reference channel and the other five code tracks 172-176 are data tracks.

The data tracks 172-176 of the disc 170 shown in FIG. 6, are coded in gray code so that, as will be shown, in a sequential change from any code number representing a given angular position of the associated shaft to any next adjacent number representing the next position of the shaft, the change requires that only one digit or bit of the number be changed.

Reference channel 171 is transparent over the entire extent of the track such that light from the light plate 40 directed towards the reference channel area 171 of code member 54 will be passed to the optical stack 60.

Referring to FIG. 7, code disc 54 is shown mounted on shaft 24. One end of the shaft 24 passes through the aperture 166 in the spacer sheet 78 of the stack 60 and serves to align the code tracks 171-178 of the code disc 54 relative to the exposed input ends of the conductive channel elements in the light channel area 49 of the plate stack 60. The shaft mounting also references the code member 54 to the light output members 143-148 of the light source 40d. Accordingly, light from the light rod 143 directed towards the code disc 54 will pass to conductive element 74 whenever the angular position of the shaft 24 is such that a clear area, such as area 177, is positioned between the light tube 143 and the input end 88 of the conductive element 74 and be conducted over the conductive element to the light detector array 41. Alternatively, when the angular position of the shaft 24 is such that an opaque area, such as area 178, is positioned between the light rod 143 and the input end 88 of the conductive channel element 74, transmission of light between the light member 143 and the optical plate stack 60 will be blocked.

Code members 51-53 are similar to the code member 54 and have an identical pattern disposed on the surface of the code members 51-53.

As the light emitting diode of each of the light sources 40a-40d is sequentially energized over the select circuit 160 by signals from the power signal generator 161, light is directed through associated code discs 51-54 to the optical stack 60. The light directed to the optical stack will be conducted over the conductive channel elements in the channel plates which are adjacent transparent areas of the code member as a function of the angular positioning of the code member. The light is conducted over the optical channel plate stack to the output edge surface of the stack to selectively illuminate detectors 41a-41f, shown in FIG. 3, which comprise the light detector array 41.

The light detector array 41 shown in FIG. 3 includes six detectors 41a-41f, each being associated with one of the six terminal ends of the conductive channel elements in the channel plates 61-66. The light detectors 41a-41f may comprise photosensitive transistors, such as the type FPF 1,100 manufactured by Fairchild Semiconductors, Inc. Noting FIG. 3, the light detectors 41a-41f are supported by a plate 187 of the detector array 41 in vertically spaced alignment. The detectors 41a-41f abut the output edge surface of the channel plate stack 60 to minimize loss of light from the stack to the detector elements 41a-41f.

The detector plate 41 includes a pair of horizontally spaced locating pegs, one of which is shown at 189, which are received in alignment apertures 191, 192 provided in the channel plate stack 60 to align the optical detectors 41a-41f with the output ends of the conductive channel elements in the channel plate stack.

The photo-transistors which comprise the detector elements 41a-41f are responsive to light conducted over the optical stack 60 from the light source 40 to change electrical conductivity. This change in conductivity is monitored by the output circuits 25 which provide outputs representing the condition of the detectors 41a-41f and correspondingly indicate over which channels light is being transmitted.

Referring to FIG. 8, the output circuits 25 comprise five output detecting circuits 201-205, each connected to one of the light detectors 41a-41c, 41e and 41f. Each output circuit, such as circuit 201, connected to detector 41a includes a differential amplifier 215 having a first input 217 connected over the detector device 41a to a voltage source +V and a reference input 218. The output 219 of the amplifier 215 is connected to a set input 220 of a phase detecting flip flop 221. A reset input 222 of the phase detecting flip flop 221 is connected to the reference input 218 of the differential amplifier 215. The reference signal which is applied to the reference input 217 of the differential amplifier 215 is provided by the light reference level detector 41d which, as shown, in FIG. 8, has a first lead 224 connected to the source +V and a second lead 223 connected to the reference input of each output circuit, such as lead 218 of output circuit 201.

Whenever a detector such as detector 41a is energized by light, the resistance of the phototransistor which comprises the detector will increase and, accordingly, the voltage +V will be extended to the input 217 of the amplifier 215. The light reference level detector 41d associated with the reference channel will be energized continuously since the code track 174 of the code disc 54 which comprises the reference channel is of a transparent material and accordingly, the reference input will always be +V.

Whenever the detector 41a is energized, the signal levels at inputs 217 and 218 of the amplifier 215 will both be at +V potential, and accordingly, the signal level at the ground signal level on set input 220 of phase detect flip flop 221 will cause the flip flop 221 to remain reset providing a logic 0 level at output 225.

On the other hand, if because of the coding of the disc 51, detector 41a is not energized, input 217 will be at approximately ground potential whereas the reference lead 218 will be at a potential of +V. Accordingly, the output 219 of the differential amplifier 215 will be a +V potential which will set the phase detect flip flop 221, thereby providing a logic 1 level at output 225 of the flip flop 221.

The output circuits 202-205 similarly provide logic 1 or logic 0 outputs as the function of the angular position of the code disc 51-53 associated therewith which provide selective transmission of light over the fiber optic array 45 to the light detector array 41. The five logic level output signals provided by the circuits 201-205 provide the gray code shown in Table 1 which represents coding for 20 angular positions of the shafts 21-24.

TABLE I

Gray Code for a Twenty Position Encoder

Digit Position	Output Circuit				
	201 (176)	202 (174)	203 (172)	204 (173)	205 (175)
0	1	1	0	0	0
$\frac{1}{2}$	0	1	0	0	0
1	0	1	0	1	0
$1\frac{1}{2}$	1	1	0	1	0
2	1	1	0	1	1
$2\frac{1}{2}$	0	1	0	1	1
3	0	0	0	1	1
$3\frac{1}{2}$	1	0	0	1	1
4	1	0	0	1	0
$4\frac{1}{2}$	0	0	0	1	0
5	0	0	1	1	0
$5\frac{1}{2}$	1	0	1	1	0
6	1	0	1	1	1
$6\frac{1}{2}$	0	0	1	1	1
7	0	1	1	1	1
$7\frac{1}{2}$	1	1	1	1	1
8	1	1	1	1	0
$8\frac{1}{2}$	0	1	1	1	0
9	0	1	1	0	0
$9\frac{1}{2}$	1	1	1	0	0
0	1	1	0	0	0

Thus, for example, when pointer 32 of dial 31 of register 26 shown in FIG. 2 is indicating a reading of zero, the orientation of the code disc 54 relative to the optical channel plate assembly 45 will be as shown in FIG. 6, with opaque areas of code tracks 174 and 176 adjacent light conductive channel elements 74 and 101, and clear areas of code tracks 171-173 and 175 adjacent light conductive channel elements 102-105. Therefore, with reference to FIG. 2, when light source 40d is energized, light directed toward the optical stack (over code disc 54) will be conducted through the optical channel plate assembly 45 over the conductive channel elements 102-105 to energize light detectors 40c-40f. Correspondingly, when light detectors 40c-40f are energized, output circuits 203-205 will provide logic 0 outputs, and output circuits 201 and 202 controlled by detectors 40a and 40b which are not energized will provide logic 1 levels as shown in Table I to represent the coding for the digit position zero.

SECOND EMBODIMENT OF THE OPTICAL ARRAY

A second embodiment of an optical channel plate assembly 245 in accordance with the present invention is shown in FIGS. 9-11. The channel plate assembly 245 includes a stack of light channel plates 261-266 each of which has four channels 267-270 formed in the upper surface thereof to receive conductive channel elements 271-274, respectively. The methods of manufacture of the channel plates 261-266 may be similar to those described above with reference to the channel plate assembly 45.

Noting FIG. 9, the forward surface 246 of the channel plate assembly 260 has a pair of forwardly projecting boss portions 247 and 248 which extend the full vertical height of the assembly 260 and define two recessed areas 249 and 250 adjacent thereto. The planar areas of the recesses 249 and 250 are sufficient to allow mounting of code discs 251 and 253, respectively, within the recess areas as shown. The code discs 251 and 253, as well as code discs 252 and 254, are supported on rotatable shafts 221-224, the code discs 252 and 254 being supported adjacent the forward surfaces of the bosses 247 and 248.

By providing forward bosses 247 and 248, and thereby establishing the peripheral portions of the code

discs 251-254 are allowed to overlap. Thus, for example, as shown in FIG. 10, a portion 255 of the code disc 252 overlaps a portion 256 of code disc 253, and a portion 257 of code disc 254 overlaps a portion 258 of code disc 253. The overlapping of portions of adjacent code discs permits a reduction in the horizontal dimension of the channel plate assembly 245 to approximately half the size of the channel plate assembly 45 shown in FIG. 3, when using similar size code discs for the respective embodiments of the channel plate assemblies. Alternatively, larger code discs may be used with the channel plate assembly 245 if it is the same size as plate assembly 45.

As can be seen in FIG. 9, the overlying portions of the conductive channel elements 272 and 274 intersect the outer surfaces of the boss portions 248 and 247, respectively, such that the code discs 251-254 are all spaced approximately the same distance from the corresponding forward edge surfaces 247, 248, 249 and 250 of the channel plate assembly 260. Light from a light source (not shown) would be directed toward portions of the code discs 251-254 that lie between the overlapping portions of the code discs. As is best shown in FIG. 11, only one-half of the planar area of each code disc is positioned forwardly of the channel plate assembly 260. Therefore, a different pattern of clear and opaque areas is used for the code discs 251-254. One example for a code disc 254 is shown in FIG. 6A. In the channel plate assembly 245, the conductive channel elements in each channel plate 261-266 converge, as shown for channel plate 261, and intersect an end surface of the channel plate assembly at common points of intersection 281-286, as best seen in FIG. 11. The respective common end terminations 281-286 of the conductive elements in the stacked plates are staggered to minimize interference between adjacent light channels, as shown. An associated light detector array (not shown) would have light detectors disposed in the same pattern as the output terminal ends 281-286 of the light conductive elements in the channel plate assembly 245.

While the channel plate assemblies provided in accordance with the present invention have been described with reference to application in an optical encoder, it will be understood that the channel plate assemblies can also be used in various other applications such as in card and punched tape illuminators and readers to conduct light from a common light source to a plurality of light detector elements, or in segmented numeric readouts. In such applications, the channel plate assemblies would provide an optical transmitting device which is simpler in construction and more economical to manufacture than optical assemblies which employ many individual fiber optic rods as employed in the prior art.

We claim:

1. A stack for providing a plurality of sets of transmission paths for conducting radiant energy selectively directed toward a first edge surface of the stack to a second edge surface of the stack, comprising a plurality of sheets of materials having a first index of refraction, each of the said sheets having a plurality of channels formed on a surface thereof extending from a first edge of the sheet to a second edge of the sheet, and a plurality of transparent channel members each positioned in a different one of said channels and extending from the first edge of said sheet to the second edge of said sheet

to provide a transmission path over said sheet, each of said channel members having an input end terminating at the first edge of the sheet and an output end terminating at the second edge of the sheet, said plurality of sheets being stacked together with the first edges thereof forming the first edge surface of said stack and the second edges thereof forming the second edge surface of said stack, each channel member being of a material having an index of refraction that is greater than the index of refraction of said sheets to permit radiation directed toward the first edge surface of said stack to be transmitted over the transmission paths provided by channel members to the second edge of said stack, and alignment means for aligning said sheets in said stack to locate the input ends of certain ones of said channel members on one sheet at predetermined positions relative to the input ends of channel members on other sheets at the first edge surface of the stack and to locate the output ends of said channel members at predetermined positions at the second edge surface of the stack to thereby provide a plurality of sets of transmission paths over said stack, such that radiant energy selectively directed toward different preselected portions of the first edge surface of the stack is conducted to the second edge surface of the stack over different ones of said sets of transmission paths.

2. An optical stack for providing a plurality of sets of light paths for conducting light selectively directed toward a portion of a first edge surface of the stack to a second edge surface of the stack comprising a plurality of sheets of a material having a first index of refraction, each of said sheets having a plurality of channels formed on a surface thereof extending from a first edge of the sheet to a second edge of the sheet, and a plurality of light channel members each positioned in a different one of said channels and extending from the first edge of said sheet to the second edge of said sheet to provide a plurality of separate light conducting paths over said sheet, each light channel member having an input end terminating at the first edge of said sheet and an output end terminating at the second edge of said sheet, said plurality of sheets being stacked together with the first edges thereof forming the first edge surface of said stack having the input ends of the light channel members exposed thereon at different locations and with the second edges thereof forming the second edge surface of said stack having the output ends of said light channel members exposed thereon at a common location each channel member being of a material having an index refraction that is greater than the index of refraction of said sheet to permit light directed toward the input ends of the light channel members to be conducted over said stack from the first edge surface to the second edge surface over said light channel member and alignment means for aligning said sheets in said stack to locate the input ends of certain ones of the channel members on one sheet in an overlying relationship with the input ends of certain ones of the channel members on another sheet in different preselected portions of said first edge surface of said stack providing a plurality of separate sets of light conducting paths to thereby permit transmission of light only over light channel members of a given set upon selective illumination of only the portion of the first edge surface of the stack wherein the input ends of such light channel members are exposed.

3. An optical stack as set forth in claim 2 wherein each of said sheets includes a pair of alignment apertures and wherein said alignment means includes a further sheet having a pair of spaced parallel alignment members which are received through the alignment apertures in said sheets.

4. A stack for providing a plurality of separate light transmission paths for conducting light incident on a first edge surface of the stack to a second edge surface of the stack, comprising a plurality of light channel plates each including a plate body of a material having a first index of refraction, said plate body including a branched channel formed on a surface thereof having a plurality of first ends which intersect the first edge surface of said light channel plate at different predetermined locations and a second end which intersects the second edge surface of said light channel plate at a predetermined location, and an integrally formed light channel member disposed in said branched channel and conforming to the shape thereof, said light channel member having input ends terminating at said predetermined locations on the first edge surface of said light channel plate and an output end terminating at said predetermined location on the second edge surface of said light channel plate, each said light channel member being of a material having an index of refraction that is greater than the index of refraction of said plate member to permit light directed toward the input ends of said light channel member to be conducted over said light channel plate from the first edge surface to the second edge surface thereof, and alignment means for aligning said sheets in said stack to locate the input ends of certain ones of the light channel members on one sheet in an overlying relationship with the input ends of certain ones of the channel members on another sheet providing a plurality of sets of light conducting paths to thereby permit transmission of light only over the light channel members of a given set upon selective illumination of a surface portion of the first edge of the stack including the input ends of the light channel members of said given set.

5. A channel plate for transmitting wavelengths of the electromagnetic spectrum between a source and detection means, comprising a plate body having top and bottom surfaces and at least two side surfaces, said plate body having a plurality of channels formed in one of said top or bottom surfaces, said channels having first end portions intersecting one of said side surfaces at separate positions, and said channels having second end portions intersecting a second side surface of said plate body at a common point of intersection, and conduction element means disposed in each of said channels and extending the full length thereof, said conduction element means being of a material capable of guiding wavelengths of the electromagnetic spectrum by substantially total internal reflection through the full length thereof, said plate body being made from a material having a predetermined index of refraction, and said conduction element means being made up of a material having a higher index of refraction than said plate body material.

6. A channel plate as defined in claim 5 wherein said top and bottom surfaces are generally planar and parallel to allow stacking of a plurality of channel plates.

7. A channel plate as defined in claim 5 wherein each channel has a predetermined cross-sectional by configuration, and wherein said conduction element means

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comprises an elongated wave transmitting body having a cross-sectional configuration allowing said conduction element means to be received in and engage the wall surfaces defining said channel.

8. A channel plate as defined in claim 7 wherein said surfaces of said plate body defining each said channel have smooth polished finishes, and wherein said conduction element means has an optically smooth outer

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peripheral surface.

9. A channel plate as defined in claim 5 wherein said plate body is made from acrylic plastic having an index of refraction of approximately 1.49, and wherein said conduction element means is made of polystyrene having an index of refraction of approximately 1.59.

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