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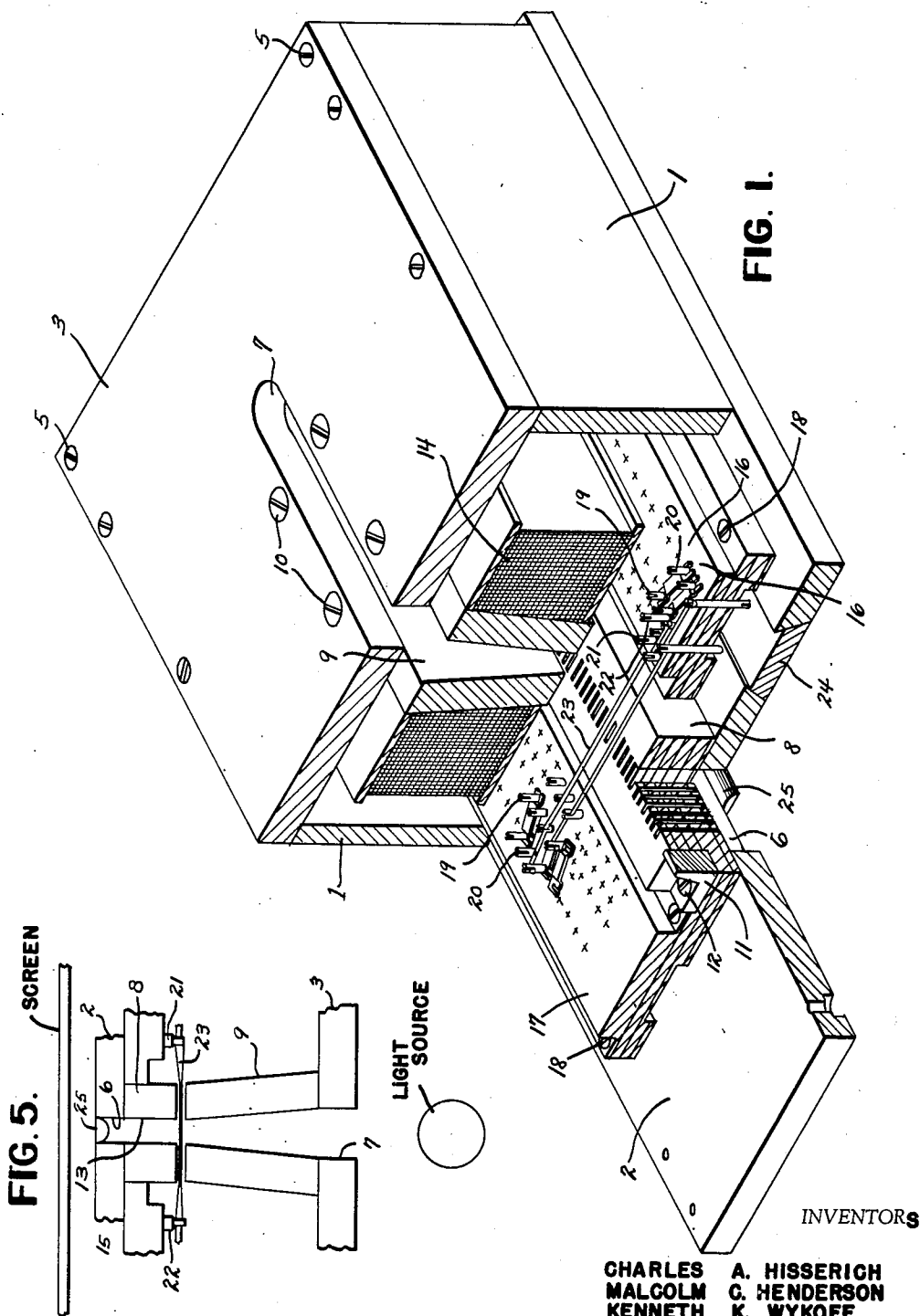
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LIGHT VALVE

Filed Aug. 2, 1944

2 Sheets-Sheet 1



BY

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FIG. 2.

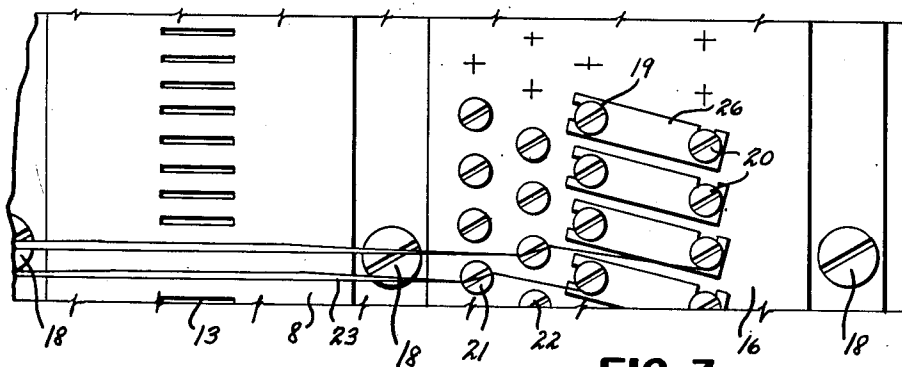
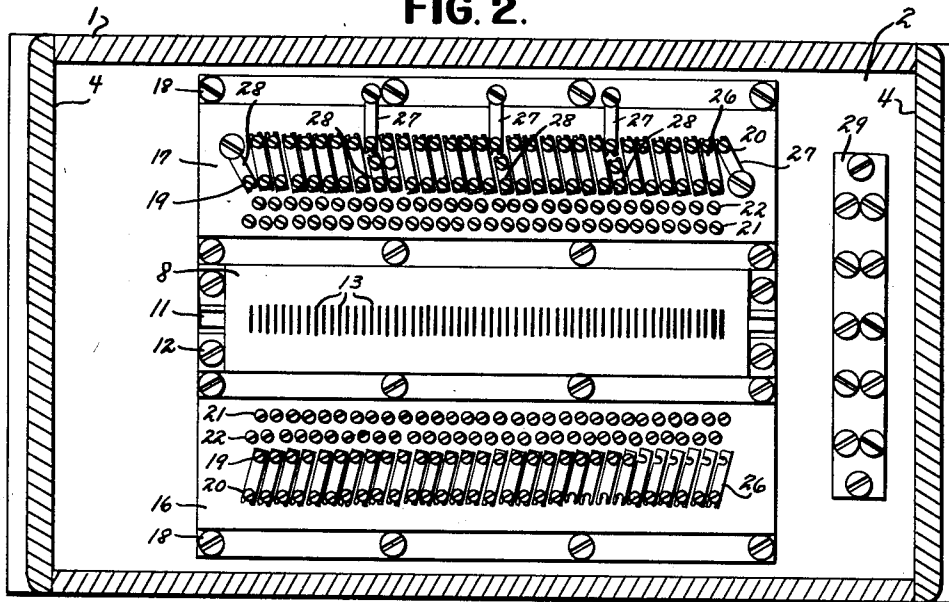


FIG. 3.

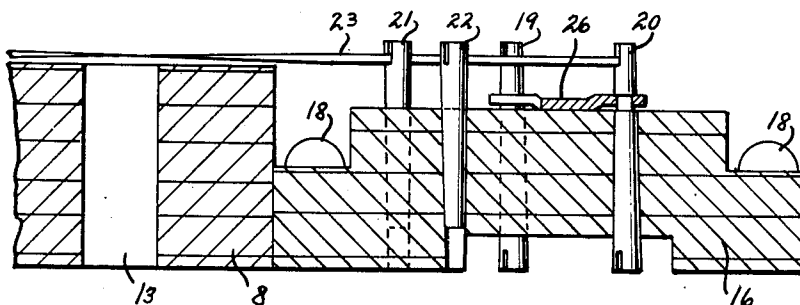


FIG. 4.

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LIGHT VALVE

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ors to the United States of America as repre-
sented by the Secretary of the Navy

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16 Claims. (Cl. 175—368)

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This invention relates to a light valve in which a moving or vibrating string or ribbon is utilized to govern the passage of light through a collimated aperture.

In the past, light valves (or translating devices, as they have sometimes been called) have ordinarily consisted of a single ribbon or a pair of closely adjacent parallel ribbons positioned in a magnetic field in such a manner that their motion was determined by the strength of the field, and the current through and the mechanical impedance of the ribbon or ribbons. The mechanical impedance, in turn, was determined by the mass per unit length of the ribbon or ribbons, their stiffness, and the tension under which they were supported. As it was desired to provide essentially uniform response over a considerable band of frequencies, these factors were necessarily adjusted to place the mechanical resonant frequency of the ribbon or ribbons at a point well outside the frequency range over which operation was desired. Otherwise, it was impossible to avoid the high response at the resonant peak within the band. This difficulty was ordinarily solved by so choosing and adjusting the ribbon or the pair of ribbons that the resonant frequency was considerably removed above the band over which it was desired to work. As the demand for increased fidelity and band width grew, it was necessary to adjust the unit so that its resonant frequency came at a higher and higher point in the spectrum. Other difficulties were introduced by this solution of the problem, because the high ribbon tensions needed to reach such frequencies reduced the sensitivity and often caused the ribbons to break, particularly if driven at high amplitudes.

The present invention overcomes these manifold objections by providing a plurality of strings or ribbons each mechanically tuned to a different resonant frequency. Thus, it is possible to tune the plurality of ribbons at a plurality of resonant frequencies to effectively cover the band of frequencies applied. Because the response of each string is thus purposely made non-uniform across the spectrum, one of the ribbons will be found to respond to a given applied frequency while the others, tuned to other frequencies, will exhibit no effective response at that particular frequency. The application of a plurality of frequencies will, in turn, cause ribbons tuned to the corresponding frequencies to respond. In this way, the multi-string valve serves as an excellent frequency analyzer. Properly calibrated, it is possible to quickly identify the frequency or frequencies of any applied voltage.

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It is thus a primary object of the invention to provide a light valve designed to operate at, rather than remote from, its resonant frequency. In turn, another object is a valve with a plurality of strings, each tuned to a different resonant frequency.

It is also an object of the invention to provide a frequency analyzer comprising a multi-string light valve whose ribbons are tuned to a series of resonant frequencies extending substantially across the band under investigation, and by means of which the presence of particular frequencies in an applied signal is indicated by the vibration of correspondingly tuned ribbons. Other objects will appear from the description below.

The invention may be embodied in a variety of forms, one of which is described in detail herein. However, it is to be clearly understood that the application described is not intended to limit the invention but is illustrative only. Many modifications will be obvious to those skilled in the art.

In the drawings:

Figure 1 is an isometric view of one form of the invention, with portions of the valve cut away for clarity.

Figure 2 is a sectional view of the same form of invention in the plane of the air gap showing the arrangement of the lower pole piece and the supports with the ribbons removed.

Figure 3 is an enlarged plan view of a portion of the lower pole piece and one of the bridge-supports showing the manner of mounting the ribbons.

Figure 4 is an end view (partially in section) of that portion of the lower pole piece and the bridge support shown in Fig. 3.

Figure 5 is a partial schematic view showing the invention used with a light source and receiving screen.

The particular unit illustrated was developed for use as a frequency analyzer in conjunction with the Echo Ranging System described in application for Letters Patent, Serial No. 520,667, filed February 1, 1944 (see Fig. 6 of that application). It comprises sixty strings, although any convenient number may be used, tuned to resonant frequencies from 500 to 2,000 cycles in 25 cycle intervals. The strings are beryllium copper ribbons approximately 2" long and 1 mil by 30 mils in cross section and are used to mask a series of light apertures 20 mils by 1/4" in size. The magnetic circuit comprises two pole pieces, separated by a 50 mil gap, and energized by a coil supplied by direct current, although a per-

manent magnet might also be used. The whole unit may conveniently be mounted in a case $5\frac{1}{4}'' \times 9\frac{1}{2}'' \times 3''$, weighing only 23 pounds. All of these dimensions and specifications may be varied for convenience to fit the particular application desired, but they illustrate the advantage of the valve in that several racks of electronic equipment may be eliminated by its use.

This valve is housed in a case formed of magnetic material comprising a pair of sides, 1, 1, a bottom 2 and a top 3, as shown in Fig. 1. The ends 4, 4 are of a non-magnetic material such as brass and the whole case is held together by means of screws 5, 5. The bottom and the top are provided with central longitudinal slots, as at 6 and 7, and the respective pole pieces 8, 9, are mounted around and adjacent to these slots by means of bolts 10, 10. At the ends of the lower pole piece 8, two non-metallic supports 11 are bolted to the bottom by means of bolts 12, 12. These supports extend slightly above the lower pole piece to space the upper pole piece from it, and thus to provide the magnetic gap across which the ribbons are strung.

The lower pole piece 8 is provided with a row of rectangular apertures, as at 13, to provide collimated passage for the light. The upper pole piece 9 is a slotted core wound with a coil of wire (730 turns of #18 enamel) 14 positioned by means of guide plates 15 to provide a magnetic field of approximately 5,000 gauss across the gap. There is thus provided as shown in Fig. 5 a path consisting of the slots, as at 6, 7 in the bottom and top of the case, the slotted core 9, and the collimated apertures 13 by means of which light may pass through the valve.

Adjacent the lower pole piece 8 is a pair of bridge-supports 16, 17 positioned on the bottom 2 by means of bolts 18. These supports are formed of a non-magnetic material, such as Bakelite, and each is arranged to mount a double row of capstans 19, 20 and a double row of frets 21, 22. These latter units may be tapered, as best shown in Fig. 4, to provide a tight friction fit. The capstans 19, 20 are designed with slots in their upper ends to which the ribbons 23 are fastened. The capstans 19 (in the row nearest the pole piece 6) in each bridge support extend through the support and their lower ends are also provided with slots to receive a screw driver for the purpose of adjusting the tension in the individual ribbons. For convenience, the bottom 2 of the case is provided with inserts 24, 24 under each bridge-support which may be removed to accomplish this adjustment. The frets 21, 22 are, like the capstans, slotted in their upper ends to receive the ribbons and to provide means (by turning) for positioning the ribbons directly over the respective apertures 13.

The conducting ribbons 23 are mounted as shown in Figs. 3 and 4. One end of the ribbon is wrapped about the upper end of one of the capstans 20, in the outer row, in the manner shown. It extends through the slot in the top of the corresponding fret 22, in the bridge support 16 (which is in alignment with the capstan), across the pole piece 6, through the slot in the correspondingly aligned fret 21 (mounted in the bridge-support 17), and to one of the capstans 19, as shown in Fig. 1. The adjacent ribbon extends from capstan 20 in support 17, through the slots in frets 22, 21, to the capstan in bridge support 16. Alternate ribbons are mounted in this fashion across the collimated apertures to

save space and yet insure that adjacent ribbons do not interfere with one another.

It should be pointed out that although the ribbons used in the illustrated application are identical and their respective resonant frequencies are determined by adjusting their respective tensions, this tuning might also be accomplished in a variety of ways. Since the resonant frequency of the ribbons is determined by tension, stiffness, mass per unit length, and length, they might be tuned to various resonant frequencies by varying any one or more of these characteristics. In the valve illustrated, tension-tuning has proved most successful, but for other applications, particularly where very high frequencies are involved, variation in the other parameters might be more desirable.

The number of ribbons used and the particular manner of mounting is a consideration governed by the space available and the use to which the invention is applied. For example, either a single ribbon or a pair of ribbons might be positioned flatly (with respect to the pole pieces) over each aperture by means of horizontally positioned capstans. Obviously, if a pair of ribbons is used, it is possible to obtain double the effective opening of the light path for the same applied signal. However, in the particular embodiment of the invention illustrated in the drawings, the ribbons are mounted vertically. As shown in Figs. 3 and 4, each ribbon is twisted through an angle of 180° as it passes from the fret in one support to the corresponding fret in the opposite support. Thus, although it is supported edgewise at the ends, as it passes across the aperture 13, it is flatwise against the pole piece 6 in order to provide adequate masking for the light. This manner of mounting is novel and has been found to provide maximum masking effect and, at the same time, to provide for maximum compliance at the frets. This method of mounting makes possible operation at much lower frequencies because of the increased compliance. The ribbons 18 may be formed of any convenient non-magnetic material such as phosphor-bronze or beryllium-copper. The use of the latter has proven very satisfactory since it has a high elastic and fatigue limit when properly heat treated and because its low electrical resistance maintains heating at a minimum.

The valve is also provided with a lens 25 which may conveniently be mounted in the slot at 6 in the bottom 2. Such a lens is preferably semi-cylindrical and may be formed from glass, Lucite or other convenient material. The valve illustrated in the drawings is intended for use with a light source and a screen, which may be coated with a fluorescent material. Such an arrangement is illustrated schematically in Fig. 5. The light source is placed below (in this case the valve is used in an up-side-down position) the pole piece 9 and the screen is positioned above the lens 25. The relative positions are, of course, determined by the optical characteristics of the lens and by the concentration of light desired on the screen.

There are several ways in which the signal may be applied to the ribbon circuit. The ribbons may be connected in series, parallel, series-parallel or connected to be driven from several sources; the particular hook-up used being determined by the impedance of the driving circuit or circuits and the amount of damping desired. In the application illustrated, the ribbons are divided into four separate circuits. This is ac-

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complished by inserting a spring-contact 26 between each pair of corresponding capstans 19, 20 in the two rows on each bridge-support except at three points. At these points, the circuit is broken and the end capstans 20, 20 are connected to contacts 27, 27. The other ends of the circuits are connected to contacts 28 which, if desired, may be brought out on the undersides of the bridge-supports. Thus one of the circuits comprises one of the contacts 27, several of the ribbons 23 extending back and forth across the pole pieces and connected together by means of the spring contacts 26, and contact 28. As used, each of the contacts 27 was connected to a terminal on terminal block 29, mounted on the bottom of the case, and all of the contacts 28 were connected to ground through another terminal on the block 29 by means of conductors (not shown). Likewise leads from coil 14 were conveniently connected to terminals on the block for external connection. As an incidental feature, the spring-contacts 26 may be bowed downwardly against the bridge supports, as shown in Fig. 3, and provided with slots to assist in maintaining the capstans tightly in place.

The valve could be connected with all of the ribbons in series in a single circuit, but the illustrated manner has proven preferable because it makes possible simpler equalization between the high and low frequency ends of the valve. Since it can be shown that one of the low frequency ribbons requires less power than one of the higher frequency ribbons vibrating at the same amplitude, it may be necessary to equalize the driving circuit to obtain a desired amplitude frequency characteristic. This may be accomplished by equalizing the various individual circuits by conventional and external means.

In operation, the signal is applied to the signal input terminals on terminal strip 29 and the terminals of coil 14 are connected to a source of D. C. This latter establishes a magnetic field across the gap between the pole pieces 6, 7 in which the ribbons are mounted. The alternating current flowing in a ribbon, in conjunction with this field, sets up a force acting to move the ribbon at right angles to the magnetic field. As the ribbon moves back and forth under the influence of the alternating current, it alternately masks and opens the light path through the valve. Any applied signal will cause vibration of each of the springs, but only the ribbon which is tuned to the particular frequency of the applied voltage will vibrate with amplitude large enough to allow the passage of appreciable portions of the light. If the applied signal is characterized by a plurality of frequencies, a plurality of correspondingly tuned ribbons will vibrate. The intensity of the individual components of the signal will, of course, determine the amplitude of vibration of the corresponding strings.

If the device is mounted as shown in Fig. 5, the light received on the screen will indicate the frequencies present in the signal applied. The screen may be calibrated, if desired, to assist in identifying the frequencies present and the amount of light received on the screen at particular points is a measure of the intensity of the signal at those particular frequencies. Additionally, the valve and the screen may be moved relative to one another if a trace or semi-permanent record of operation is desired, as for example, in the system described in the co-pending application identified herein.

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Having described our invention, we claim:

1. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their matching poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors positioned in said air gap, each of said conductors resonant at a different frequency; means on said frame for mounting said conductors across corresponding ones of said apertures; means for supplying an alternating signal to said conductors whereby resonant movement of certain of said conductors results in a substantial increase in the intensity of light transmitted by the corresponding of said apertures.

2. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their matching poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors positioned in said air gap, each of said conductors resonant at different frequencies; means for supplying an alternating signal to said conductors; means attached to said frame for mounting said conductors across associated ones of said apertures to prevent substantial movement of said conductors except when said signal is characterized by a frequency corresponding to the resonant frequency of one of said conductors.

3. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors positioned in said air gap, each of said conductors resonant at different frequencies; means for supplying an alternating signal to said conductors; means attached to said frame for mounting said conductors across associated ones of said apertures to prevent substantial movement of said conductors except when said signal is characterized by frequencies corresponding to the resonant frequencies of certain of said conductors.

4. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors, each of said conductors resonant at a different frequency; means for supplying an alternating signal to said conductors; means mounting said conductors in said air gap across associated ones of said apertures to substantially prevent transmission of light through said apertures except when said signal is characterized by a frequency corresponding to the resonant frequency of one of said conductors.

5. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their matching poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors, each of said conductors resonant at a different frequency; means for supplying an alternating signal to said conductors; means mounting said conductors in said air gap and across associated ones of said apertures to substantially prevent transmission of light through

said apertures except when said signal is characterized by frequencies corresponding to the resonant frequencies of certain of said conductors.

6. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets; a plurality of mechanically resonant electrical conductors, each of said conductors resonant at a different frequency; means for supplying an alternating signal to said conductors; means mounting said conductors in said air gap and across associated ones of said apertures to substantially increase the transmission of light through one of said apertures when said signal is characterized by a frequency corresponding to the resonant frequency of the one of said conductors associated with said aperture.

7. A light valve comprising: a frame; a pair of magnets mounted on said frame with an air gap between their poles, said magnets provided with a plurality of aligned apertures for transmitting light through said magnets axially with respect to their poles; a plurality of mechanically resonant electrical conductors, each of said conductors resonant at a different frequency; means for supplying an alternating signal to said conductors; means mounting said conductors in said air gap and across associated ones of said apertures to substantially increase the transmission of light through certain of said apertures when said signal is characterized by frequencies corresponding to the resonant frequencies of said conductors associated with said certain of said apertures.

8. A frequency analyzer comprising: a light source; a screen; a frame; a pair of magnets mounted thereon with an air gap formed between one pole of each magnet, said magnets provided with a plurality of aligned apertures positioned axially with respect to said poles to transmit light from said source through said magnets on to said screen; a plurality of mechanically resonant electrical conductors, each of said conductors resonant at a different frequency; means for mounting said conductors in said air gap and across corresponding ones of said apertures to govern the transmission of light from said source on to said screen; means for supplying an alternating signal to said conductors whereby the frequency spectrum of said signal is indicated on said screen.

9. A frequency analyzer comprising: a light source; a screen; a frame; a pair of magnets having an air gap between one pole of each and mounted between said light source and said screen provided with a plurality of aligned apertures for transmitting light from said source to said screen; a plurality of electrical conductors, each mechanically resonant at a different frequency; means for supplying an alternating signal to said conductors; and means positioning said conductors in said air gap and across associated ones of said apertures to prevent transmission of light from said source to said screen except when said signal is characterized by a frequency corresponding to the resonant frequency of one of said conductors.

10. A frequency analyzer comprising: a light source; a screen; a frame; a pair of bar magnets mounted between said light source and said screen provided with a plurality of aligned apertures for transmitting light from said source to said screen; said bar magnets positioned to provide an air gap between one pole of each, a plu-

ality of electrical conductors, each mechanically resonant at a different frequency; means for supplying an alternating signal to said conductors; and means positioning said conductors in said air gap and across associated ones of said apertures to prevent transmission of light from said source to said screen except when said signal is characterized by frequencies corresponding to the resonant frequencies of certain of said conductors.

11. A frequency analyzer comprising: a light source; a screen; a frame; a pair of substantially flat bar magnets mounted in said frame with one flat side of one magnet separated from the flat side of the other magnet by an air gap and positioned between said light source and said screen provided with a plurality of aligned apertures for transmitting light from said source to said screen; a plurality of electrical conductors, each mechanically resonant at a different frequency; means for supplying an alternating signal to said conductors; and means positioning said conductor in said air gap and across associated ones of said apertures to substantially increase the transmission of light from said source to said screen through one of said apertures when said signal is characterized by a frequency corresponding to the resonant frequency of the one of said conductors associated with said one of said apertures.

12. In the device described in claim 11, indicator means, associated with said screen, for identifying the frequency characterizing said signal.

13. A frequency analyzer comprising: a light source; a screen; a frame, a pair of bar magnets having substantially flat pole faces mounted in said frame between said light source and said screen provided with a plurality of aligned apertures perpendicular to said pole faces for transmitting light from said source to said screen; said magnets positioned with respect to each other to form an air gap between matching pole faces; a plurality of electrical conductors, each mechanically resonant at a different frequency within a determined band; means for supplying an alternating signal having frequencies within said band to said conductors; and means positioning said conductors in said air gap and across associated ones of said apertures to substantially increase the transmission of light from said source to said screen through certain of said apertures when said signal is characterized by frequencies corresponding to the resonant frequencies of said conductors associated with said certain of said apertures.

14. In the device described in claim 13, indicator means, associated with said screen, for identifying the frequencies characterizing said signal.

15. A light valve comprising: a frame; a pair of magnets mounted thereon with an air gap separating a pole of one from a pole of the other, said magnets provided with an aligned aperture perpendicular to said air gap for transmitting light through said magnets; a ribbon-shaped electrical conductor, twisted about its axis; means for positioning said conductor in said gap and across said aperture with one of the flat sides of said conductor substantially in a plane perpendicular to the axis of said aperture; means for supplying an alternating signal to said conductor whereby the movements of said conductor across the gap between said magnets and in the field

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thereof regulate the intensity of the light transmitted through said aperture.

16. A light valve comprising: a frame; a pair of magnets mounted thereon with an air gap separating a pole of one from a pole of the other, said magnets provided with a plurality of aligned apertures perpendicular to said air gap for transmitting light through said magnets; a plurality of ribbon-shaped electrical conductors, twisted about their respective axes; means for positioning each of said conductors in said gap and across an associated one of said apertures with one of the flat sides of each of said conductors substantially in a plane perpendicular to the axis of its associated aperture; and means for supplying an alternating signal to said conductors whereby the movements of said conductors

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across the gap between said magnets and in the field thereof regulate the intensity of light transmitted through their associated apertures.

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