United States Patent

Ibbett et al.

[15] **3,640,625**

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[54] **MULTIPLEX SPECTROMETER**

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[52] **U.S. Cl.** **356/97,** 250/233, 356/98

[51] **Int. Cl.** **G01j 3/00,** G01j 3/02

[58] **Field of Search** 356/81, 86, 87, 51, 96–101; 250/237, 233, 226, 232

[56] **References Cited**

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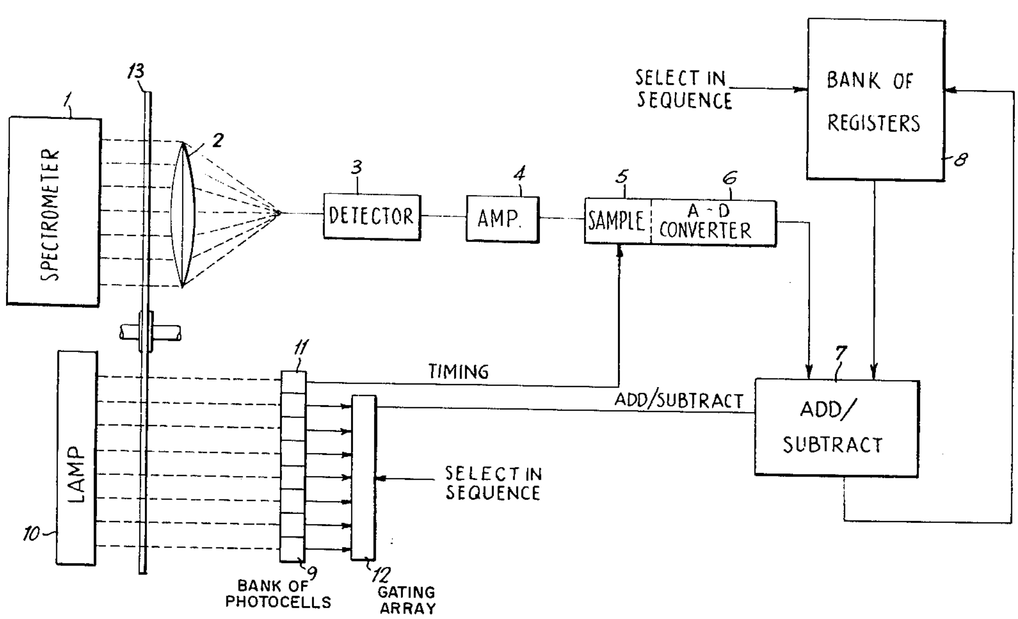
[57] **ABSTRACT**

A multiplex spectrometer has its spectral line information encoded by transmitting the line through rows of apertures presented in sequence. The apertures occur in a pattern derived from a matrix of binary numbers. Decoding is achieved by adding or subtracting the output in a store containing addresses equal to the number of columns in the matrix.

5 Claims, 3 Drawing Figures



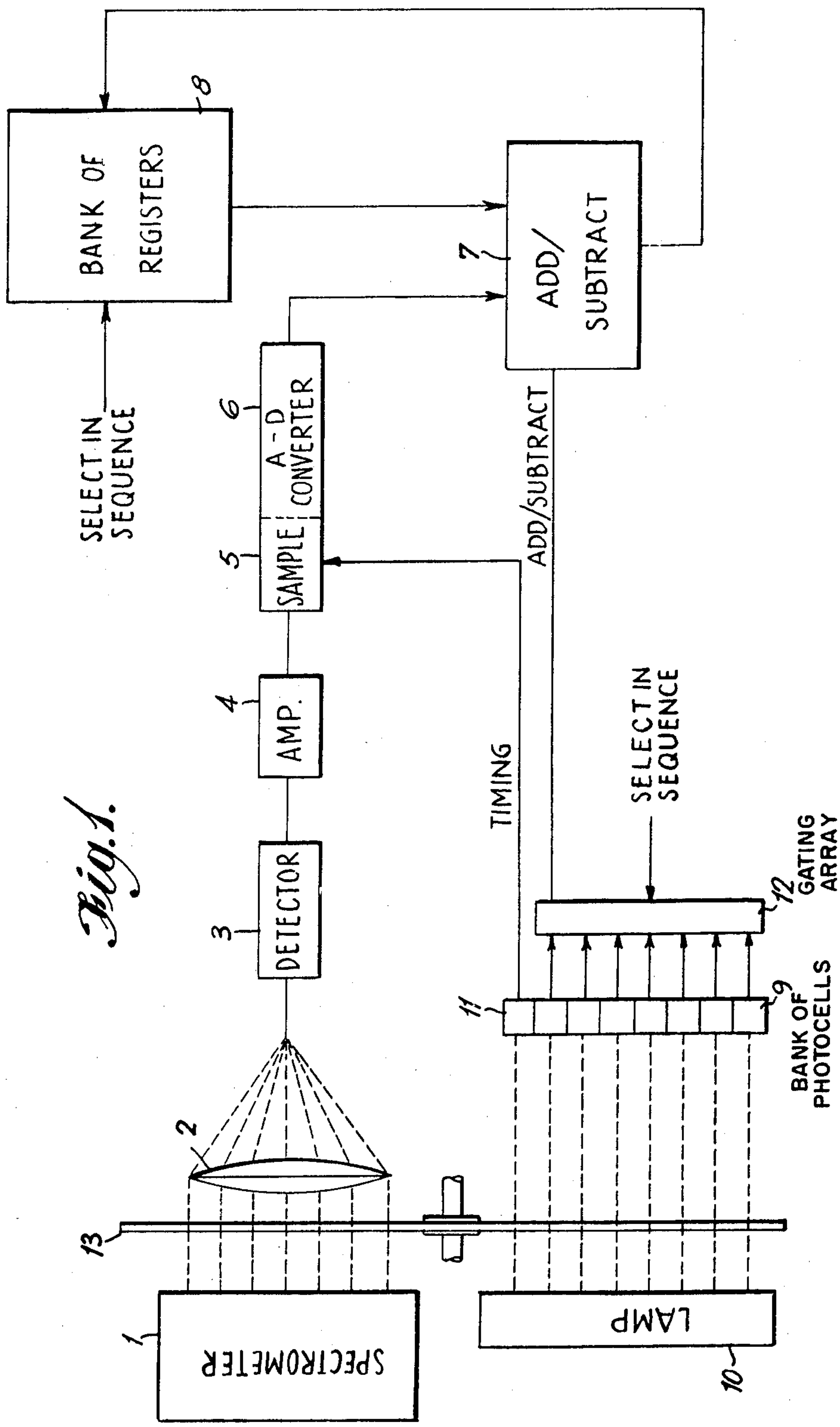

BANK OF REGISTERS
8
ADD/ SUBTRACT
7
SELECT IN SEQUENCE
SAMPLE
5
A-D CONVERTER
6
ADD/SUBTRACT
AMP.
4
DETECTOR
3
TIMING
SELECT IN SEQUENCE
GATING ARRAY
12
BANK OF PHOTOCELLS
9
11
2
13
SPECTROMETER
1
LAMP
10

Fig. 1.

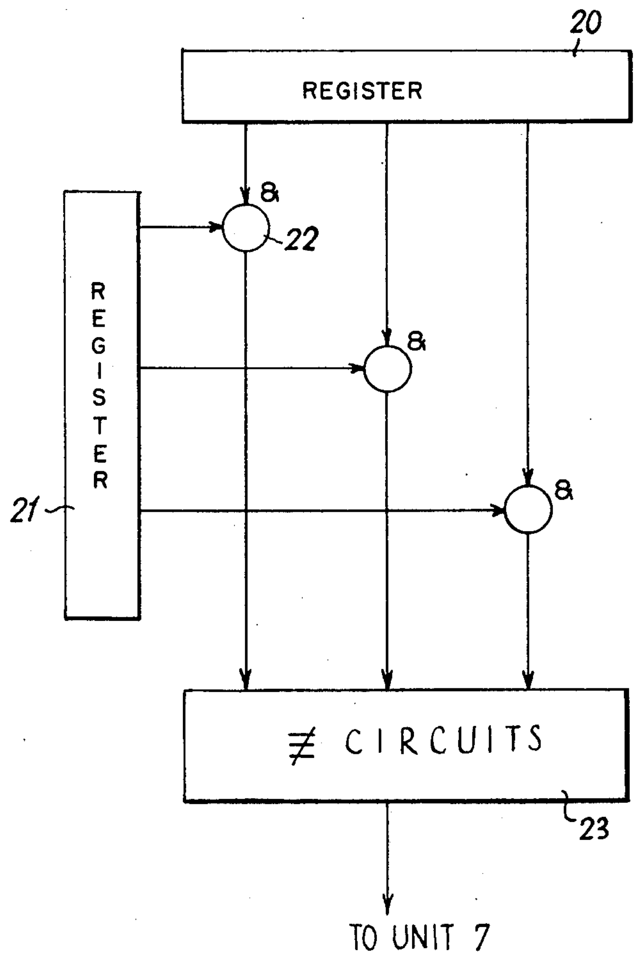


Fig. 2.

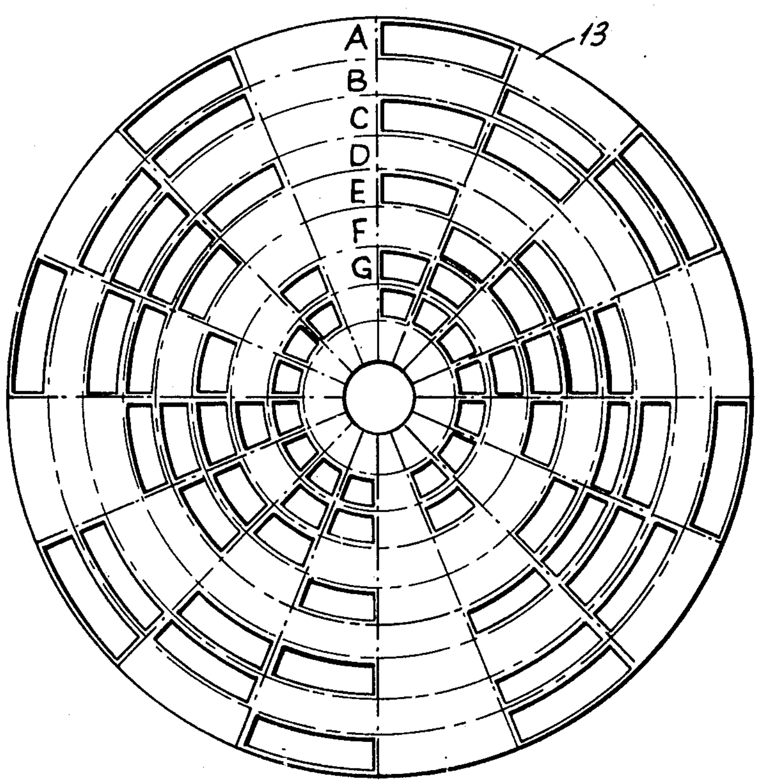


FIG.3.

MULTIPLEX SPECTROMETER

This invention relates to spectrometers. It is an object of the invention to provide a spectrometer with the capability of multiplex operation, by which all the spectral information is encoded and passed through a single detector and then decoded.

Accordingly, the present invention comprises a spectrometer in which the spectral line output is focused on to a single photodetector through a coding device which alternately passes and blocks transmission through a plurality of channels spaced along the spectral line in different time-varying coding patterns in each channel and which the output of the detector is applied to a plurality of storage registers corresponding in number to the number of channels, the successive inputs to each channel being cumulatively added or subtracted in an individual sequence in each channel based on the coding patterns of the coding device in such a manner that each register finally contains information derived solely from the corresponding channel.

The coding device may comprise a disc of a radius at least equal to the length of the spectral line of the spectrometer and carrying a plurality of apertures at positions in a matrix the rows of which are defined by radial lines and the columns of which are defined by rings of different radii. Apertures are provided at selected points of the matrix so formed in a pattern that will be more fully described below. Alternatively, in place of a disc, a drum may be used or else a plurality of fixed apertures controlled by shutters may be provided which are successively opened and closed in time-varying patterns.

The requirement for the coding is that the coding of each column of the matrix is mutually orthogonal and preferably the ratio open times to closed times in each column should be the same. It is also advantageous if the number of apertures in every row is constant, since this minimizes the dynamic range of the signal at the detector. In fact the dynamic range of the output signal is then determined only by the dynamic range of the spectrum itself.

A set of codes possessing the required properties can be obtained for 2^n-1 channels by performing a matrix multiplication on the matrix formed by writing the binary numbers 1 to 2^n and its transpose, and multiplying these together with modulo 2 addition of the subproducts which form an element. In the resulting matrix an "0" indicates a closed aperture and a "1" indicates an open aperture. Each column of the matrix gives the respective code for a channel and the number of channels contributing to the signal at the detector at any one instant is determined by the number of "1's" in a row.

It is possible to provide a code for situations where the number of channels is not equal to 2^n-1. In such cases columns, but not rows, of the next higher matrix can be eliminated without affecting the uniqueness of the decoding. However, the number of apertures in every row is no longer constant.

The decoding operation that is required in the respective storage registers is obtained from the matrix by adding the output of the detector to a storage register when the aperture of the corresponding channel is open (i.e., has a value "1") and subtracting the output of the detector from a storage register when the aperture of the corresponding channel is closed (i.e., has the value "0"). It can be shown that this computation will always give the required result that the cumulative total standing in without register is derived solely from the corresponding channel.

Where the coding device comprises a disc, control of addition to or subtraction from the storage registers may be obtained by encoding the desired patterns in half the disc and then duplicating the patterns in the other half. A row of photocells positioned along a radial line then reads the coded patterns as the disc rotates. Each photocell controls a corresponding storage register so as to cause addition when the cell is energized and subtraction when the cell is not energized.

In order that the invention may be more fully understood reference will now be made to the accompanying drawing in which FIG. 1 illustrates an embodiment thereof, and FIG. 2 shows a modification and FIG. 3 illustrates in frontal view a suitable apertured disc.

In FIG. 1 a spectrometer 1 provides a line spectrum, which may be in any waveband, and its spectrum is focused by means of a lens system 2 to a single photodetector 3. The output of detector 3 is amplified in an amplifier 4 and then applied to a sampling circuit 5. The output of sampling circuit 5 is applied to an analogue-to-digital converter 6 and thence as one input to an adder/subtractor unit 7. The other input of the unit 7 is obtained from a register in a bank of registers 8 and the output of the unit is returned to the same register in the bank 8.

A bank 9 of photocells energized from a lamp 10 is used to control unit 7 to determine whether at any instant the output of converter 6 is to be added in unit 7 or subtracted therein. The photocells are selected in sequence through a gating array 12. An additional photocell 11 provides reference pulses to control the operation of sampling circuit 5. These reference pulses can also be used to provide a timing pulse train which selects each register of the bank of registers 8 in sequence and in synchronism therewith operates gating array 12 to ensure that the appropriate photocell of bank 9 controls unit 7 at the time when the output of a corresponding register from bank 8 is being fed thereto.

The line spectrum from spectrometer 1 is encoded by means of a disc 13 which is interposed between spectrometer 1 and the lines system 2 and between lamp 10 and photocells 9. Disc 13 carries patterns of apertures arranged in a matrix with the rows lying along radial lines and the columns on circumferential rings. For a seven column matrix with the columns labeled A–G inclusive, a suitable pattern of codes is as follows:

A	B	C	D	E	F	G
1	0	1	0	1	0	1
0	1	1	0	0	1	1
1	1	0	0	1	1	0
0	0	0	1	1	1	1
1	0	1	1	0	1	0
0	1	1	1	1	0	0
1	1	0	1	0	0	1

In the above encoding pattern a "1" indicates the presence of an aperture and an "0" the absence of an aperture. It will be seen that every column has four "1's" or transmitting sections and similarly every row has four "1's." Thus, at any instant detector 3 receives the output of four channels and each channel contributes four samples. The above code is encoded in half of the disc and a similar code is repeated for the other half of the disc. The second code serves to appropriately energize the bank 9 of seven photocells to control the decoding process. In addition an eight column of apertures is provided for enabling the reference pulses to be produced.

FIG. 3 illustrates in frontal view the apertured disc 13. The apertures are arranged in the light-scattering matrix of rows and columns with the rows lying along radial lines and the columns on circumferential rings. The columns are labeled A to G inclusive and the pattern of apertures is as set forth in the table above. In addition disc 13 has an inner ring of apertures provided in each row for the purpose of energizing the photocell 11 providing the reference pulses. As mentioned above, the entire pattern is repeated twice to enable encoding and decoding to take place simultaneously.

It can be shown that if the output from the detector, to which all of a row contributes at any instant is added to a particular register when the associated channel contributes to the output at that instant and is subtracted from the associated register when the associated channel does not contribute to the output, then the resulting content of a register when the disc has rotated half a revolution through all the rows of the matrix contains information derived only from the associated channel. As an example channel A and channel B is decoded below writing a plus sign (+) for addition and a minus sign (−) for subtraction:

A

+		+		+		+
	−	−			−	−
+	+			+	+	
			−	−	−	−
+		+	+		+	
	−	−	−	−		
+	+		+			+
4	0	0	0	0	0	0

B

−		−		−		−
	+	+			+	+
+	+			+	+	
			−	−	−	−
−		−	−		−	
	+	+	+	+		
+	+		+			+
0	4	0	0	0	0	0

Thus, the register relating to channel A contains contributions from channel A only and similarly the register associated with channel B contains contributions from channel B only. This is the required result and is t rue for all the channels.

In operation of the apparatus disc **13** is rotated and during the time that each row of apertures in the disc is passing a signal to detector **3**, each cell of bank **9** is selected in sequence by gating array **12** and a series of add or subtract signals is provided. In synchronism with the selection of the photocells **9**, the corresponding register of bank **8** is selected and its contents fed to unit **7** where the output of converter **6** is added or subtracted.

In place of the decoding arrangement described above photocell bank **9**, lamp **10** and gating array **12** can be replaced by the decoding arrangement illustrated in FIG. **2**. In this arrangement two registers **20** and **21** are provided. Register **20** is a binary counter which is set initially to zero and which is incremental along one each time a measurement is made. Thus the binary number in register **20** will correspond to the numerical value of the row of the encoding matrix being used. In the above example register **20** will increment each time the disc **13** is stepped by one row. Register **21** contains a binary representation of the register of the bank **8** currently being incremented. In the above example there are seven registers in bank **8** and hence register **21** will increment from 1 to 7 each time that the count in register **20** is increased by one.

Corresponding pairs of digits in registers **20** and **21** are fed to two input AND gates such as gate **22** and the outputs of all the AND gates are fed to a NOT EQUIVALENT circuit **23** to produce the add/subtract signal which controls unit **7**.

While the encoding device has been shown as a disc, which disc also control the decoding of the system, it will be appreciated that either or both of these functions can be controlled by alternative arrangements. Thus, encoding can be achieved by apertures having shutters controlled in accordance with a program generating the appropriate code and similarly the decoding arrangements can be controlled by the

same program.

In operation the measurements can be continued for a number of cycles to improve the signal-to-noise ratio of the results. This is preferable to attempting to improve the signal-to-noise ratio by lengthening the time of each measurement.

We claim:

1. Spectrometer apparatus comprising:

means for producing a spectrum,

a single photodetector for producing an electrical output provides in response to radiation incident thereon,

means for focusing said spectrum onto said photodetector,

a movable coding matrix device positioned between said spectrum producing means and said focusing means for encoding said spectrum by defining a plurality of channels spaced along said spectrum and alternately passing and blocking transmission of said spectrum through each of said plurality of channels in accordance with respective time varying coding patterns for each channel,

a plurality of storage registers, one for each channel, coupled to receive the output of said photodetector,

means coupled between said photodetector and said registers for either accumulatively adding or subtracting each of the successive outputs from the photodetector in each register in an individual sequence based on a received decoding signal in such a manner that after the sequence for each register is completed the information from the photodetector not derived from that channel which corresponds to that particular register cancels and attenuation information derived from that channel which corresponds to that particular register only remains and accordingly each register contains information derived solely from its corresponding channel, and

decoding means synchronized with said coding matrix device for producing a decoding signal determining the sequence in which the outputs are added and subtracted for each register so that for each of the other channels the number of outputs added equals the number of outputs subtracted and applying said determining signal to the adding or subtracting means.

2. Spectrometer apparatus as in claim **1** in which the coding device carries a plurality of apertures at selected points in a matrix of rows and columns.

3. Spectrometer apparatus as in claim **2** in which the coding device comprises a disc having apertures in the matrix the rows of which are defined by radial lines and the columns of which are defined by rings of different radii.

4. Spectrometer apparatus as in claim **2** in which the number trial apertures in every row of the matrix is constant.

5. Spectrometer apparatus as in claim **2** in which the coding device has the matrix repeated twice and one of the matrices is used for controlling said adding and subtracting means.

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