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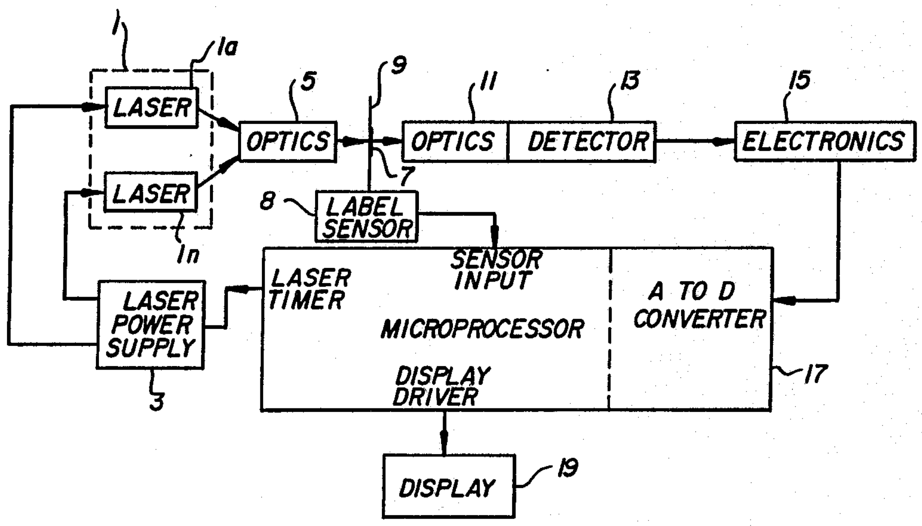

(57) Abstract

An authentication system for authenticating an article with a taggent thereon is disclosed (9), in which the taggent has a predetermined light resonance absorption spectrum. The system comprises a laser device (1) for providing a source of light at a plurality of predetermined wavelengths which correspond to particular wavelengths within the absorption spectrum of the taggent. The light from the laser device is passed through or is reflected from the taggent and a detector (13) detects the light at the predetermined wavelengths and produces an output in response thereto. A microprocessor (17) is coupled to the detector device for receiving the output of the detector, comparing the detected light with preset values at the predetermined wavelengths, and generating one of a plurality of determined output messages (19) to indicate whether or not positive authentication has occured. The laser device can be a plurality of lasers (1a, b) each emitting light at a different predetermined wavelenght, or a tunable laser which is tuned in the range of the absorption spectrum of the taggent in the label.

* See back of page

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AUTHENTICATION APPARATUS USING RESONANCE ABSORPTION OF LIGHT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is directed to an apparatus for authenticating articles and for detecting counterfeit articles by means of a label attached to or incorporated in the article. In particular, the present invention is directed to an apparatus for authenticating articles using a label containing a predetermined amount of a taggent whose absorption of light varies with wavelengths in a known and unique manner. A label on an article is subjected to light of a plurality of predetermined wavelengths, and the transmission or reflection of light at each of the predetermined wavelengths is detected and compared with preset values to determine if the label contains the taggent and thus, the article is authentic.

Description of the Prior Art

As a result of technology advances in copying techniques and reproduction techniques, many articles are becoming very vulnerable to being counterfeited. This problem is becoming particularly acute in items such as credit cards, video tapes, cassette tapes, designer fashion accessories and clothing. In addition, an even more serious problem is occurring with regard to the counterfeiting of currency and other financial paper. A related problem is the unauthorized use of a financial item, such as a credit card, registered security or identity document.

Many techniques have been developed for labeling articles to prevent counterfeiting or fraudulent use. Techniques such as holograms on credit cards and magnetic coding on various articles have been in use for some time. Also, techniques using luminophores and narrow band spectral filters with materials having light absorption characteristics have been used. These prior art techniques have been less than fully effective either because the counterfeiters have found ways to duplicate the label, or the apparatus for detecting the label and verifying its authenticity has been too expensive to be utilized in the quantities necessary for preventing counterfeiting.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system for authenticating an article by means of detecting light from a laser device which passes through or is reflected from a label on the article and then comparing the detected light with preset values at predetermined wavelengths.

It is another object of the present invention to provide a system for authenticating articles by placing a label on the article wherein the label contains a taggent having a predetermined light absorption spectrum and passing light of predetermined wavelengths through the label and then detecting the light.

It is a further object of the present invention to provide a label to be applied to an article for the purpose of authenticating the article, wherein the label contains a taggent having a predetermined light resonance absorption spectrum.

The present invention is directed to an authentication system for authenticating an article with a taggent thereon, the taggent having a predetermined light resonance absorption spectrum. The taggent may be incorporated into printing ink used in producing a tag, sticker, or value document; may be incorporated into plastics which become an integral part of the article; or may be applied by coating or impregnating means with other substances affixed to the article or document to be authenticated. The system comprises a laser device for providing a source of light at a plurality of predetermined wavelengths which correspond to particular wavelengths within the absorption spectrum of the taggent. The light from the laser device is passed through or reflected from the taggent and a detector detects the light at the predetermined wavelengths and produces an output in response thereto. A microprocessor is coupled to the detector device for receiving the output of the detector, comparing the detected light with preset values at the predetermined wavelengths, and generating one of a plurality of predetermined output messages to indicate whether or not positive authentication has occurred. The laser device can be a plurality of lasers each emitting light at a different predetermined wavelength, or a tunable laser which is tuned in the range of the absorption spectrum of the taggent in the label.

The article to be authenticated can include the taggent or can include a label having a taggent thereon wherein the taggent has a predetermined light resonance absorption spectrum. The absorption spectrum is unique for the particular material of the taggent.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of the authentication system of the present invention.

Figure 2 is an absorption spectrum of a taggent used in connection with the present invention.

Figure 3 is an absorption spectrum of another taggent used in connection with the present invention.

Figure 4 is a first embodiment of a label and optical detector array used in the authentication system of the present invention.

Figure 5 is a second embodiment of a label and optical detector array used in the authentication system of the present invention.

Figure 6 is an absorption spectrum of still another taggent used in connection with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Many substances exhibit light absorption spectra which are characterized by relatively narrow wavelength dependent characteristics. The relative width of the characteristic is defined by $\Delta\lambda/\lambda$, where λ is the wavelength of the center of the characteristic, and $\Delta\lambda$ is the width of the characteristic between the wavelengths at which the absorption is one-half that at its peak. For most absorption characteristics in liquids and solids, $\Delta\lambda/\lambda$ is relatively large, i.e. greater than 10^{-2}; however, much narrower features do exist for some particular substances. The present invention utilizes substances with narrow absorption characteristics as taggents in labels for authentication.

Lasers are particularly well suited as light sources in the authentication system of the present invention. Lasers provide a light output which is intense and is usually confined to a narrow wavelength range. Different lasers have different characteristic wavelength ranges, and some lasers can be tunable so that they provide outputs in different wavelength ranges. In the present invention, the lasers selected have wavelength ranges which include and correspond to the absorption spectrum of the taggents in the labels.

The wavelength dependence of the absorption of the light from the laser by the taggent in the label is essentially independent of the absorption of the material in which the taggent is placed provided that sufficient light for measurement is transmitted by the material and that the material does not have narrow absorption characteristics of its own in the wavelength ranges being used.

Referring to Figure 1, the authentication system of the preferred embodiment of the present invention comprises lasers 1a and 1n which are powered by laser power supply 3. The output of the lasers passes through an optical system 5 which may include lenses, collimators and/or fiber optics, and then through a label 7 on an article 9 which is the article which is to be authenticated. After passing through the label 7, the light from the label passes through optical system 11 which may include lenses, collimators and/or fiber optics, and is detected by a detector device 13. The output of the detector device 13 is applied to circuit 15 which may include amplifiers, reference voltage generators and/or analog-to-digital converters, and then to the input of microprocessor 17. The microprocessor 17 normalizes outputs of the detector device 13 at the various wavelengths with the incident intensities, respectively, by forming n ratios, one for each of the n lasers. The microprocessor attempts to match these ratios, or a combination of these ratios, with preset values stored in its memory and the result of the comparison is displayed on display 19. Normally the display 19 will indicate whether the article is authentic or counterfeit. Microprocessor 17 receives an input from label sensor 21 which indicates that an article having a label is positioned between the laser and detector. Microprocessor 17 also provides a laser timing signal to laser power supply 3, the laser timing signal is used primarily when lasers 1a - 1n are pulsed lasers. The laser timing signal may provide for the timing of laser pulses, such that each pulse energizes one laser of predetermined wavelength at a time with n sequential signals corresponding to n lasers then processed by detector device 13 and electronic circuit 15 thence for storage and comparison by microprocessor 17.

Laser device 1 is a laser device with multiple wavelength capabilities. This can be accomplished using either a tunable laser which can be tuned to various wavelength ranges or by using a plurality of lasers emitting light in different wavelength ranges.

An example of a tunable laser which can be used for the laser device 1 is an LNA tunable laser as described in J. J. Aubert et al, Optics Communications, Vol. 69, pp. 299 - 302 (January 1989), which is tunable over a spectral range of 1050 - 1090 nm. Other examples include GaAlAs diode lasers having a spectral range of 770 - 850 nm and output power in the milliwatt range which can be used for the laser device 1. The lasers may be tuned over a fairly broad range of wavelengths by means of varying their temperature or input current (See R. Kimball et al, SPIE, Vol. 740, pp. 41 - 46 (1987)) in order to supply different wavelength ranges required. Alternatively, a plurality of lasers emitting light in different wavelength ranges can be used in place of the single laser device 1.

The lasers can be pulsed sequentially to simplify the optical detectors and electronics, or alternatively, a single tunable laser can be tuned through the predetermined ranges.

A second preferred embodiment of the invention provides for the laser device and the detector device to be on the same side of the label or article to be authenticated. In this manner reflected rather than transmitted light is detected. In all other respects, this second embodiment is identical to the first preferred embodiment described above.

A label of the present invention includes a quantity of a wavelength selective absorbing substance or taggent incorporated into a plastic or paper-like sheet used as a document, identi- fication or credit card, currency, or tag attached to a commercial item. Furthermore, the taggent can be incorporated into ink or adhesive which is subsequently applied to the plastic or paper-like sheet. The label is applied to the article so that the label can transmit or reflect some light in the wavelength ranges.

One example of a wavelength selective absorbing substance with narrow absorption characteristics is Nd_2O_3. Figure 2 is a low resolution absorption spectrum of Nd_2O_3 in $Y_3Al_5O_{12}$ over the spectral range of 0.2 - 1.0 micrometers. $Y_3Al_5O_{12}$ (YAG) is a transparent crystalline material compatible with rare earth oxides. Even at low resolution, many narrow characteristics ($\Delta\lambda/\lambda$ much less than 10^{-2}) can be seen. Various compounds of most of the rare earths exhibit such spectra as do many other substances which can be conveniently incorporated in plastic, paper, ink and adhesives.

The quantity of the taggent needed in a label can be calculated using Nd_2O_3 as an example. The relative absorption of light by a planar homogeneous layer is given by $1-e^{-\sigma n \ell}$ where σ is the absorption cross-section for the individual molecule, n is the number density of the molecules, and ℓ is the thickness of the layer. An absorption of 10% is easily measured. For this case, the absorption is given approximately by $\sigma n \ell \approx 0.1$. For some narrow characteristics of Nd_2O_3 $\sigma \approx 10^{-19} cm^2$. Since n equals approximately $5 \times 10^{21} cm^{-3}$, the necessary thickness ℓ equals 2 micrometers. The area of the label is governed by optical considerations. An area of 1 mm^2 is thus reasonable. The amount of Nd_2O_3 needed for a label is then calculated to be less than 10 micrograms. For some taggents with narrow absorption features, σ is considerably larger and thus even less material is needed.

Another example of a taggent is Sm_2O_3. Figure 3 is a low resolution absorption spectrum of Sm_2O_3 in $Y_3Al_5O_{12}$ over the spectral range 0.2 - 2.5 micrometers.

Referring to Figure 2, using a taggent with Nd_2O_3 three GaAlAs diode lasers of wavelengths of 795, 801 and 809 nanometers will have low, high and low transmission respectively. The transmission can be quantified for a given label type. The lasers can be pulsed sequentially to simplify the optical detector and electronics. For a taggent with Sm_2O_3, three LNA lasers with wavelengths of 1050, 1070 and 1090 nanometers will have high, low and high transmission respectively, and the transmission can be quantified for a given label type.

The optical detectors 13 can for example be photo-diodes. For the lasers described above, silicon photodiodes are suitable. However, for other lasers, other optical detectors may be used.

In operation, laser 1 comprises a plurality of lasers 1a ... 1n or a tunable laser, and the article being authenticated has a label which comprises at least a single taggent in a specified location. The system also includes at least one optical detector 13. The presence of the label is sensed by label sensor 21 and the measurement process is initiated. The lasers 1a ... 1n, operating in different wavelength ranges, are sequentially pulsed. The transmission through or reflection from the label to the detector is measured for each laser and the signals are digitized. The signals are compared to preset values stored in the microprocessor memory. The result of this comparison is displayed usually in a pass or fail indication. The use of different label substances with different absorption spectra or characteristics provides a variety of mutually exclusive labels.

The use of an optical detector array, such as shown in Figures 4 and 5, permits spatial information to be added to the taggent characteristics. Spatial information can be added by varying the position of the label on the article, or by placing the taggent on the article in a predetermined spatial pattern. Referring to Figure 4, label 9 has taggent in locations 1, 3 and 4. Detector 13 comprises five photodiodes A, B, C, D and E. The output of each photodiode is compared with preset values in the microprocessor 17. In the array shown in Figure 4, only detectors A, B and D will indicate an absorption spectrum, while detectors C and E will not. Thus in the example shown, it is not only important that a particular absorption spectrum be present, but also that the absorption spectrum be detected only on certain ones of the detectors 13.

In some applications, it may be advantageous to optimize the speed of the authentication process. In this situation, it would thus be disadvantageous to use sequentially pulsed lasers. Therefore, rather than using a plurality of sequentially pulsed lasers, a plurality of lasers may be used where the laser beams are guided by appropriate optics, including lenses, collimators and/or fiber optics, through a single area in a label to a corresponding multiplicity of optical detectors. This permits the simultaneous detection in different wavelength ranges, thereby reducing the detection time. Referring to Figure 5, lasers 1a, 1b and 1c transmit light simultaneously through label 7 with the beam from each laser reaching only the corresponding photodiode 13.

In addition, if the label is moved or scanned relative to the laser-photodiode combination, spatial variations in the label can be measured. An example of spatial variation which can be measured by scanning the label relative to the laser-detector path is a bar code printed with ink containing the taggent, or a bar code printed with conventional ink overlaying a uniform stripe of ink containing the taggent.

In some applications it may be undesirable, if not impossible, to perform a transmission measurement. For example, if a label is affixed directly to an opaque material, such as a metal automobile part, or if it would prove inconvenient to insert a label between a laser and detector. In these situations, the measurement can be performed using reflection, either by using a reflective substance under the taggent in the label, or by choosing an appropriate wavelength dependent reflecting substance. In general substances with wavelength dependent absorption, such as Nd_2O_3 and Sm_2O_3, also exhibit wavelength dependent reflections.

The present invention can also be combined with an authentication system using nuclear resonance absorption such as that disclosed in U. S. Patent No. 4,742,340, issued May 3, 1988. A taggent of Eu_2O_3, which is used for the nuclear resonance absorption, is relatively transparent and has no narrow absorption features in the wavelength regions of interest for Nd_2O_3. Figure 6 is a typical absorption spectrum for Eu_2O_3 in $Y_3Al_5O_{12}$. The small amount of Nd_2O_3 needed for the label absorbs only a slight amount of the gamma radiation used in the nuclear absorption measurement. It is thus possible to arrange a geometry in which gamma radiation and laser light absorption are measured simultaneously or sequentially with the sequential measurement being made by moving the label between a gamma radiation detector and light detector.

A similar combination of nuclear resonance absorption and light resonance absorption labels can be provided by substituting Sm_2O_3 for the Nd_2O_3 described above.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims, rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are, therefore, to be embraced therein.

CLAIMS

1. An authentication system for authenticating an article with a taggent thereon having a predetermined light resonance absorption spectrum, said system comprising:

(a) laser means for providing a source of light at at least one predetermined wavelength within the absorption spectrum of the taggent;

(b) detector means for detecting the light at the at least one predetermined wavelength and for producing an output in response thereto;

(c) means for positioning the article with the taggent thereon between said laser means and said detector means such that the light from said laser means passes through said taggent and is then detected by said detector means wherein light at said predetermined wavelength is absorbed by the taggent;

(d) processor means coupled to said detector means for receiving the output of said detector means and for comparing the output of said detector means to preset values stored in said processor means, and for producing an output in accordance with the comparison.

2. An authentication system as set forth in Claim 1, wherein said processor means includes calculating means for calculating ratios of detector output for transmitted or reflected light to detected output for incident light,

respectively, at each predetermined wavelength from said laser means and with means for comparing said ratios with preset values stored in said processor means.

3. An authentication system as set forth in Claim 1, wherein said laser means comprises a plurality of lasers each emitting light in a different predetermined wavelength range.

4. An authentication system as set forth in Claim 1, wherein said laser means comprises at least one tunable laser, said tunable laser being tunable to at least two said predetermined wavelength ranges.

5. An authentication system as set forth in any one of Claims 1 - 4, wherein said detector means comprises a plurality of detectors arranged in predetermined spatial pattern corresponding to a predetermined spatial pattern of the taggent on the article.

6. An authentication system as set forth in Claim 1, wherein said detector means comprises at least one photodiode.

7. An authentication system as set forth in Claim 1, wherein light from said laser passes through the article and wherein said laser means and detector means are arranged to be positioned on opposite sides of the article.

8. An authentication system as set forth in Claim 1, wherein light from said laser is reflected by the article and wherein said laser means and detector means are arranged to be positioned on the same side of the article.

9. An authentication system as set forth in Claim 1, wherein said taggent comprises Nd_2O_3.

10. An authentication system as set forth in Claim 1, wherein said taggent comprises Sm_2O_3.

11. A label for application to an article to authenticate the article, said label comprising a taggent having a predetermined light resonance absorption spectrum wherein said taggent absorbs light of at least one predetermined wavelength.

12. A label as set forth in Claim 11, wherein said label comprises ink applied to the article.

13. A label as set forth in Claim 11, wherein said label is formed in or on a sheet of paper.

14. A label as set forth in Claim 11, wherein said label is formed in or on a plastic card, sheet, stripe or other plastic item.

15. A label as set forth in Claim 11, wherein said taggent comprises Nd_2O_3.

16. A label as set forth in Claim 11, wherein said taggent comprises Sm_2O_3.

17. A label as set forth in any one of Claims 11, 15 or 16, wherein the quantity of taggent is such that light transmission is $1-e^{-\sigma n \ell}$ where:

σ = the absorption cross-section for an individual molecule

n = the density of the molecules

ℓ = the thickness of the taggent;

and where the absorption cross-section σ is a varying function of wavelength in the wavelength range where the laser means operates.

18. A label for application to an article to authenticate the article, said label comprising a taggent having a predetermined light resonance reflection spectrum wherein said label reflects light of at least one predetermined wavelength.

19. A label as set forth in Claim 18, wherein said label comprises ink applied to the article.

20. A label as set forth in Claim 18, wherein said label is formed in a sheet of paper.

21. A label as set forth in Claim 18, wherein said label is formed in or on a plastic card, sheet, stripe or other plastic item.

22. A label as set forth in Claim 18, wherein said taggent comprises Nd_2O_3.

23. A label as set forth in Claim 18, wherein said taggent comprises Sm_2O_3.

24. A label as set forth in any one of Claims 18, 22 or 23, wherein quantity of taggent is such that reflection from the article will depend upon wavelength through the combination of parameters $\sigma n \ell$ where:

σ = the absorption cross-section for an individual molecule

n = the density of the molecules

ℓ = the thickness of the taggent;

and where the absorption cross-section σ is a varying function of wavelength in the wavelength range where the laser means operates.

25. A label as set forth in any one of Claims 11, 15, 16, 18, 22 or 23, wherein the taggent is present in a spatial pattern such as a bar code or other spatial pattern which thereby conveys data in addition to authenticating means.

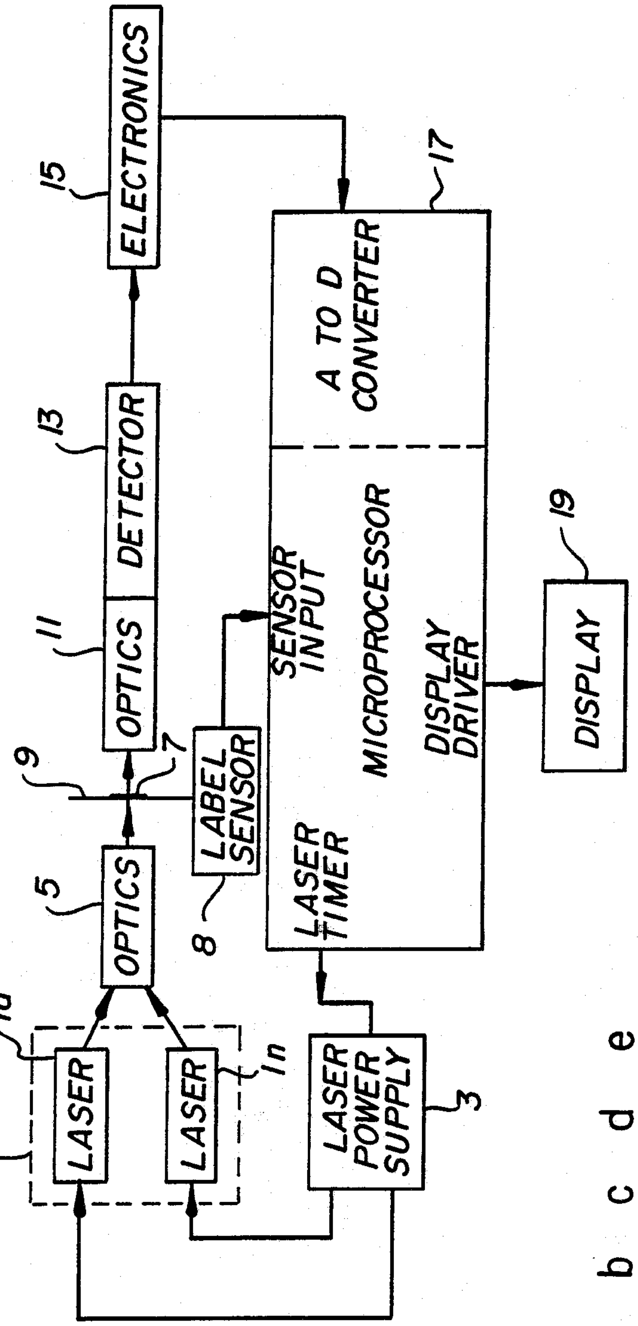

FIG. 1

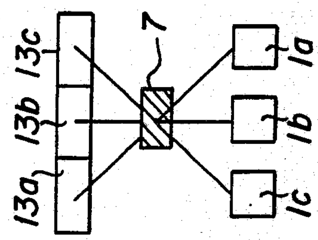

FIG. 5

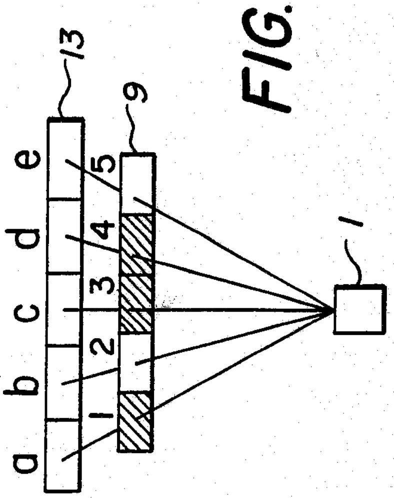

FIG. 4

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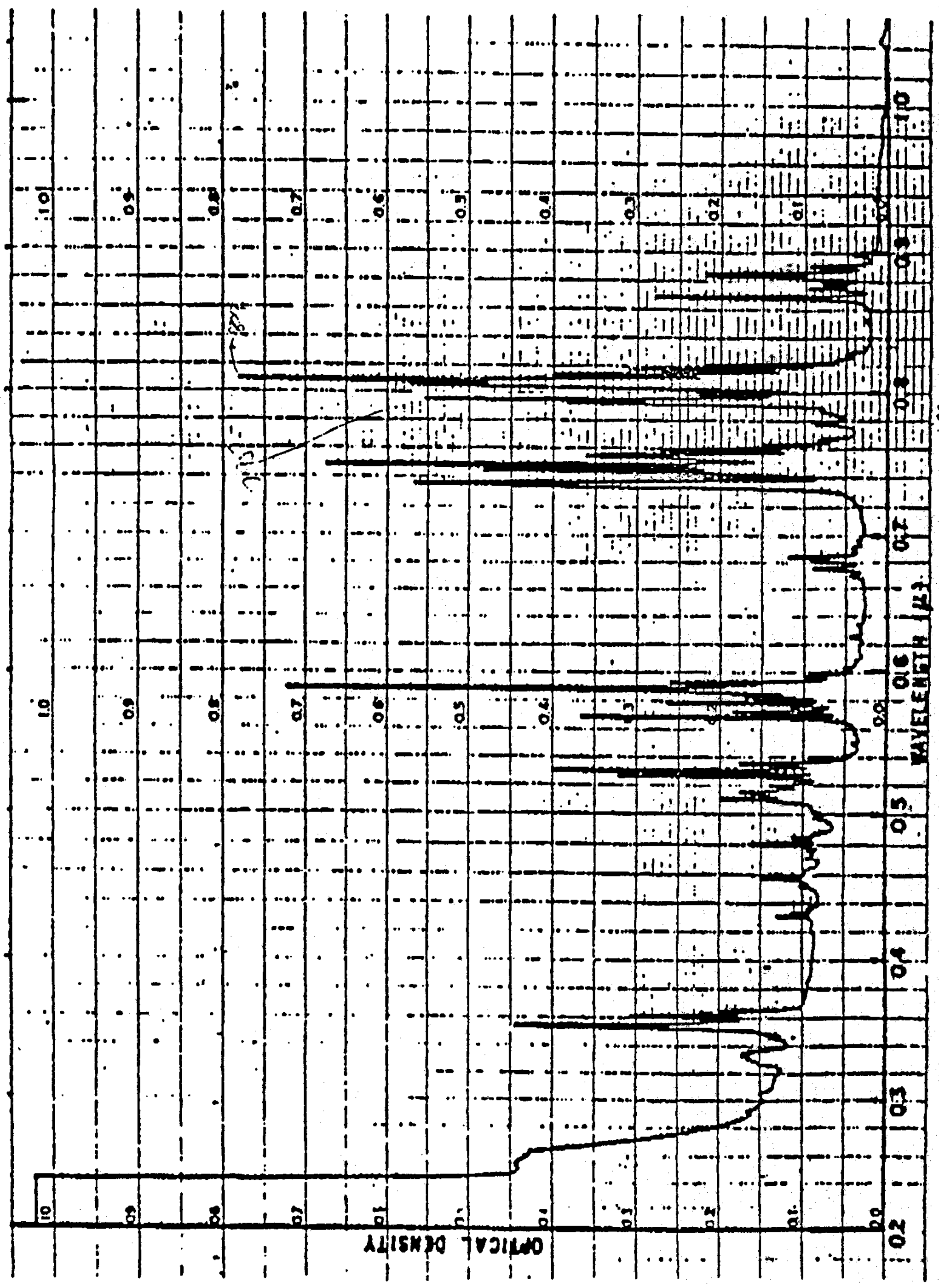
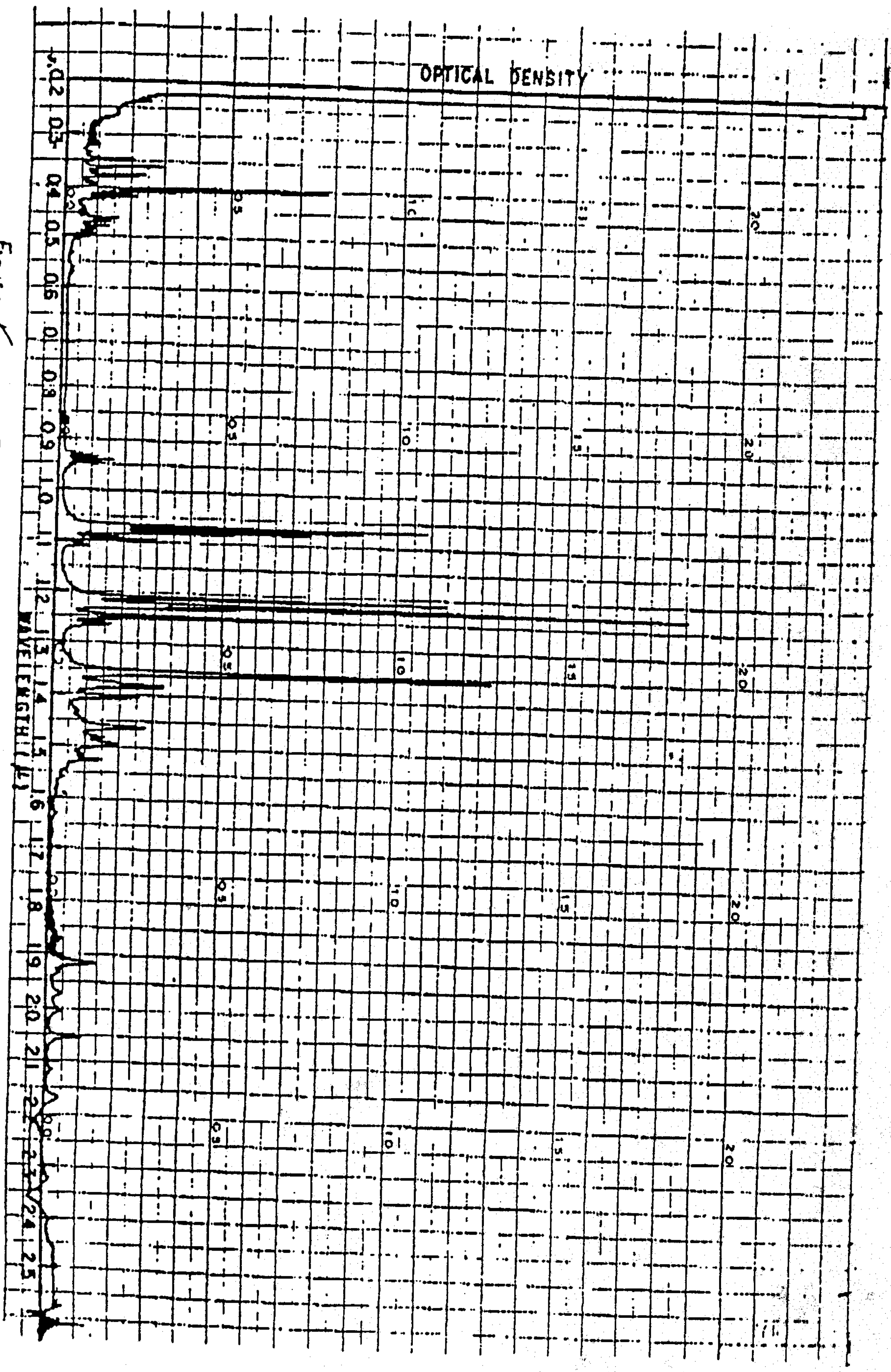


Room temperature absorption spectrum of $Nd^{3+}:Y_3Al_5O_{12}$ from 0.2 to 1.0 μ

Figure 1.

Figure 1



Room temperature absorption spectrum of $Sm^{3+}:Y_3Al_5O_{12}$ from 0.2 to 2.5 μ.

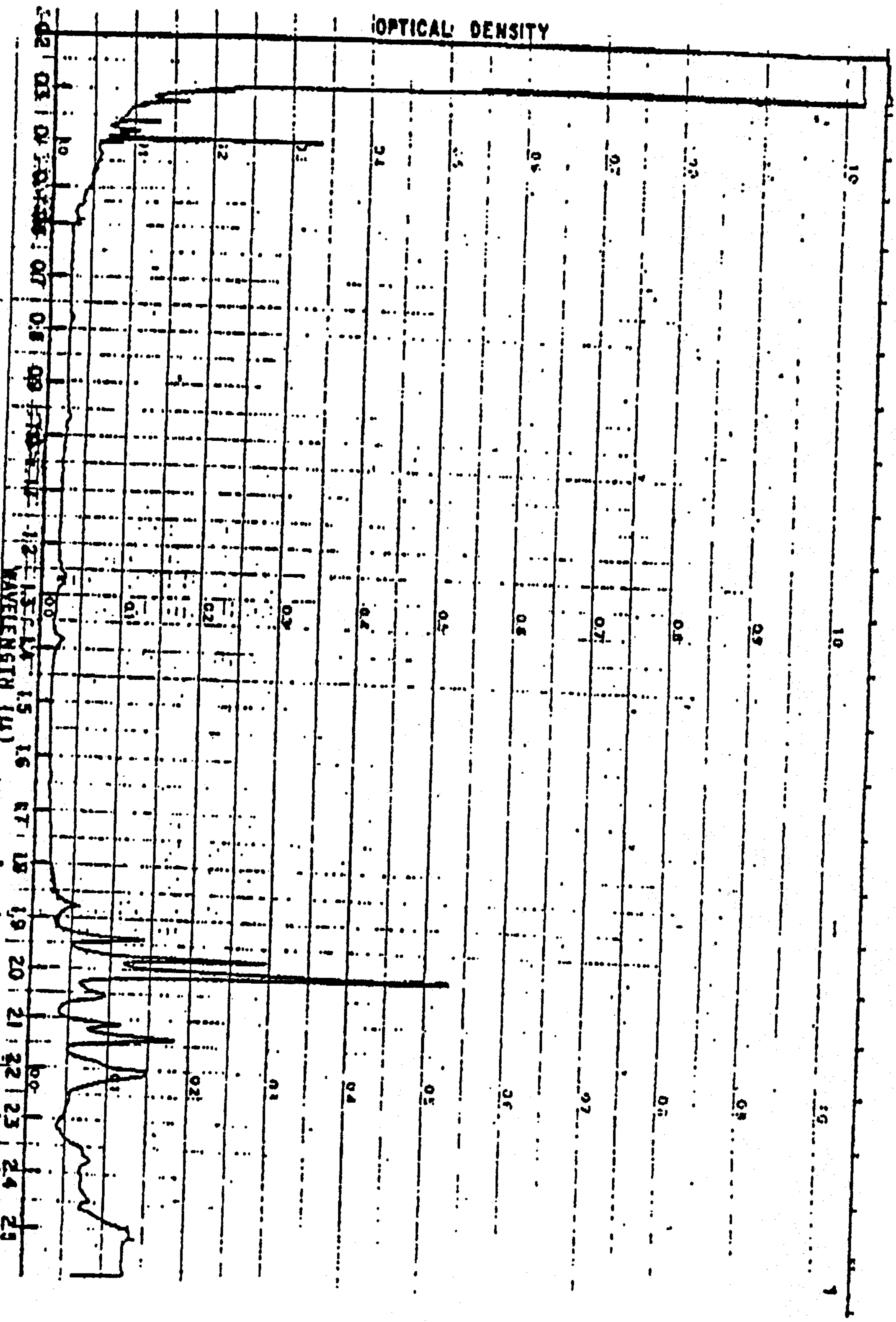


Figure 6 - Room temperature absorption spectrum of Eu^{3+}:Y_3Al from 0.2 to 2.5 μ.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/03504

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G06K 9/74
U.S. CL: 356/71

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	356/71, 448, 433 340/572, 600

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US,A 4,742,340 NOWIK 03 May 1988 (Note col.1, lines 64-68) For detecting authenticity of an article having a label containing an isotape.	1,11,18
Y	US,A 4,544,266 ANTES 01 October 1985 (Note col.3, lines 8-31) Two lasers generate light rays having wavelengths.	3, 4
Y	US,A 2,844,066 FRIEL 22 July 1958 (Note col lines 24-25) The relationship involved is expressed mathematically by Beer's Law.	17, 24

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
17 September 1990	07 NOV 1990
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ISA/US	LaCharles P. Keesee