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[54] **ACOUSTIC IMAGING SYSTEM**

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[51] **Int. Cl.** **G01n 29/04,** G01n 23/20

[58] **Field of Search** ..... 250/51.5, 59, 65, 49.5 A, 250/49.5 ED, 84.5; 73/67.5–67.9

[56] **References Cited**

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[57] **ABSTRACT**

This invention relates to an acoustic imaging system characterized by a crystalline plate having a lattice structure which is distorted upon the incidence of an acoustic pressure pattern image, means for impinging a beam of various energy such as X-rays, electron beam or neutron beam upon the plate at an angle with respect to the plane of the plate, and means for detecting the diffraction pattern of the stream of particles corresponding to the acoustic image on the plate.

18 Claims, 3 Drawing Figures

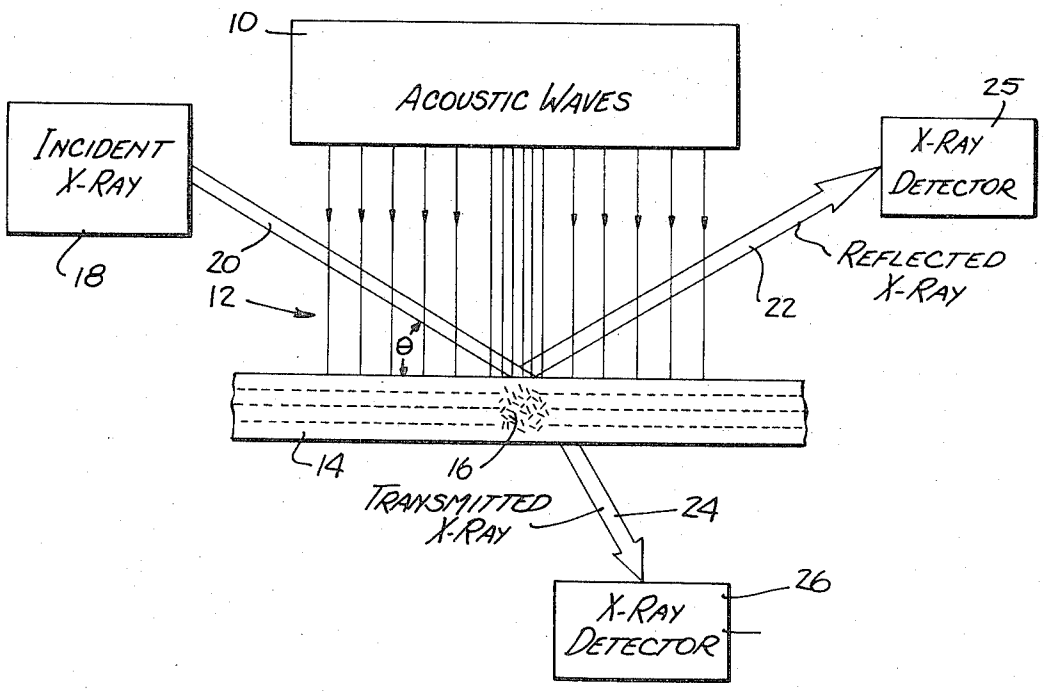


Fig. 1.

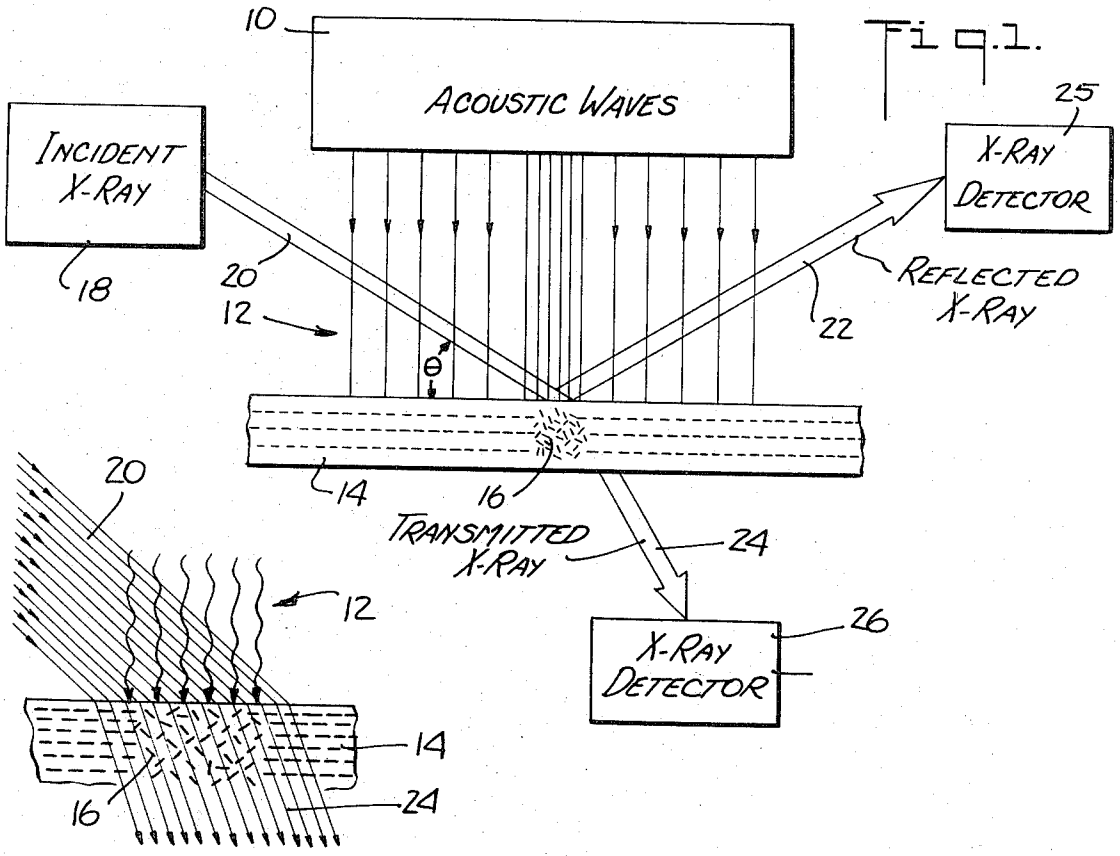
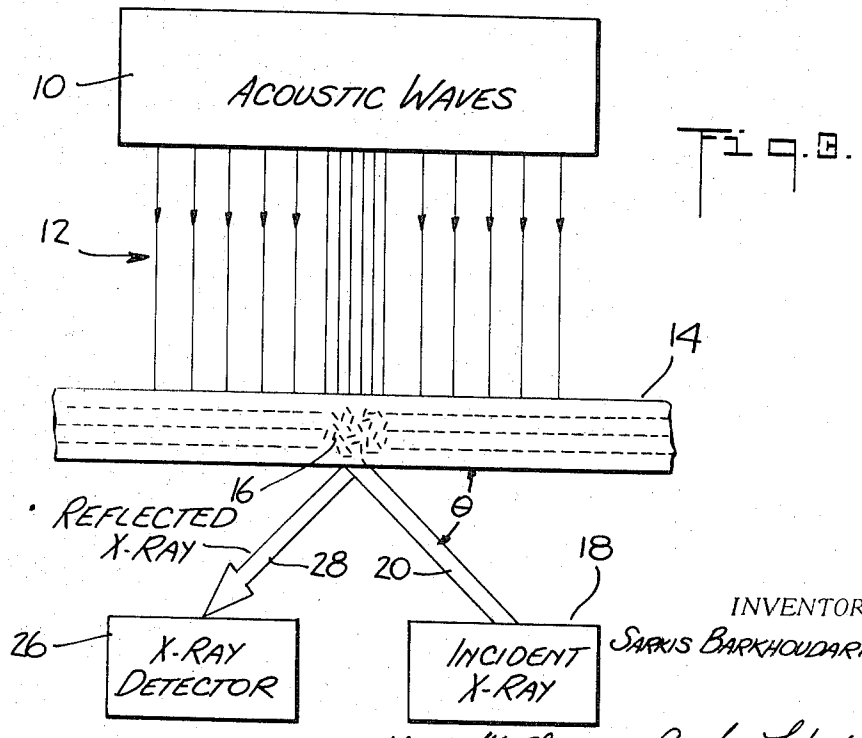


Fig. 2.

Fig. 3.



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ACOUSTIC IMAGING SYSTEM

This invention relates to ultrasonic imaging systems.

Present acoustic imaging systems employ piezoelectric transducers to detect acoustic images by converting them to corresponding electrical images. A limitation of this prior art system was the need of piezoelectric materials which are all limited by temperature considerations. That is, the piezoelectricity degrades approaching the Curie temperature and vanishes therebeyond. In addition, because only non-electroded areas of a piezoelectric transducer can image and only electroded areas can transmit, the prior art single-crystal transceivers were partially electroded. This partial electroding reduced the transmitted acoustic energy and masked, according to the pattern of the electrode, the received image. Also, vacuum was required because of the usage of secondary electron emission techniques and both X and Y scanning was necessary, such as complicated TV tube systems, for example. Related patents in this area include: U.S. Pat. No. 2,739,243 Mar. 20, 1956; U.S. Pat. No. 2,903,617 Sept. 8, 1959; U.S. Pat. No. 2,919,574 Jan. 5, 1960; U.S. Pat. No. 2,957,340 Oct. 25, 1960; U.S. Pat. No. 3,013,170 Dec. 12, 1961; U.S. Pat. No. 3,030,540 April 17, 1962; U.S. Pat. No. 3,054,004 Sept. 11, 1962; U.S. Pat. No. 3,137,837 June 16, 1964; U.S. Pat. No. 3,213,675 Oct. 26, 1965; U.S. Pat. No. 3,236,944 Feb. 22, 1966.

The present invention involves a novel combination of elements combined in such a way as to afford a very efficient solution to the difficulties encountered with the prior art, as will become apparent as the description proceeds.

In view of the foregoing, this invention contemplates the provision of a new and improved acoustic imaging system including a crystalline face plate mounted for receiving an acoustic pressure pattern image impinging thereon. The lattice structure of the crystalline face plate is distorted by the incidence of the acoustic pressure pattern. Means are provided for impinging a beam of energy such as X-rays, electron beam or neutron beam, upon the plate at an angle with respect to the plane of the plate. In addition, means are provided for detecting the diffraction pattern of the stream of particles corresponding to the acoustic image on the plate. Said means may include a scanning line-shaped beam, photographic film or a phosphorescent plate, for example.

There has thus been outlined rather broadly the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described more fully hereinafter. Those skilled in the art will appreciate that the conception on which this disclosure is based may readily be utilized as the basis for the designing of other structures for carrying out the several purposes of the invention. It is important, therefore, that this disclosure be regarded as including such equivalent constructions as do not depart from the spirit and scope of the invention.

Several embodiments of the invention have been chosen for purposes of illustration and description, and are shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a schematic view of one form of an acoustic imaging system constructed in accordance with the concept of my invention, wherein both the acoustic and detecting energy are incident from the same side;

FIG. 2 is an enlarged schematic view of a crystalline face plate showing the distortion of the lattice structure due to an ultrasonic acoustic pressure pattern image impinging thereon; and

FIG. 3 is a schematic view similar to FIG. 1, but showing another form of acoustic imaging system constructed according to this invention, wherein the acoustic energy incidence is on the opposite side of the face plate with respect to the detecting energy.

In the embodiment of FIG. 1, an acoustic energy source **10**, whose output is represented by lines **12** of planar ultrasonic energy, is shown in proximity to a crystalline face plate **14**. The crystalline face plate can be fabricated from a suitable crystalline metal which meets the chemical and physical requirements of the environment. This face plate could be fabricated from a single-crystal, high temperature metal such as copper, gold, or titanium, for example. As best seen in FIG. 2, the lines of ultrasonic energy **12** are in the form of an ultrasonic acoustic pressure pattern image which impinges upon the lattice structure of the crystalline face plate and causes a corresponding distortion thereof, as at **16**. Reverting to FIG. 1, a source of X-rays **18** whose output as shown by a beam of energy **20** is mounted in proximity to the crystalline face plate **14** and at angle θ with respect thereto. It is noted that the acoustic energy lines **12** and the beam of energy **20** are incident on the same side of the face plate **14**. The beam of energy **18** may be X-rays, electrons or neutrons, for example. A portion **22** of the X-rays is reflected and a portion **24** thereof is transmitted. An X-ray detector **25** is mounted for detecting the reflected pattern of the X-rays corresponding to the acoustic image on the plate **14**, and an X-ray detector **26** is mounted for detecting the diffraction pattern of the X-rays corresponding to the acoustic image on the plate **14**. This X-ray detector receives a line-shaped X-ray beam and, hence, it may be in the form of a linear scanning device. Photographic film or a phosphorescent plate may be used, for example.

The X-ray intensity supplied depends upon the voltage and current. The voltage may be of the order of about 10,000 volts. The voltage determines the wave length, which is compatible with the lattice dimensions of the material of the crystalline face plate **14**, and the current should be of such a value that the detector can respond thereto.

In operation, the ultrasonic acoustic waves **12** distort the lattice structure of the crystalline face plate **14**, as at **16**, which in turn affects the interference of the X-rays by unbalancing the equation

$$2d \sin \theta = n \lambda$$

thereby producing an X-ray diffraction pattern similar to the acoustic pattern impinging on the crystalline plate, where:

d = the thickness of the face plate **14**.

θ = the angle of incidence of the X-ray

n = 1, 2, 3, (Multiples of standing waves)

λ = the wave length of the X-ray determined by the applied voltage in accordance with the formula:

$$ev = h\,c/\lambda,$$

where e is the electron charge, v is the voltage, h is the Planck constant, and c is the velocity of light.

The thickness and the surface of the face plate **14** are dependent upon how thin the metal can be fabricated. The thickness may be of the order of about 0.002 inches.

In the embodiment of FIG. **3**, the ultrasonic acoustic waves **12** impinge upon the crystalline face plate **14** to distort the lattice structure in the same manner as described more fully hereinbefore in connection with the embodiment of FIG. **1**. The stream of particles **20** from the X-ray source **18** impinge upon the crystalline face plate **14** at an angle θ with respect to the plane of the plate and are reflected as at **28** to the detector **26**. It is noted that the beam of energy **20** is incident on the opposite side of the face plate **14** with respect to the acoustic energy lines **12**. The detector **26** functions in the same manner as described hereinbefore in connection with the embodiment of FIG. **1**.

It will thus be seen that the present invention does indeed provide an improved ultrasonic imaging system which has no Curie temperature limitation and which is superior in simplicity and efficiency as compared to prior art such systems.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, various modifications thereof, after study of this specification, will be apparent to those skilled in the art to which the invention pertains.

What is claimed and desired to be secured by letters patent is:

1. An ultrasonic imaging system comprising a crystalline face plate for receiving an acoustic pressure pattern image impinging thereon, the lattice structure of said crystalline face plate being distorted by the incidence of said acoustic pressure pattern, means for impinging a beam of penetrating radiation upon said plate at an angle with respect to the plane of said plate, and means for detecting the diffraction pattern of said beam corresponding to the acoustic image on said plate.

2. An ultrasonic imaging system according to claim **1** wherein said beam comprises X-rays.

3. An ultrasonic imaging system according to claim **2** wherein said X-rays are subjected to a voltage of about 10,000 volts.

4. An ultrasonic imaging system according to claim **2** wherein the thickness of the crystalline plate is determined by the formula:

$$d = n\,\lambda/2 \sin\theta$$

where

d = thickness of crystalline face plate

θ = the angle of incidence

n = 1, 2, 3, (Multiples of standing waves)

λ = wave length of the X-ray

determined by the applied voltage in accordance with $ev = h\,c/\lambda$, where e is the electron charge, v is the voltage, h is the Planck constant, and c is the velocity of light.

5. An ultrasonic imaging system according to claim **1** wherein said beam comprises electrons.

6. An ultrasonic imaging system according to claim **1** wherein said beam comprises neutrons.

7. An ultrasonic imaging system according to claim **1** wherein said crystalline face plate is fabricated from a single-crystal high-temperature metal.

8. An ultrasonic imaging system according to claim **1** wherein said crystalline face plate is fabricated from copper.

9. An ultrasonic imaging system according to claim **1** wherein said crystalline face plate is fabricated from gold.

10. An ultrasonic imaging system according to claim **1** wherein said crystalline face plate is fabricated from titanium.

11. An acoustic imaging system according to claim **1** wherein said crystalline face plate has a thickness of about 0.002 inches.

12. An acoustic imaging system according to claim **1** wherein at least a portion of said beam is reflected and wherein said means for detecting the diffraction pattern comprises means for detecting said reflected beam.

13. An acoustic imaging system according to claim **1** wherein at least a portion of said beam in transmitted and wherein said means for detecting the diffraction pattern comprises means for detecting said transmitted beam.

14. An acoustic imaging system according to claim **1** wherein said acoustic pressure pattern image and said beam impinges on the same side of said face plate.

15. An acoustic imaging system according to claim **1** wherein said acoustic pressure pattern image and said beam impinges on opposite sides one with respect to the other of said face plate.

16. An acoustic imaging system according to claim **2** wherein said means for detecting the diffraction pattern comprises photographic film.

17. An acoustic imaging system comprising a crystalline face plate for receiving an acoustic pressure pattern image impinging thereon, the lattice structure of said crystalline plate being distorted upon the incidence of said acoustic pressure pattern, said crystalline face plate having a thickness of less than about 0.002 inches, said crystalline face plate being fabricated from a single-crystal high-temperature metal, means for impinging X-rays upon said face plate at an angle with respect to the plane of said plate, at least a portion of said X-rays being reflected, and means for detecting the diffraction pattern of said reflected X-rays corresponding to the acoustic image on said plate, said last named means comprising means for detecting said reflected X-rays.

18. An acoustic imaging system comprising a crystalline face plate for receiving an ultrasonic acoustic pressure pattern image impinging thereon, the lattice structure of said crystalline plate being distorted upon the incidence of said ultrasonic acoustic pressure pattern, said crystalline face plate having a thickness determined by the formula:

$$d = n\,\lambda/2 \sin\theta$$

where

d = thickness of crystalline face plate

θ = the angle of incidence,

n = 1, 2, 3, (Multiples of standing waves)

λ = wave length of the X-ray determined by the applied voltage in accordance with $ev = h\,c/\lambda$, where e is the electron charge, v is the voltage, h is the Planck constant, and c is the velocity of light, said crystalline face plate being fabricated from a single-crystal high-temperature metal, means for impinging X-rays upon said face plate at an angle with respect to the plane of said plate, and means for detecting the diffraction pattern of said X-rays corresponding to the acoustic image on said plate.

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