

[54] **OPTICAL ANGULAR
ACCELEROMETER**

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represented by the Secretary of the
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[58] Field of Search**324/162, 175; 350/99, 104;
73/167**

[56] **References Cited**

FOREIGN PATENTS OR APPLICATIONS

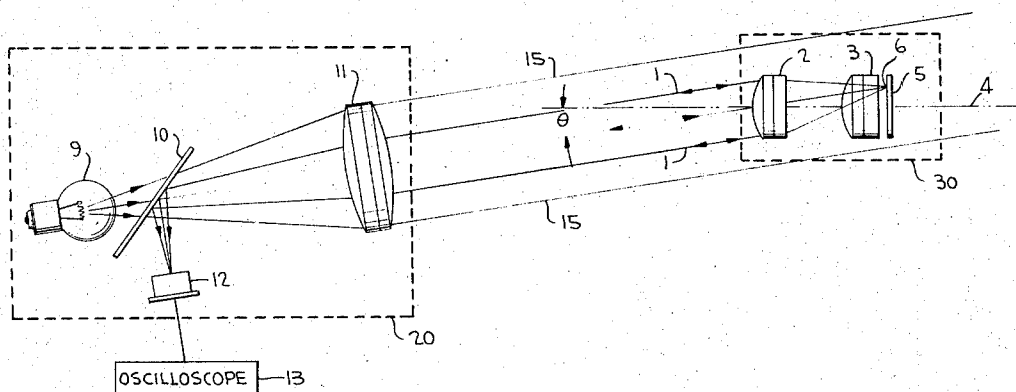
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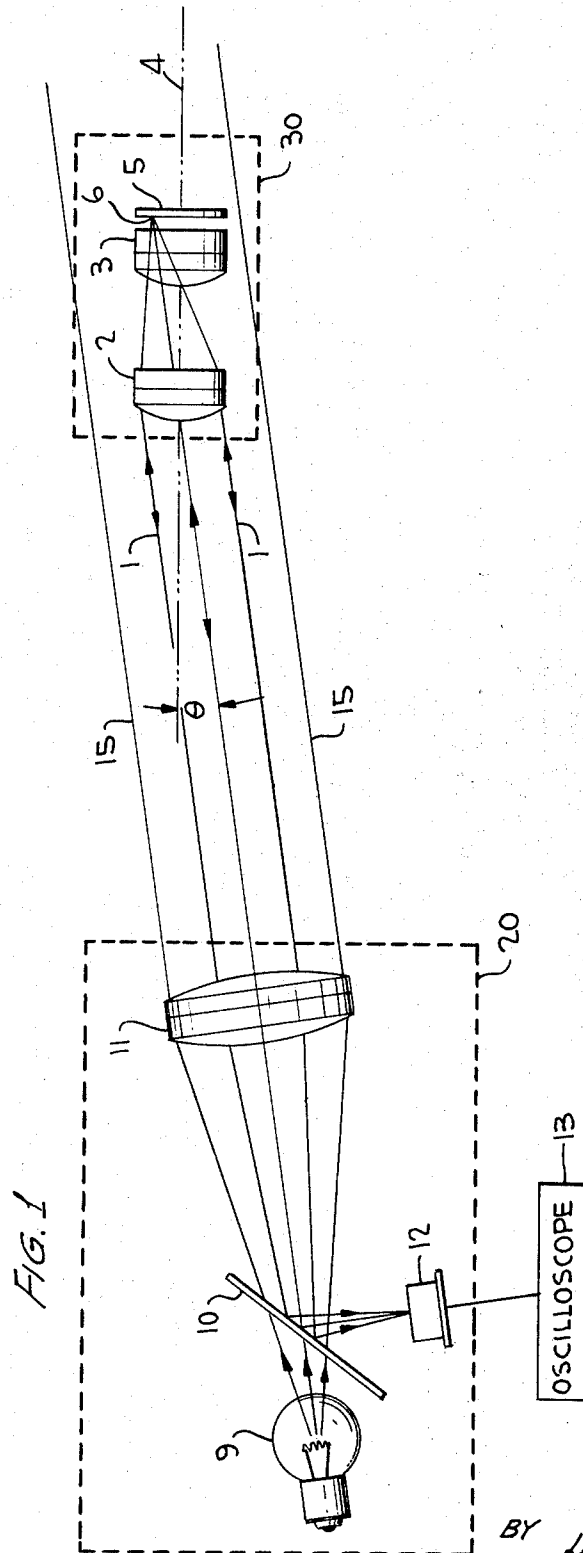
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[57] **ABSTRACT**

An optical system for determining the angular velocity of a rotating member. The system consists of two major optical assemblies. One assembly is a catadioptric retroreflector attached to the rear end of the projectile. The other assembly is a sensor box comprising a lamp, photodetector, beam splitter, and collimating lens. The sensor box projects a collimated beam of light onto the retroreflector. Light returned by the retroreflector reenters the sensor box and is directed to the photodetector. The retroreflector contains a mirror with alternate reflecting and nonreflecting sectors. As the retroreflector rotates with the spinning member, the light returned to the sensor box is amplitude modulated. The photodetector responds to the modulation of the returning light and generates a corresponding electrical signal whose frequency is in direct proportion to the rotational rate of the spinning member.

10 Claims, 2 Drawing Figures



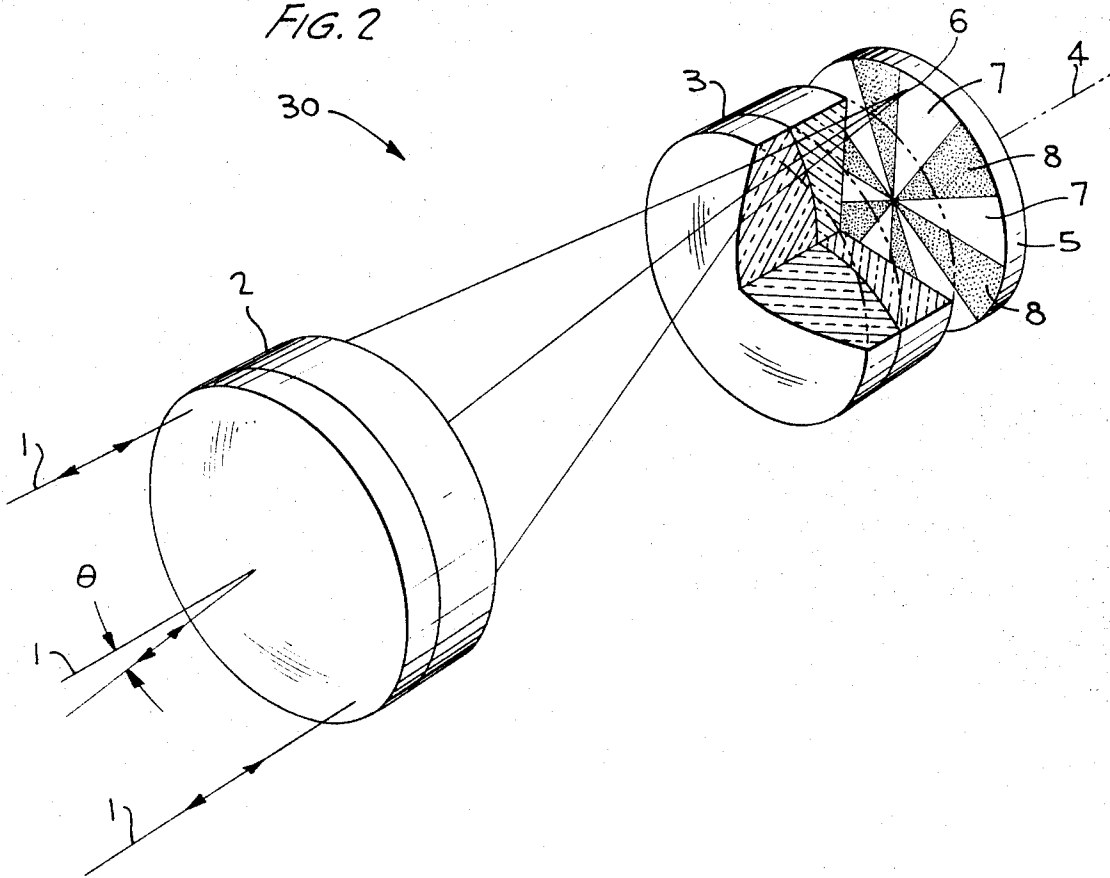


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FIG. 2



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OPTICAL ANGULAR ACCELEROMETER

RIGHTS OF GOVERNMENT

The invention described herein may be manufactured, used, and licensed by or for the United States Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to optical devices, and more particularly, to optical devices that measure the angular velocity of a remote rotating member.

2. Description of the Prior Art

In one phase of testing fuzes or fuze components for use in artillery shells or other spinning projectiles, knowledge of the angular acceleration to which they are subjected is important. Such knowledge can be obtained with the aid of various rotary accelerators such as that disclosed in U.S. Pat. No. 3,444,733 to Curchack for an Artillery Simulator. In that device, test projectiles are fired from an air gun into a spinning catcher. The catcher is a metal tube containing a mass with which the projectile impacts. Upon impact the projectile undergoes longitudinal deceleration and begins to pick up the rotation of the spinning catch tube. Present techniques for determining the angular acceleration of such a projectile have been limited to photographing the projectile with a high speed movie camera or telemetering the output of accelerometer mounted in the projectile. The former method requires considerable time to reduce the data and involves expensive photography equipment. The latter method can also be highly expensive in that the telemetry unit may be destroyed when the projectile impacts.

Accordingly, the primary object of the present invention is to provide a simple optical device that will remotely sense the angular velocity of a rotating projectile from which the angular acceleration can be computed.

Another object is to provide an optical angular accelerometer for measuring the angular acceleration of a rotating test projectile that is rugged enough to withstand the forces generated upon the impact of the projectile.

An additional object of the present invention is to provide an optical angular accelerometer which allows a remote measurement of rotational velocity of a spinning member that is inexpensive and simple to construct.

SUMMARY OF THE INVENTION

Briefly, in accordance with the invention, an optical angular accelerometer is provided that allows real time readout of the angular velocity of a rotating projectile that is remote from the measuring system. The accelerometer comprises two major optical assemblies, the first of which is a catadioptric retroreflector mounted on the end of the rotating projectile. The other assembly which is remote from the rotating projectile comprises a light source, photodetector, beam splitter and collimating lens. This assembly projects a collimated beam of light onto the retroreflector as the projectile enters the catch tube of the Artillery Simulator. The retroreflector contains a mirror with alternate

reflecting and nonreflecting sectors. As the projectile and hence the retroreflector rotates, the light reflected from the mirror becomes amplitude modulated and, by virtue of the characteristics of the catadioptric retroreflector, returns to the second assembly along the same light path of the incident beam. The amplitude modulated light re-enters the second assembly and is directed to the photodetector. The photodetector responds to the modulation of the returning light and generates a corresponding electrical signal whose frequency is in direct proportion to the rotational rate of the projectile.

BRIEF DESCRIPTION OF THE DRAWINGS

The specific nature of the invention as well as other objects, aspects, uses and advantages thereof will clearly appear from the following description and from the accompanying drawings, in which:

FIG. 1 is a schematic diagram illustrating the optical geometry involved with the device of the present invention; and

FIG. 2 is perspective drawing of the optical components comprising the catadioptric retroreflector assembly of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows the two major optical assemblies that comprise the device of the present invention, the first being a sensor box 20 located in any convenient measuring position and the second being a catadioptric retroreflector 30 that is mounted on one end of the spinning projectile which is necessarily remote from the sensor box 20. Within sensor box 20, a lens 11 forms a collimated beam 15 from the light from lamp 9. The axis of collimated beam 15 makes an angle θ with the optical axis 4 of retroreflector 30. A portion 1 of collimated beam 15 is intercepted by an objective lens 2 of retroreflector 30. A mirror 5 is located in the focal plane of objective lens 2, and has radially disposed thereon a plurality of alternate reflective and non-reflective sectors. The portion of the collimated beam 1 entering objective lens 2 is focused to a point 6 on the surface of mirror 5. Lens 3 is a field lens whose function will be discussed hereinafter. If the spot of light 6 falls on a nonreflecting sector of mirror 5, no light will be reflected back out through objective lens 2. If, however, retroreflector 30 is rotated about axis 4 until a reflecting sector of the mirror 5 aligns with the spot 6, the light will be reflected back out through objective lens 2, parallel to its original direction by virtue of the characteristics of retroreflector 30. If retroreflector 30 is rotated about axis 4, a beam of light will be reflected back toward lens 11 of sensor box 20 every time a reflecting sector of mirror 5 lines up with the spot 6. These reflected light beams will enter lens 11 and be redirected by a beam splitter 10 and brought to a focus on a photosensitive element 12. Photosensitive element 12, which may be comprised of a simple photodetector, will generate an electrical pulse each time a reflected light beam enters sensor box 20. The final result will be a series of pulses whose period T can be mathematically expressed as

$$T = (1 / NR)$$

where n is the number of mirrored sectors and R is the rotational speed of the retroreflector. The series of pulses generated can be fed by photosensitive element 12 to an oscilloscope 13 and may be photographed on a time scale. From this permanent record, the period T can be ascertained and the above equation can be solved for R , the rotational speed of the retroreflector. If this angular velocity is determined over short time intervals, the angular acceleration can be derived therefrom.

FIG. 2 illustrates the arrangement of the optical components of catadioptric retroreflector 30 of FIG. 1. The components of FIG. 2 are mounted in a cylindrical holder (not shown) that retains them in the proper relation. In one version, the holder has a flanged base for fastening the retroreflector to the rear of the projectile. A portion of field lens 3 has been cut away for clarity. The complete operation of the retroreflector shown in FIG. 2 is described in my co-pending U.S. application Ser. No. 77,165, filed Oct. 1, 1970. Briefly, the catadioptric retroreflector reflects an incident light beam back in a direction parallel to itself while minimizing the loss of light in the return beam.

In operation, light rays 1 entering objective lens 2 must make some angle θ with the retroreflector's optical axis 4. This is so because the focused spot of light 6 has to be positioned off axis to be modulated by the rotating sectors of mirror 5. Field lens 3 is placed immediately in front of mirror 5. This lens improves the off axis reflectivity of the system as a whole by redirecting the light rays so they strike the mirror symmetrically about the normal to the mirror at point 6. Field lens 3 serves an important function towards improving the overall efficiency of the retroreflector, as explained more fully in my aforementioned co-pending application.

Mirror 5 in FIG. 2 is shown with six reflecting sectors 7 and six nonreflecting sectors 8. Obviously, non-reflecting sectors 8 may be either black, opaque sectors or transparent sectors. In the latter case, the light passes through the sectors to be absorbed by some non-reflecting material behind the mirror. For the 12 sector pattern shown in FIG. 2, six pulses will be generated by the photodetector 12 of FIG. 1 for every rotation of the object to which retroreflector 30 is attached. In the retroreflector constructed to verify the principles of the present invention, a 48-sector mirror was used. A pulse was obtained for every 15° of rotation.

In order to maintain the dynamic balance of the projectile, the retroreflector is usually centered on the rear surface of the projectile. In this case, optical axis 4 of the retroreflector is coincident with the longitudinal or spin axis of the projectile. However, this is not a necessary condition for the proper operation of the invention. The retroreflector may be fastened anywhere on the projectile so long as its optical axis is parallel to the spin axis and light from the sensor box 20 can enter objective lens 2.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

I claim as my invention:

1. Apparatus for measuring the angular acceleration of a rotating member, comprising:

- a. a source of light;
- b. means for directing an incident beam of light from said source towards said rotating member at an oblique angle to the spin axis of said rotating member;
- c. a catadioptric retroreflector mounted on said rotating member for periodically reflecting said incident light beam back in a direction parallel to itself; and
- d. means remote from said rotating member for measuring the frequency of reception of said reflected beams of light.

2. The apparatus of claim 1 wherein the optical axis of said catadioptric retroreflector is positioned parallel to said spin axis of said rotating member.

3. The apparatus of claim 2 wherein said catadioptric retroreflector comprises:

- a. an objective lens for collecting said incident beam of light;
- b. means located in the focal plane of said objective lens for periodically reflecting said incident beam of light; and
- c. means located between said objective lens and said reflecting means for minimizing the loss of light in the reflected beams.

4. The apparatus of claim 3 wherein said means located between said objective lens and said reflecting means comprises a field lens that refracts said incident beam of light prior to its impingement upon said reflecting means.

5. The apparatus of claim 4 wherein said reflecting means comprises a reticle centered on said optical axis and having a plurality of alternating reflective and non-reflective sectors radially disposed thereon.

6. The apparatus of claim 5 wherein said light source comprises a laser.

7. The apparatus of claim 5 wherein said means for directing an incident beam of light towards said rotating member comprises:

- a. a lens for transforming the light from said source into a collimated beam; and
- b. means positioned between said light source and said lens for redirecting said reflected beams towards said frequency measuring means.

8. The apparatus of claim 7 wherein said redirecting means comprises a beam splitter.

9. The apparatus of claim 7 wherein said redirecting means comprises a half-silvered mirror.

10. The apparatus of claim 7 wherein said measuring means comprises a photosensitive device that produces an electrical pulse upon the receipt of each reflected light beam.

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