

Oct. 6, 1970

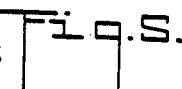
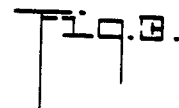
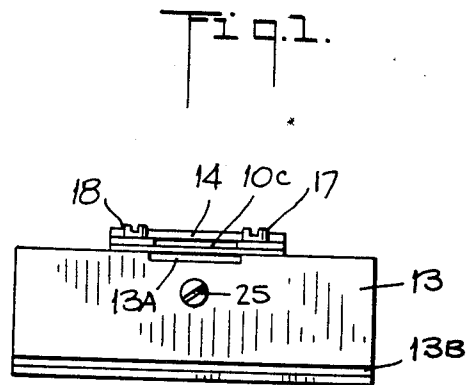
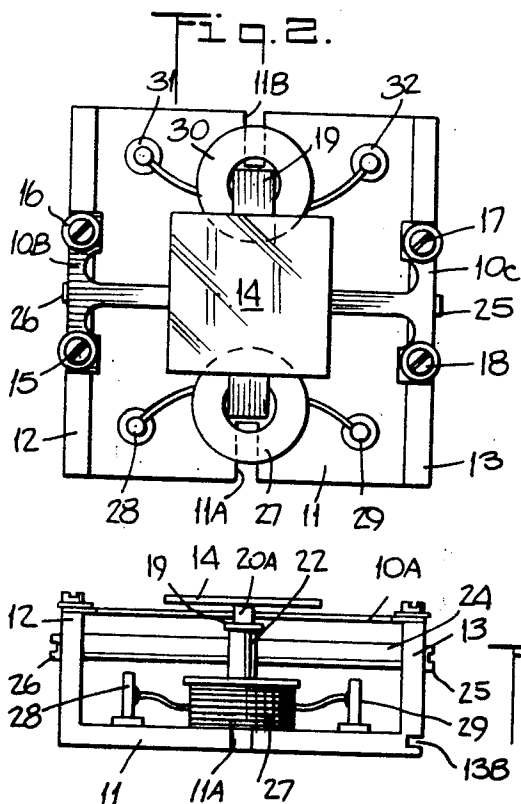
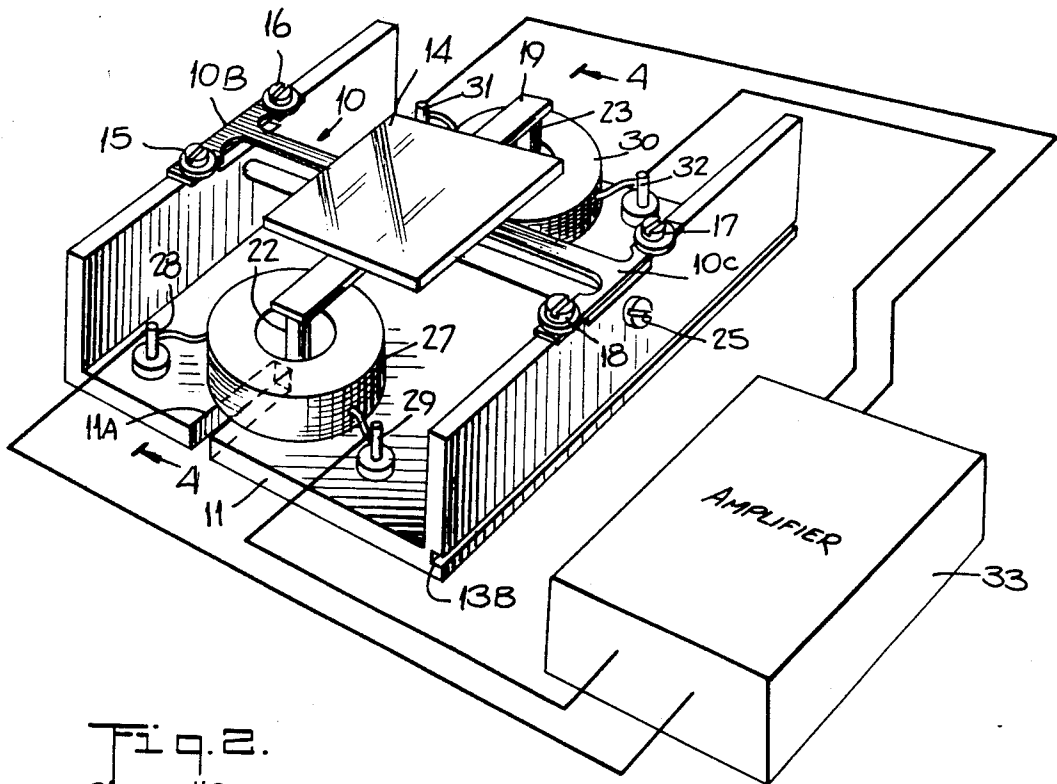
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3,532,408

RESONANT TORSIONAL OSCILLATORS

Filed May 20, 1968

2 Sheets-Sheet 1



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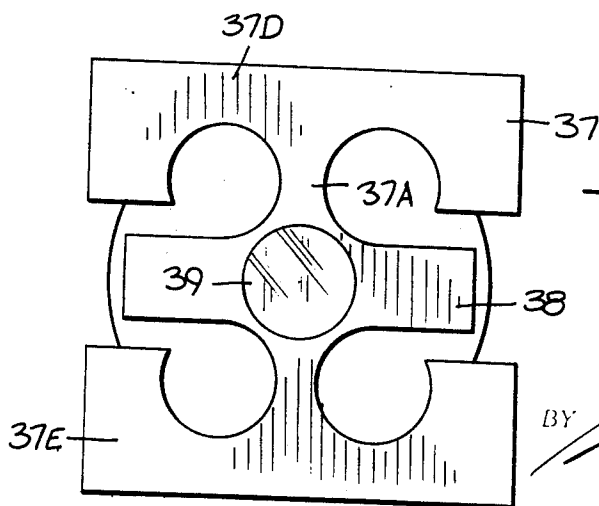
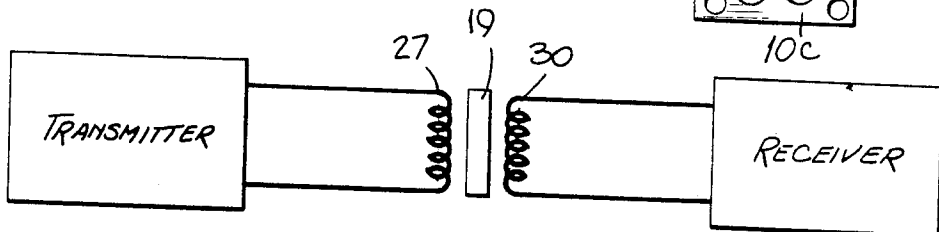
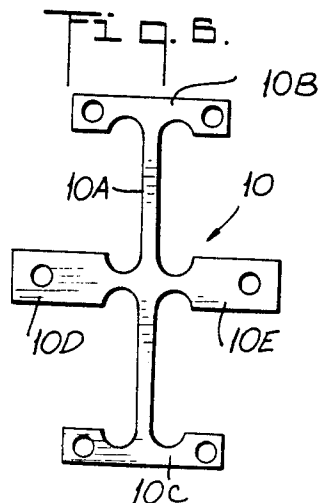
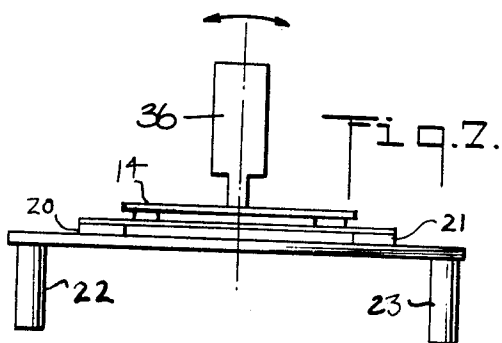
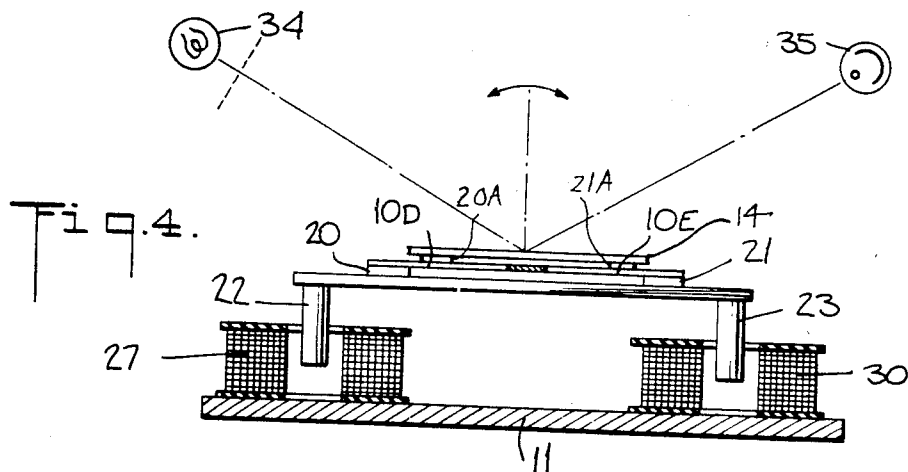
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RESONANT TORSIONAL OSCILLATORS

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2 Sheets-Sheet 2



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3,532,408

RESONANT TORSIONAL OSCILLATORS

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Continuation-in-part of application Ser. No. 692,217, Dec. 20, 1967. This application May 20, 1968, Ser. No. 730,425

Int. Cl. G02b 17/00; G02f 1/34

U.S. Cl. 350—6

9 Claims

ABSTRACT OF THE DISCLOSURE

A resonant torsional oscillator adapted to serve as an optical chopper which requires a vibratory action at a constant rate, the oscillator being constituted by a flat torsional spring suspended between end supports and having cross arms extending outwardly from its center, which arms are secured to an armature having magnetic pole pieces at either end, the pole pieces being associated with fixed coils, whereby when the oscillator is actuated the armature see-saws about the axis of the spring at a constant rate which is determined by the moments of the armature and the arms secured thereto as well as the elastic properties of the spring.

RELATED APPLICATION

This application is a continuation-in-part of my co-pending application Ser. No. 692,217, of the same title, filed Dec. 20, 1967 now abandoned.

This invention relates generally to resonant electromechanical oscillators, and more particularly to a highly compact, light-weight and low-power torsional oscillator which is substantially insensitive to shock and vibration, and is adapted to provide a vibratory action of high amplitude at a constant rate.

Various forms of optical devices are currently in use to chop, modulate, pulse, scan, sweep or otherwise control a light beam or other beams of radiant energy. Such devices are incorporated in mass spectrometers, bolometers, star trackers, colorimeters, horizon sensors and in various instruments which utilize or analyze ion, nuclear, X-ray, laser beams or beams in the visible, ultra-violet or infrared region.

Existing optical devices for this purpose usually make use of motor-driven discs, drums, mirrors or prisms. Devices using motors are relatively big and heavy and have large power requirements, particularly at higher frequencies, thus necessitating extra size and weight provisions for inverters or similar power supplies. Also in use are electromechanically-actuated armature devices in which the pivoted armature is mounted in jeweled bearings. Optical modulators of these types are relatively inefficient and unstable, they are lacking in shock resistance and have other drawbacks which limit their usefulness.

It is also known to use resonant tuning forks to vibrate optical elements, and while such forks overcome many of the drawbacks found in motor-driven choppers, they are comparatively expensive and are unable to produce large angular excursions of the optical elements when operated at low power. Moreover, when a low-frequency vibrator is required to operate at a rate as low as 1 to 10 Hz., the physical size of a fork adapted to vibrate at this low rate is so sensitive to shock and vibration as to preclude a light-weight compact design.

Accordingly, it is the main object of this invention to provide a resonant torsional oscillator which is of compact, light-weight design and which is especially adapted for use in space-operated vehicles and in other installations where weight and equipment space are at a premium.

More specifically it is an object of this invention to provide a torsional oscillator in which a flat torsional spring is suspended between end supports, the spring having cross-arms extending laterally therefrom, the arms being secured to an armature, whereby when the oscillator is actuated the armature see-saws about the longitudinal axis of the spring at a constant rate which is determined by the moments of the armature and the arms and the elasticity characteristics of the torsional spring.

A significant aspect of the invention is that the torsional oscillator is relatively insensitive to shock forces which may arise in hostile environments, the oscillator having prolonged operating life, for there is no need for lubrication or other care, operating wear is almost non-existent, and reliability is of a high order.

Also an object of the invention is to provide a torsional oscillator of exceptionally high "Q" which oscillator is also capable of maintaining a substantially constant frequency throughout a temperature range extending upwards of 85° C.

While the invention will be described in conjunction with an optical scanner, it is to be understood that it is also useful whenever there is need for a vibratory action at a constant rate. For example, by converting the vibratory action of the torsional oscillator into rotary movement by means of a mechanical or magnetic escapement, a constant speed motor is provided thereby. When operating as a torsional oscillator, the drive pulses in the associated electromagnetic circuit are generated at a rate determined by the resonance characteristics of the torsional element. Hence these pulses may be used as a stable frequency voltage source. The device is also usable as a selective electromechanical filter.

Briefly stated, these objects are accomplished in a resonant torsional oscillator comprising a flat torsional spring suspended between end supports, the spring having a pair of cross arms extending outwardly from its center and secured to an armature, magnetic pole pieces being attached to the opposite ends of the armature, one pole piece cooperating with a fixed input or pick-up coil, the other with a fixed drive or output coil, a voltage pulse induced in the pick-up coil by movement of the associated pole piece being applied to the input of an amplifier which supplies drive pulses to said drive coil to sustain the device in oscillation and to cause said armature to see-saw about said torsional spring at a constant rate.

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 is a perspective view of one preferred embodiment of a torsional oscillator functioning as a light scanner in accordance with the invention and its associated operating circuit;

FIG. 2 is a plan view of the light scanner;

FIG. 3 is a side view of the light scanner;

FIG. 4 is a longitudinal section taken in the plane indicated by line 4—4 in FIG. 1;

FIG. 5 is an end view of the light scanner;

FIG. 6 separately shows the torsional element;

FIG. 7 shows an optical filter attached to the armature of the torsional oscillator;

FIG. 8 shows the torsional device as it functions as a resonant filter; and

FIG. 9 illustrates in plan view another embodiment of the torsional spring element.

Referring now to the drawings, and more particularly to FIGS. 1 to 6, there is shown a torsional oscillator in accordance with the invention, the oscillator being adapted to function as an optical chopper to modulate, pulse, scan, sweep or otherwise control a beam of radiant energy

3
impinging on the optical element being vibrated by the oscillator.

The oscillator comprises a torsion member, generally designated by numeral 10, the member being bridged across a channel-like frame 11 having parallel side walls 12 and 13, which in practice may be fabricated of aluminum or other light-weight high-strength metal. Centrally mounted upon torsion member 10 is a mirror or reflector 14, such that in operation, the reflector is caused to vibrate about the longitudinal axis of the torsional member, thereby periodically deflecting a light or other beam of radiant energy impinging thereon at a rate determined by the resonance characteristic of the oscillator. Conversely and with suitable optics, the scanner may be adapted to survey an area or pattern.

As shown separately in FIG. 6, torsion member 10 is formed by a strip having T-shaped mounting terminals 10B and 10C at either end thereof and a pair of cross-arms 10D and 10E extending outwardly from the center of the strip. Torsion member 10 may be fabricated of beryllium copper, stainless steel or other material having suitable spring characteristics but is preferably made of a spring metal which has temperature stability, such as Ni-Span-C or Elinvar.

Terminals 10B and 10C are affixed by a pair of spaced screws 15-16 and 17-18, respectively, to the upper edges of side walls 12 and 13 of the frame. As best seen in FIG. 3, a notch 13A is formed in side wall 13 to relieve the upper edge of this wall in the space between screws 17 and 18 which hold terminal 10C to this edge, the terminal being bridged across the notch. A similar notch arrangement is provided for terminal 10B. The width of terminals 10B and 10C on either side of the junction of strip 10A is reduced to minimize the effect of the twisting action of the strip on the terminals. Thus the torsional strip 10A is effectively isolated from the side walls of the supporting frame, the junction points of the strip lying midway above the notches in the side walls.

Secured to the cross arms 10D and 10E of the torsion member by spacers 20 and 21 is an armature 19 of a metal, such as iron, having soft magnetic properties. Reflector 14 is mounted above the cross arms 10D and 10E and is secured thereto by the spacers 20A and 21A, thus giving the torsional strip 10A, which lies intermediate reflector 14 and the armature 19, freedom to flex. Secured to the ends of armature 19 and extending laterally therefrom are small permanent magnets 22 and 23.

Extending between side walls 12 and 13 below strip 10A and in parallel relationship therewith is a tension rod 24, the ends of the rod being engaged by set screws 25 and 26, threadably received in walls 12 and 13. Rod 24 is made of the same alloy as the torsion member 10 and acts to impose a constant tension on the torsional member regardless of temperature changes and its effect on the frame metal. The amount of tension is adjusted by means of the set screws. Inasmuch as temperature variations or adjustment of the set screws to effect a change in tension imposes a force on the side walls 12 and 13 which tends to bend them, wall 13 is provided with a longitudinal groove 13B to form a hinge permitting this wall to yield to the extent necessary.

The resonance frequency of the torsional oscillator is determined by the moment of armature 19 and arms 10D and 10E as well as the dimensions and Young's modulus of the torsion member 10. A small adjustment in this frequency may be made by varying the tension imposed on the torsional member 10. Armature 19 and mirror 14 secured thereto see-saw about the longitudinal axis of torsion strip 10A at a rate determined by the resonance frequency of the oscillator. Since the only forces which affect the see-saw action are those producing a torque on strip 10A, most extraneous shock forces are applied to the oscillator in directions having no perceptible effect on the see-saw action. Hence the device is relatively immune from shock. In this connection it is assumed that the

moments on either side of the longitudinal or zero axis are equal.

Magnet 22 reciprocates within a fixed input or pick-up coil 27 whose leads are connected to terminal studs 28 and 29 mounted on insulators on the base of frame 11 adjacent one end thereof. Magnet 23 reciprocates within a fixed output or drive coil 30 whose leads are connected to terminal studs 31 and 32 mounted on insulators on the base of frame 11 adjacent the other end thereof.

When operating as an oscillator, the movement of pole piece 22 induces a voltage pulse in pick-up coil 27, which is applied to the input of an amplifier 33. In practice the amplifier may be a single stage transistor circuit operated by a small battery. This voltage is amplified to produce an output pulse which is applied to drive coil 30, causing this coil to attract magnet 23 and thereby actuate the armature. This action occurs repetitively at a constant rate determined by the operating frequency of the torsional element.

An example of a scanner function is shown in FIG. 4, wherein a light beam from an illuminated pattern 34 is directed toward reflector 14, and is reflected thereby onto a suitable photosensitive detector 35, which then provides read-out information. Alternatively, the device may serve as an optical filter comparator by mounting a filter element or several filters 36 above the armature, as shown in FIG. 7.

For a chopper function, the member 36 mounted above the armature (FIG. 7) is made opaque. In an actual embodiment, with a torsional element of beryllium copper with dimensions of $1\frac{1}{16}'' \times \frac{3}{32}'' \times .005''$, a mirror motion of 20° at 50 cycles was obtained, using a D-C power of only 20 milliwatts. The unit was self-starting and reached full amplitude in about ten seconds. The Q was found to be approximately 800 in air and about 1200 in vacuo, the difference being due to windage of the moving parts.

As shown in FIG. 8, it is also possible to use the device as an electromechanical selective filter wherein an input signal from a transmitter is applied to input coil 27 which acts to excite the torsional element and to produce an output signal in output coil 30 which is fed to a receiver, the output signal being generated only if the input signal is close to the resonance characteristic of the torsional element. In this instance, it is desirable that armature 19 be of non-magnetic material to avoid permeability-inter-coupling of the input and output coils.

With a high Q arrangement, the electromechanical filter is highly selective and rejects all input frequencies other than those close to the mechanical resonance frequency. To assure a quicker response and to provide for a broader band-pass characteristic, the Q may be reduced. This may be accomplished by air-damping, as by attaching vanes to the ends of the see-saw armature. The vanes are preferably disposed in a plane offering maximum air resistance, that is, in a plane parallel to the mirror. Alternatively, capsules containing a fine heavy powder may be attached to the ends of the armature or a viscous member connected from the center of the armature to a fixed point. Such damping and the resultant reduction in Q permits greater operating tolerances at the transmitter as well as the receiver.

In practice, a filter of this type can be made for very low frequencies, as low as 1 Hz. This range is generally impractical with other known methods.

The torsional member shown in FIG. 6 may be stamped out of a single plate of spring metal. It is also possible, as shown in FIG. 9 to stamp out a torsional member with dimensions corresponding to that of a supporting frame, wherein the plate 37 is die-cut to define a flat torsional element 37A whose ends are provided with T-shaped terminals 37B and 37C, cross arms 37D and 37E extending outwardly from the center of the element and being attached to an armature 38. A mirror 39 is mounted on top of the torsional element.

In some instances, as pointed out previously, such as in a filter arrangement having a broad-band character-

5

istic, it is desirable that the Q of the oscillator have a relatively low value. But in most applications, it is desirable to optimize the efficiency of the oscillator and to minimize the loss of energy.

Thus in the arrangement shown in FIGS. 1, 2 and 5, the base of frame 11, which is preferably fabricated of aluminum or an aluminum alloy, is provided with a pair of slots 11A and 11B which extend longitudinally from the opposing ends of the frame inwardly toward positions directly below magnets 22 and 23, respectively. These slots, as will now be explained, serve to increase the Q by a significant amount.

As is well known, a moving or changing magnetic field induces a current flow in the conductor or coil disposed at right angles to the lines of force. In the torsional oscillator shown in these figures, the reciprocating magnets 22 and 23 induce currents in the conductive base of frame 11 which effectively constitutes a perfect shorted turn. These induced currents are tantamount to lost energy supplied by the motion of the magnets. By putting in slots 11A and 11B, the shorted turns below the magnets are effectively opened, thereby reducing eddy currents substantially and enhancing the Q by approximately thirty to fifty percent.

In lieu of open slots, the area of the frame base adjacent the coils may be made of non-conductive material. In addition, if an enclosure is to be used, it too may be made of a non-conductor to minimize the induction of eddy currents by moving magnets 22 and 23 in proximate conductors. To further heighten the Q, the torsional oscillator may be enclosed in an evacuated housing to eliminate the damping effects of air.

Tension rod 24, as shown in FIG. 5, is made of the same alloy as the torsion member 10, and acts to impose a constant tension thereon regardless of the effect of temperature changes on the frame metal. However, when the temperature varies throughout a range running as high as 85° C., while the rod functions to maintain the tension on the torsion member constant, the elasticity of this member changes with temperature, this change having an appreciable effect on frequency at higher temperatures.

Hence it is desirable, when the oscillator is to operate under conditions where it may be subjected to high temperatures, to impose an increased tension thereon to compensate for the loss of elasticity which gives rise to a decrease in frequency with an increase in temperature. To accomplish this result, tension rod 24 is made of a material such as aluminum or other suitable alloy, which has a greater coefficient of expansion than the metal of the torsion member. Thus the increased tension imposed by the tension rod as the temperature goes up, compensates for the reduction in operating frequency normally encountered, thereby maintaining a substantially constant frequency.

When torsion members of materials such as Elinvar or Ni-Span-C or others are used, tension rod 24 will then be of other compositions. For alloys with a negligible change of elasticity with temperature, the tension rod may be of an alloy such as Invar which maintains a constant dimension with temperature.

What is claimed is:

1. A resonant torsional device comprising:

- (A) a torsional spring suspended between end supports subjecting said spring to tension, the spring having cross arms extending outwardly from its center and perpendicular to the suspended part,
- (B) an armature secured to said arms whereby when

6

said spring undergoes torsional movements, said armature undergoes a see-saw action producing oscillation in a plane at right angles to the longitudinal axis of the spring at a rate determined by the elastic characteristics of said spring and the moment of said arms and armature,

- (C) magnetic pole pieces connect to and projecting laterally from the ends of said armature,
- (D) a fixed input coil disposed to receive one of said pole pieces,
- (E) a fixed output coil disposed to receive the other of said pole pieces,
- (F) an electronic amplifier whose input is connected to said input coil and whose output is connected to said output coil to sustain said device in oscillation at said rate,
- (G) an optical element mounted on said arms at its intersection with said spring and oscillating therewith at right angles to the longitudinal axis of said spring, and
- (H) a tension bar disposed between said side walls, and set screws in said walls engaging the ends of said bar to adjust the tension imposed on said spring.

2. A device as set forth in claim 1, wherein said input and output coils are both mounted on a conductive base having slots therein to prevent eddy currents from being induced by the pole pieces.

3. A device as set forth in claim 1, wherein said device is enclosed in an evacuated housing to prevent air damping.

4. A device as set forth in claim 1, wherein said optical element is a mirror.

5. A device as set forth in claim 1, wherein said optical element is a filter.

6. A device as set forth in claim 1, wherein said optical element is an opaque vane.

7. A device as set forth in claim 1, wherein said end supports are formed by the side walls of a channel-shaped frame member, the ends of the spring having T-shaped terminals secured to the upper edges of said side walls.

8. A device as set forth in claim 1, wherein said tension bar and said spring are both made of the same metal to maintain a constant tension on said spring despite changes in ambient temperature.

9. A device as set forth in claim 1, wherein said tension bar is made of a metal having a higher temperature coefficient of expansion than said spring to increase the tension on said spring with an increase in temperature.

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U.S. Cl. X.R.

178—7.6; 331—156; 350—285