MAGNETIC JOINT AND OPTICAL MOUNT USING THE SAME

INVENTOR:

Vladimir G. Krylov

FIELD OF THE DISCLOSURE

[0001] This disclosure relates generally to the mounting, positioning, and actuation of a payload, and in particular, to a magnetic joint and use thereof in mounting and actuation of an optical component.

BACKGROUND

[0002] Optical scanners can be used to steer a laser beam or a sensor that defines an imaging system field of view. Optical scanners may be used in materials processing, marking, packaging, optical coherence tomography, laser light shows, laser-based templating, and numerous other applications. The majority of optical scanners are mechanical systems using one of two implementations. A first implementation has two mirrors, each actuated along one rotational axis and positioned orthogonally to the other mirror to achieve a two-dimensional scanning field. A second implementation has a single mirror actuated in two orthogonal axes commonly known as tip-tilt. Both of these implementations, as they are currently available, have a number of non-trivial drawbacks.

Summary

[0002a] In an ~~aspect~~example, there is a laterally unconstrained magnetic joint comprising:

a first component comprising a permanent magnet material; and a second component comprising a permanent magnet or ferromagnetic material, wherein the first component and the second component are magnetically attracted to each other, and wherein the first component and the second component interface via continuous interface surfaces of different curvature that form and maintain point contact throughout a range of angular and lateral actuation. In an ~~aspect~~example, there is magnetic joint, comprising:

a first component having a first body extending along a first axis to a first interface surface, the first interface surface defining a first radius of curvature; and

a second component having a body extending along a second axis to a convex second interface surface in contact with the first interface surface, the second interface surface defining a second radius of curvature that is different from the first radius of curvature;

wherein at least one of the first component and the second component comprises a permanent magnet and wherein the first and second components are magnetically attracted to each other. In an ~~aspect~~example, there is a system comprising:

a payload having a first surface and an opposite second surface;

at least one linear actuator; and

a magnetic joint between the payload and the at least one linear actuator, the magnetic joint including

a first component with a first body defining a first interface surface, and

a second component defining a convex second interface surface in contact with the first interface surface, wherein at least one of the first component and the second component comprises a permanent magnet, and wherein the first component is laterally unconstrained with respect to the second component

[0002b] In one aspect, the present disclosure refers to a system comprising:
a payload having a first surface and an opposite second surface; at least one linear actuator; and
a magnetic joint between the payload and the at least one linear actuator, the magnetic joint including a first component with a first body comprising a permanent magnet and defining a first interface surface, wherein a first axis passes through a geometric center of the first interface surface and is perpendicular to the first interface surface, and a second component defining a convex second interface surface in contact with the first interface surface, wherein a second axis passes through a geometric center of the second interface surface and is perpendicular to the second interface surface; wherein a magnetic field produced by interaction of the first component with the second component biases the magnetic joint towards an equilibrium position in which the second axis is collinear with the first axis; wherein a joint axis of the magnetic joint is perpendicular to the first interface surface and to the second interface surface when the magnetic joint is in any position, and the joint axis also passes through the geometric center of each of the first interface surface and the second interface surface when the magnetic joint is in the equilibrium position; and wherein when the magnetic joint is in the equilibrium position, the first axis and the second axis are collinear with the joint axis.

[0002c] In another aspect, the present disclosure refers to a magnetic joint assembly, the assembly comprising: a first component comprising a permanent magnet magnetized along a first axis, the first component having a planar first interface surface intersecting the first axis; and a second component comprising a ferromagnetic material and having a convex second interface surface in point contact with the first interface surface, wherein a second axis intersects the second interface

surface, wherein the first component and the second component are magnetically attracted to each other along a joint axis that is perpendicular to at least one of the first interface surface and the second interface surface, wherein the first component and the second component maintain point contact throughout a range of angular and lateral actuation, and wherein a magnetic field produced by interaction between the permanent magnet and the ferromagnetic material biases the magnetic joint assembly towards an equilibrium position in which the joint axis is collinear with the first axis and with the second axis.

[0002d] In yet another aspect, the present disclosure refers to a magnetic joint assembly, the assembly comprising: a first component extending along a first axis and comprising a first permanent magnet magnetized along the first axis, the first component having a planar interface surface intersecting the first axis; and a second component extending along a second axis and comprising a second permanent magnet magnetized along the second axis, the second component having a convex second interface surface in point contact with the planar interface surface, the second axis intersecting the convex second interface surface; wherein the first component and the second component are magnetically attracted to each other along a joint axis that is perpendicular to the convex second interface surface, wherein the first component and the second component maintain point contact throughout a range of angular and lateral actuation, and wherein a magnetic field produced by interaction of the first component and the second component biases the assembly towards an equilibrium position in which the joint axis is collinear with the first axis and with the second axis.

[0002e] In yet another aspect, the present disclosure refers to a magnetic joint comprising:
a first component comprising a permanent magnet material; and a second component comprising a permanent magnet or ferromagnetic material, wherein the first component and the second component are magnetically attracted to each other, and wherein the first component and the second component interface via continuous interface surfaces of different curvature that maintain point contact throughout a range of angular and lateral actuation; and a linear actuator coupled to and arranged to actuate one of the first or second components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Embodiments of the present disclosure are illustrated as examples and are not limited by the figures of the accompanied drawings, in which:

[0004] FIG. 1A illustrates a perspective view of a laterally unconstrained magnetic joint that includes a first component and a second component magnetically attracted to each other along a joint axis, in accordance with an embodiment of the present disclosure.

[0005] FIG. 1B illustrates a perspective view of the magnetic joint of FIG. 1A showing freedom of movement about X and Y axes, in accordance with an embodiment of the present disclosure.

[0006] FIG. 1C illustrates the magnetic joint of FIG. 1A with arrows representing possible movement of the first component relative to the second component, in accordance with an embodiment of the present disclosure.

Claims

1. A laterally unconstrained magnetic joint comprising:

a first component comprising a permanent magnet material; and

a second component comprising a permanent magnet or ferromagnetic material, wherein the first component and the second component are magnetically attracted to each other, and wherein the first component and the second component interface via continuous interface surfaces of different curvature that form and maintain point contact throughout a range of angular and lateral actuation.

2. The laterally unconstrained magnetic joint of claim 1, wherein the first interface surface is planar.

3. The laterally unconstrained magnetic joint of claim 2, wherein the first interface surface includes a non-magnetic interface material.

4. The laterally unconstrained magnetic joint of claim 1 further comprising a ferrofluid between the first interface surface and the second interface surface.

5. The laterally unconstrained magnetic joint of claim 1, wherein the first component is free to articulate relative to the second component within the constraints of the continuous interface surfaces.

6. The laterally unconstrained magnetic joint of any of claims 1-5, wherein the first component is rotationally symmetrical about a first axis and the second component is rotationally symmetrical about a second axis.

7. A magnetic joint comprising:

a first component having a first body extending along a first axis to a first interface surface, the first interface surface defining a first radius of curvature; and

a second component having a body extending along a second axis to a convex second interface surface in contact with the first interface surface, the second interface surface defining a second radius of curvature that is different from the first radius of curvature;

~~wherein at least one of the first component and the second component comprises a permanent magnet and wherein the first and second components are magnetically attracted to each other.~~

~~8. The magnetic joint of claim 7, wherein the first component comprises the permanent magnet and the second component comprises a ferromagnetic material, the first permanent magnetized along the first axis.~~

~~9. The magnetic joint of any of claim 7, wherein movement of the first component is laterally unconstrained with respect to the second component.~~

~~10. The magnetic joint of claim 9, wherein movement of the first component is in a direction perpendicular to a joint axis that is perpendicular to the first interface surface and to the second interface surface.~~

~~11. The magnetic joint of claim 7, wherein the first component is rotationally symmetrical about the first axis and the second component is rotationally symmetrical about the second axis.~~

~~12. The magnetic joint of claim 7, wherein the first interface surface makes a point contact with the second interface surface.~~

~~13. The magnetic joint of claim 7, wherein the first interface surface is planar.~~

~~14. The magnetic joint of claim 13, wherein the second interface surface has a profile that is part of a (i) circle, (ii) parabola, (iii) a hyperbola, (iv) an ellipse, or (v) a sine wave.~~

~~15. The magnetic joint of any of claims 7-14 further comprising a ferrofluid between the first interface surface and the second interface surface.~~

~~16. The magnetic joint of any of claims 7-14, wherein the magnetic joint has a range of articulation of at least ±7.5°.~~

1~~17~~. A system comprising:

a payload having a first surface and an opposite second surface;

at least one linear actuator; and

a magnetic joint between the payload and the at least one linear actuator, the magnetic joint including

a first component with a first body comprising a permanent magnet and defining a first interface surface, wherein a first axis passes through a geometric center of the first interface surface and is perpendicular to the first interface surface, and

a second component defining a convex second interface surface in contact with the first interface surface, wherein a second axis passes through a geometric center of the second interface surface and is perpendicular to the second interface surface;

wherein ~~at least one of the first component and the second component comprises a permanent magnet, and wherein the first component is laterally unconstrained with respect to the second component~~ a magnetic field produced by interaction of the first component with the second component biases the magnetic joint towards an equilibrium position in which the second axis is collinear with the first axis;

wherein a joint axis of the magnetic joint is perpendicular to the first interface surface and to the second interface surface when the magnetic joint is in any position, and the joint axis also passes through the geometric center of each of the first interface surface and the second interface surface when the magnetic joint is in the equilibrium position; and

wherein when the magnetic joint is in the equilibrium position, the first axis and the second axis are collinear with the joint axis.

218. The system of claim 171, wherein the first component is magnetically attracted to the second component along a joint axis ~~extending perpendicularly to the first interface surface and to the second interface surface~~.

319. The system of claim 182, wherein the second interface surface has a profile that is part of a circle, a parabola, a hyperbola, an ellipse, or a sine wave.

420. The system of claim 161, wherein the first interface surface makes point contact with the second interface surface.

215. The system of claim 161, wherein the at least one actuator includes a first linear actuator coupled to a first magnetic joint and a second linear actuator coupled to a second laterally unconstrained magnetic joint.

226. The system of claim ~~21~~ 5 further comprising an additional joint coupled to the payload, wherein the additional joint, the first laterally unconstrained magnetic joint and the second laterally unconstrained magnetic joint are coupled to the first surface of the payload in a triangular arrangement.

237. The system of claim 226, wherein the triangular arrangement defines a right triangle.

248. The system of any of claims 171-236, wherein the payload comprises a mirror.

259. The system of any of claims 171-236, wherein the payload has a tilt actuation range of at least 10 degrees.

10. The system of any one of claims 1-9, wherein the first component is rotationally symmetrical about the first axis and/or the second component is rotationally symmetrical about the second axis.

11. The system of any one of claims 1-10 further comprising a ferrofluid between the first interface surface and the second interface surface.

12. The system of any one of claims 1-11, wherein the second component comprises a second permanent magnet magnetized along the second axis.

13. The system of any one of claims 1-12, wherein the first component includes a non-magnetic bearing material, the first interface surface being a planar surface of the non-magnetic bearing material.

14. The system of claim 13, wherein the non-magnetic bearing material comprises sapphire and wherein the second interface surface includes a layer of titanium nitride.

15. The system of any one of claims 1-14, wherein the magnetic joint is a first magnetic joint, the system further includes a second magnetic joint, and wherein the at least one actuator includes a first linear actuator coupled to the first magnetic joint and a second linear actuator coupled to the second magnetic joint.

16. The system of claim 15 further comprising an additional joint coupled to the payload, wherein the additional joint, the first magnetic joint and the second magnetic joint are coupled to the first surface of the payload in a triangular arrangement.

17. A magnetic joint assembly, the assembly comprising:

a first component comprising a permanent magnet magnetized along a first axis, the first component having a planar first interface surface intersecting the first axis; and

a second component comprising a ferromagnetic material and having a convex second interface surface in point contact with the first interface surface, wherein a second axis intersects the second interface surface,

wherein the first component and the second component are magnetically attracted to each other along a joint axis that is perpendicular to at least one of the first interface surface and the second interface surface, wherein the first component and the second component maintain point contact throughout a range of angular and lateral actuation, and wherein a magnetic field produced by interaction between the permanent magnet and the ferromagnetic material biases the magnetic joint assembly towards an equilibrium position in which the joint axis is collinear with the first axis and with the second axis.

18. The assembly of claim 17, further comprising a non-magnetic interface material on the first component, the non-magnetic interface material including the first interface surface, and wherein the second component comprises a second permanent magnet magnetized along the second axis and in the same direction as the permanent magnet of the first component.

19. The assembly of claim 17 further comprising a ferrofluid between the first interface surface and the second interface surface, the ferrofluid comprising ferromagnetic particles suspended in a carrier fluid.

20. The assembly of claim 19, wherein the first component has a first cross-sectional size and the second component has a second cross-sectional size that is substantially the same as the first cross-sectional size.

21. A magnetic joint assembly, the assembly comprising:

a first component extending along a first axis and comprising a first permanent magnet magnetized along the first axis, the first component having a planar interface surface intersecting the first axis; and

a second component extending along a second axis and comprising a second permanent magnet magnetized along the second axis, the second component having a convex second interface surface in point contact with the planar interface surface, the second axis intersecting the convex second interface surface;

wherein the first component and the second component are magnetically attracted to each other along a joint axis that is perpendicular to the convex second interface surface, wherein the first component and the second component maintain point contact throughout a range of angular and lateral actuation, and wherein a magnetic field produced by interaction of the first component and the second component biases the assembly towards an equilibrium position in which the joint axis is collinear with the first axis and with the second axis.

22. The assembly of claim 21, wherein the first component has a first cross-sectional area perpendicular to the first axis and the second component has a second cross-sectional area

perpendicular to the second axis, the second cross-sectional area being substantially the same as the first cross-sectional area.

23. A magnetic joint comprising:

a first component comprising a permanent magnet material; and

a second component comprising a permanent magnet or ferromagnetic material, wherein the first component and the second component are magnetically attracted to each other, and wherein the first component and the second component interface via continuous interface surfaces of different curvature that maintain point contact throughout a range of angular and lateral actuation; and

a linear actuator coupled to and arranged to actuate one of the first or second components.

24. The magnetic joint of claim 23, wherein:

the first component has a first body extending along a first axis to a first interface surface, the first interface surface defining a first radius of curvature; and

the second component has a body extending along a second axis to a convex second interface surface in contact with the first interface surface, the second interface surface defining a second radius of curvature that is different from the first radius of curvature.

25. The magnetic joint of claim 24, wherein the first interface surface is planar and the second interface surface is convex.

26. The magnetic joint of claim 25, wherein the first interface surface includes a non-magnetic interface material.

27. The magnetic joint of claim 23, wherein the first component is magnetically attracted to the second component along a joint axis extending perpendicularly to the first interface surface and to the second interface surface.