

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2007265639 B2**

(54) Title
Apparatus and method for measuring sidewall thickness of non-round transparent containers

(51) International Patent Classification(s)
G01B 11/06 (2006.01)

(21) Application No: **2007265639** (22) Date of Filing: **2007.05.31**

(87) WIPO No: **WO08/002375**

(30) Priority Data

| | | |
|-------------------|-------------------|--------------|
| (31) Number | (32) Date | (33) Country |
| 11/474,589 | 2006.06.26 | US |

(43) Publication Date: **2008.01.03**

(44) Accepted Journal Date: **2012.05.31**

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(56) Related Art
EP 1288613
US 6806459
US 5291271
WO 2002/033349
FR 2544856
US 4500203

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
3 January 2008 (03.01.2008)

PCT

(10) International Publication Number
WO 2008/002375 A1

(51) International Patent Classification:
G01B 11/06 (2006.01)

(21) International Application Number:
PCT/US2007/012862

(22) International Filing Date: 31 May 2007 (31.05.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/474,589 26 June 2006 (26.06.2006) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG,

ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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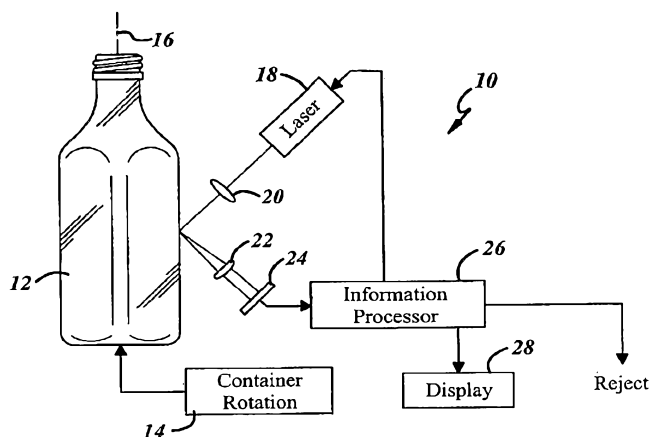
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS AND METHOD FOR MEASURING SIDEWALL THICKNESS OF NON-ROUND TRANSPARENT CONTAINERS



(57) Abstract: An apparatus for inspecting sidewall thickness of non-round transparent containers includes a conveyor (14) for holding a container (12) in stationary position and rotating the container around an axis (16). A light source (18) directs light energy onto a sidewall of the container on the conveyor. An anamorphic lens system (22) having a lens system axis (46) directs onto a light sensor (18) energy reflected from portions of the inside and outside surfaces of the container sidewall that are substantially parallel to the lens system axis. An information processor (26) is responsive to the sensor for determining sidewall thickness at increments of container rotation as a function of separation at the sensor between light energies reflected from the inside and outside surfaces of the container sidewall.

WO 2008/002375 A1

APPARATUS AND METHOD FOR MEASURING SIDEWALL THICKNESS OF NON-ROUND TRANSPARENT CONTAINERS

The present disclosure is directed to inspection of transparent containers for
5 commercial variations that affect optical properties of the containers, and more
particularly to an apparatus and method for electro-optically measuring sidewall
thickness of non-round transparent containers.

BACKGROUND AND SUMMARY OF THE DISCLOSURE

10 Any discussion of the prior art throughout the specification should in no way be
considered as an admission that such prior art is widely known or forms part of common
general knowledge in the field.

Electro-optical techniques have been employed for measuring sidewall thickness
of transparent containers. For example, U.S. Patent 6,806,459 discloses an apparatus and
15 method for measuring sidewall thickness of a container, which includes a conveyor for
moving the container transversely of its axis through an inspection station while
simultaneously rotating the container around its axis by "rolling" the container along a
rail at the inspection station. A light source and an illumination lens system direct onto
the sidewall of the container a line-shaped light beam having a long dimension
20 perpendicular to the axis of the container, parallel to the direction of movement through
the inspection station and of sufficient length to illuminate the container sidewall as it is
rolled along the rail at the inspection station. An anamorphic imaging lens system directs
onto a light sensor light energy reflected from portions of the outside and inside sidewall
surfaces that are perpendicular to the illumination light energy. An information
25 processor is responsive to light energy directed onto the light sensor by the imaging lens
system for determining the thickness of the container between the outside and inside
sidewall surfaces as the container is rolled along the rail. Although the apparatus and
method disclosed in the noted patent are well suited for measuring sidewall thickness of
round containers, such apparatus and method are not well suited for measuring sidewall
30 thickness of non-round containers that cannot be made to roll along the rail at the
inspection station.

U.S. Patent 5,291,271 discloses an apparatus and method for electro-optically
measuring the thickness of a container wall. A light source directs a light beam onto the
outside surface of the container at an angle such that a portion of the light beam is

reflected from the outside surface, and a portion is refracted into the container wall, reflected from the inside wall surface and then re-emerges from the outside wall surface. A lens system is disposed between a light sensor and the container wall for focusing onto the sensor light energy reflected from the outside and inside wall surfaces. The lens system has an image plane in which the sensor is disposed and an object plane collinear with the illumination light beam. The container is held in stationary position and rotated around its axis. An information processor scans the sensor at increments of container rotation, and determines wall thickness of the container between the inside and outside surfaces as a function of the separation between the points of incidence of the reflected light energies on the sensor. Although the apparatus and method disclosed in this patent again is well suited for measuring sidewall thickness of round containers, such apparatus and method are not well suited for measuring sidewall thickness of non-round containers inasmuch as the illumination beam cannot track undulations in the sidewall of a non-round container as the container rotates.

It is an object of the present invention to overcome or ameliorate at least one of the disadvantages of the prior art, or to provide a useful alternative.

The present disclosure embodies a number of aspects that can be implemented separately from or in combination with each other.

According to a first aspect, the present invention provides an apparatus for inspecting sidewall thickness of a non-round transparent container, which includes:

a conveyor for holding a container in stationary position and rotating the container around an axis,

a light source for directing light energy onto a sidewall of a container on said conveyor,

a light sensor for directing onto said light sensor light energy reflected from portions of the inside and outside surfaces of the container sidewall, and

an information processor responsive to said sensor for determining sidewall thickness at increments of container rotation as a function of separation at said sensor between light energies reflected from the inside and outside surfaces of the container sidewall, wherein

said light sources directs onto said container sidewall a line-shaped light beam having a long dimension perpendicular to said axis, and

an amorphic lens system having a lens system axis directs onto said sensor light energy reflected from portions of the inside and outside surfaces of the container sidewall that are substantially parallel to said lens system axis.

5 An apparatus for inspecting sidewall thickness of non-round transparent containers, in accordance with another preferred aspect of the present disclosure, includes a conveyor for presenting containers in sequence and holding each container in turn in stationary position while rotating the container around an axis. A light source directs light energy onto a sidewall of a container as it is held and rotated on the conveyor. An anamorphic lens system having a lens system axis directs onto a light
10 sensor portions of the light energy reflected from inside and outside surfaces of the container sidewall in planes substantially perpendicular to the lens system axis.

The term "substantially perpendicular" refers to light energy reflected in planes perpendicular to the lens system axis within a narrow acceptance angle of the lens system, such as 1° in an exemplary embodiment of the disclosure.

15 Advantageously, the light energy portions reflected from inside and outside surfaces of the container sidewall in planes substantially perpendicular to the lens system axis sweep back and forth along the anamorphic lens system, as the container rotates, due to the non-roundness of the container. Preferably, an information processor is responsive to the light sensor for determining sidewall thickness at increments of
20 container rotation as a function of separation at the sensor between light energy portions reflected from the inside and outside surfaces of the container sidewall.

According to a another aspect, the present invention provides a method of inspecting sidewall thickness of a non-round container, which includes the steps of:

- (a) holding the container in stationary position while rotating the container
25 around an axis,
- (b) directing a line-shaped light beam onto a sidewall of the container, said line-shaped light beam having a long dimension perpendicular to said axis,
- (c) directing onto a light sensor through an anamorphic lens system portions
of said light beam reflected from inside and outside surfaces of the container sidewall
30 that are substantially perpendicular to light energy directed onto the container sidewall as viewed from a direction parallel to said axis, and

(d) determining container sidewall thickness at increments of container rotation as a function of separation between light energy portions at said sensor reflected from the inside and outside surfaces of the container sidewall.

Advantageously, the invention, at least in a preferred form, provides an apparatus
5 and method for measuring sidewall thickness of non-round transparent containers.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure, together with additional objects, features, advantages and aspects thereof, will best be understood from the following description, the appended claims and
10 the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a container sidewall thickness measurement apparatus in accordance with an exemplary embodiment of the present disclosure;

FIG. 2 is a schematic diagram of a portion of the apparatus illustrated in FIG. 1 showing the illumination and imaging lens systems of the exemplary embodiment in
15 greater detail;

FIG. 3 is a top plan view of the illumination lens system of FIG. 2, being taken from the direction 3 in FIG. 2;

FIG. 4 is a top plan view of the imaging lens system in the exemplary embodiment of FIG. 2, being taken from the direction 4 in FIG. 2;

FIG. 5 is a schematic illustration of reflections and refractions of light energy at the container sidewall, being an enlargement of the portion of FIG. 2 within the area 5;
20 and

FIGS. 6A-6K are schematic diagrams that illustrate reflections from the container sidewall at successive stages of container rotation.

25

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a schematic diagram of an apparatus 10 for inspecting sidewall thickness of a non-round transparent container 12, such as a glass container, in accordance with an exemplary embodiment of the present disclosure. Apparatus 10
30 includes a conveyor 14 for presenting sequential containers 12, holding each container 12 in turn in stationary position and rotating the container around an axis 16. The axis of rotation of the container preferably is coincident with the central axis of the container, although the axis of rotation may depart from the central axis of the container due to

wobble or the like caused by malformation of the container. An exemplary conveyor 14 for presenting sequential non-round containers in turn for inspection, holding the containers in stationary position and rotating the containers around an axis for inspection is illustrated in U.S. Patent 6,557,695. See also U.S. Patent 4,124,112. Other conveyors
5 can be employed.

A light source 18 is disposed to direct light energy through an illumination lens system 20 onto the sidewall of container 12 held and rotated on conveyor 14. Light energy reflected from the inside and outside surfaces of the container sidewall are directed by an anamorphic imaging lens system 22 onto a light sensor 24. An
10 information processor 26 is responsive to sensor 24 for determining sidewall thickness at increments of container rotation as a function of separation at the sensor between light energies reflected from the inside and outside surfaces of the container sidewall. Sidewall thickness information can be presented to an operator at a display 28 and/or can be used by the information processor to activate a reject mechanism associated with the
15 conveyor for separating containers having a sidewall thickness outside of a desired range. Sidewall thickness data can, of course, be stored or otherwise used for production system analysis and control.

FIGS. 2 and 3 illustrate an exemplary embodiment of illumination lens system 20 in greater detail. Light source 18, which preferably is a laser that provides a collimated
20 output beam of small diameter, directs the output beam through illumination lens system 20. The beam is spread into a fan by lens 30 and collimated by lens 32. This beam is converged by lens 34 into a very narrow or line-shaped light beam at the average location of the container side, preferably a position about midway between the sidewall position of FIG. 6A and the sidewall position of FIG. 6F. This line-shaped light beam 36
25 (FIG. 3) preferably has a long dimension perpendicular to axis 16. The length of line-shaped light beam 36 is coordinated with the dimensions of the container to produce reflections throughout the positions of FIGS. 6A-6K. In the illustrated exemplary embodiment of the disclosure, illumination lens system 20 includes sequential cylinder lenses 30, 32, 34. Other optics can be employed for converting the output of light source
30 18 into a line-shaped light beam at the container sidewall.

Referring now to FIGS. 2 and 4, imaging lens system 22 is an anamorphic lens system. In the illustrated exemplary embodiment, lens system 22 preferably includes a cylinder lens 38 and a fresnel lens 40. The combination of cylinder lens 38 and fresnel

lens 40 has an image plane in which sensor 24 is disposed and an object plane collinear with the long dimension of line-shaped illumination light beam 36 at the outside sidewall surface of container 12. As shown in FIG. 5, illumination beam 36 intersects the outside surface of the sidewall of container 12, with a portion 42 being reflected from the outside sidewall surface and a portion 44 being refracted into the container sidewall, reflected from the inside surface of the container sidewall, and re-emerging from the outside surface of the container sidewall. Anamorphic lens system 22 functions to direct onto sensor 24 light energies 42,44 reflected from portions of the inside and outside surface of the container sidewall that are substantially parallel to the axis 46 (FIG. 4) of anamorphic lens system 22. Stated differently, anamorphic lens system 22 functions to direct onto sensor 24 portions of reflected light energies 42,44 that are reflected in planes substantially perpendicular to lens system axis 46. The terms "substantially parallel" and "substantially perpendicular" refer to portions of the reflecting surface or the reflected light energy that are within the narrow acceptance angle of the anamorphic lens system, such as an angle of 1° in an exemplary embodiment of the disclosure. Reflected light energy 48 (FIG.4) that is not within this narrow acceptance angle of lens system 22 - i.e., is not reflected from a surface portion that is substantially parallel to lens system axis 46 and not reflected in a plane that is substantially perpendicular to axis 46 - is directed away from sensor 24. In other words, the reflected light energy must be reflected from surface portions that are substantially perpendicular to the rays of illumination beam 36 as viewed from a direction parallel to axis 16, that is from the direction of FIGS. 3 and 4. Light sensor 24 preferably comprises a linear array light sensor in which the light sensor elements are disposed along a line in a plane that includes container axis of rotation 16. Light sensor 24 alternatively may comprise an area array sensor in which only a portion is used for wall thickness measurement purposes. Anamorphic lens system axis 46 (FIG. 4) preferably is perpendicular to axis of rotation 16 (FIG. 1).

FIGS.6A-6K illustrate operation of apparatus 10. In FIG. 6A, a first corner 50 of the container sidewall is opposite light sensor 24, so that the inside and outside surfaces at corner 50 are substantially parallel to the axis of imaging anamorphic lens system 22, and portions 42, 44 of the light energy reflected from corner 50 are substantially perpendicular to the axis of lens system 22 and are directed onto sensor 24. In FIG. 6B, container 12 has rotated in the direction 52 so that light energies 42,44 reflected from the

portions of the container sidewall near corner 50 that are substantially parallel to the axis of lens system 22 have "moved up" lens system 12. In FIGS. 6C-6F, the reflections 42,44 from the portions of the container sidewall that are substantially parallel to the axis of lens system 22 first "move up" the lens system (FIG. 6C) and then "move down" the lens system (FIGS. 6D-6F) until the reflections from the portions of the container sidewall that are substantially parallel to the axis of lens system 22 are about at the midpoint of the container sidewall between corner 50 (FIG. 6F) and the next corner 54 (FIG. 6G) in the direction 52 of container rotation. Between the position of FIG. 6F and the position of FIG. 6I, the reflections 42,44 from the portions of the container sidewall that are substantially parallel to the axis of the imaging lens system "move down" the length of the lens system, which is to say that the reflected light portions 42,44 that are substantially perpendicular to the axis of the lens system "move down" the lens system. From the position of FIG. 6J to the position of FIG. 6K, corner 54 moves to a position opposite lens system 22, so that FIG. 6K is identical to FIG. 6A except that sidewall corner 50 in FIG. 6A is now replaced by the succeeding sidewall corner 54 in FIG. 6K. This process continues from FIG. 6K preferably for at least one full rotation of the container. Thus, light energies 42,44 reflected from the inside and outside surfaces of the container sidewall in planes substantially perpendicular to the lens system axis sweep back and forth along the anamorphic lens system 22 due to non-roundness of the container as it rotates. Information processor 26 scans sensor 24 at increments of container rotation, which may comprise fixed angular increments of container rotation, fixed time increments as the container is rotated at constant velocity and/or varying time increments as the container accelerates or decelerates, and develops a map of container sidewall thickness as a function of angle of rotation of the container. There thus have been disclosed an apparatus and method for determining sidewall thickness of a transparent non-round container that fully satisfy all of the objects and aims previously set forth. The disclosure has been presented in conjunction with an exemplary embodiment, and, a number of modifications and variations have been discussed. Other modifications and variations readily will suggest themselves to persons of ordinary skill in the art in view of the foregoing discussion. For example, although container 12 in the exemplary embodiment of the disclosure has a rounded "square" sidewall geometry, it will be apparent that other non-round container sidewall geometries can be accommodated, including for example triangular geometries, oval geometries, flask-

shaped geometries, etc. The disclosure is intended to embrace all such modifications and variations as fall within the spirit and broad scope of the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. An apparatus for inspecting sidewall thickness of a non-round transparent container, which includes:
 - 5 a conveyor for holding a container in stationary position and rotating the container around an axis,
 - a light source for directing light energy onto a sidewall of a container on said conveyor,
 - a light sensor for directing onto said light sensor light energy reflected from portions of the inside and outside surfaces of the container sidewall, and
 - 10 an information processor responsive to said sensor for determining sidewall thickness at increments of container rotation as a function of separation at said sensor between light energies reflected from the inside and outside surfaces of the container sidewall, wherein
 - 15 said light sources directs onto said container sidewall a line-shaped light beam having a long dimension perpendicular to said axis, and
 - an amorphic lens system having a lens system axis directs onto said sensor light energy reflected from portions of the inside and outside surfaces of the container sidewall that are substantially parallel to said lens system axis.
- 20 2. An apparatus according to claim 1 wherein said light energy reflected from said sidewall portions sweep back and forth along said lens system, as the container rotates, due to non-roundness of the container.
- 25 3. A method of inspecting sidewall thickness of a non-round container, which includes the steps of:
 - (a) holding the container in stationary position while rotating the container around an axis,
 - (b) directing a line-shaped light beam onto a sidewall of the container, said
 - 30 line-shaped light beam having a long dimension perpendicular to said axis,
 - (c) directing onto a light sensor through an anamorphic lens system portions of said light beam reflected from inside and outside surfaces of the container sidewall

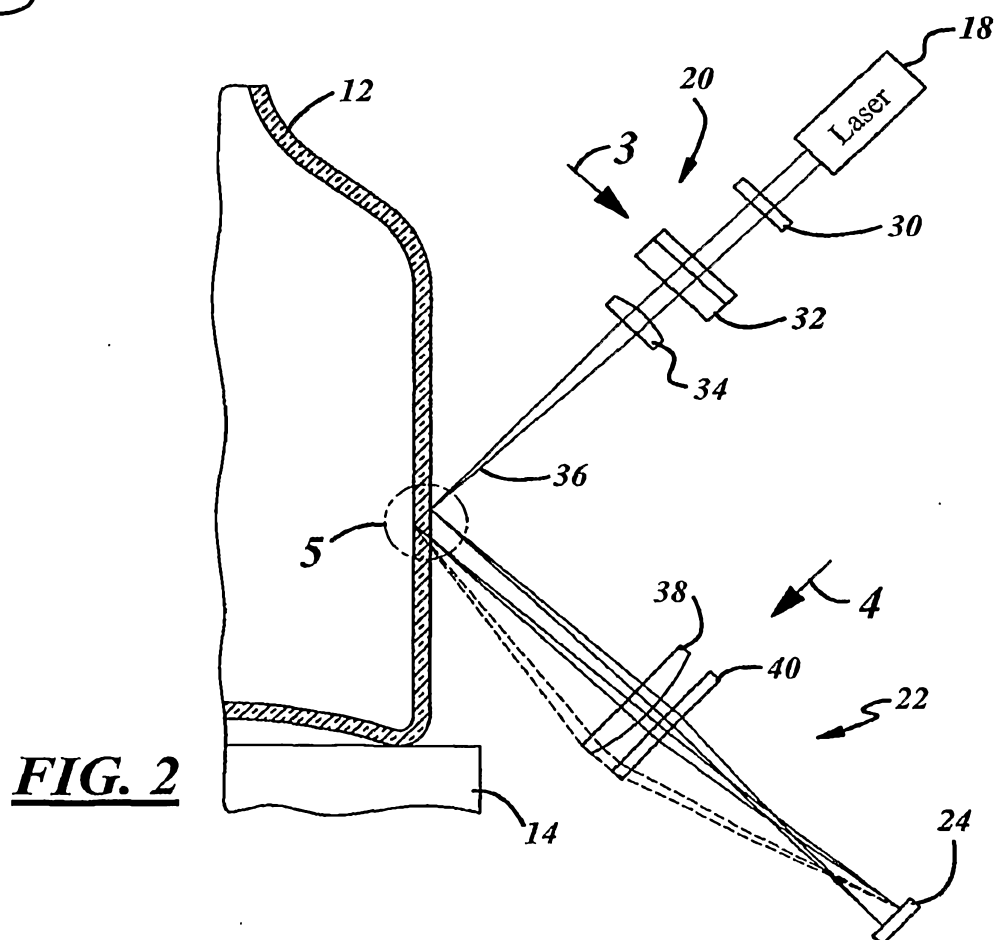
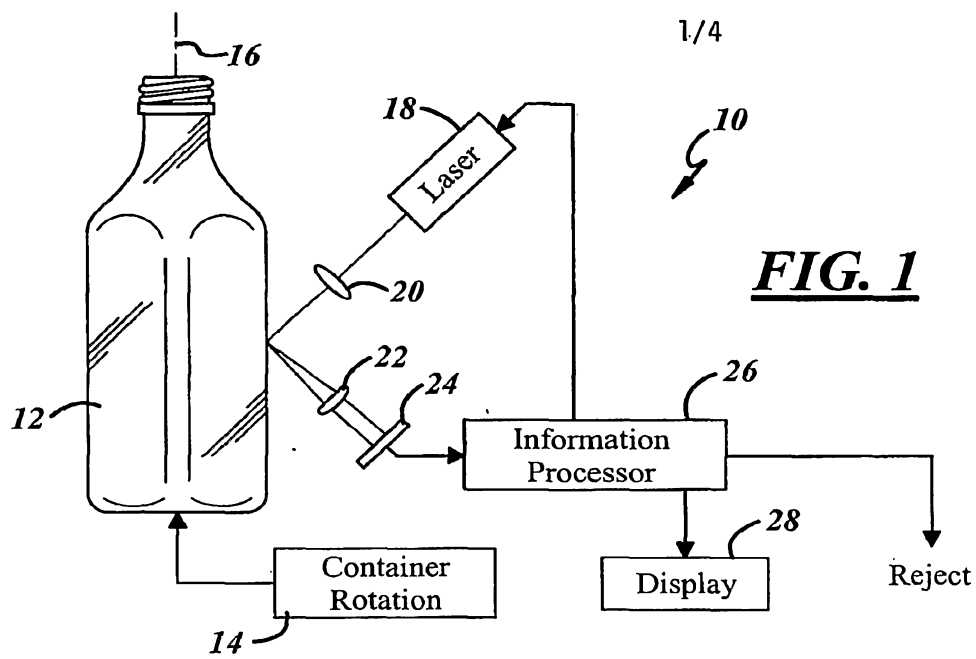
that are substantially perpendicular to light energy directed onto the container sidewall as viewed from a direction parallel to said axis, and

(d) determining container sidewall thickness at increments of container rotation as a function of separation between light energy portions at said sensor reflected
5 from the inside and outside surfaces of the container sidewall.

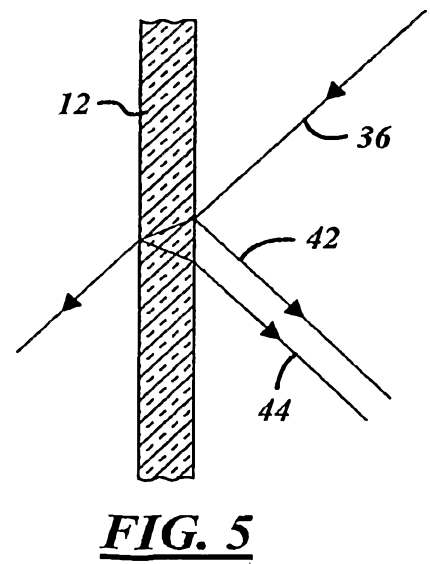
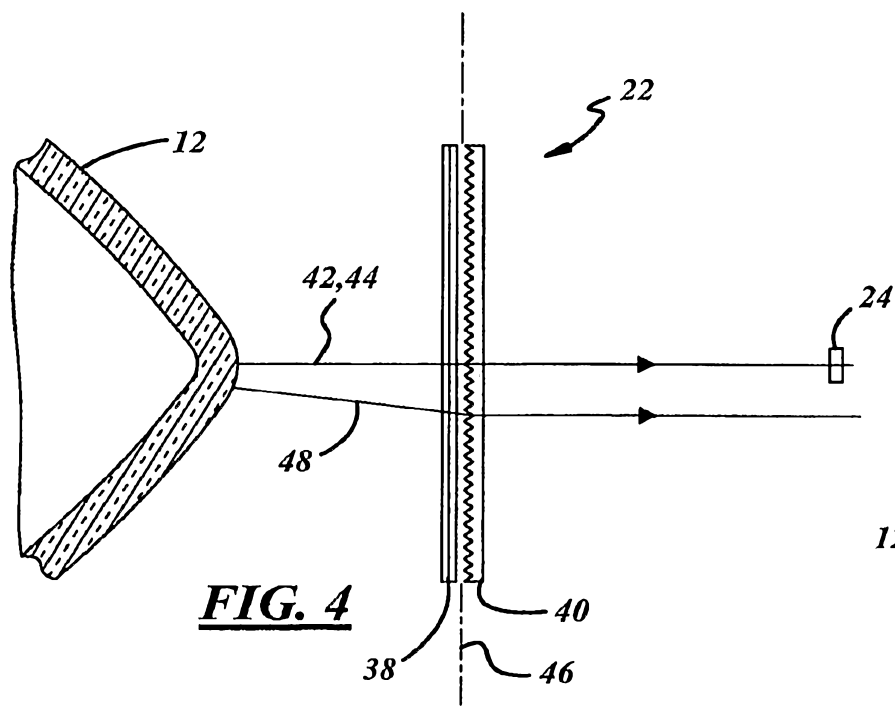
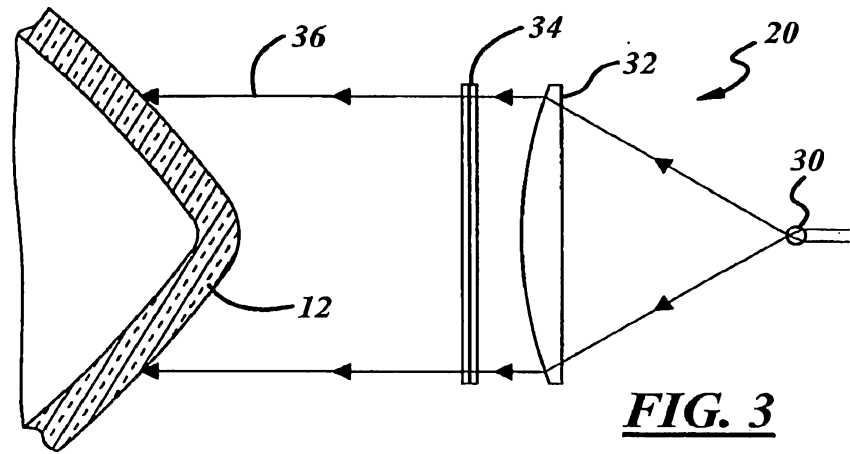
4. An apparatus for inspecting sidewall thickness of a non-round transparent container, substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or
10 examples.

5. A method of inspecting sidewall thickness of a non-round container substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.

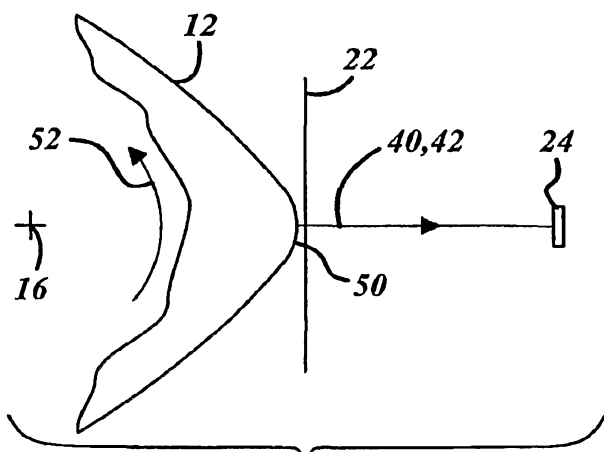
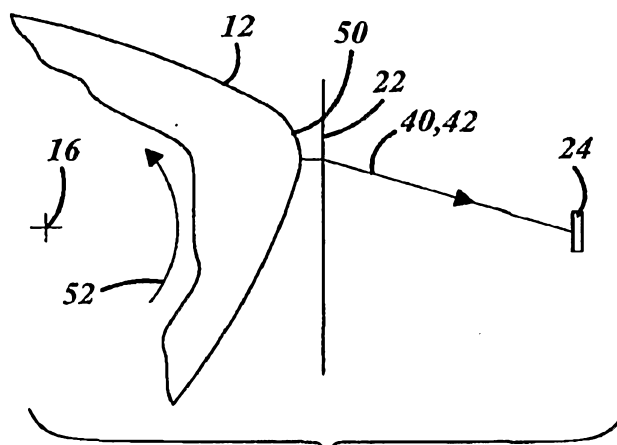
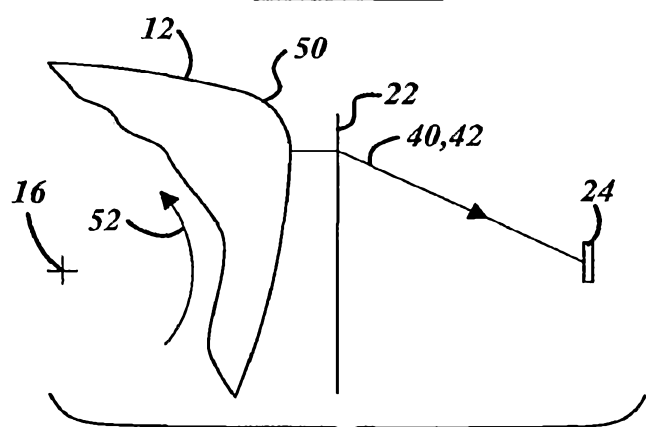
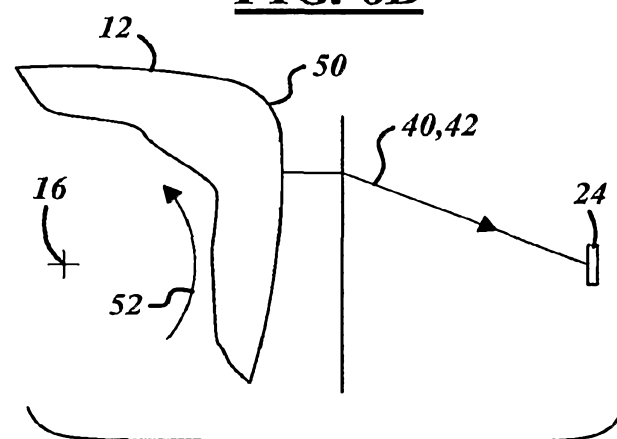
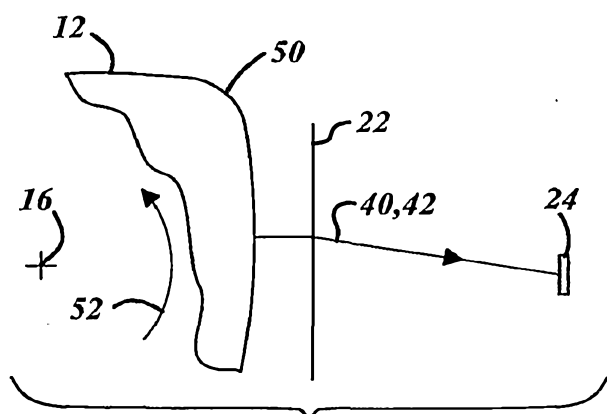
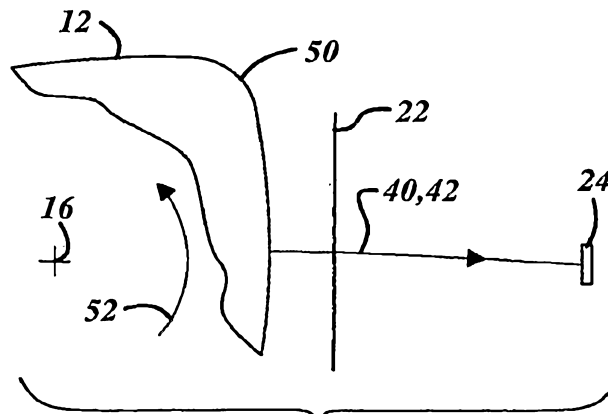
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**FIG. 6A****FIG. 6B****FIG. 6C****FIG. 6D****FIG. 6E****FIG. 6F**

4/4

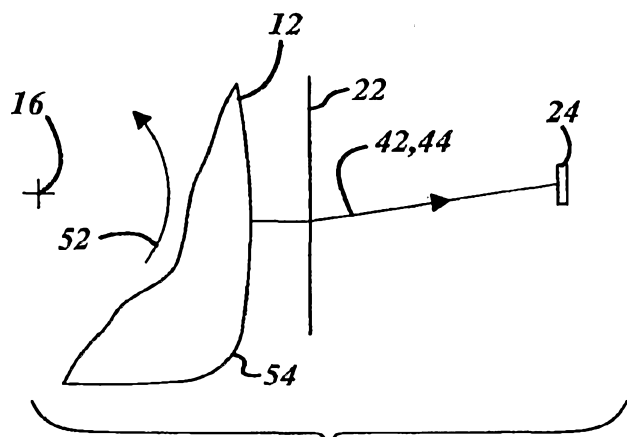


FIG. 6G

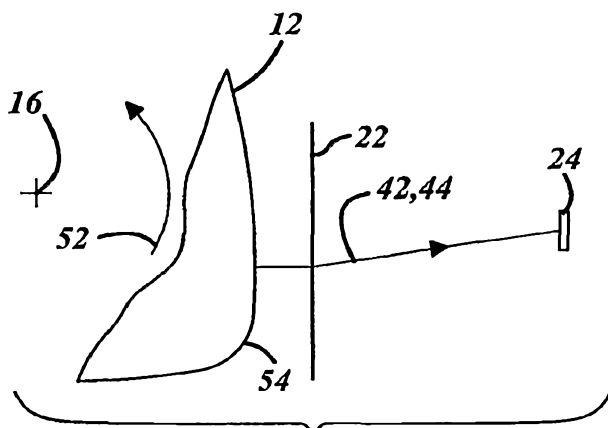


FIG. 6H

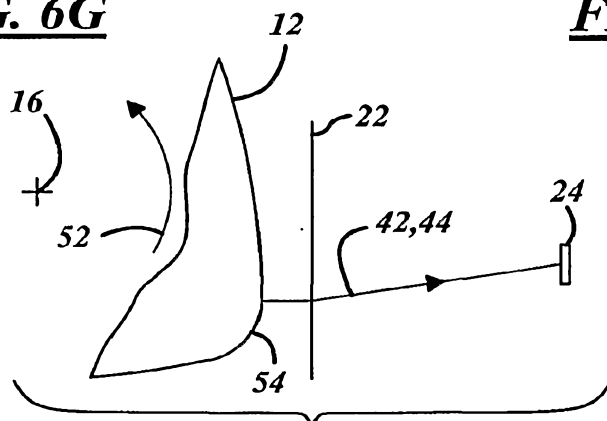


FIG. 6I

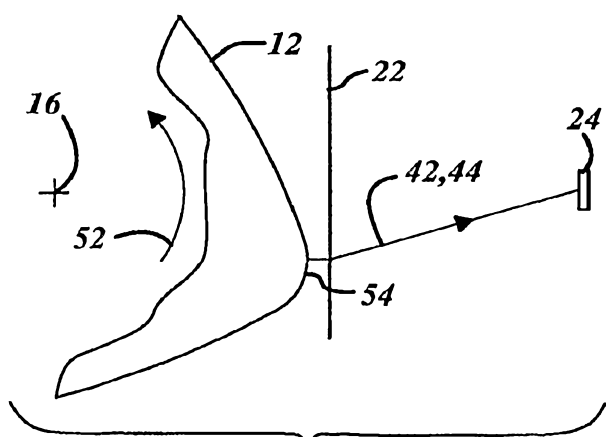


FIG. 6J

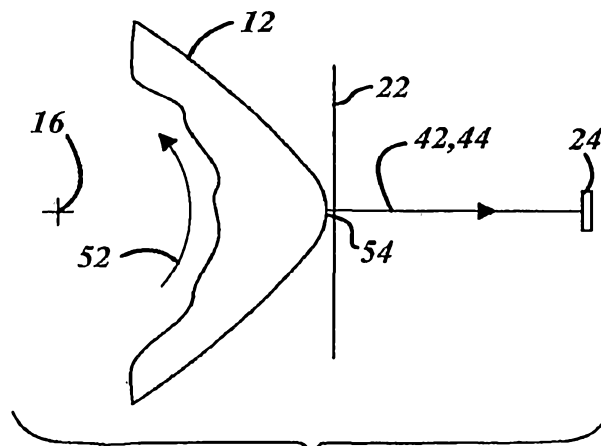


FIG. 6K