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1 LENS PARAMETER MEASUREMENT USING OPTICAL SECTIONING

The present invention relates generally to the measurement of contact lens parameters by using an optical sectioning technique, and more particularly pertains to a lens parameter measurement using optical sectioning.

The accurate measurement of contact lens parameters has presented a problem in the prior art. While a current method for measuring a contact lens diameter (D) is reliable, no method exists at all for measuring the front radius of curvature (FC) of a contact lens. The method for measuring the back radius of curvature (BC) of a contact lens is instrument/operator specific, and the methods for measuring the center thickness (CT) of a contact lens involve physically deforming or destroying the lens.

The measurement of the base curve and center thickness of a contact lens can be very difficult. The current base curve measurement is performed by an ultrasound technique for measuring the back sag at a predetermined diameter. Aside from errors introduced by variations in the temperature of the solution in which the contact lens is immersed, the lens itself is not perfectly spherical, and thus does not fulfill the requirements of the geometrical equation used to transform back sagittal height readings into radius of curvature values. In addition, the device cannot measure the front radius of curvature of the contact lens, nor can it measure the asphericity or toricity of

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1 either the front or back curve of the contact lens. The
center thickness is measured by lowering a plunger onto
a wet contact lens mounted on a pedestal, and measuring
the difference in height from the pedestal alone. This
5 measurement technique suffers from variable rates of
material deformation from the measuring force
attributable to material modulus, inconsistent plunger
counter weight force, and lens design. A noncontacting
measurement technique would be much preferable.

10 Accordingly, the present invention is directed
to a method of measuring desired parameters of a contact
lens by optical sectioning comprising:

- a. positioning a contact lens on a support
fixture;
- 15 b. generating a line of light;
- c. directing the line of light through a
selected diameter of the contact lens;
- d. detecting as an image the light scattered
at the surfaces of the contact lens at the selected
20 diameter; and
- e. analyzing the detected light image to
measure the desired parameters of the contact lens.

The present invention is further directed to
an apparatus for measuring desired parameters of a
25 contact lens by optical sectioning comprising:

- a. a support fixture for positioning a
contact lens being measured;
- b. means for generating and directing a line
of light through a selected diameter of the contact
30 lens; and

1 c. means for detecting as an image the light
scattered at the surfaces of the contact lens at the
selected diameter, and for analyzing the detected light
image to measure the desired parameters of the contact
5 lens.

The subject invention provides an optical
sectioning technique for measuring at least four basic
parameters of a contact lens comprising the diameter
(D), front radius of curvature (FC), back radius of
10 curvature (BC), and center thickness (CT), which can be
measured directly or deduced from a cross-section of the
lens. The present invention uses a line or sheet of
light to illuminate and highlight a cross-sectional view
of an immersed lens. That cross-sectional view contains
15 all of the information necessary to obtain all four
parameters directly, without contacting or destroying
the lens.

In one embodiment, the 4880 Å line of an Ar^{2+}
laser is collimated, and then focused with a cylindrical
20 lens onto a contact lens. The resulting line of light
is directed onto a support fixture with a cup which
contains a slotted pedestal. The cup is filled with a
saline solution, and the lens is placed on a pedestal
completely immersed under the surface of the solution,
25 and the line of light is adjusted so as to pass through
the middle of the contact lens. A charge coupled
television (CCTV) camera detects the light scattered
from the surfaces of the contact lens, and a software
program analyzes the image to obtain the desired
30 parameters of the contact lens.

1 The present invention has many advantages over
present prior art techniques. It is noncontacting, and
operates in reflection so that the optical inspection
can be performed "in-package", and is very compact.
5 Also, it combines in one instrument the functions now
accomplished by a micro-comparator, ultrasound gauge,
Rehdergauge, and microscope. Additionally, the front
curve radius of the contact lens can be measured, which
is not presently possible and could be of great benefit,
10 particularly for aspheric contact lenses.

 The optical sectioning technique provides a
very useful method for determining a contact lens
diameter, front and back curvature, thickness and power.
The measurement of these parameters is much more
15 accurate than any current prior art methods, and can
advantageously be used to measure lenses in packages.
The optical sectioning technique is also much more
accurate than all current prior art methods, and is less
expensive than the multiple instruments in usage today.
20 The measurement technique is noncontacting,
nondestructive, and nonintrusive. Image processing is
employed to enhance the image and calculate the lens
parameters. It also can measure aspects of contact
lenses which no other prior methods can measure, such as
25 the asphericity of the front and back surfaces. Lens
designs using asphericity cannot be measured using any
known prior art method, nor can any unintentional
asphericity be detected. The optical sectioning
technique can also be applied to bifocal lenses,

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1 particularly concentric annular ring contact lens
designs.

The technical approach is to form a line of
light which is directed through a lens, immersed in a
5 saline solution, and positioned on a pedestal. The line
of light travels parallel to the lens center of rotation
axis and bisects the lens. Scattered light is imaged
onto a CCD camera, and the resultant image is enhanced
and analyzed. The optical elements used in the
10 detection system can include a flat, a wedge, and an
imaging lens system. The resultant image is analyzed
using a nonlinear least squares fitting data processing
approach.

A wideband light source is preferably used to
15 decrease pixellation from speckle. The instrument is
designed for compactness and ease of usage with
interchangeable sample holders or cells for different
types of contact lenses, single button operation, and
easy calibration.

20 In accordance with the teachings herein, the
present invention provides a method and apparatus for
measuring desired parameters of a contact lens by
optical sectioning which comprises positioning a contact
lens on a support fixture. A line of light is generated
25 and directed through a selected diameter of the contact
lens. An image is detected of the light scattered at
the surfaces of the contact lens at the selected
diameter, and the detected light image is analyzed to
measure and determine the desired parameters of the
30 contact lens.

1 In greater detail, the analysis provides the
measured parameters of at least four basic parameters of
a contact lens comprising the diameter (D), front radius
of curvature (FC), back radius of curvature (BC), and
5 center thickness (CT). The analysis can provide
additional measured parameters of the contact lens which
include the front radius of curvature with aspheric
form, the back radius of curvature with aspheric form,
the lenticular curve radius, the peripheral curve
10 radius, the sagittal height, aspherical deviations, and
the power of the lens.

The line of light is directed onto a support
fixture which includes a container in which a pedestal
is positioned, and the container is filled with a saline
15 solution. The contact lens is placed on the pedestal
completely immersed in the solution, and the line of
light is directed over the edge of the container and
through a selected diameter of the contact lens. A
charge coupled television (CCTV) imaging camera detects
20 the image of the light scattered from the surfaces of
the contact lens. The imaging camera is preferably
positioned at a right angle to a light source used to
illuminate the contact lens. The imaging camera is
elevated with respect to and views the lens at an angle
25 greater than the critical angle relative to the surface
of the saline solution, which is the minimum angle at
which light is transmitted and below which all light is
reflected and none transmitted by the surface of the
saline solution.

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1 The optical sectioning measurement can
advantageously be utilized on a contact lens which is
immersed in saline packaging solution in a packaging
container.

5 The detection system can include an optical
flat, an optical prism mounted on the optical flat, and
an optical imaging system.

 The image is analyzed by a software program
which uses a nonlinear least squares fitting data
10 processing approach. The analysis includes an image
processing macro routine which combines several
morphological routines into one sequence which is
executed for each image, the result of which is stored
digitally, and the stored image is then input to a
15 software routine for calculation of selected parameters
of the contact lens. The parameter calculation is based
upon a nonlinear regression based upon the residuals
error from a Taylor Series expansion of an expected
contact lens curve profile.

20 The beam of light is shaped and focused in an
arrangement in which light from a light source passes
through a spatial filter, is collimated by a collimating
lens, and is focused by a cylindrical lens into a line
of light at the contact lens being measured. The line
25 of light is directed onto the support fixture which
includes a central support button, surrounded by
alignment posts to properly position a contact lens
within the support fixture. The central support button
and alignment posts are positioned at a level A in the
30 fixture, and the top of the alignment posts do not

1 extend above a level B. An optical flat with a prism
positioned thereon is slidably positioned on slide rails
at the level B. A cavity in the fixture is filled with
saline solution, and the optical flat is guided by the
5 slide rails to slide to one side while clearing the area
over the central support button and alignment posts.
The contact lens being measured is lowered into the
saline solution between the alignment posts, and comes
to rest on top of the central support button in an
10 essentially horizontal position. The optical flat is
then slid to a second opposite side to position it
above the contact lens for an optical sectioning
measurement.

In the detection arrangement, light from the
15 illuminated contact lens is directed by imaging optics
onto a camera, an image is captured by a frame grabber
and digitally stored in memory, the stored digital image
is then subjected to image processing, including image
enhancement, curve fitting, and measurement of
20 parameters of the lens by the application of selected
known algorithms which are available commercially in
software.

The foregoing objects and advantages of the
present invention for a lens parameter measurement using
25 optical sectioning may be more readily understood by one
skilled in the art with reference being had to the
following detailed description of several preferred
embodiments thereof, taken in conjunction with the
accompanying drawings wherein like elements are

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1 designated by identical reference numerals throughout
the several views, and in which:

Figure 1 illustrates a flow chart of a
preferred process for lens parameter measurement using
5 optical sectioning pursuant to the present invention;

Figure 2 illustrates one embodiment on an
optical arrangement for shaping and focusing a beam of
light in which light from a source passes through a
spatial filter, is collimated by a collimating lens, and
10 is focused by a cylindrical lens into a line of light at
the contact lens being measured;

Figures 3, 4 and 5 are respectively top
planar, and end and side elevational, views of a support
fixture for holding a contact lens during the
15 measurement technique of the present invention;

Figures 6 and 7 are respectively side
elevational and top planar views of a central support
button and surrounding alignment posts to properly
position a contact lens within a support fixture;

20 Figures 8 and 9 are respectively top planar
and side elevational views of an optical glass flat,
having a prism positioned on top thereof, positioned on
slide rails;

Figure 10 is a side elevational view of only
25 the optical flat and slide rail assembly; and

Figure 11 illustrates a curve fit
approximation to the measured points of a contact lens
pursuant to the processing techniques of the present
invention, with the curve being of sag in pixels versus

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1 distance in pixels across a measured cross-section of a
contact lens.

The present invention provides a
nondestructive measurement technique for measuring all
5 of the physical dimensions of a hydrated contact lens.
The measurable dimensions include the front curve
radius, lenticular curve radius, peripheral curve
radius, back curve radius, diameter, center of lens
thickness, sagittal height, power, and aspherical
10 deviations. The lenticular and peripheral juncture is
also discernible. Heretofore in the prior art, many of
these parameters were not measurable and, if measurable,
suffered from inaccuracies and/or damage or destruction
of the lens being measured.

15 Figure 1 illustrates a flow chart of a
preferred process in which light from a light source 10
is shaped at 12 into a desired beam shape as a line of
light which is directed onto a lens positioned in a lens
holding fixture at 14. An image of the illuminated lens
20 is directed by imaging optics 16 onto a camera 18, and
an image is captured by a frame grabber 20, and
digitally stored in memory at 22. The stored digital
image is then subjected to image processing, including
image enhancement at 24, curve fitting at 26, and
25 measurement of pertinent parameters of the lens by the
application of appropriate algorithms at 28, and the
measured parameters are then displayed at 30.

The light source may be any high intensity
light generator such as a laser diode, arc lamp, or high
30 radiance LED. Reduction to practice has been with a

1 laser, however a high radiance LED may be preferred in
some embodiments. A preferred wavelength may be
infrared (IR) just in the invisible range. The required
light intensity is dependent upon the sensitivity of the
5 detection system. At the extremes, too high an
intensity could damage or modify the lens being
measured, while at the other extreme, no detectible
image would be generated. The ideal is a small thin
line of intense light in a small source.

10 Figure 2 illustrates one embodiment of an
optical arrangement for shaping and focusing a beam of
light, in which light from a source 34 passes through a
spatial filter 36, and is collimated by a collimating
lens 38. A cylindrical lens 40 focuses the collimated
15 beam into a line of light at the contact lens 41. A
mirror 42 is angularly adjustable to properly position
the focused line of light relative to the contact lens.
The contact lens is positioned on a pedestal 44 in an
observation support cup 46 in which it is immersed in
20 saline solution.

 Figure 2 illustrates a basic approach to
providing the cross-sectioning light and picking up the
scattered light image. A line of light can be formed by
spatially filtering, collimating and cylindrically
25 focusing an Ar^{2+} (4880 A, nominally 20 mW) laser beam.
The resultant line of light beam passes through a
mounting cell, as shown in Figures 2-10, holding a lens
immersed in saline solution. The scattered light is
received by a lens which focuses it onto a detection
30 camera.

1 The lens being measured can be positioned
using a support fixture 14, such as that illustrated in
greater detail in Figures 3-10. Figures 3, 4 and 5 are
respectively top planar, and end and side elevational,
5 views of a support fixture for holding a contact lens
during the measurement technique of the present
invention. Figures 6 and 7 are respectively side
elevational and top planar views of a central support
button and surrounding alignment posts to properly
10 position a contact lens within the support fixture.
Figures 8 and 9 are respectively top planar and side
elevational views of an optical glass flat, having a
prism positioned on top thereof, positioned on slide
rails in the support fixture, and Figure 10 is a side
15 elevational view of only the optical flat and slide rail
assembly.

Referring to Figures 3-10, a central support
button 50 and cooperating alignment posts 52 are
positioned at level A, Figure 5, in the fixture 14. The
20 top of the alignment posts 52 do not extend above a
level B in the fixture 14. An optical flat 54 with a
prepositioned 10 degree wedge prism 56 is slidably
engaged on slide rails 58 which rest at level B in the
fixture 14. The lower surface of the optical flat 54 is
25 positioned slightly below the level of the saline
solution to remove any optical distortions as might
otherwise be caused by ripples on the surface of the
saline solution.

In operation, a cavity 60 in the fixture is
30 filled with saline solution. The optical flat 54 guided

1 by the slide rails 58 is slided to the right (in Figure
5) so as to clear the area over the button 50 and
cooperating alignment posts 52. The lens being measured
is dropped or lowered into the saline solution between
5 the three essentially uniformly positioned alignment
posts 52. As the lens sinks in the saline solution, it
normally touches (bumps) one or more of the alignment
posts 52 and comes to rest on the top of the support
button 50 in an essentially horizontal position. The
10 optical flat 54 is then slided to the left extreme (in
Figure 5) which positions it properly above the lens for
an optical sectioning measurement.

The mounting cell 14 is designed to allow most
of the excess laser light to be absorbed at the bottom
15 of the cell out of the view of the camera. The optical
flat 54 and wedge prism 56 are used with the cell in the
detection system to aid in correcting image distortions
produced by the surface of the solution covering the
lens and the viewing angle.

20 The lens can be correctly positioned by hand
with respect to the scanning line of light, or the
position of the scanning line of light can be adjusted,
as by the mirror 42, so as to cause an image to occur on
a desired diameter (normally the center diameter) of the
25 lens being measured. In appropriate circumstances, the
contact lens might be rotated to position the line of
light along a different meridian (different angular
diameter) of the lens. In a continuous mode of
operation, such as on a production line, the light
30 source is energized, and the image from the camera is

1 checked to verify that the light image is on the desired
proper diameter. Either the camera or the holder can be
physically adjusted so as to place the image on a
selected diameter. The slight adjustment movement can
5 be provided by motors or by a positioning cylinder.

The energized light source causes a detectable
line of light (through a vertical section of the contact
lens) to be imaged, and allows for either the holder or
the camera to be spatially adjusted. Movement must be
10 only to and fro so that the line of light illuminating
the lens is maintained in parallel alignment with the
imaging camera so as to not introduce distortion into
the subsequent image enhancement and measurement.

When the light source illuminates the mounted
15 lens, light is scattered by the surfaces of the lens and
produces a bright area on the external surfaces of the
lens (the illuminated surfaces contacted by the line of
light). The prism 56 provides a suitable magnification
(spread) of the image which is relayed by an imaging
20 optical system 60 so as to nearly fill the detection
area or screen of the imaging camera 18. One
advantageous position for the imaging camera 18 is at a
right angle to the light source at the level of the
contact lens specimen. Practicality dictates that the
25 camera be elevated and view the lens at an angle. The
camera views the contact lens over the edge of the cup
and at an angle greater than the critical angle. The
critical angle is defined as the minimum angle at which
light is transmitted through the surface of the saline
30 solution, and below which all light is reflected by the

1 surface of the saline solution and none transmitted. A
saline-air interface correction is required as explained
herein-below. The imaging camera is positioned to
account for the Scheinpflug effect, i.e. all optical
5 paths are of equal length. The raw image is captured by
a frame grabber 20 and transferred to digital
storage 22.

As illustrated in Figures 8 and 9, the
illuminating light 62 is usually positioned normally to
10 the surface of the optical flat 54 directly above a
contact lens 64, and is in the form of a line of
light 66.

The image detection apparatus can incorporate
a COHU Model 4810 Camera and Data Translation Model 2855
15 Frame Grabber. A Melles-Griot Cooke Triplet lens
optimized for infinite conjugate images a cross-
sectional image onto the camera, accounting for the
Scheinpflug condition.

Software has been developed to process the
20 image, including image acquisition, filtering, sorting
and calculations. An image processing macro routine
combines many of the morphological routines into one
sequence which is executed for each image, the result of
which is stored digitally. The stored image is then
25 input to a software routine for sorting and calculation
of parameters. In greater detail, the image is acquired
and preprocessed by several stages of filtering for the
purpose of removing extraneous background noise. The
filtered image is then thresholded so that only the lens
30 profile is visible. The profile is then fit to

1 cartesian coordinates, smoothed with a sliding three
point filter, and translated into two arrays, a first
array for the back surface, and a second array for the
front surface. Each surface is then inputted to a curve
5 fitting algorithm and its function coefficients
calculated.

The parameter calculation is based upon a
powerful nonlinear regression technique based upon the
residuals error from a Taylor Series expansion of the
10 expected curve profile. In greater detail, the
estimates of the time residual differences between
empirical values of the fitting function and actual
values, and the estimated residuals, are incrementally
improved by expanding the actual functional residuals
15 with a linear Taylor series about the estimated values.
This equation is reorganized in terms of the actual and
estimated residuals, and a set of parameters is found
which minimizes the sum of the squares of the true
residuals. This function has a minimum value when all
20 of its partial derivatives with regard to the fitting
function coefficients are zero. This set of nominal
equations is solved by obtaining the first order
approximations to the incremental improvements mentioned
above. The process is then iterated using the improved
25 values until the increments fall below a specified
tolerance. This method tends to converge very rapidly,
and allows the data to be fit to any arbitrary function
for contact lenses, which allows the output of the
software to be used as feedback in a manufacturing
30 process.

1 Figure 11 illustrates a curve fit
approximation to the measured points of a contact lens
pursuant to the processing techniques of the present
invention, with the curve being of sag in pixels versus
5 distance in pixels across a measured cross-section of a
contact lens.

Optical sectioning of a lens is provided by
the present invention to improve the accuracy of lens
parameter measurements. The most critical parameters
10 include center thickness, thickness profile, radii of
curvature and asphericity of the front curve, back curve
and lenticular curve, and the diameter as a function of
radial and azimuthal position. From these values the
lens power can also be readily calculated from known
15 equations.

In the optical sectioning technique, the lens
is optically sectioned using a pseudo-coherent light
source which is scattered sufficiently from the
illuminated surface of the lens material. The image is
20 captured by a solid state camera and frame grabber, and
analyzed using typical image processing algorithms. In
one embodiment, the technique was evaluated using an
Argon ion laser emitting at the 488 nm line with a power
of 30 mW, a COHU 4810 CCD camera and a Data Translation
25 2855 frame grabber. Tests were conducted using several
dozen soft hydrogel contact lenses. The results
indicated that the optical or laser sectioning technique
measured the center thickness, the thickness profile,
the radii of curvature of the front curve and the back
30 curve, the diameter, the lenticular radius of curvature,

1 and the asphericity as a function of radial and
azimuthal position repeatably and with sufficient
accuracy. Therefore, the lens power could be calculated
with repeatability and accuracy.

5 While several embodiments and variations of
the present invention for a lens parameter measurement
using optical sectioning are described in detail herein,
it should be apparent that the disclosure and teachings
of the present invention will suggest many alternative
10 designs to those skilled in the art.

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1 WHAT IS CLAIMED IS:

1. A method of measuring desired parameters of a contact lens by optical sectioning comprising:
 - a. positioning a contact lens on a support
5 fixture;
 - b. generating a line of light;
 - c. directing the line of light through a selected diameter of the contact lens;
 - d. detecting as an image the light scattered
10 at the surfaces of the contact lens at the selected diameter; and
 - e. analyzing the detected light image to measure the desired parameters of the contact lens.
2. A method as claimed in claim 1, wherein
15 the analyzing step provides the measured parameters of at least four basic parameters of a contact lens comprising the diameter (D), front radius of curvature (FC), back radius of curvature (BC), and center thickness (CT).
- 20 3. A method as claimed in claim 1, wherein the analyzing step provides the measured parameters of the contact lens which include the front radius of curvature with aspheric form, the back radius of curvature with aspheric form, the center thickness, the
25 diameter, the lenticular curve radius, the peripheral curve radius, the sagittal height, aspherical deviations, and the power of the lens.
4. A method as claimed in claim 1, wherein the line of light is directed onto a support fixture
30 which includes a container in which a pedestal is





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1 positioned, the container is filled with a saline
solution, and the lens is placed on the pedestal
completely immersed in the solution, and the line of
light is directed over the edge of the container and
5 through a selected diameter of the contact lens.

5. A method as claimed in claim 4, wherein a
charge coupled television (CCTV) imaging camera detects
the image of light scattered from the surfaces of the
contact lens.

10 6. A method as claimed in claim 5, wherein
the imaging camera is elevated with respect to and views
the lens at an angle greater than the critical angle
relative to the surface of the saline solution, which is
the minimum angle at which light is transmitted and
15 below which all light is reflected and none transmitted
by the surface of the saline solution.

7. A method as claimed in claim 1, wherein
the contact lens is immersed in saline packaging
solution in a packaging container.

20 8. A method as claimed in claim 1, wherein
the detection system includes an optical flat, an
optical prism mounted on the optical flat, and an
imaging lens system.

25 9. A method as claimed in claim 1, wherein
the image is analyzed by a software program which uses a
nonlinear least squares fitting data processing
approach.

30 10. A method as claimed in claim 1, wherein
the step of analyzing includes an image processing macro
routine which combines several morphological routines



1 into one sequence which is executed for each image, the
result of which is stored digitally, and the stored
image is then input to a software routine for
calculation of selected parameters of the contact lens.

5 11. A method as claimed in claim 10, wherein
the parameter calculation is based upon a nonlinear
regression based upon residuals error from a Taylor
Series expansion of an expected contact lens curve
profile.

10 12. A method as claimed in claim 1, wherein
the step of generating includes the steps of shaping and
focusing a beam of light in which light from a light
source passes through a spatial filter, is collimated by
a collimating lens, and is focused by a cylindrical lens
15 into a line of light at the contact lens being measured.

13. A method as claimed in claim 1, wherein
the line of light is directed onto the support fixture
which includes a central support button, surrounded by
alignment posts to properly position a contact lens
20 within the support fixture.

14. A method as claimed in claim 13, wherein
the central support button and alignment posts are
positioned at a level A in the fixture, and the top of
the alignment posts do not extend above a level B in the
25 fixture, an optical flat with a prism positioned thereon
is slidably positioned on slide rails and rests at the
level B, a cavity in the fixture is filled with saline
solution, the optical flat is guided by the slide rails
to slide to one side while clearing the area over the
30 central support button and alignment posts, the contact



1 lens being measured is lowered into the saline solution
between the alignment posts, and comes to rest on the
central support button in an essentially horizontal
position, and the optical flat is then slid to a
5 second opposite side to position it above the contact
lens.

15 15. A method as claimed in claim 14, wherein
the optical flat has its lower surface immersed in the
saline solution to eliminate optical distortions by the
10 surface of the solution.

16. A method as claimed in claim 1, wherein
the contact lens is immersed in saline solution while
positioned on the support fixture.

17. A method as claimed in claim 1, wherein
15 light from a light source is shaped into a line of light
which is directed onto a contact lens positioned in the
support fixture, light from the illuminated contact lens
is directed by imaging optics onto a camera, an image is
captured by a frame grabber and digitally stored in
20 memory, the stored digital image is then subjected to
image processing, including image enhancement, curve
fitting, and measurement of parameters of the lens by
the application of selected algorithms.

18. A method as claimed in claim 1, wherein
25 the detecting step is performed with a camera positioned
to view the contact lens through a prism and at an angle
relative to a vertical.

19. Apparatus for measuring desired
parameters of a contact lens by optical sectioning
30 comprising:



- 1 a. a support fixture for positioning a
contact lens being measured;
- b. means for generating and directing a line
of light through a selected diameter of the contact
5 lens; and
- c. means for detecting as an image the light
scattered at the surfaces of the contact lens at the
selected diameter, and for analyzing the detected light
image to measure the desired parameters of the contact
10 lens.

20. Apparatus as claimed in claim 19, wherein
the support fixture includes a container in which a
pedestal is positioned, the container is filled with a
saline solution, and the lens is placed on the pedestal
15 completely immersed in the solution, and the line of
light is directed over the edge of the container and
through a selected diameter of the contact lens.

21. Apparatus as claimed in claim 20, wherein
a charge coupled television (CCTV) imaging camera
20 detects the image of light scattered from the surfaces
of the contact lens.

22. Apparatus as claimed in claim 21, wherein
the imaging camera is elevated with respect to and views
the lens at an angle greater than the critical angle
25 relative to the surface of the saline solution, which is
the minimum angle at which light is transmitted and
below which all light is reflected and none transmitted
by the surface of the saline solution.

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1 23. Apparatus as claimed in claim 19, wherein
the contact lens is immersed in saline packaging
solution in a packaging container.

24. Apparatus as claimed in claim 19, wherein
5 the detection system includes an optical flat, an
optical prism mounted on the optical flat, and an
imaging lens system.

25. Apparatus as claimed in claim 19, wherein
said generating and directing means includes an
10 arrangement in which light from a light source passes
through a spatial filter, is collimated by a collimating
lens, and is focused by a cylindrical lens into a line
of light at the contact lens being measured.

26. Apparatus as claimed in claim 19, wherein
15 the support fixture includes a central support button,
surrounded by alignment posts to properly position a
contact lens within the support fixture.

27. Apparatus as claimed in claim 26, wherein
the central support button and alignment posts are
20 positioned at a level A in the fixture, and the top of
the alignment posts do not extend above a level B in the
fixture, an optical flat with a prism positioned thereon
is slidably positioned on slide rails and rests at the
level B, a cavity in the fixture is filled with saline
25 solution, the optical flat is guided by the slide rails
to slide to one side while clearing the area over the
central support button and alignment posts, the contact
lens being measured is lowered into the saline solution
between the alignment posts, and comes to rest on the
30 central support button in an essentially horizontal



1 position, and the optical flat is then slid to a
second opposite side to position it above the contact
lens.

28. Apparatus as claimed in claim 19,
5 including means for immersing the contact lens in saline
solution while positioned on the support fixture.

29. Apparatus as claimed in claim 19, wherein
light from the illuminated contact lens is directed by
imaging optics onto a camera, an image is captured by a
10 frame grabber and digitally stored in memory, and the
stored digital image is then subjected to image
processing for measurement of the parameters of the
lens.

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* C L M S *

1 ABSTRACT OF THE DISCLOSURE

An arrangement for measuring desired parameters of a contact lens by optical sectioning which comprises a support fixture on which a contact lens is positioned. The support fixture includes a container in which a pedestal is positioned, and the container is filled with a saline solution. The contact lens is placed on the pedestal completely immersed in the saline solution. A line of light is generated and directed by imaging and shaping optical elements over the edge of the container and through a selected diameter of the contact lens. An imaging camera detects and image of the light scattered at the surfaces of the contact lens at the selected diameter, which is captured by a frame grabber and is digitally stored for subsequent image processing and determination of the desired parameters of the contact lens. The analysis provides at least four basic parameters of the contact lens including the diameter (D), front radius of curvature (FC), back radius of curvature (BC), and center thickness (CT), and can also provide the lenticular curve radius, the peripheral curve radius, the sagittal height, aspherical forms and deviations of the several measured curvatures, and the power of the lens.

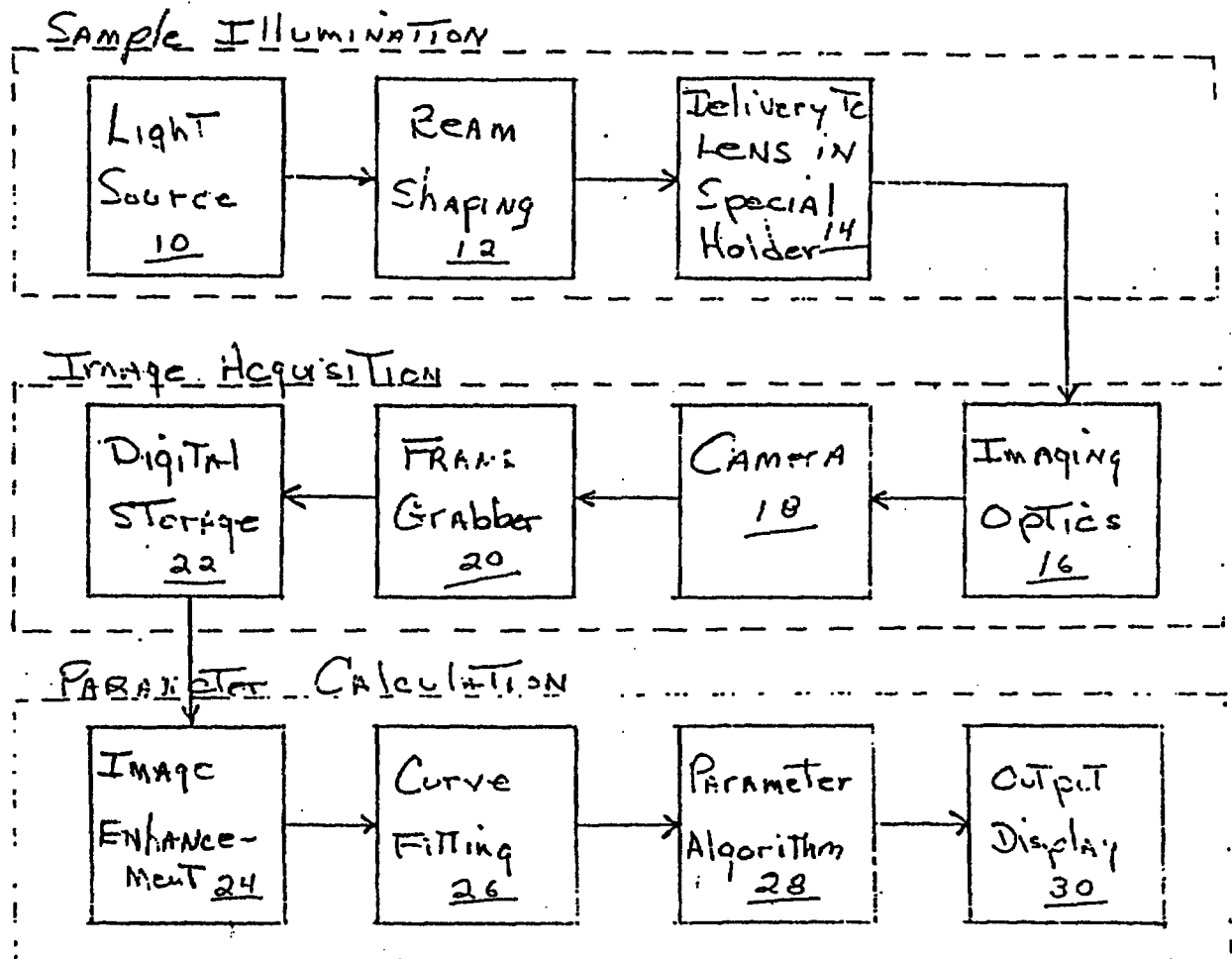
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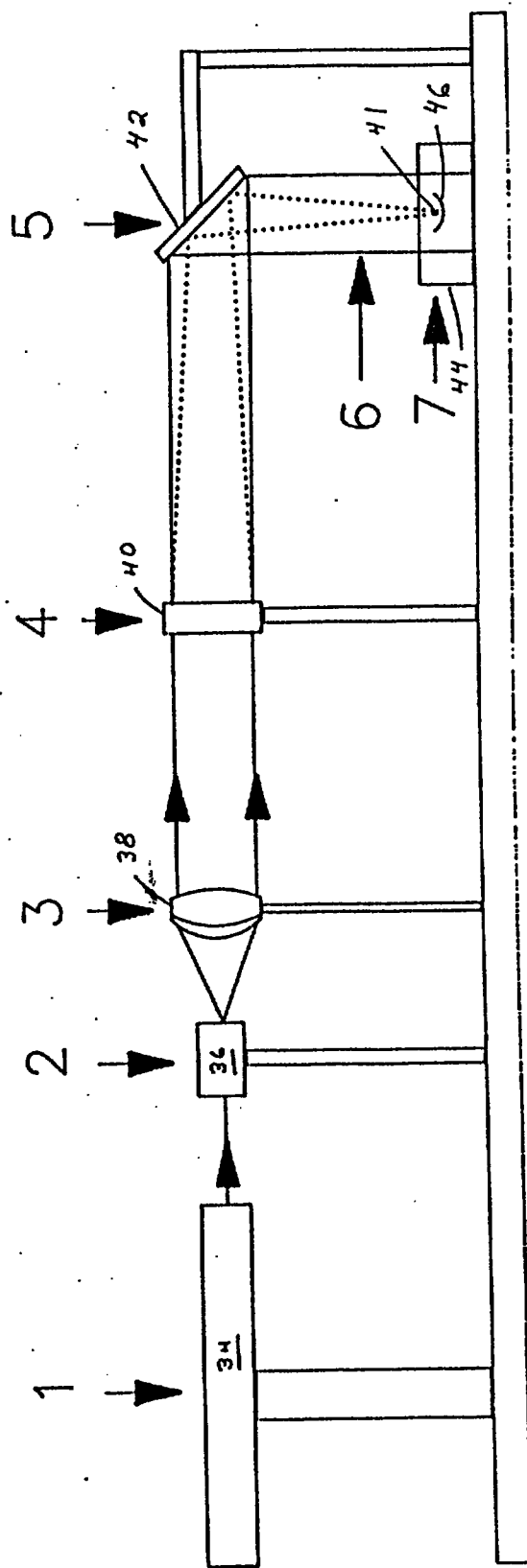


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Flow Chart
Laser Cross Sectioning
Fig. 1

Laser Sectioning Optical System Layout



1 — Argon Ion Laser, 30 mW. @ 488 nm.

2 — Spatial Filter

3 — Collimating Lens

4 — Cylindrical Lens

5 — Turning Mirror

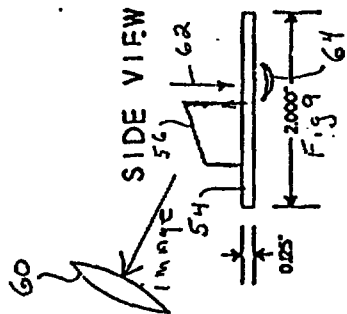
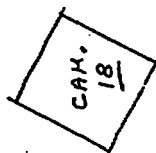
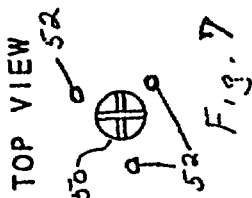
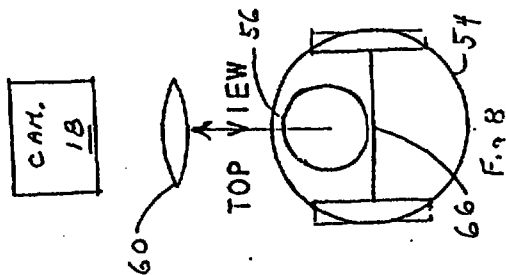
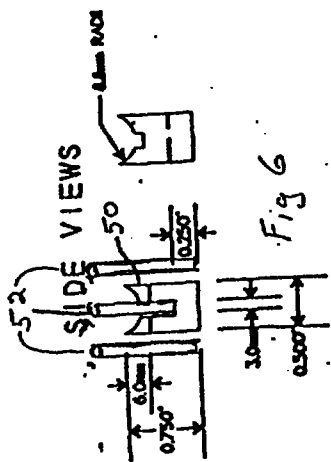
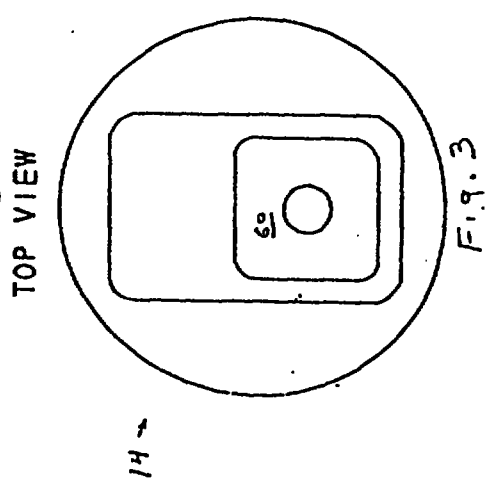
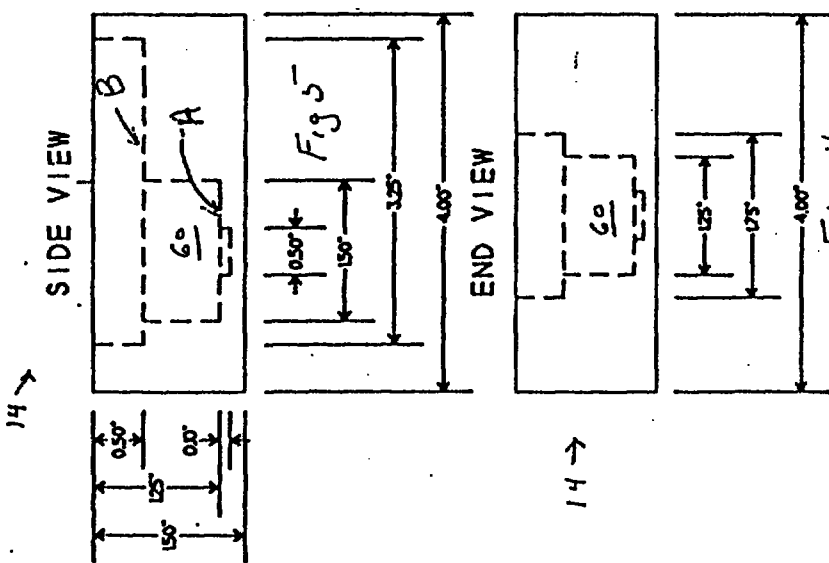
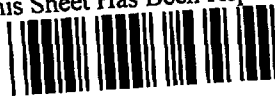
6 — Sheet of Laser Light, Focussed at Plane of Lens

7 — Observation Cup With Immersed Lens on Pedestal

Figure 2



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OPTICS RESEARCH GROUP

LENS PARAMETERS BY LASER SECTIONING

Curve Fit Approximation

Sag (pixels)

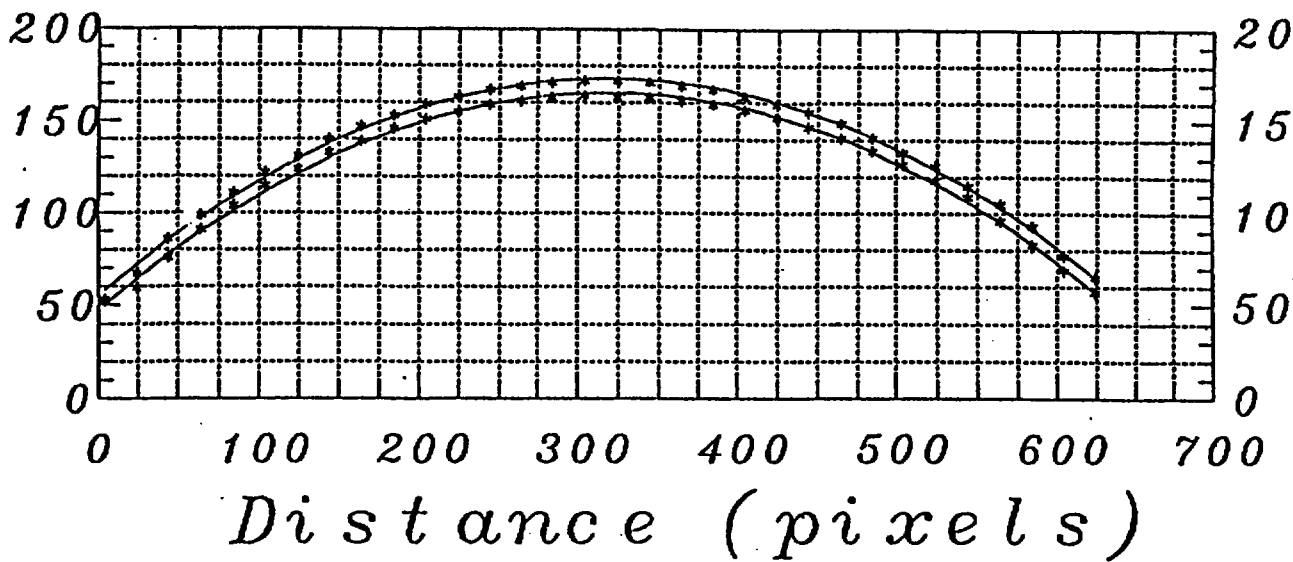


Fig. 11

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1 LENS PARAMETER MEASUREMENT USING OPTICAL SECTIONING

The present invention relates generally to the measurement of contact lens parameters by using an optical sectioning technique, and more particularly pertains to a lens parameter measurement using optical sectioning.

The accurate measurement of contact lens parameters has presented a problem in the prior art. While a current method for measuring a contact lens diameter (D) is reliable, no method exists at all for measuring the front radius of curvature (FC) of a contact lens. The method for measuring the back radius of curvature (BC) of a contact lens is instrument/ operator specific, and the methods for measuring the center thickness (CT) of a contact lens involve physically deforming or destroying the lens.

The measurement of the base curve and center thickness of a contact lens can be very difficult. The current base curve measurement is performed by an ultrasound technique for measuring the back sag at a predetermined diameter. Aside from errors introduced by variations in the temperature of the solution in which the contact lens is immersed, the lens itself is not perfectly spherical, and thus does not fulfill the requirements of the geometrical equation used to transform back sagittal height readings into radius of curvature values. In addition, the device cannot measure the front radius of curvature of the contact lens, nor can it measure the asphericity or toricity of

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☐ Claim(s) :	paged ... to paged ...
☒ Drawing(s) :	part of ... to paged ...
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LENS PARAMETER MEASUREMENT USING OPTICAL SECTIONING
1 ABSTRACT OF THE DISCLOSURE

An arrangement for measuring desired parameters of a contact lens by optical sectioning which comprises a support fixture on which a contact lens is positioned. The support fixture includes a container in which a pedestal is positioned, and the container is filled with a saline solution. The contact lens is placed on the pedestal completely immersed in the saline solution. A line of light is generated and directed by imaging and shaping optical elements over the edge of the container and through a selected diameter of the contact lens. An imaging camera detects and image of the light scattered at the surfaces of the contact lens at the selected diameter, which is captured by a frame grabber and is digitally stored for subsequent image processing and determination of the desired parameters of the contact lens. The analysis provides at least four basic parameters of the contact lens including the diameter (D), front radius of curvature (FC), back radius of curvature (BC), and center thickness (CT), and can also provide the lenticular curve radius, the peripheral curve radius, the sagittal height, aspherical forms and deviations of the several measured curvatures, and the power of the lens.

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FIGURE 1

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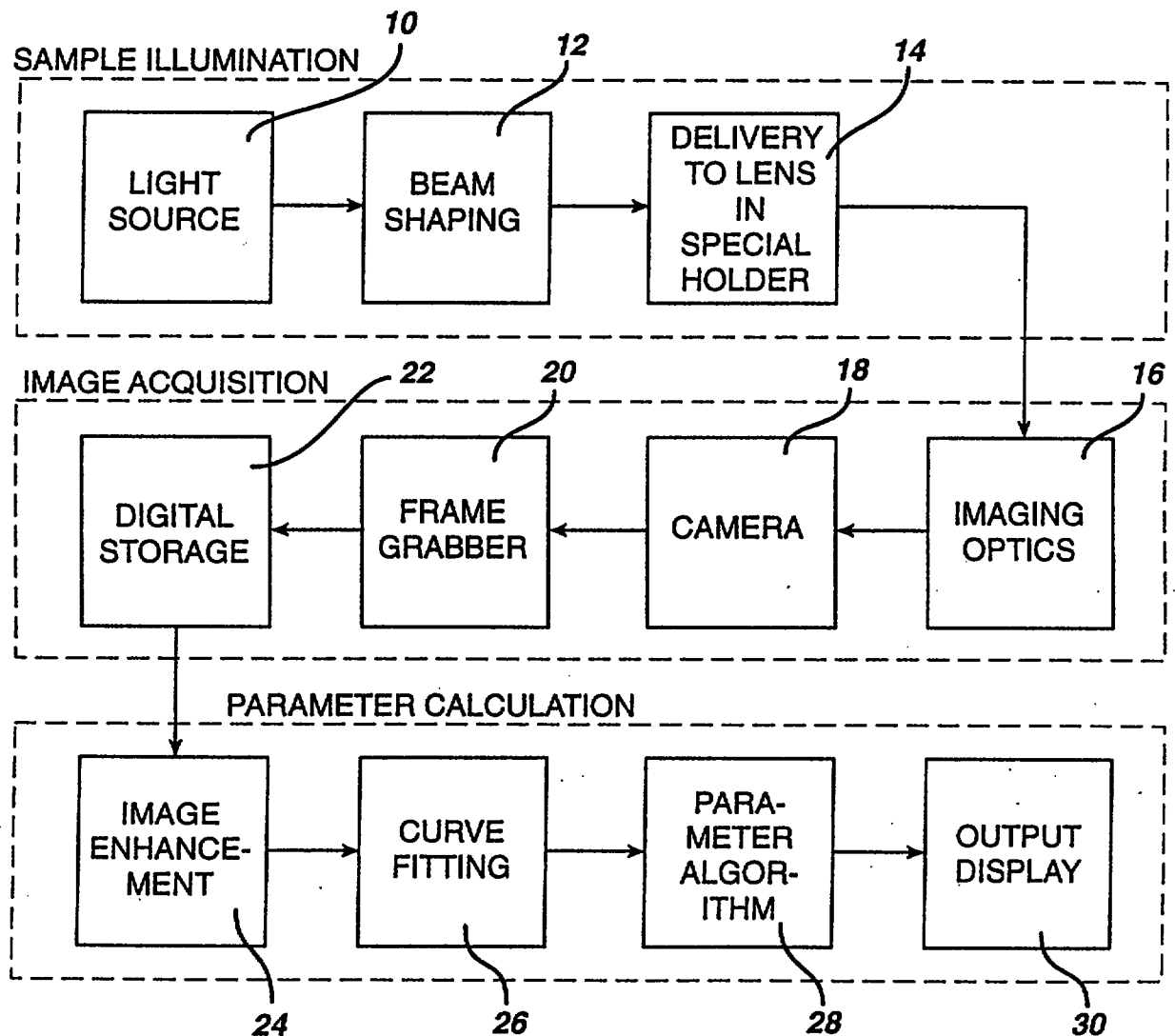


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FIG. 1



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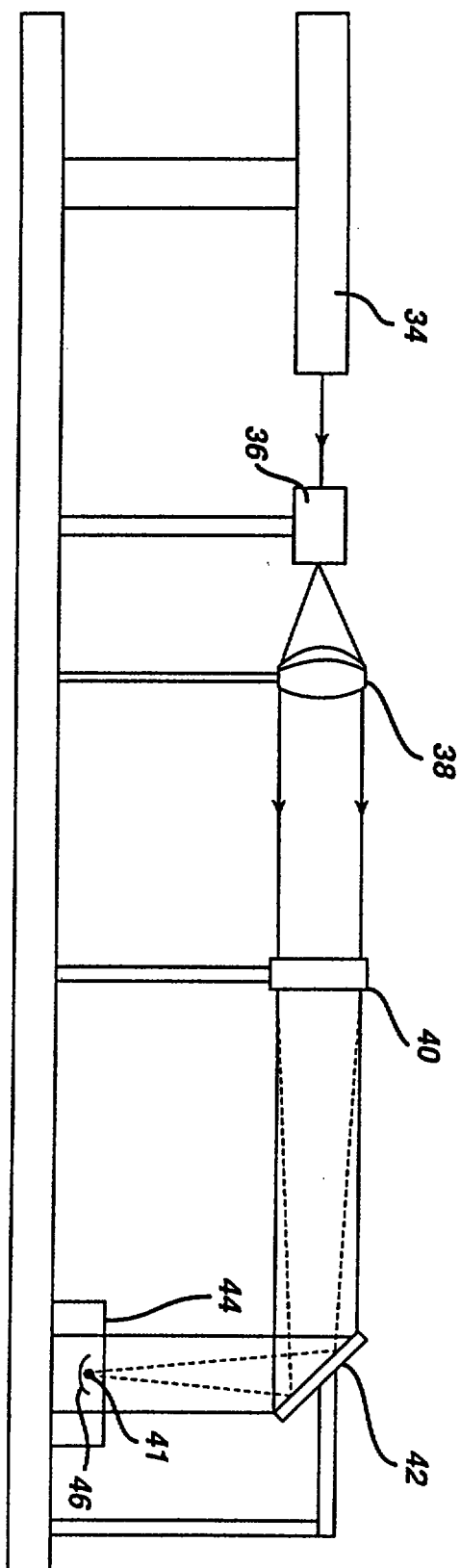


FIG. 2

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FIG.3

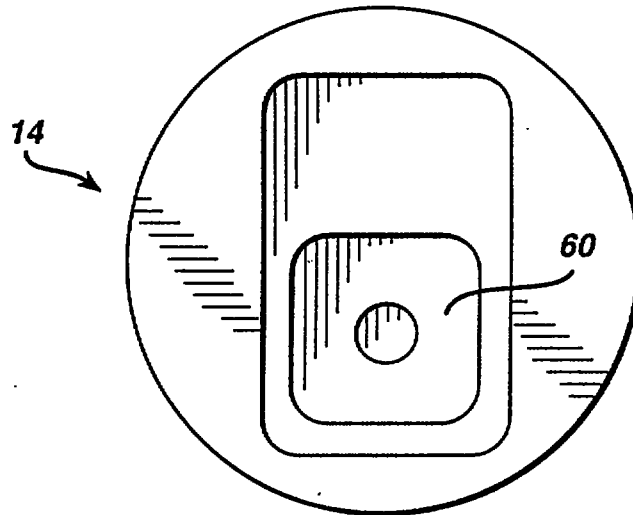


FIG.4

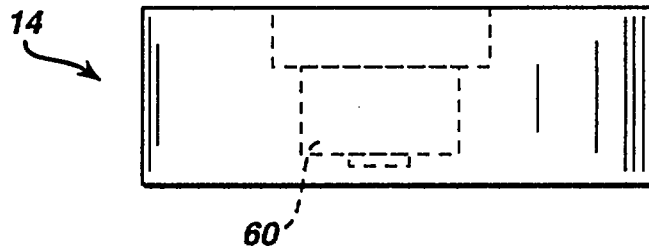
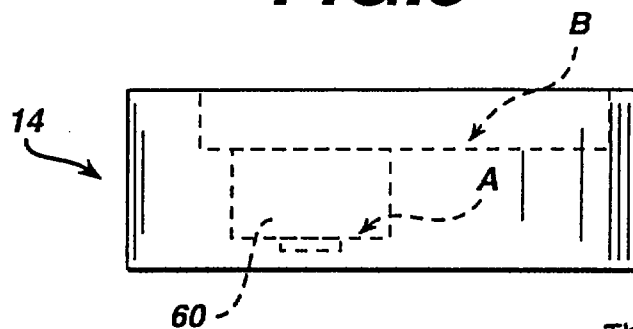


FIG.5



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FIG.6

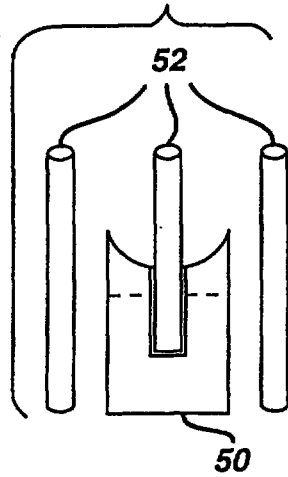


FIG.7

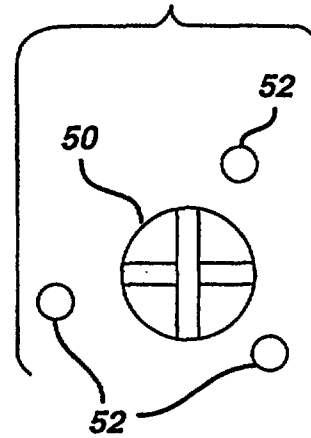


FIG.8

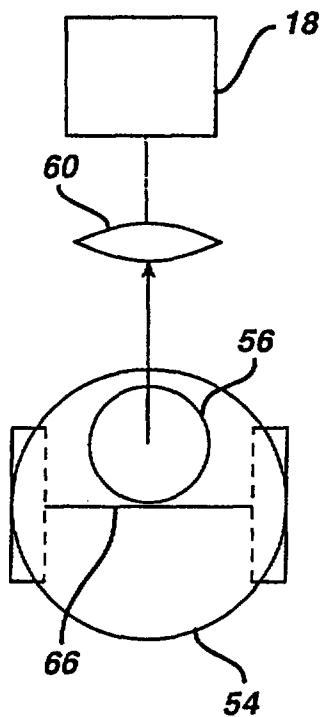


FIG.9

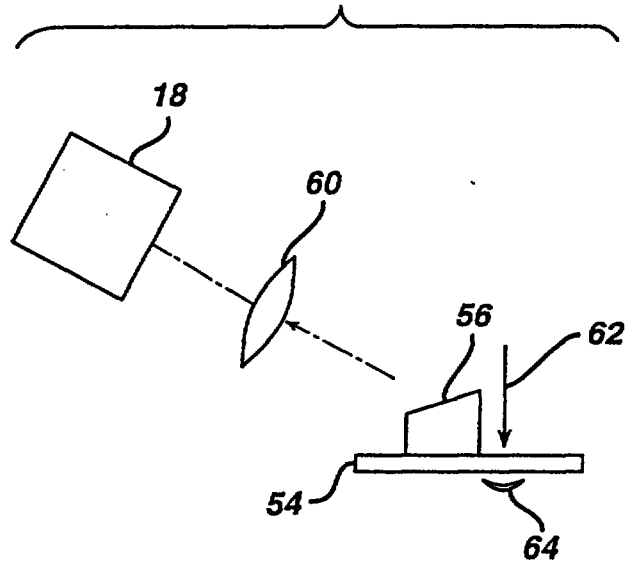
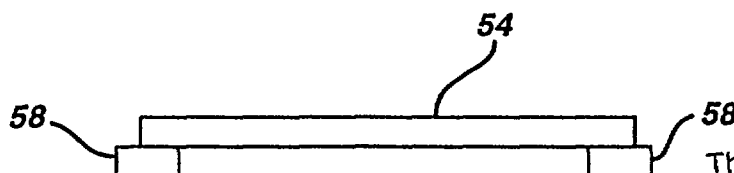
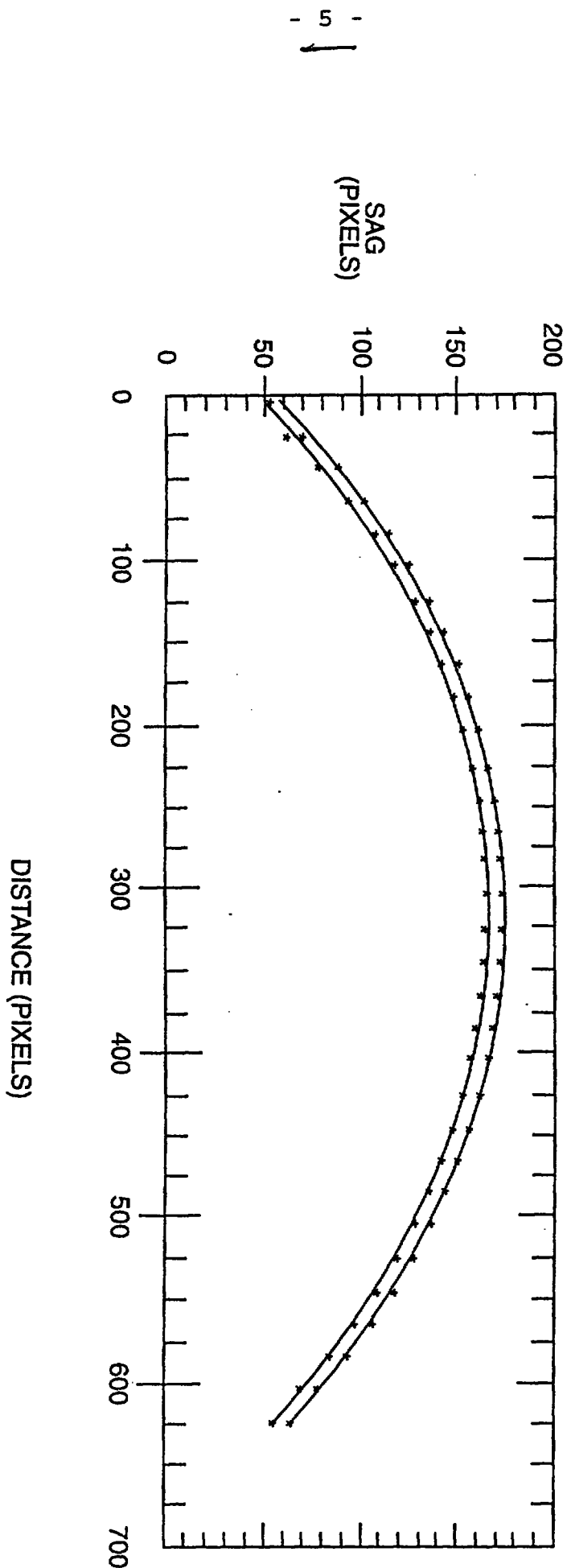


FIG.10



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FIG. 11



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AUSTRALIAN PATENT OFFICE
SEARCH REPORTApplication No.
SG 9610634-9

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

An arrangement for measuring desired parameters of a contact lens (41) by optical sectioning which comprises a support fixture (14) on which a contact lens is positioned. The support fixture includes a container in which a pedestal is positioned, and the container is filled with a saline solution. The contact lens is placed on the pedestal completely immersed in the saline solution. A line of light (66) is generated and directed by imaging and shaping optical elements over the edge of the container and through a selected diameter of the contact lens. An imaging camera (18) detects and image of the light scattered at the surfaces of the contact lens at the selected diameter, which is captured by a frame grabber (20) and is digitally stored for subsequent image processing and determination of the desired parameters of the contact lens. The analysis provides at least four basic parameters of the contact lens including the diameter (D), front radius of curvature (FC), back radius of curvature (BC), and centre thickness (CT), and can also provide the lenticular curve radius, the peripheral curve radius, the sagittal height, aspherical forms and deviations of the several measured curvatures, and the power of the lens.

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positioned, the container is filled with a saline solution, and the lens is placed on the pedestal completely immersed in the solution, and the line of light is directed over the edge of the container and through a selected diameter of the contact lens.

5. A method as claimed in claim 4, wherein a charge coupled television (CCTV) imaging camera detects the image of light scattered from the surfaces of the contact lens.

6. A method as claimed in claim 5, wherein the imaging camera is elevated with respect to and views the lens at an angle greater than the critical angle relative to the surface of the saline solution, which is the minimum angle at which light is transmitted and below which all light is reflected and none transmitted by the surface of the saline solution.

7. A method as claimed in claim 1, wherein the contact lens is immersed in saline packaging solution in a packaging container.

8. A method as claimed in claim 1, wherein the step of detecting as an image the light scattered at the surfaces of the contact lens at the selected diameter includes using an optical flat, an optical prism mounted on the optical flat, and an imaging lens system.

9. A method as claimed in claim 1, wherein the image is analyzed by a software program which uses a nonlinear least squares fitting data processing approach.

10. A method as claimed in claim 1, wherein the step of analyzing includes an image processing macro routine which combines several morphological routines

