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(54) Title: CENTER MASKING ILLUMINATION SYSTEM AND METHOD

(57) Abstract

Methods and apparatus for center masking a condenser lens of a transmitted light microscope to simultaneously maximize resolution, contrast and depth of field utilizing at a conjugate plane of the aperture plane where an image of the rear aperture of the condenser lens has been created, a plurality of light sources to illuminate two or more of the faces of a multi-face mirror in the shape of a pyramid which moves relative to the light sources to vary the amount of center masking continuously over a range including zero while directing multiple oblique beams of light onto the objective lens.

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# CENTER MASKING ILLUMINATION SYSTEM AND METHOD

## BACKGROUND OF THE INVENTION

The present invention relates to illumination systems and in particular to illumination systems for transmitted light microscopes which provide center masking (masking the central area of the condenser) methods and apparatus. The terms "mask" and "masking" as used herein refer to any method or devise which has the effect of permitting or directing illumination light onto some areas of a condenser lens and preventing other areas of the condenser from receiving all or some of the available illumination light.

The idea of improving resolution and contrast in a transmitted light microscope by preventing areas of a condenser lens from receiving full illumination (center masking) has been discussed for many years but has never been successfully incorporated into a commercial microscope. The two main reasons for the lack of commercialization of center masking are the absence of a practical device for producing such center masking and the lack of physical space at the rear aperture of a condenser in which to locate center masking apparatus.

In order for center masking to be effective, it is necessary that the size of the area of the condenser masked be carefully matched to both the objective lens being used and the specimen under investigation. Too much or too little center masking can have a noticeable effect and in some cases even degrade the image relative to conventional axial illumination. Thus, to be fully effective, a center masking illumination system should provide continuous masking over a significant range from very little masking (preferably zero) to a significant amount of masking, and be useful with a wide variety of commonly used condensers including

high power condensers as well as condensers with physically inaccessible rear apertures.

Mechanical devices are known which can provide center masking by expanding or contracting an opaque mask disposed at the center of the rear aperture of a condenser. These devices, which have been designed to occlude all illumination on a path directly to the objective to provide dark-field illumination, at their minimum possible occlusion still provide too much center occlusion which in many cases can degrade the image rather than produce image enhancement. These prior art devices are also incompatible with condensers with either too little or no space available at the rear aperture to accommodate the masking mechanism.

## SUMMARY OF THE INVENTION

The present invention provides continuous center masking over a significant range which includes zero (no masking effect) and is compatible with any condenser regardless of the limited space available at its rear aperture. In addition, in one of its embodiments, the present invention provides illumination which comprises a plurality of independent (each with its own wave front) oblique light beams.

While almost all transmitted light microscopes have, since the time of Abbe, used an illumination beam which is axial (aligned with the axis of the objective lens) and a full cone (all of the central area of the condenser is illuminated), it turns out that both the axial alignment of such illumination and the full illumination of the condenser can be detrimental to the quality of the image. My United States Patent 5,345,333 fully explains the advantages of oblique illumination. By

masking a central area of the condenser, a form of spacial filtering is effected that enhances both contrast and resolution at the same time.

The diffraction theory of microscopic vision teaches that when examining with transmitted light an object having very closely spaced structural details, such as the markings of a diatom, the primary image at the back focal plane of the objective lens will consist of a central beam surrounded by orders of diffraction wavelets. Each concentric diffraction wavelet is made up of two or more spectra ( which can be seen as brightly colored spots of light). The number and arrangement of the spectra depend on the pattern of the markings, and the wavelength of light being used. The distance of the diffraction wavelets from the central beam is greater the finer the markings on the specimen (the smaller the spacing between structural details).

The diffraction theory further teaches that in order to resolve fine details in the specimen it is necessary to collect and recombine at least one order of wavelets with the central beam (zero order) or any two successive orders of wavelets. The more successive orders of wavelets recombined with the zero order, the more the resolution and sharpness of the image increases.

By reducing the magnitude of the zero order wavelet relative to the non-zero order wavelets, the non-zero order wavelets are able to make a greater contribution which results in an image of greater contrast and resolution. Masking the right amount of the center of the condenser has the dual effect of reducing the relative magnitude of the zero order wavelet without losing its information, and of enhancing the effect of the

oblique rays of the beam which increases the number of non-zero order wavelets forming the image. Contrast and resolution are thus increased.

The present invention is embodied in both apparatus and methods and has as one of its essential elements the precise masking of the central area of a condenser lens over a continuous range, including zero, to increase contrast and resolution. Except where dark-field is desired, the degree of masking of the center of the condenser is limited to permit illumination to travel directly from the condenser to the objective to form a bright-field image. Since the outer diameter of the area of the condenser that sees illumination light is unaffected by the center masking, the numerical aperture (NA) remains maximal.

Another element of the present invention is the creation of an image of the rear aperture of the condenser at a conjugate plane remote from the condenser lens (i.e., between the condenser lens and the light source) where there is physical space to locate apparatus for shaping and manipulating (masking) the illuminating light beam.

The preferred embodiment of the invention includes a plurality of independent (having distinguishable wave fronts) light beams which are oblique to the optical axis of the objective and which can be manipulated to mask the central area of the condenser over a range that includes zero.

It is an object of the present invention to provide an improved illumination system for a transmitted light microscope in which enhanced resolution and/or contrast are achieved by center masking of the condenser.

It is another object of the present invention to provide a method of illuminating a specimen to be observed by a microscope using spatial filtering in which a particular area or areas of a condenser are masked to increase image resolution and contrast.

Another object of the invention is to provide a microscope wherein an image of the aperture of the condenser lens is created at a conjugate plane remote from the condenser lens where there is space to locate apparatus for masking the illuminating beam of the microscope.

Yet another object of the invention is to provide a microscope having a condenser lens and an objective lens with an illumination system that includes a plurality of independent light beams that are directed onto the condenser lens and travel to the objective lens by paths that are oblique to the optical axis of the objective lens and wherein a central area of the condenser is masked.

Still another object of the invention is to provide such an illumination system wherein the size of the effective central masking of the condenser lens is continuously variable over a range that includes zero.

A further object of the invention is to provide masking apparatus for a microscope condenser lens including a variable size central mask and a variable size peripheral mask (iris).

Another object of the invention is to provide a method of enhancing the image of a specimen viewed by a transmitted light microscope including creating an image of the rear aperture of the microscope condenser lens at a location remote from the condenser lens, masking

the central area of the condenser lens at the image of the aperture and varying the size of the central mask to optimize the image.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, aspects and advantages of the invention will be better understood from the following detailed description of the preferred embodiments of the invention with reference to the drawings in which:

FIGURE 1 is an optical schematic illustration showing basic microscope optical structure in which the invention resides and a relay system for creating a conjugate image of the rear aperture of the condenser lens to a more convenient location in space between the condenser and light source (conjugate plane);

FIGURE 2 is a side view of a mask wheel and housing;

FIGURE 3 is a plan view of the mask wheel of FIGURE 2 showing a plurality of different size masks;

FIGURE 4 is a top view of the illuminated pyramid mirror of FIGURE 5 showing illumination light directed onto a conjugate aperture;

FIGURE 5 is a schematic side view of the mask of the present invention in the form of a four-faced pyramid mirror illuminated by two light beams;

FIGURE 6 is the same as FIGURE 4 with the mirror and light source in a different relative position (mirror below light sources);

FIGURE 7 is the same as FIGURE 5 with the mirror and light source in a different relative position (mirror below light sources);

FIGURE 8 is the same as FIGURE 4 with the mirror and light

source in a different relative position (mirror above light sources);

FIGURE 9 is the same ad FIGURE 5 with the mirror and light source in a different relative position (mirror above light sources);

FIGURE 10 is a top view of a pyramid mirror of the invention shown with four light sources and a rack and pinion for moving the mirror;

FIGURE 11 is a side view of FIGURE 10 without the light sources shown;

FIGURE 12 is a top view of a cone mirror and ring light directed onto a conjugate aperture; and

FIGURE 13 is a side view of FIGURE 12.

## DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Figure 1, a condenser lens 11 (condenser), an objective lens 12 (objective) and eyepiece 13 form the basic optics of a transmitted light microscope as is well know in the art. Condenser 11, and objective 12, as well as eyepiece 13, are for simplicity and convenience depicted as a single lens or doublet lens element, although it is not intended that such optical elements be restrict to simple lens design embodiments. It is typical, for example, for a condenser lens to comprise several pieces of glass and frequently incorporates other elements as well, such as an iris diaphragm. Thus, throughout this description wherever reference is made to an objective lens, a condenser lens relay lenses or an eyepiece, it is to be understood that the reference is to any suitable optical configuration known in the art and not to only the lens configurations shown.

A beam 10, from a light source 40, illuminates the condenser 11 which focuses the light onto an object (specimen) 14. The beam 10 then diverges onto the objective lens 12 which projects an image of the specimen onto the eyepiece 13 which further magnifies the image so that an observer 16 is able to see a sharp image of the specimen 14. The location at which the condenser lens 11 focuses light onto the specimen 14 is commonly referred to as the specimen plane or image plane **I**. At other locations in the system the image of the specimen is also in focus such as at plane $\mathbf{I_1}$ between the objective 12 and the eyepiece 13 and at the plane $\mathbf{I_2}$ of the retina 17 of the eye 21 of the observer 16. The planes

$I_1$ and $I_2$ are conjugate planes of the image plane **I** and as such, whatever is in focus at plane **I** will be in focus at planes $I_1$ and $I_2$, and what is not in focus in plan **I** will not be in focus at planes $I_1$ and $I_2$.

The illumination beam 10 passes through the condenser 11 at what is commonly referred to as the rear aperture 15 of the condenser which is located at the aperture plane **A**. Like the image plane **I**, the aperture plane **A** also has conjugate planes within the system where the aperture plane is in focus. The other aperture planes include the objective aperture $A_0$ and aperture plane $A_1$ at the pupil 18 of the eye 21. The aperture plane **A** is not in focus at the image plane **I** or its conjugate planes $I_1$ and $I_2$, and the image plane **I** is not in focus at the aperture plane **A** or its conjugate planes $A_1$ and $A_0$. Consequently, it is possible, for example, to insert illumination beam masking apparatus at the aperture plane **A** to control the areas of the condenser 11 that are illuminated to effect resolution, contrast and depth of field without such beam shaping elements being visible to the observer 16 at the image plane **I** or conjugate planes $I_1$ and $I_2$.

One such masking device commonly known in the art and frequently built into condenser lenses at or near the rear aperture is an iris diaphragm (iris) 19 which typically provides a variable diameter opening through which the periphery of the illumination beam 10 is restricted from passing through the condenser 11. Put somewhat differently, the iris 19 functions to determine the maximum diameter of the condenser 11 that receives illumination light 10. It is well known in

the art that closing down an iris, to reduce the outer area of the condenser illuminated, decreases resolution of the image but at the same time increases contrast and depth of field due to a reduction in the numerical aperture (NA) of the condenser. Because iris 19 resides at the aperture plane **A** (not shown exactly at the aperture plane **A** for purposes of illustration and clarity), the observer 16 is unaware of the changes in the diameter of the illumination beam 10 resulting from changes of the setting of the iris 19 other than its effect on the resolution, contrast and depth of field of the image. That is, the observer does not see a change in the diameter of the field of view due to a change in the diameter of the illumination beam 10 at the condenser 11.

Because typically there is little or no space at the rear aperture 15 of condenser 11 in which to locate masking apparatus other than a simple iris, relay lenses 41 are located opticly between the condenser 11 and the light source 40 to create an image 15' of the condenser rear aperture 15 at a plane $\mathbf{A_2}$ which is conjugate to plane **A** and at a location where there is ample space for masking apparatus. Locating masking apparatus at plane $\mathbf{A_2}$, has the same effect on the condenser 11 as masking apparatus located at the condenser rear aperture 15 itself. Because of the space available at conjugate plane $\mathbf{A_2}$, more elaborate masking apparatus can be used in the system as compared to that which will fit in the limited space at the rear aperture 15.

The numerical aperture (NA) of the condenser, which is a measure of the maximum angle of a light beam from the condenser to the

specimen 14, is inversely proportional to depth of field. Thus, as is well known, closing the iris 19 reduces the numerical aperture of the condenser and increases contrast and depth of field. But, as the iris is closed, resolution is sacrificed (decrease). Thus, prior art systems typically require a trade-off between resolution, on the one hand, and contrast and depth of field, on the other. The art of microscopy with prior art microscopes frequently involves choosing the correct balance between depth of field and resolution to obtain the best possible image of the object under investigation. With the present invention, the microscopist can maximize resolution, contrast and depth of field for a given specimen and objective lens.

Referring, in addition, to Figures 2 and 3, a transparent mask wheel 31 formed of a clear glass is rotatably disposed within a mask wheel frame (turret) 32 for rotation about the wheels central axis 33. Applied to the surface 34 of the mask wheel 31 are a plurality of opaque or semi-opaque disc-shaped masks 36 of different diameters. While opaque masks are illustrated by way of example, the mask 36 may alternatively be made of filter material, such as neutral density filters, so as to only reduce the intensity of the illumination (rather than occlude it altogether), in a given area of the condenser aperture 15. While masks of circular geometry are illustrated by way of example, it will be apparent to those skilled in the art that the invention is not so limited and that masks of different geometry are within the scope of the invention.

The mask wheel 31 is advantageously disposed immediately adjacent to the condenser rear aperture 15 (Figure 1) so that as the

wheel is rotated about its axis 33, the various circular masks 36 are presented at the rear aperture 15. The wheel 31 can also be disposed at the conjugate image 15' of the rear aperture 15 and produce the same results since image 15' is at a conjugate plane of the aperture plane **A**.

Although the mask wheel 31 does not provide continuous center aperturing, it does permits central masks 36 of different sizes (or different shapes and densities) to be easily and quickly coupled with condenser

lens 11. In this way the best available and most effective center mask 36 for the objective lens and the specimen under investigation can be readily determined empirically by rotating the wheel 31 until the best image is seen. Because the masks 36 are at either the aperture plane **A**, or a conjugate plane $\mathbf{A_2}$ of the aperture plane **A**, the placing of a mask 36 in the optical path of the microscope does not show up at the observation image plane $\mathbf{I_2}$. Zero aperturing is provided by positioning the wheel 31 so that no disc 36 is aligned with the condenser 11.

For each specimen/objective combination there is an optimum amount of center masking of the condenser that will produce the best image and it has been observed that even slight variations from that optimum can result in significant degradation of the image. Thus, in the preferred embodiment of the invention center masking is continuous so that very precise matching of center masking to the particular specimen/objective combination can be achieved. For some specimens it is advantageous to vary the amount of illumination light excluded from

the central area of the condenser as well as the size of that area. It has been found that in such cases the image is enhanced by allowing a fraction of the normal illumination to reach the center region of the condenser rather than exclude all light therefrom.

Referring to Figures 1,4, and 5, a pyramid shaped mirror 41 having four reflective surfaces 42, 43, 44, and 46 is disposed adjacent to aperture 15' which is at the conjugate aperture plane $A_2$. Illumination light at the aperture 15' is also effectively the illumination at the rear aperturing 15 of the condenser 11 itself.

When the pyramid mirror 41 is used, the light source 40 is replaced by a multiple light source, such as illuminated fiber optic guides 48 and 51. By way of illustration, two of four possible light sources are shown. Light source 48, directs a light beam 49 onto mirror surface 42 while light source 51 directs a light beam 52 onto mirror surface 46. Mirror 41 is movable along is axis 22 relative to light sources 48 and 51. While light sources 48 and 51 have been indicated as illuminated fiber optic guides, the illumination of various surfaces of the mirror 41 can be achieved with other light sources which are well known to those skilled in the art. Thus, the invention is not limited to the use of fiber optic guides as the only means for providing illumination light for the system.

The beams 49 and 52 are directed onto, and reflect off of, the mirror surfaces 42 and 46, respectively, as reflection beams 50 and 55, respectively. The size of the beams 49 and 52 when they reach the

mirrored surfaces 42 and 46 is such that in one position of the mirror 41 relative to the light sources 48 and 51 (that shown in Figure 5) both the apex 60 of the mirror 41 and the periphery 47 of conjugate aperture 15' are illuminated. In that position of mirror 41 reflection beams 50 and 55 illuminate all of quadrants 57 and 58 of the aperture 15', as seen in Figure 4. In this position there is zero center masking in quadrants 57 and 58 as no part of the condenser in those quadrants has been prevented from receiving any illumination light.

Referring to Figures 6 and 7, the mirror 41 is there shown in a position relative to the light sources 48 and 51 that is below the position shown in Figure 5. Lowering the mirror 41 has the effect of reducing the angle of the reflection beams 50 and 55 so that they no longer include the periphery 47 of the projected aperture 15'. Under these conditions of illumination only the central area of quadrants 57 and 58 of aperture 15' are illuminated - the area of the quadrants adjacent the aperture perimeter 47 is not illuminated. Thus, lowering the mirror 41 relative to the light sources 48 and 51 has a similar effect to closing down an iris at the aperture plane to reduce the diameter of the illuminating beam that is seen by the rear aperture of the condenser lens and objective lens. As the term "mask" is used herein, the pyramid mirror 41 is a mask in that it prevents certain areas of the condenser lens from receiving light from an illumination source.

Referring to Figures 8 and 9, the mirror 41 is shown in a position relative to the light sources 48 and 51 that is above that position shown in Figure 6. Raising the mirror 41 to a location where beams 49 and 52

do not illuminate an upper portion of the pyramid mirror 41 (including the apex 60) results in the central portion of the quadrants 57 and 58 being masked (not getting illuminated). The reflection beams 50 and 55, however, do include the periphery 47 of the aperture 15' so the full diameter of the conjugate aperture 15´ is illuminated.

The particular shape of the aperture (mask) that is formed by the pyramid mirror 41 as it is positioned to prevent illumination from reaching the central area of the aperture 15´ is particularly advantageous in that the periphery 47 of the aperture 15´ continues to be illuminated even as the central area that is not illuminated increases. In addition, the separate faces of the mirror 41 each produce an oblique beam with an independent wave front that superposes with the other beams from other faces of the
mirror 41.

By raising and lowering the mirror 41, continuous center masking over a range that includes zero is achieved. The system allows traditional full axial illumination (no masking as seen in Figure 4), center masking (masking central areas of the condenser as seen in Figures 8 and 9) (to the extreme of a type of dark field illumination), and peripheral aperturing (equivalent to an iris diaphragm) as seen in Figures 6 and 7.

The advantages of center masking (raising the mirror 41 above the no-aperturing position) over peripheral aperturing (lowering the mirror 41 below the no-aperturing position) are: (1) the N.A. is reduced with peripheral aperturing whereas it remains maximal with center masking; (2) with center masking the illuminating light rays that ultimately reach

the objective are all oblique relative to the optical axis of the objective lens increasing the number of higher order diffraction wavelets that form the image thereby increasing resolution; and, (3) center masking reduces the relative magnitude of the zero order (raises the relative magnitude of the higher order wavelets) thereby increasing contrast.

Because the pyramid mirror 41 and the associated light sources 48 and 51 are located at a conjugate aperture 15' of the rear aperture 15 of condenser 11, where there is unobstructed space for the mirror to be raised and lowered (see Figure 1), it is possible to raise part of the mirror 41 above the conjugate aperture 15' (see Figure 9) to the extent required to produce the center masking necessary. This would not be possible if the mirror 41 was located at the rear aperture 15 of the condenser 11 itself since the mirror would for many adjustments want to occupy the same space occupied by the condenser 11.

It is, the movement of the mirror 41 relative to the light sources 48 and 51 that produces the variable masking described above. Thus, the mirror can be fixed and the light sources 48 and 51 moved in a direction parallel to the axis 22 of the pyramid mirror 41 or the light sources 48 and 51 can be fixed and the pyramid mirror 41 moved in a direction along its axis 22. Although both arrangements are within the scope of the present invention, where there are a plurality of light source, it has been found more practical to raise and lower the mirror 41 to produce the required masking.

The invention has thus far been described with reference to an

arrangement of parts that includes two light sources directing beams onto adjacent faces of a four face pyramid mirror. In the preferred embodiment there are four light sources of illuminating all four faces of the mirror.

Referring to Figures 10 and 11, four fiber optic light sources 64 are positioned to direct a light beam onto each of the four faces 42, 43, 44 and 46 of the mirror 41. Once again, while fiber optic light guides offer several advantages, other sources of illumination light are well know in the art and can be used with the present invention. By selecting particular light sources 64 to be operative (provide a light beam) and by varying the intensities of the operative light sources 64, a wide variety of illumination combinations is possible. With the present invention a microscopist is able to carefully tailor the illumination to the specimen, objective lens and type of investigation being conducted to obtain the image desired. Contrast, resolution, depth of field and shadowing are all variables that the present invention put under control of the microscopist. In general, the best results are achieved for two dimensional viewing when two light sources 64 illuminate adjacent faces (43 and 44 for example) of the mirror 41 (the other two faces are not illuminated at all). For 3-D viewing all four light sources 64 can be used to illuminate all four faces of the mirror 41 with adjacent pairs of mirror faces providing the image for each eyepiece of a binocular viewing system (not shown). Other combinations may prove more advantageous for particular circumstances.

A number of mechanical or electrical mechanical devises for raising

or lowering the pyramid mirror 41 can be imagined and are well within the skill of the art and as such form no part of the invention. Such systems require that the pyramid mirror be capable of being raised and lowered in small increments and that once located at the desired position, the mirror remains there until moved to a new position. One such system is shown and described with reference to Figures 10 and 11.

The pyramid mirror 41 is affixed to a base 66 which in turn is affixed to a vertically oriented rack member 67. Rack member 67 combines with a pinion 68 which is turned by a knob 69 attached to the pinion 68.

By turning the knob 69 the pinion is rotated causing the rack 67 to move up or down depending on the direction that the knob is turned, and in turn, the base 66 moves up and down with the rack 67 carrying with it the pyramid mirror 41. The rack and pinion members permit the mirror 41 to be easily vertically adjusted relative to the fixed light sources 64 and thereby achieve the results described above. Other arrangements using a ramp and cam, or a pneumatic or hydraulic ram, to name only two, are possible and any such mechanism can be oriented to suit the conditions and still produce the desired relative movement between the mirror 41 and its associated light sources 64. The particular mechanical or electro-mechanical system employed to raise or lower the mirror 41 does not form any part of the invention, as such systems are well know to those skilled in the art.

The present invention has been described with reference to a pyramid mirror having four faces. Because outstanding results are

achieved for two dimensional viewing by using adjacent faces of a four face pyramid mirror, and 3D viewing is achieved by using adjacent pair faces of a four face pyramid mirror for creating left and right eye views, the four face pyramid mirror shown and described is a preferred embodiment. The invention, however, is not limited to a pyramid mirror of four faces and a pyramid of three faces or a pyramid of more than four faces may in special cases have advantages. Thus, the invention is not limited to a pyramid mirror of four faces but includes pyramid mirrors having a number of different faces.

Where the number of faces of pyramid mirror 41 are infinite, the pyramid mirror becomes a cone mirror as seen in Figure 12 and 13. By employing the combination of a ring light with a cone-shaped mirror movable relative to the ring shaped light, continuous center aperturing including zero is achieved.

Referring to Figures 12 and 13, a cone-shaped mirror 71 is mounted on a base 72 which can be raised or lowered by the operation of a rack and pinion 73 to which the base is attached. A ring shaped light 76 surrounds the upper portion of the pyramid mirror 71 and provides a source of illumination which is reflected by the mirror surface 77 of the cone shaped mirror 71. Just as described in connection with the pyramid shaped mirror 41 in Figures 5 - 10, movement of mirror 71 relative to the ring light 76 can produce center masking, peripheral aperturing, and zero masking.

While the combination of the cone-shaped mirror 71 and the ring

light 76 does not provide independent wave fronts as does the pyramid mirror combination and thus does not have all the benefits of superposed independent wave fronts, it does provide for continuous center masking over a range that includes zero which is an important advance in that art.

The invention having been fully described, it is not to be limited to the details herein set forth, but is of the full scope of the appended claims.

## CLAIMS

What is claimed is:

1. In an illumination system for a light microscope of the type utilizing a condenser lens with a rear aperture and a center, the combination comprising:

a light source providing illumination light for the condenser;

mask means optically disposed between the light source and the rear aperture of the condenser, said mask means operative to prevent illumination light from reaching an area of the condenser including its center wherein the size of the area prevented from receiving illumination light is variable over a range that includes zero.

2. The illumination system of claim 1 wherein the size of the area prevented from receiving illumination light is continuously variable.

3. The illumination system of claim 1 further comprising:

lens means creating an image of the rear aperture of the condenser lens at a location optically between the light source and the condenser lens and remote from the condenser lens; and wherein

said mask means is located immediately adjacent the image of the rear aperture of the condenser lens.

4. The illumination system of claim 2 further comprising:

lens means creating an image of the rear aperture of the condenser lens at a location optically between the light source and the condenser lens and remote from the condenser lens; and wherein

said mask means is located immediately adjacent the image of the rear aperture of the condenser lens.

5. The illumination system of claim 1 wherein said mask means includes a plurality of different size masking discs.

6. The illumination system of claim 5 wherein said masking discs are semi-opaque permitting a fraction of the light they receive pass through.

7. The illumination system of claim 2 wherein said mask means comprises:

a mirror having the shape of a multi- sided pyramid; and

a light source directing light onto at least two sides of said mirror.

8. The illumination system of claim 3 wherein said mask means comprises:

a mirror having the shape of a multi- sided pyramid; and

a light source directing light onto at least two sides of said mirror.

9. The illumination system of claim 8 wherein said mirror and light source are movable relative to each other.

10. The illumination system of claim 2 wherein said mask means comprises:

a mirror having the shape of a cone; and

said light source is the shape of a ring disposed surrounding said mirror directing light onto said mirror.

11. In an illumination system for a light microscope of the type having a condenser lens wherein the condenser lens has a center, an optical axis and a rear aperture at the aperture plane, and the microscope further has

an objective lens with an optical axis, the combination comprising:

lens means creating an image of the rear aperture of the condenser lens at a location remote from the condenser lens and at a conjugate plane of the aperture plane;

a pyramid shaped mirror having a plurality of reflective faces disposed at the image of the rear aperture of the condenser lens;

a plurality of light sources illuminating a plurality of faces of said mirror wherein said faces reflect the illumination onto the image of the aperture and said mirror is movable relative to said light sources.

12. The illumination system of claim 11 wherein the light reflected onto the image of the rear aperture ultimately travels to the objective lens along paths that are oblique to the optical axis of the objective lens.

13. The illumination system of claim 11 wherein a first relative position between said light sources and said mirror the image of the aperture of the condenser lens is fully illuminated and no area is masked, and wherein relative movement in one direction away from said first position masks illumination from an area of the projected aperture that includes its center.

14. The illumination system of claim 13 wherein continued movement away from said first position continuously increases the size of the area of the image of the aperture that is masked.

15. The illumination system of claim 13 where relative movement between said mirror and said light sources away from said first position in the opposite direction masks illumination from an area of the image of the aperture that is adjacent to the perimeter of the image of the

aperture and does not include its center.

16. The illumination system of claim 15 wherein continued movement away from said first position in the opposite direction continuously increases the size of the area of the image of the aperture that is masked.

17. In a process for increasing the resolution and contrast of the image of a specimen being investigated created in a transmitted light microscope wherein the microscope has a condenser lens with a center, the steps comprising:

directing illumination light onto the condenser lens;

masking the illumination light to prevent illumination light from reaching areas of the condenser lens that include its center;

varying the amount of masking over a range that includes no illumination light prevented from reaching the condenser lens until the amount of masking produces the best image for the investigation being performed.

18. The process of claim 17 wherein the range of masking is continuous.

19. The process of claim 18 where the masking does not include the periphery of the condenser lens.

20. In a process for increasing the resolution and contrast of the image of a specimen under investigation created in a transmitted light microscope where the microscope has an illumination source, an objective lens with an optical axis, and a condenser lens with a rear aperture at an aperture plane and a center, the steps comprising:

creating an image of the rear aperture of the condenser at a location in space remote from the condenser lens and at a conjugate plane to the condenser aperture plane;

disposing masking apparatus at the projected image of the rear aperture, wherein the masking apparats is operative to prevent illumination light from reaching areas of the image of the rear aperture of the condenser lens over a range that includes the condenser lens center;

selecting the area within the range that produces the best image for the investigation being conducted.

21. In the process of claim 20, the steps further comprising:

illuminating the image of the rear aperture of the condenser lens with a plurality of independent beams, each with its own wavefront.

22. In the process of claim 21 wherein the masking apparatus includes a pyramid shaped mirror having a plurality of reflective faces, and wherein said mirror and the illumination source have relative movement.

23. In the process of claim 22 the steps further comprising;

increasing the area of illumination light prevented from reaching the condenser lens by relative movement between the illumination source and said masking apparatus in a first direction and decreasing the area of illumination light prevented from reaching the condenser lens by relative movement between the illumination source and said masking apparatus in an opposite direction to the first direction.

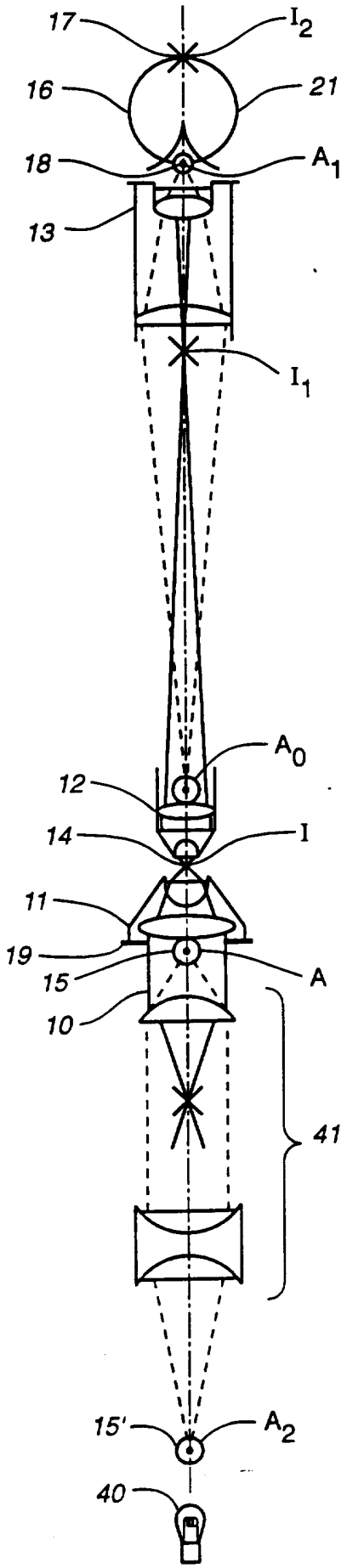



FIG._1

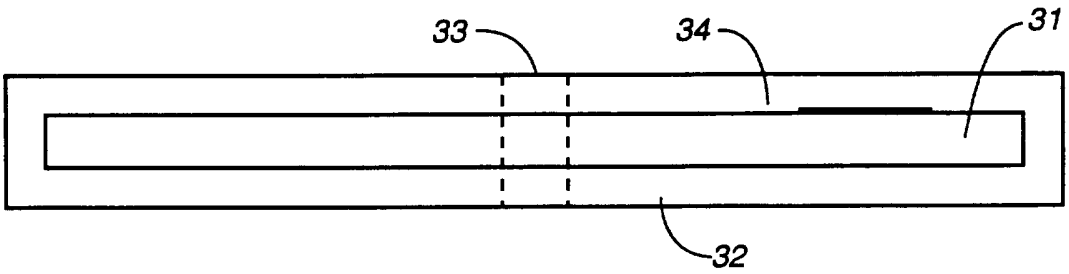



FIG._2

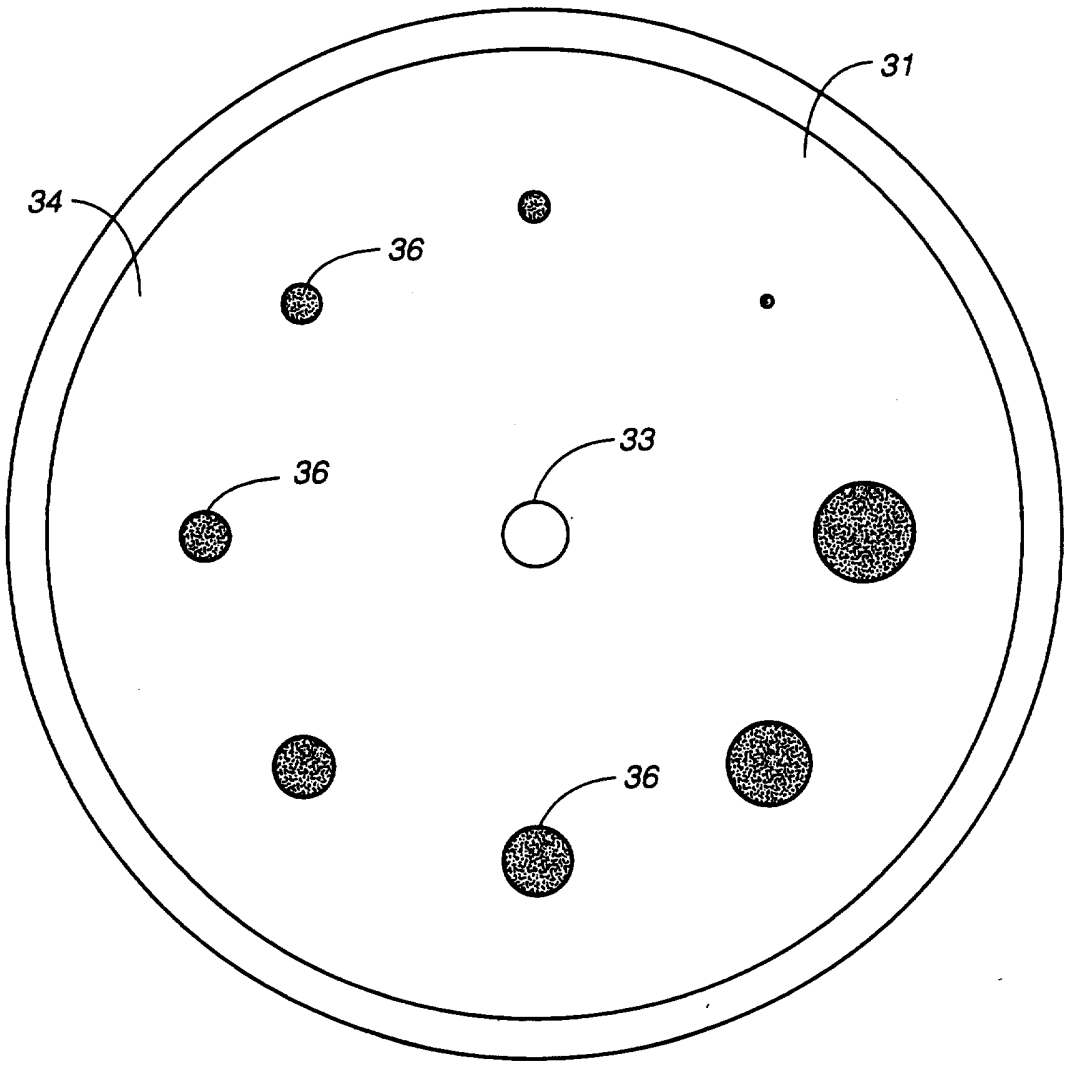



FIG._3

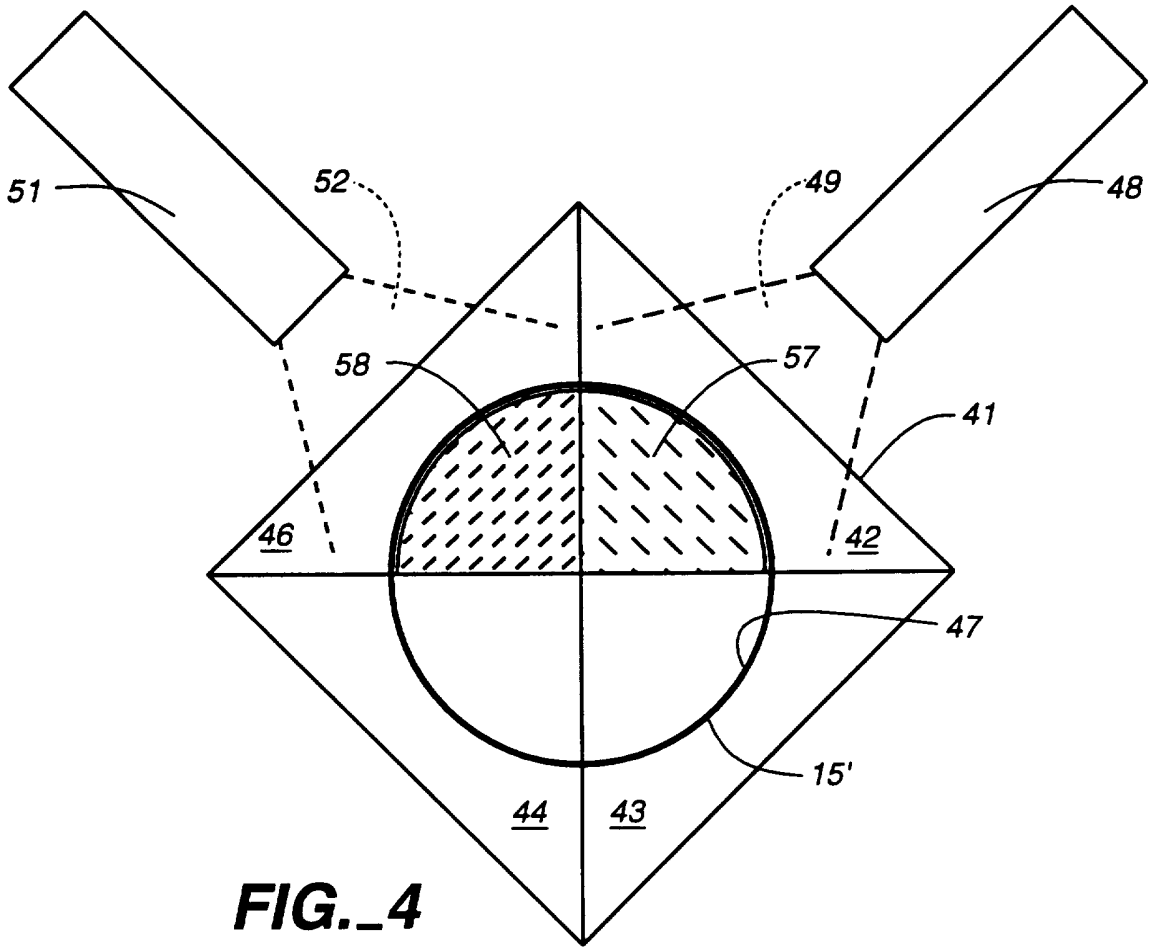

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FIG._4

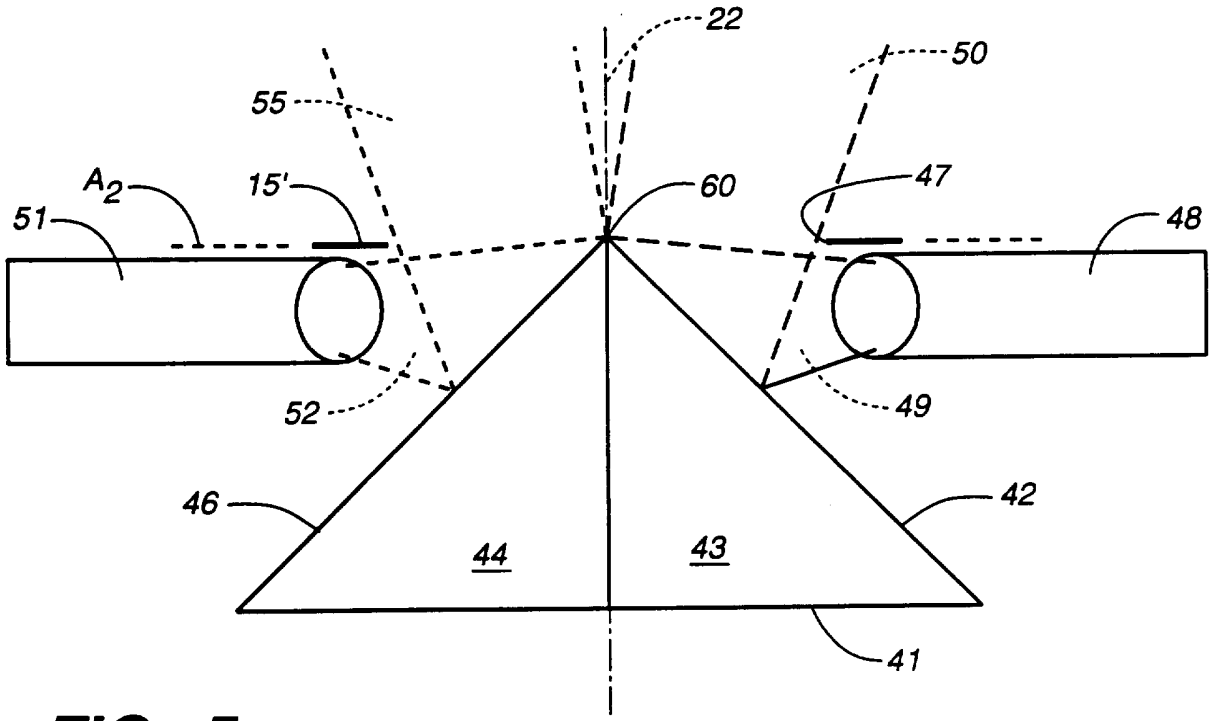

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FIG._5

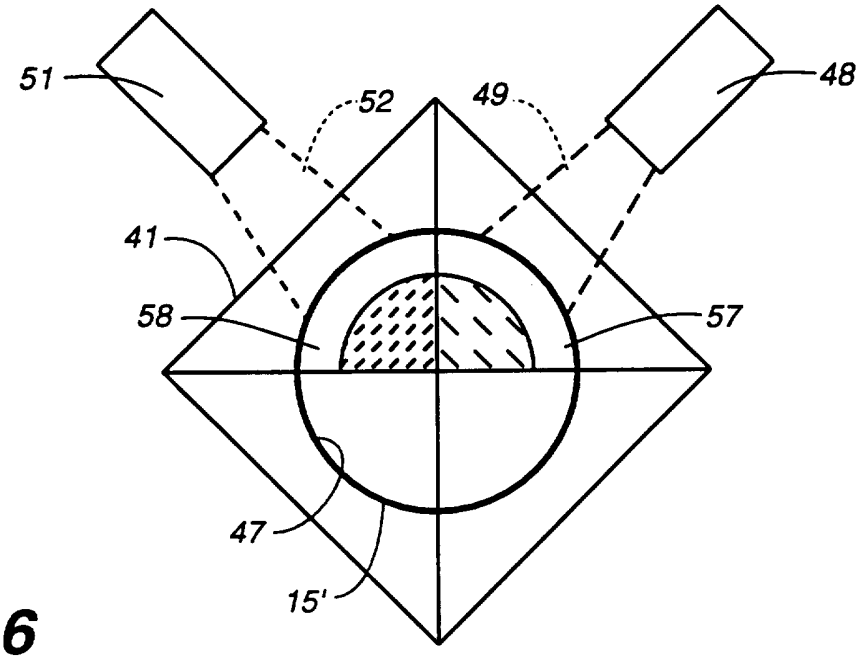



FIG._6

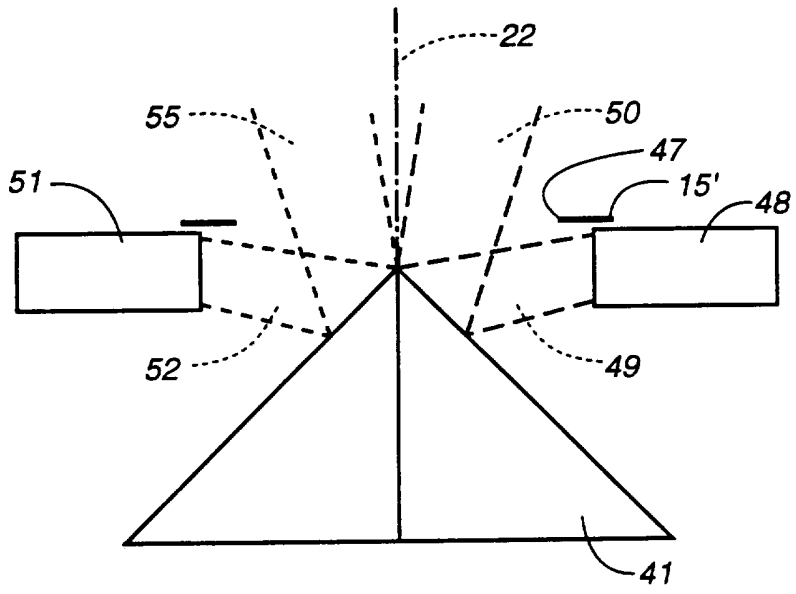



FIG._7

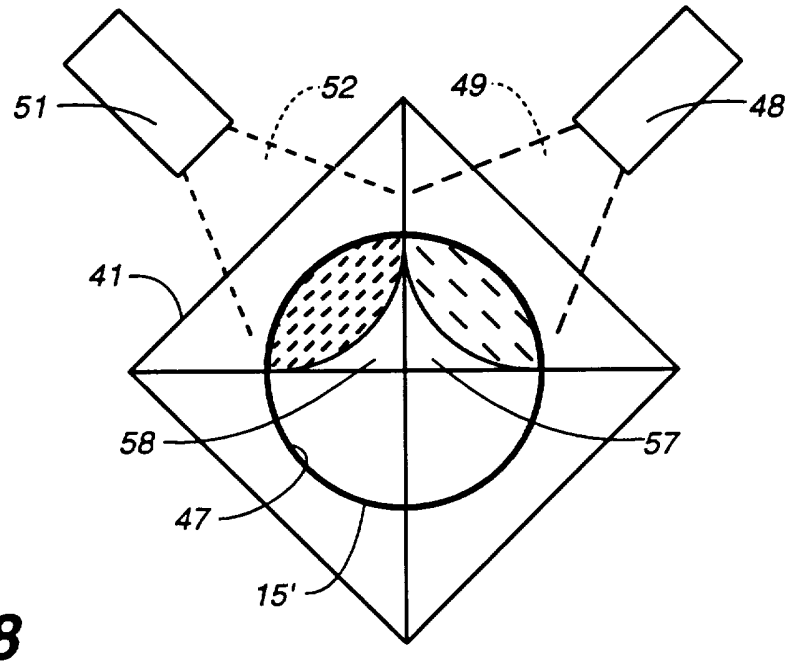



FIG._8

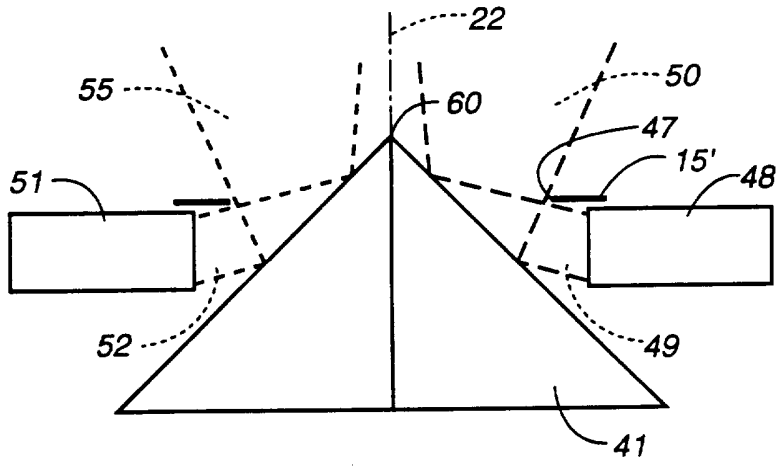



FIG._9

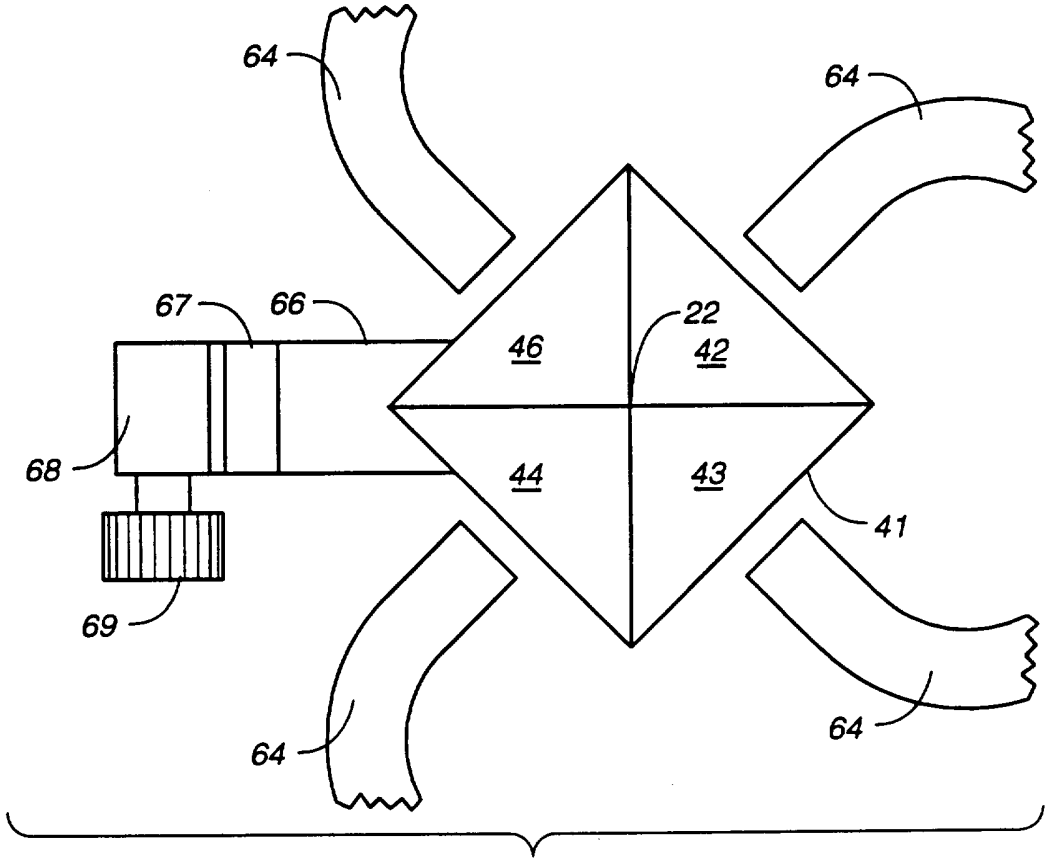



FIG._10

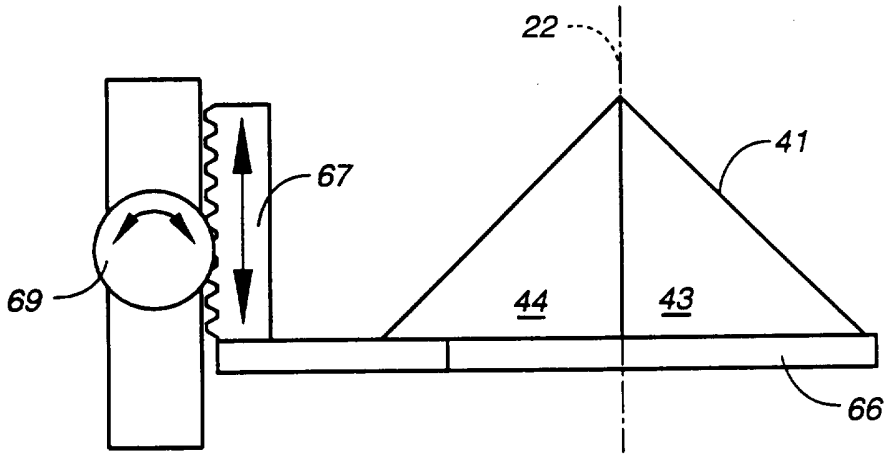



FIG._11

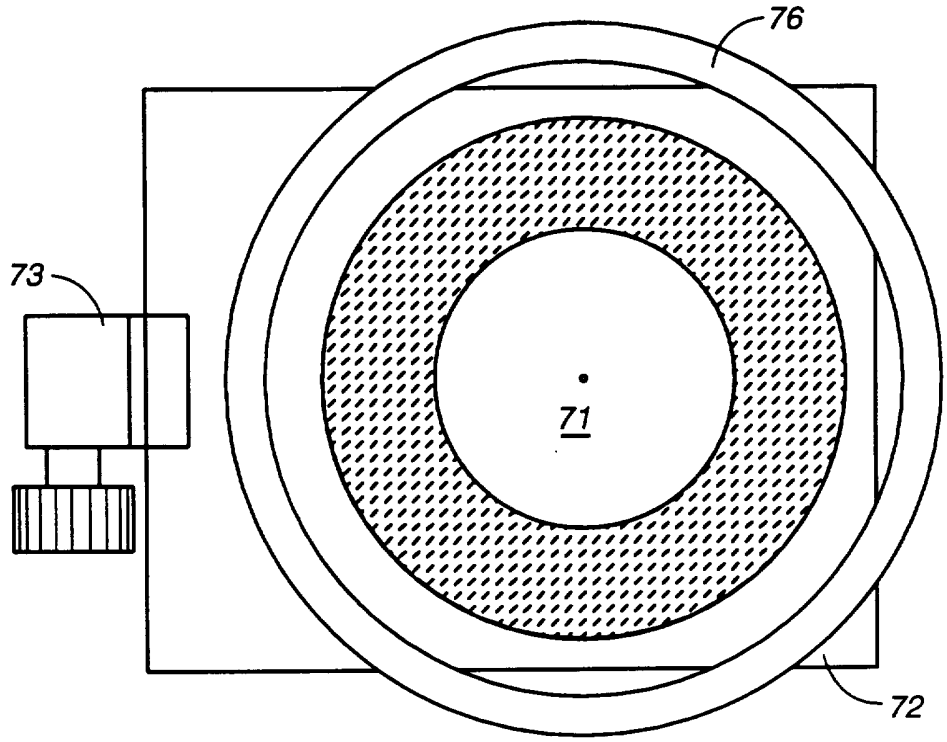



FIG._12

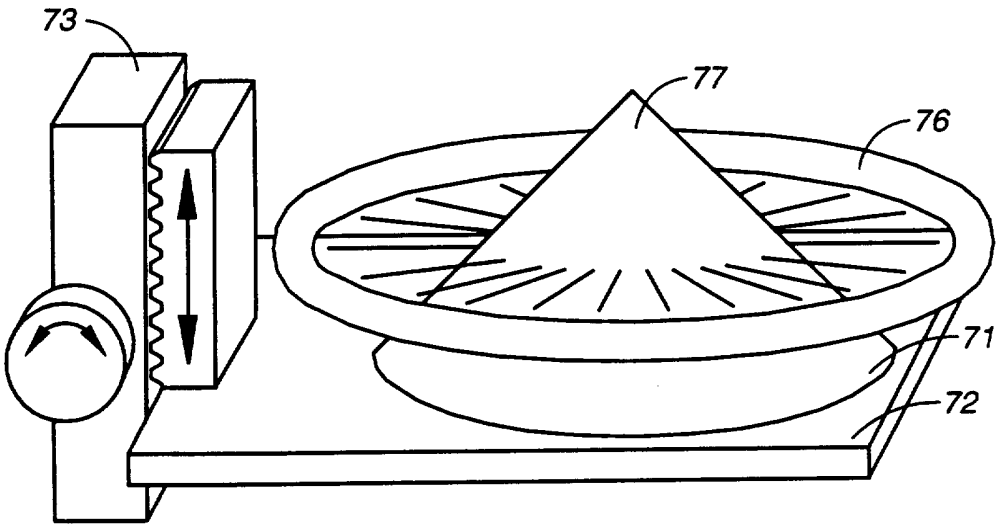



FIG._13