KING & SCHICKLI, PLLC

WARREN D. SCHICKLI
MICHAEL S. HARGIS
ANDREW D. DORISIO
MICHAEL T. SANDERSON

PATRICK M. TORRE, PH.D.
BRETT G. CORBLY
TREVOR T. GRAVES
REBECCA A. KREFFT

OF COUNSEL

J. RALPH KING

247 NORTH BROADWAY
LEXINGTON, KENTUCKY 40507-1058
(859) 252-0889 TEL
(859) 252-0779 FAX
INFO@IPLAW1.NET

WRITER'S DIRECT E-MAIL: PAT@IPLAW1.NET

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January 13, 2009

Donald G. Keach, Director
Intellectual Property Development
ASTeCC Building, Room A144
UNIVERSITY OF KENTUCKY
RESEARCH FOUNDATION
Lexington, Kentucky 40506-0286

Re: U.S. Patentability Opinion
Square Tube Mirror (STM)-based Imaging System
Your Reference: UKRF No. 1618
Our Reference: 434-378 CRR

Dear Don:

This letter provides our opinion concerning patentability of the above-referenced invention, based on the results of a search of the records of the U.S. Patent and Trademark Office.

Summary of the Opinion

Only limited, though potentially meaningful, patent protection appears to be available for the device as described in the present disclosure materials. This is because at least U.S. Patent No. 4,475,126 to Akins broadly teaches a substantially rectangular mirror having interior mirrored surfaces. No references were found anticipating or rendering obvious the method for providing a three-dimensional image using a square tube mirror as set forth in the present disclosure, and therefore meaningful patent protection appears to be available for the method of the invention. It may also be possible to secure some limited scope of patent protection for the device of the invention, in combination with the specific method. It will likely be necessary to present narrowly tailored claims to the device, for example incorporating the specific dimensions of the device or alternatively a specific relationship between a cross-sectional dimension of the first and second openings of the device, to overcome the teachings of the '126 patent.

Basis of the Opinion

A search of the records of the United States Patent and Trademark Office was conducted based upon the materials provided during the filing of a provisional application for the above-referenced invention. The following areas were searched:

Class 345 **COMPUTER GRAPHICS PROCESSING AND SELECTIVE VISUAL DISPLAY SYSTEMS**
Subclasses: 419, 421

Class 348 **TELEVISION**
Subclasses: 51, 59, e13.002, e13.005, e13.007, e13.011, e13.021, e13.026, e13.027, e13.028

Class 352 **OPTICS: MOTION PICTURES**
Subclass: 65

Class 359 **OPTICAL: SYSTEMS AND ELEMENTS**
Subclasses: 616, 617

Class 382 **IMAGE ANALYSIS**
Subclass: 154

Class 396 **PHOTOGRAPHY**
Subclasses: 324, 327, 331

Forward and backward citations were performed on the most relevant references. The U.S. classification search was supplemented with searches on the EAST system, as well as by searches in the Japanese and European patent databases.

References

The following patents and published patent applications were analyzed (copies are submitted herewith):

Patent No./Publication No.	Inventor(s)	Issue/Publication Date
4,475,126	Akins	October 2, 1984
5,757,548	Shimomukai	May 26, 1998
7,420,750	Kuthirummal et al.	September 2, 2008
6,668,082	Davison et al.	December 23, 2003

Patent No./Publication No.	Inventor(s)	Issue/Publication Date
2005/0254817	McKee	November 17, 2005
7,065,242	Petrov et al.	June 20, 2006
7,362,881	Hattori et al.	April 22, 2008
7,106,365	Sogawa	September 12, 2006
7,132,933	Nakai et al.	November 7, 2006
7,263,209	Camus et al.	August 28, 2007
2004/0252863	Chang et al.	December 16, 2004
7,181,136	Perisic	February 20, 2007
2003/0156187	Gluckman et al.	August 21, 2003
6,208,813	Carlsson et al.	March 27, 2001
5,546,226	Herington	August 13, 1996
6,278,460	Myers et al.	August 21, 2001
2006/0204038	Yokota et al.	September 14, 2006
2006/0115119	Nagaoka et al.	June 1, 2006
2008/0031514	Kakinami	February 7, 2008
6,963,661	Hattori et al.	November 8, 2005
6,122,597	Saneyoshi et al.	September 19, 2000

The Invention

The present invention disclosure teaches a square tube mirror assembly for imaging, in particular for use in three-dimensional reconstruction of viewed objects. The principal element of the invention is a square tube mirror (STM), comprising four mirrored surfaces arrayed in an interior of a cylinder (or other suitable supporting structure) to form a substantially square or rectangular interior mirrored surface. The STM may have a front opening which is larger in cross-section than the rear opening, providing angled side walls.

Viewing an object through the STM provides nine different views of the object, as if from nine different view points and orientations simultaneously. One image is the view of the object obtained by looking directly through the STM. Four of the images (left, right, top, bottom images) are generated by reflecting the object once. Four of the images (top-left, top-right, bottom-left, and bottom-right images) are generated by reflecting the object twice. Information obtained from these views can be used to compute a depth of the viewed objects, allowing three-dimensional reconstruction of an object using a single camera and from a single photographic image.

The STM is used in conjunction with a light source and a suitable imager such as a digital camera. Anticipated uses include imaging devices for obtaining images of objects such as an interior of a patient's mouth, of vehicles, and the like, for preparing computer-generated three-dimensional reproductions thereof. In another embodiment, arrays of STMs according to the invention are used to generate three-dimensional reproductions of the surrounding environment for use in a vision device for an automatic driving system.

The invention further includes a method for preparing a three-dimensional reproduction of a viewed object from the images obtained as described above. For each pixel in the original object (or scene), that is, the central image, it is necessary only to do a horizontal line search and a vertical line search for corresponding points in the reflected images. For a particular scene point in the center view of the group of nine images as set forth above, corresponding points (that is, on the same horizontal and vertical line) are located in the left, right, top, and bottom images of the group. Because the images are reflections by mirrors having reflection factors less than 1 (in the present embodiment, calculated at 0.77-0.79), the intensity values of pixels in the adjacent images are less than those of the center image, and are adjusted according to the reflection factor. Also, the location of a corresponding point may overlap boundaries of multiple adjacent pixels, and therefore this must be taken into account. Therefore, various methods may be employed to match corresponding points (in adjoining images) to particular scene points in the center image, including cross co-relationship (finding corresponding points in 2x2 or 4x4 pixel areas) curvature distribution match, and slope comparison.

Next, after identifying corresponding points, is the step of computing a three dimensional depth for those points. To do so, the camera center is identified and the focal length thereof is computed in pixel length to provide a camera calibration. Next, a depth for selected scene points is calculated. For each scene point A, an image point B is designated, with B' and B" being the corresponding points of B. Thus, a, c are known. The depth of point A may be expressed as the formula $d = b[1 + k/(k + f)]/[b/(k + f) - c/h - \tan(g)]$.

Discussion of References

As to the structure of the STM, perhaps the closest reference found is U.S. Patent No. 4,475,126 to Akins for a Visual Image Display Apparatus (the '126 patent). The '126 patent is now expired, eliminating any consideration of infringement. Broadly, the '126 patent teaches a four-mirror arrangement for providing multiple images from a single source. Specifically, the '126 teaches four mirrors radiating outwardly from a central object (see Figure 1, reproduced below), in the depicted embodiment a television screen 10 (*Col. 2, ll 63-66*). The '126 patent teaches use of four trapezoidal mirrors 16, 18, 20, 22 radiating outwardly from the central object, typically a spherical object rather than planar. The structure of the '126 patent, in combination with the spherical image display surface, creates the image of a sphere having segments of its surface repeating the primary image (*Col. 3, ll 11-13*). The '126 patent further teaches preferential use of front surface mirrors to prevent ghost or double images (*Col. 3, ll52-58*).

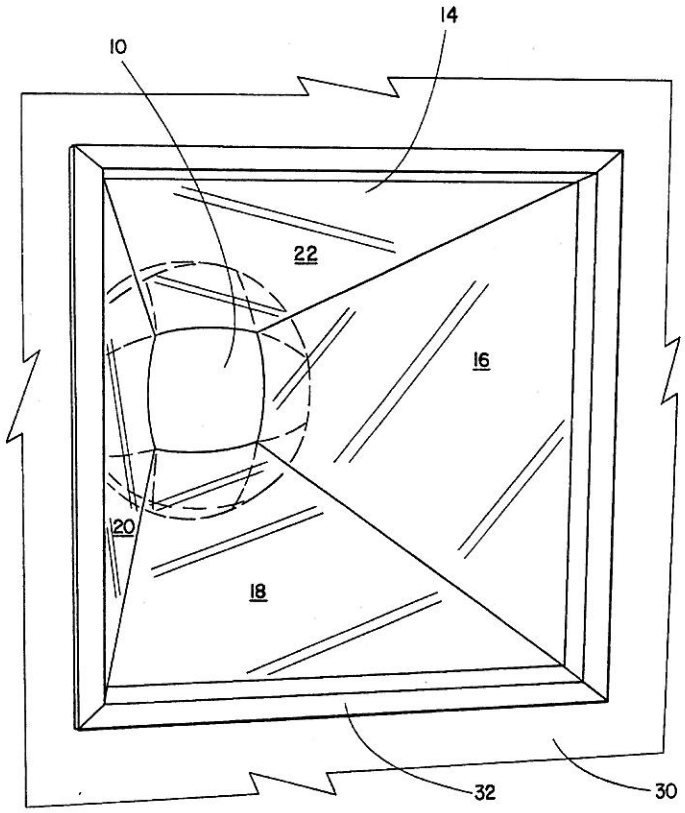

Fig. 1

There is no express teaching in the '126 patent of generation of 9 images as in the present disclosure. However, overall the structure of the mirror device of the '126 patent is similar to that of the present invention.

See also U.S. Patent No. 5,757,548 to Shimomukai (the '548 patent) for a Kaleidoscope, and Pattern Generating Apparatus and Pattern Generating Method Utilizing the Same. This patent expired in 2006 for failure to pay a maintenance fee, and therefore again infringement is not a concern.

With reference to *Figure 5* of the'548 patent (see below) there is disclosed a four-sided rectangular mirror tube A4 having mirrored interior surfaces. The mirror tube narrows from a first opening to a second opening.

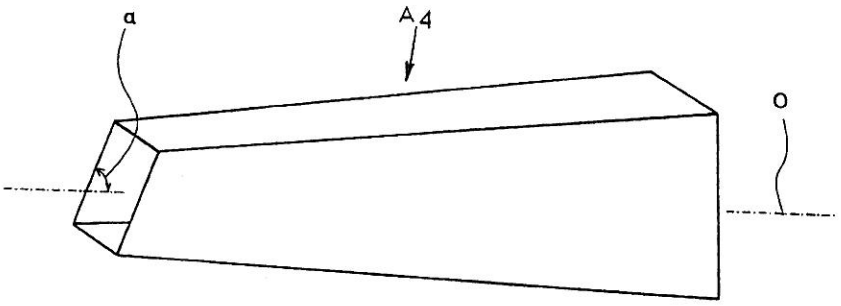

FIG. 5

The device of the'548 patent differs from the present STM in a teaching of inclined, concave, or convex tip surfaces (inclined in the embodiment shown in *Figure 5*). It is this tip surface which generates the kaleidoscope effect (see *Col. 2, ll 6-8*: "The inclination of the cut tip surface generates projections which extend outward from the periphery of the generated spherical pattern.").

With reference to the method for generating a three-dimensional image from a single imager as set forth in the present disclosure, U.S. Patent No. 6,668,082 to Davison et al. for Image Processing Apparatus (the '082 patent) teaches a method comprising identification of matching points corresponding to points on an actual object. However, in contrast to the present disclosure, use of multiple images taken from multiple locations around or near the object of interest is disclosed (see *Figure 2* and also *Col. 2, ll 28-37*). Further, the '082 patent provides

no teaching of an STM or like structure for providing the images for processing to a 3D representation.

The remaining references are considered cumulative of the teachings above, or are cited only to define the state of the art, and are therefore not discussed in detail. The references generally disclose various iterations of mirrored surfaces for generating multiple images from a single image, and also stereoscopic 3-D imaging systems mounted on vehicles. None teach structures corresponding to the STM of the present disclosure. For example, U.S. Patent No. 7,420,750 to Kuthirummal et al. for Catadioptric single camera systems having radial epipolar geometry and methods and means thereof teaches a single camera system (see *Col. 2, ll 42-59*) for simulating virtual viewpoints. However, the Kuthirummal reference specifically requires radial epipolar geometry, and teaches mirrors in the shape of a cylinder or a truncated cone.

The Law on Patentability

In order to be patentable under U.S. law, an invention must be useful, new or novel, and non-obvious in view of what has been done in the past (known as the "prior art"). Usefulness (utility) is rarely an issue, especially with mechanical types of inventions. An invention lacks novelty, or is "anticipated," if each and every element of it is shown in a single piece of prior art (such as a U.S. patent issued more than one year ago). Finally, an invention is "obvious" if, even though not anticipated as defined above, the teachings of the prior art or the general knowledge available to the skilled artisan (at the time of the making of the invention) would have motivated a skilled artisan to make it.

Analysis and Opinion

In view of the structure set forth in the '126 patent, a broad scope of patent protection for the present device is likely not available. This is because the '126 teaches a very similar structure, that is, a rectangular structure having mirrored interior surfaces, wherein the rectangular structure slopes from a larger first opening to a smaller second opening. Claims directed to the structure of the present invention are likely to be considered anticipated by the teachings of the '126 patent. Of course, if there is a structural distinction (other than the dimensions of the present device) which was not apparent from the invention disclosure materials, it should be brought to my attention and we can reconsider this portion of the analysis.

On the other hand, none of the references we analyzed appear to teach or suggest the particular method for generating a three-dimensional image from the 9 image series provided by the STM of the present disclosure. Accordingly, meaningful patent protection should be available for that aspect of the invention. It may also be possible to secure claims (although somewhat narrow in scope) to the device of the invention in view of the method. It is likely that

particular dimensions, relative sizes of the STM openings, or other structural limitations which render the device suitable for the method will have to be incorporated to secure any scope of protection. While I would anticipate such claims to be rejected initially by a Patent Examiner as legally "obvious" in view of the references discussed above, it should be possible to overcome such a rejection.

Please review the references and my analysis, and let me know if you agree. If a utility patent application is deemed desirable after considering this opinion, it is anticipated that the application will cost $8000.00 to prepare and file, exclusive of drawing costs and filing fees.

If you have an questions regarding the references, my analysis, or any other aspect of this opinion, please don't hesitate to call.

Very truly yours,

KING & SCHICKLI, PLLC

Pat

Patrick M. Torre

PMT/vdc
Enclosures