

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DENTAL IMAGING TECHNOLOGIES CORPORATION

Petitioner

v.

3SHAPE A/S

Patent Owner

U.S. Patent No. 11,076,146 to Fisker *et al.*

Issue Date: July 27, 2021

Title: FOCUS SCANNING APPARATUS

DECLARATION OF MOHIT GUPTA, Ph.D.

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Exhibit No.	Description
1001	U.S. Patent No. 11,076,146 (“the ’146 patent”)
1002	Declaration of Dr. Mohit Gupta (“Gupta Decl.”)
1003	<i>Curriculum Vitae</i> of Dr. Mohit Gupta
1004	Prosecution History of U.S. Patent No. 11,076,146
1005	U.S. Patent App. Pub. No. 2008/0024768 to Noam Babayoff (“Babayoff”)
1006	T. Wilson <i>et al.</i> , “Real-time three-dimensional imaging of macroscopic structures,” <i>Journal of Microscopy</i> , Vol. 191, Pt. 2, August 1998, pp. 116-118 (“Wilson”)
1007	U.S. Patent App. Pub. No. 2005/0237581 to Knighton <i>et al.</i> (“Knighton”)
1008	U.S. Patent App. Pub. No. 2003/0043089 to Hanson <i>et al.</i> (“Hanson”)
1009	U.S. Patent App. Pub. No. 2009/0087050 to Michael Gandyra (“Gandyra”)
1010	M. A. A. Neil <i>et al.</i> , “Method of obtaining optical sectioning by using structured light in a conventional microscope,” <i>Optics Letters</i> , Vol. 22, No. 24, December 15, 1997, pp. 1905-1907 (“Neil”)
1011	L. Zhang <i>et al.</i> , “Projection Defocus Analysis for Scene Capture and Image Display,” <i>ACM SIGGRAPH 2006</i> , July 2006, pp. 907-915 (“Zhang”)
1012	Declaration of Dr. James L. Mullins (“Mullins Decl.”)

I. INTRODUCTION

1. I, Mohit Gupta, Ph.D., resident at 910 Cornell Court, Madison, Wisconsin, hereby declare as follows:

2. I have been retained by Foley & Lardner LLP to provide my opinion concerning the validity of U.S. Pat. No. 11,076,146 (“the ’146 patent,” EX1001).

3. I am being compensated for my time by the hour in preparing this declaration, but my compensation is not tied to the outcome of this matter.

II. QUALIFICATIONS

4. In forming the opinions expressed in this Declaration, I have considered and relied upon my education, background, and experience. In addition, I have reviewed and relied upon additional materials in preparation of this Declaration, as described below.

5. My experience and education are detailed in my curriculum vitae (“CV”), a copy of which is provided as EX1003. My CV also lists publications on which I am a named author. I have not previously provided expert testimony.

6. I have over 17 years of experience working with three-dimensional (“3D”) imaging and scanning. As detailed below, I have worked on many projects that are highly relevant to the subject matter of the ’146 patent.

7. I obtained my Bachelor’s degree in Computer Science from the Indian Institute of Technology, Delhi in 2003. I obtained my Master’s degree in Computer

Science from Stony Brook University in 2005. I then earned a Ph.D. in Robotics from the Robotics Institute, Carnegie Mellon University in 2011.

8. I am an Associate Professor of Computer Sciences at the University of Wisconsin-Madison, where I have been since 2016. After I received my Ph.D. from the Robotics Institute of Carnegie Mellon University in 2011, I was a postdoctoral research scientist at Columbia University from 2011-2015. I currently direct the WISION Lab at the University of Wisconsin-Madison with research interests broadly in computer vision and computational imaging.

9. I have published more than 50 research papers and 15 patents and patent applications in the areas of 3D imaging, computational imaging, and computer vision over the past 15 years. I received the Marr Prize (honorable mention) for best paper at IEEE ICCV 19, a Sony Faculty Innovation Award, and an NSF CAREER award. My research is supported by NSF, ONR, DARPA, Snap, Sony, Intel and the Wisconsin Alumni Research Foundation. I am in the process of co-authoring a book on active 3D imaging including methods that use projectors and cameras for 3D scanning.

10. I have extensive research experience in 3D imaging. I have performed research on active 3D cameras, including LiDAR and structured light 3D scanning, since 2007, which I started during my Ph.D. program at Carnegie Mellon University's Robotics Institute.

11. Active cameras consist of a light source which emits coded light on the scene, *i.e.*, its intensity is modulated over space, and/or time. Examples include LiDAR, time-of-flight sensors, structured light laser scanners, and depth from projector defocus/focus. These sensors are mainstream, getting deployed in several applications such as autonomous vehicles, security and surveillance, industrial inspection, medical and biometric imaging, as well as consumer devices.

12. My research has focused on designing active 3D cameras that can transition outside the lab to extreme real-world conditions, including outdoors (e.g., in sunlight and poor weather), and for optically challenging and geometrically intricate objects such as glass and metal (e.g., for an industrial robot sorting machine parts), for high-speed dynamic objects, and under multi-camera interference.

13. Due to its practical relevance, most of my work in these areas has been patented, and some of it has been licensed for deployment in automotive 3D sensing and surveillance applications. One of these imaging techniques was licensed by Omron, a leading manufacturer of industrial automation systems, who recently released a product that uses this technology for robotic inspection and automation (<https://automation.omron.com/en/us/products/family/VT-S730>).

14. Some of my research work has been related to a 3D imaging system based on depth from projector defocus. This method measures 3D geometry by

estimating scene depths at each camera pixel. The underlying technique is based on projecting a single or multiple patterns on the scene of interest using a projector, and then capturing one or more images of the reflected light. The idea is that the projected pattern is in focus (appears sharp) for scene points that are on the projector's focal plane, whereas the pattern is blurred for scene points that are out of focus. Therefore, by estimating the amount of blur in the projected patterns by evaluating a contrast / correlation measure, scene depths (distance of scene points from projector / camera) can be computed. This method was described in detail in 2006 by Li Zhang and Shree Nayar in their paper "Projection Defocus Analysis for Scene Capture and Image Display," ACM SIGGRAPH 2006, July 2006, pp. 907-915 ("Zhang") (EX1011).

15. One topic with this type of imaging is dealing with translucent materials or objects where light bounces multiple times before reaching the sensor. I proposed techniques using multiple focal planes that are robust to non-ideal and optically challenging materials such as translucent objects and geometrically complex objects with multiple interreflections and intricate geometries. These techniques project multiple shifting projector patterns on the scene at different focus settings, and then evaluate a measure at each focus setting to determine the "best in-focus" setting for each image pixel. This setting is then used to determine the scene depths at each pixel.

16. My Ph.D. thesis is titled “Scene Recovery and Rendering Techniques Under Global Light Transport,” and explains research conducted at the Robotics Institute of Carnegie Mellon University between 2005-2011. The overall goal of the thesis was to develop active 3D imaging techniques based on projecting light patterns on scenes of interest. The thesis resulted in several publications at top computer vision venues. The thesis has a chapter (Chapter 2) that describes research on depth from projector defocus with multiple projected patterns and focus settings.

17. I have authored or co-authored the following references regarding imaging and scanning:

- Mohit Gupta, Qi Yin, and Shree Nayar, “Structured Light in Sunlight,” IEEE International Conference on Computer Vision (ICCV), 2013.
- Mohit Gupta, Srinivasa Narasimhan, and Yoav Schechner, “On Controlling Light Transport in Poor Visibility Environments,” Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2008.
- Ruilin Xu, Mohit Gupta, and Shree Nayar, “Trapping Light for Time-of-Flight,” Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2018.

- Mohit Gupta, Shree Nayar, Matthias Hullin, and Jaime Martin, “Phasor Imaging: A Generalization of Correlation Based Time-of-Flight Imaging,” ACM Transactions on Graphics (ACM TOG 2015).
- Mohit Gupta and Shree Nayar, “Micro Phase Shifting,” Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2012.
- Shree Nayar and Mohit Gupta, “Diffuse Structured Light,” Proc. IEEE International Conference on Computational Photography (ICCP), 2012.
- Mohit Gupta, Amit Agrawal, Ashok Veeraraghavan and Srinivasa Narasimhan, “3D Scanning in the Presence of Interreflections, Subsurface Scattering and Defocus,” International Journal of Computer Vision (IJCV 2012).
- Jinwei Gu, Toshihiro Kobayashi, Mohit Gupta and Shree Nayar, “Multiplexed Illumination for Scene Recovery in the Presence of Global Illumination,” IEEE International Conference on Computer Vision (ICCV), 2011.
- Mohit Gupta, Yuandong Tian, Srinivasa Narasimhan and Li Zhang, “A Combined Theory of Defocused Illumination and Global Light Transport,” International Journal of Computer Vision (IJCV 2011).

- Mohit Gupta, Yuandong Tian, Srinivasa Narasimhan and Li Zhang, “(De) Focusing on Global Light Transport for Active Scene Recovery,” Proc. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2009.
- Nathan Matsuda, Oliver Cossairt, and Mohit Gupta, “MC3D: Motion Contrast 3D Scanning,” IEEE International Conference on Computational Photography (ICCP) 2015.
- Jongho Lee and Mohit Gupta, “Stochastic Exposure Coding for Handling Multi-ToF-Camera Interference,” IEEE International Conference on Computer Vision (ICCV), 2019.
- Mohit Gupta and Shree Nayar, “Systems, Methods, and Media for Performing Shape Measurement,” Inventors:, Patent granted, May 2017: US 2015/0176982 A1
- Mohit Gupta, “Scene Recovery and Rendering Techniques Under Global Light Transport,” Ph.D. Thesis, Carnegie Mellon University, 2011.

18. I understand that anticipation of a claim requires that every element of a claim is disclosed expressly or inherently in a single prior art reference.

19. I further understand that obviousness must be analyzed from the perspective of a person of ordinary skill in the relevant art (a “POSA”) at the time

the invention was made. In analyzing obviousness, I understand that it is important to understand the scope of the claims, the level of skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and any secondary considerations. I understand that such secondary evidence can include evidence of commercial success caused by an invention, evidence of a long-felt need that was solved by an invention, evidence that others copied an invention, or evidence that an invention achieved a surprising result. I understand that such evidence must have a nexus, or causal relationship to the elements of a claim, in order to be relevant to the obviousness or non-obviousness of the claim.

20. I also understand that the '146 patent was filed on March 19, 2021, and claims priority to U.S. Provisional Patent App. Ser. No. 61/187,744, filed on June 17, 2009 (the "purported Effective Date"). EX1001, Cover. I have analyzed obviousness in this report as of the purported Effective Date or somewhat before, understanding that as time passes, the knowledge of a POSA will increase.

21. I understand that under certain circumstances the owner of the '146 patent might try to prove an even earlier date of invention, *i.e.*, earlier than June 17, 2009. If this occurs, I reserve the right to revise my opinion(s). I will refer to the relevant time period as 2009 in this declaration, with the understanding that this does not include the time period on or after the purported Effective Date.

22. I understand claim terms of a patent in IPR shall be construed using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

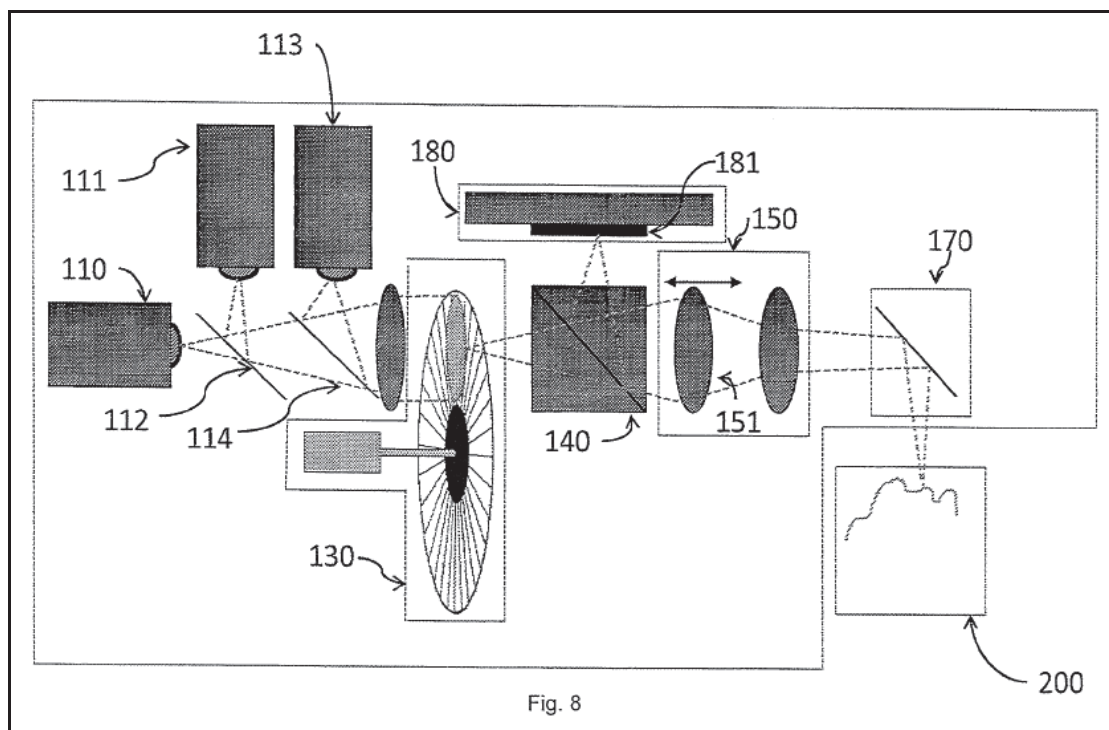
23. I have reviewed the concepts disclosed in the '146 patent based on the language of the claims, the specification of the '146 patent, and the knowledge of a person of ordinary skill as of the purported Effective Date. I have also reviewed the petition for *inter partes* review.

24. In forming my opinion, I have relied on the '146 patent claims and disclosure, the prosecution history of the '146 patent, the pertinent exhibits to the Petition for *inter partes* review of the '146 patent, my own experience and expertise, and the knowledge of the person of ordinary skill in the relevant art in the 2009 timeframe.

25. In 2009, I believe that a POSA would have had a bachelor's degree in Computer Engineering, Computer Science, Electrical Engineering, Physics, or an equivalent field, as well as at least one or two years of design experience, or alternatively, at least five years of comparable industry experience. In particular, a POSA would have had experience with and knowledge of 3D imaging systems and 3D modeling techniques.

III. THE TECHNOLOGY CLAIMED IN THE '146 PATENT

26. The '146 patent relates to a scanner for intraoral scanning of objects such as teeth. EX1001, Abstract, 1:24-30, claim 1. The scanner obtains the 3D geometry of at least part of the surface of the object and also determines the color of at least part of the surface of the object. *Id.*, 2:43-45, 33:45-34:18. An example embodiment of the device for scanning for surface shape and color is shown in FIG. 8 as follows:



Id., FIG. 8.

27. The scanner includes a pattern generator to create a pattern of light, such as a line pattern or checkerboard pattern, on the object being scanned. *Id.*, 8:38-57, 27:20-28, 28:4-13. The pattern is made to be time-varying by rotating

and/or translating a pattern element such that, for example, the pattern moves across the object being scanned. *Id.*, 3:9-14, 4:62-65, 8:38-58, 10:57-59. The scanner further varies the position of a focal plane for the scanner and obtains images with the time-varying pattern on the object at the different focal plane positions. *Id.*, 3:34-46, 6:62-7:50, 12:1-5. The scanner then uses images from the focal plane positions to determine for each pixel the focal plane for which the pixel is most in-focus and uses that information to determine the 3D surface information for the pixel. *Id.*, 3:59-4:8.

28. The scanner further includes three light sources that emit red, green, and blue light. *Id.*, 33:45-48. In the preferred embodiment, one light source is switched on at a time, and an image is taken of the object for each of the light sources individually. *Id.*, 33:53-60. The color of the surface of the object is then determined based on the amplitude signal for each color in the captured images. *Id.*, 33:64-67.

29. The '146 patent tersely mentions in a single sentence that the scanner head may be wireless. *Id.*, 9:16-21. The '146 patent also tersely mentions in a single sentence that the camera used to obtain the images can be a high-speed camera with multiple analog-to-digital (A/D) converters per line of pixels. *Id.*, 8:1-8.

30. The current claims of the '146 patent were added by preliminary

amendment prior to examination, and the claims went directly to allowance.

EX1004. In the Notice of Allowance, the Examiner indicated as follows:

With respect to current claim 1 (previously numbered as claim 2), the Examiner stated that the distinct features of the claim were:

- a pattern generator configured to generate, using a light source, a probe light with a plurality of configurations in the form of a time-varying illumination pattern; and
- an optical system for transmitting the probe light towards the object along an optical path thereby illuminating at least a part of the object with the time-varying illumination pattern, and for transmitting at least a part of the light returned from the object to the at least one camera to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern.

With respect to current claim 21 (previously numbered as claim 22), the Examiner stated that the distinct features of the claim were:

- using a light source and a pattern generator to generate a probe light with a plurality of configurations in the form of a time-varying illumination pattern;
- transmitting the probe light, through a tip of intraoral scanner inserted

into the oral cavity, towards the object along an optical path, thereby illuminating at least a part of the object with the time-varying illumination pattern; and

- transmitting at least a part of the light returned from the object to at least one camera accommodating an array of sensor elements to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern.

Id., Notice of Allowability, May 28, 2021, p. 2.

31. I understand that, for purposes of this proceeding, all claim terms should be given their ordinary and customary meaning unless a claim construction is provided for a term. I point out the following particular statements in the '146 patent for the claim terms “time-varying illumination pattern” and “high-speed camera.”

32. The '146 patent states that a time varying pattern is: a pattern that varies in time (EX1001, 4:62-65); and can be created by moving a pattern across the object being scanned by rotating and/or translating a pattern element (*Id.*, 3:11-14, 8:54-57, 10:57-59).

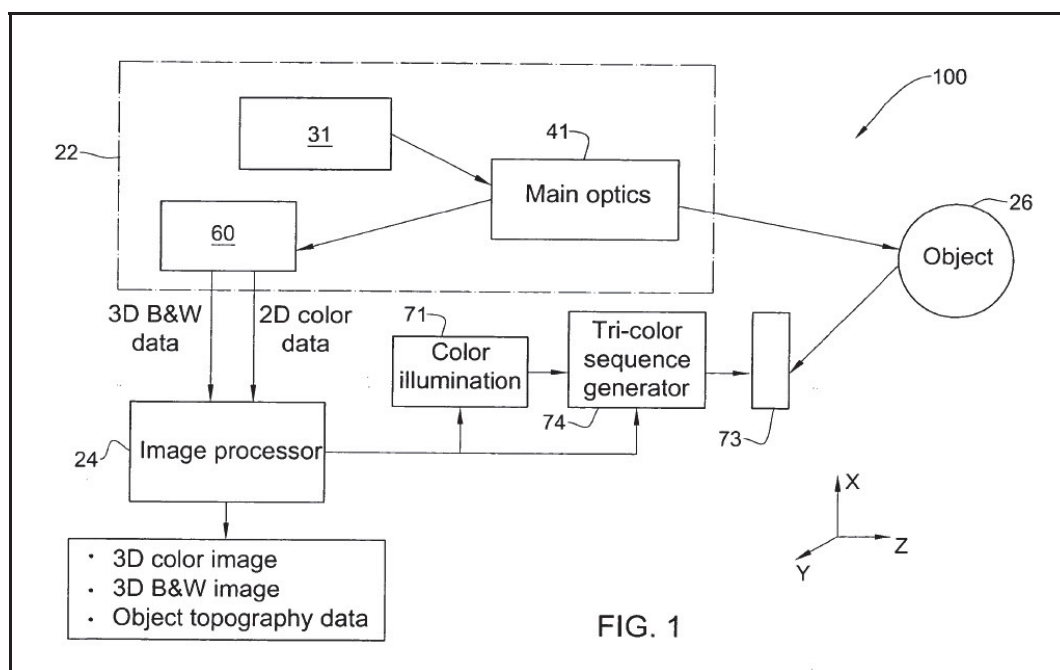
33. The '146 patent states that a standard camera has one A/D converter per line of pixels, but that a “high-speed” camera accommodates multiple A/D

converters per line of pixels. *Id.*, 8:1-8.

IV. OVERVIEW OF PRIOR ART

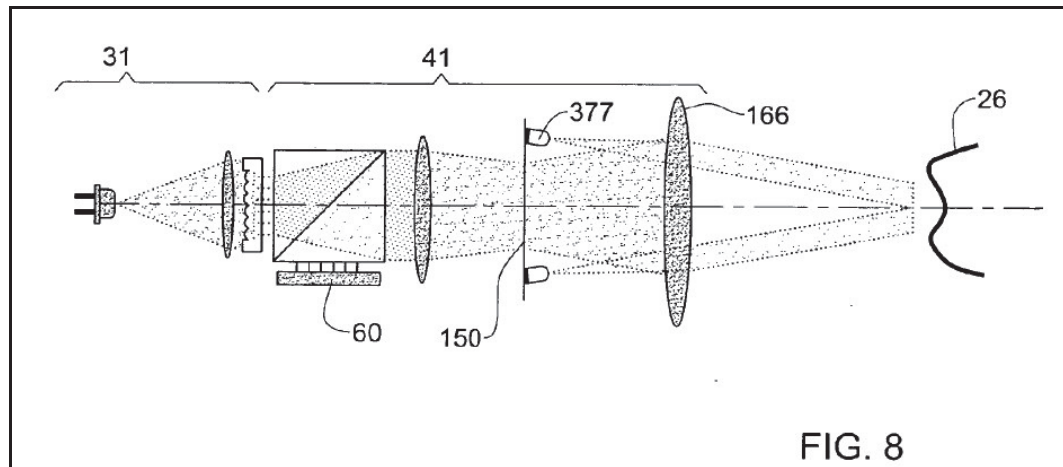
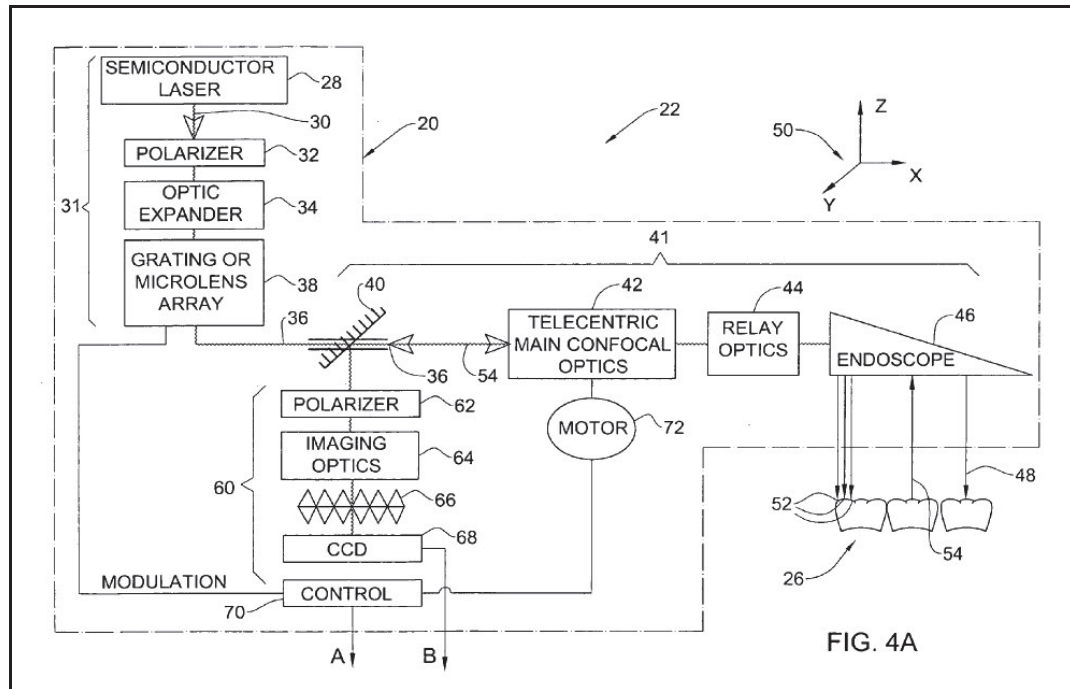
A. Babayoff

34. Babayoff discloses a scanner for the intraoral scanning of objects such as teeth. EX1005, Abstract, [0001], [0009], [0129]. The scanner obtains the 3D geometry of at least part of the surface of the object and also determines the color of at least part of the surface of the object. *Id.*, [0010]-[0015], [0021]-[0048], [0063]-[0066], [0129]-[0131], [0134]-[0150]. An example embodiment of the device for scanning for surface shape and color is shown in FIG. 1:



Id., FIG. 1.

35. Babayoff teaches examples of the scanner in FIGS. 4A and 8 as follows:



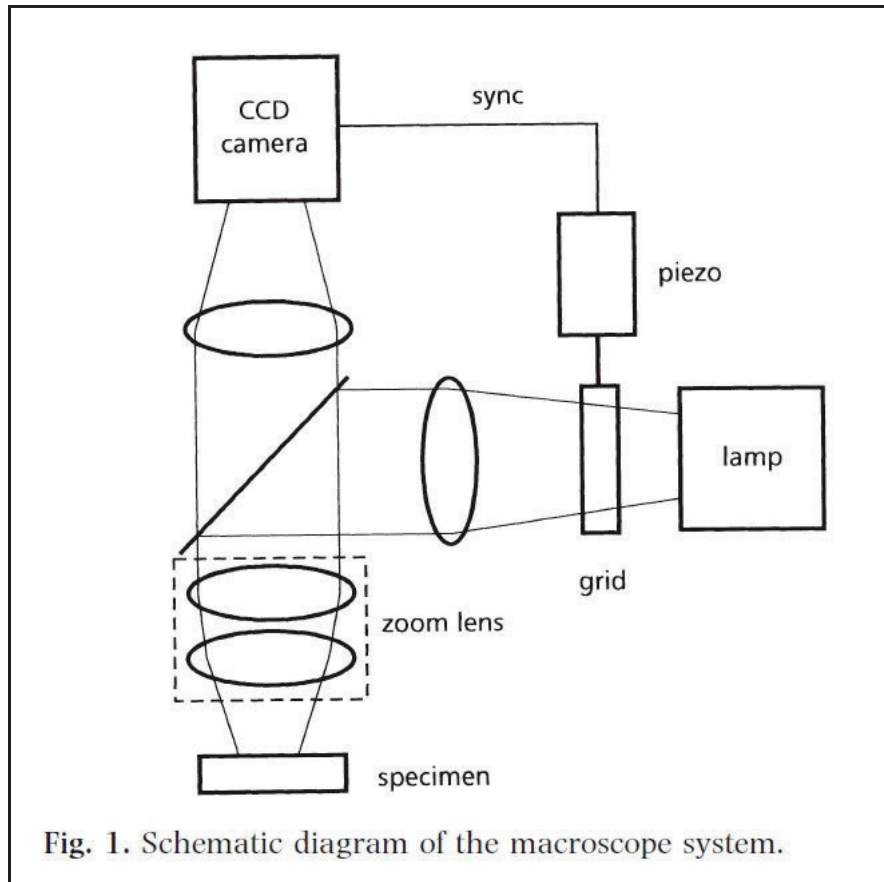
36. The scanner is a confocal scanner, varies the position of a focal plane for the scanner, and obtains images of the object at the different focal plane positions using an image sensor. *Id.*, [0010]-[0011], [0032], [0142]. The scanner then uses images from the focal plane positions to determine for each pixel the focal plane for which the pixel is most in-focus and uses that information to determine the 3D surface information for the pixel. *Id.*, [0013]-[0015], [0034],

[0143].

37. The scanner further includes three light sources that emit red, green, and blue light. *Id.*, [0063]-[0066], [0079], [0130], [0157]. In a preferred embodiment, only one light source is switched on at a time, and an image is taken of the object for each of the light sources individually. *Id.* The color of the surface of the object is then determined based on the signal for each color in the captured images. *Id.*, [0063], [0079], [0130], [0145].

B. Wilson

38. Similar to Babayoff, Wilson discloses a confocal imaging system and explains that to obtain a more accurate optically sectioned image of a macroscopic structure using a confocal optical system, it is better to take three images instead of only one image, where each of the three images is taken with a grid pattern (also called a fringe pattern) projected onto the structure at a different spatial position to create a time-varying illumination pattern. EX1006, pp. 116-118, Fig. 1. Wilson teaches that the optically sectioned image can then be obtained from the three images using a look-up table that is valid for the grid pattern used to obtain the images. *Id.*, p. 118. Wilson shows in Fig. 1 a schematic diagram of the confocal microscope system.



Id., Fig. 1.

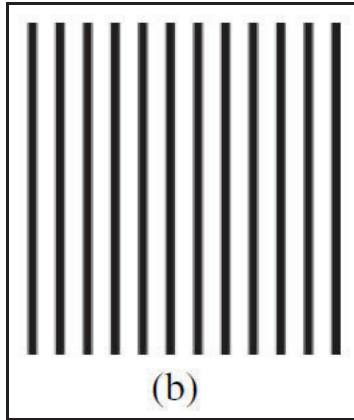
39. Wilson uses the grid to introduce a grid (fringe) pattern onto the object, and the grid is moved by a piezoelectric device (piezo) in a sawtooth fashion synchronized to the camera frame rate such that three successive camera images correspond to a spatial shift of one-third of a period of the projected image of the grid. *Id.*, p. 118. The grid in Wilson is, for example, a series of lines. *Id.* Moving the grid in the sawtooth fashion as in Wilson creates a time-varying illumination pattern. *Id.* Wilson shows an example where the system has been used to obtain an optically sectioned image of a wristwatch mechanism. *Id.*, pp. 117-

118, Fig. 2. Wilson explains that equation (3) in Wilson follows from a more detailed theory as provided by Neil. EX1006, pp. 116, 118. Neil in turn shows an equation (4) for calculations. EX1010, p. 1905.

C. Zhang

40. Similar to Babayoff, Zhang discloses a coaxial imaging system, and Zhang explains that an alternative to a camera focus/defocus method for obtaining 3D shape information is a projection defocus method in which an illumination pattern is shifted across a scene to allow for measuring depth information for a 3D shape. EX1011, pp. 907-910, Figs. 1, 2. Zhang explains that multiple images are taken as the illumination pattern is shifted across the scene, and depth information is determined for each camera pixel using the captured images and knowledge of the illumination pattern. *Id.* Zhang provides an example of the illumination pattern as a periodic stripe pattern that is shifted across the scene and can be formed, for example, by a Digital Light Processing (DLP) or Liquid Crystal Display (LCD) projector. *Id.*, pp. 907, 909, Fig. 2.

41. An example of the illumination pattern that is shifted across the scene is shown in Figure 2(b) of Zhang as follows:



Id., Fig. 2(b).

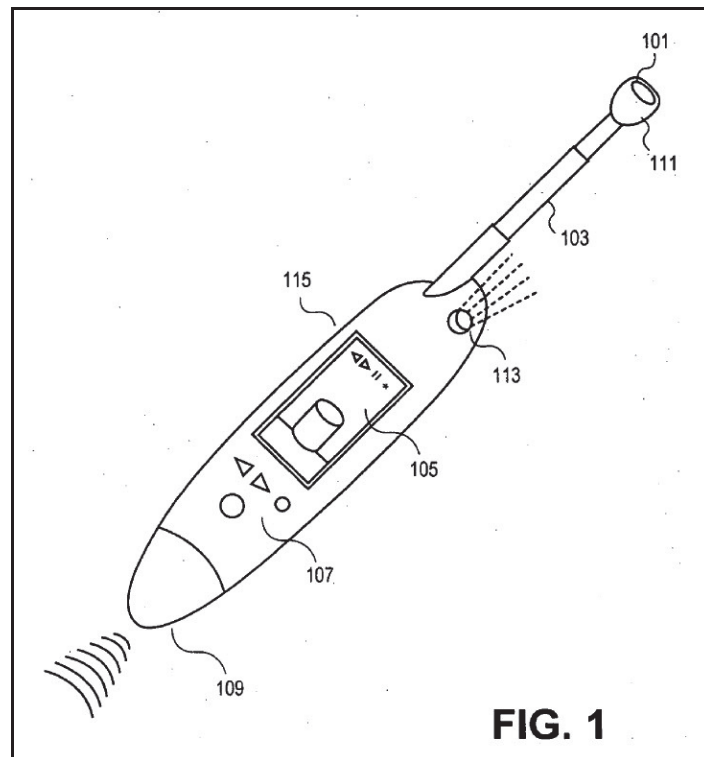
42. Zhang provides the motivation for using a projection defocus method with a shifting illumination pattern as an alternative to a camera focus/defocus method by explaining that the projection defocus method for obtaining 3D shape information is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and texture, which makes it superior to camera defocus for depth estimation. *Id.*, 907-908, 914.

D. Knighton

43. Knighton discloses a hand-held scanner similar to Babayoff's for scanning an object to obtain 3D information for the surface of the object. EX1007, Abstract, [0024]-[0025], [0033], [0038], [0045], [0049], [0093], FIGS. 1, 3. Knighton similarly discloses the capture of multiple images at distinct focus positions and then producing a depth map for the three-dimensional data based on the light intensities from the captured images. *Id.*, [0026]-[0027], [0047]-[0053],

FIG. 4. Knighton teaches that the processor 301 for performing the processing can be included in the hand-held device such that the processing is performed locally at the hand-held device to generate the 3D geometry data. *Id.*, [0025], [0029], [0038]-[0039], [0041], [0049], [0054], [0093], FIG. 3. Knighton further explains that the hand-held device can include a communications device and an antenna for wirelessly transmitting the data for the 3D geometry. *Id.*, [0033], [0038], [0045], [0049], [0054], [0093], FIGS. 1, 3.

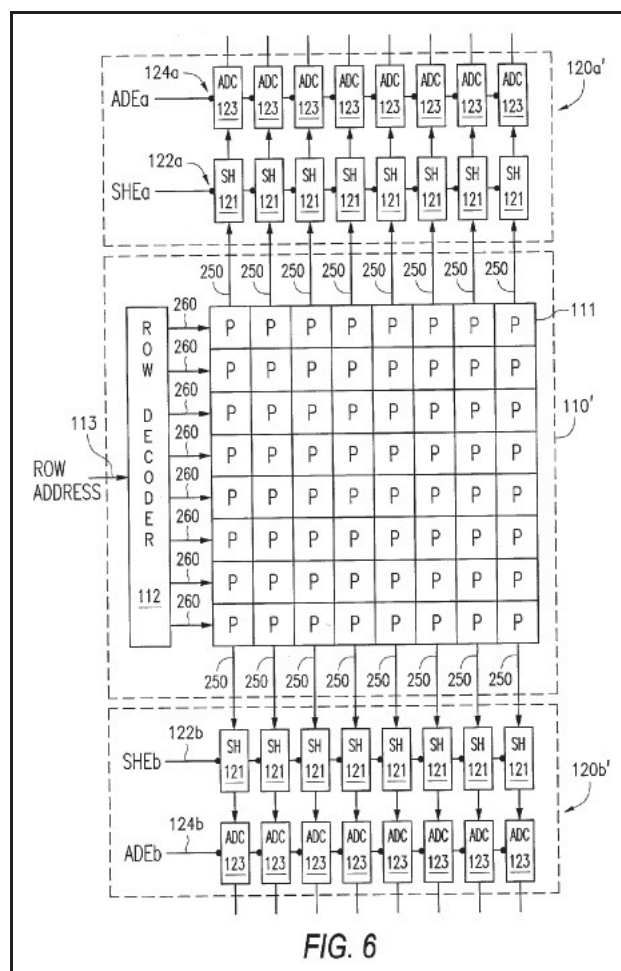
44. FIG. 1 of Knighton is shown below with the wireless communication device 109 for wirelessly transmitting data from the hand-held scanner.



Id., FIG. 1.

E. Hanson

45. Hanson discloses that an image sensor can have multiple A/D converters per line of pixels in a pixel array to increase the speed of the image sensor. EX1008, Abstract, [0017], [0028], [0030]-[0037], FIGS. 3, 5, 6. FIG. 6 of Hanson shows a pixel array 110' as well as analog processing and digitizing circuits 120a', 120b', which each include a plurality of A/D converters 123.

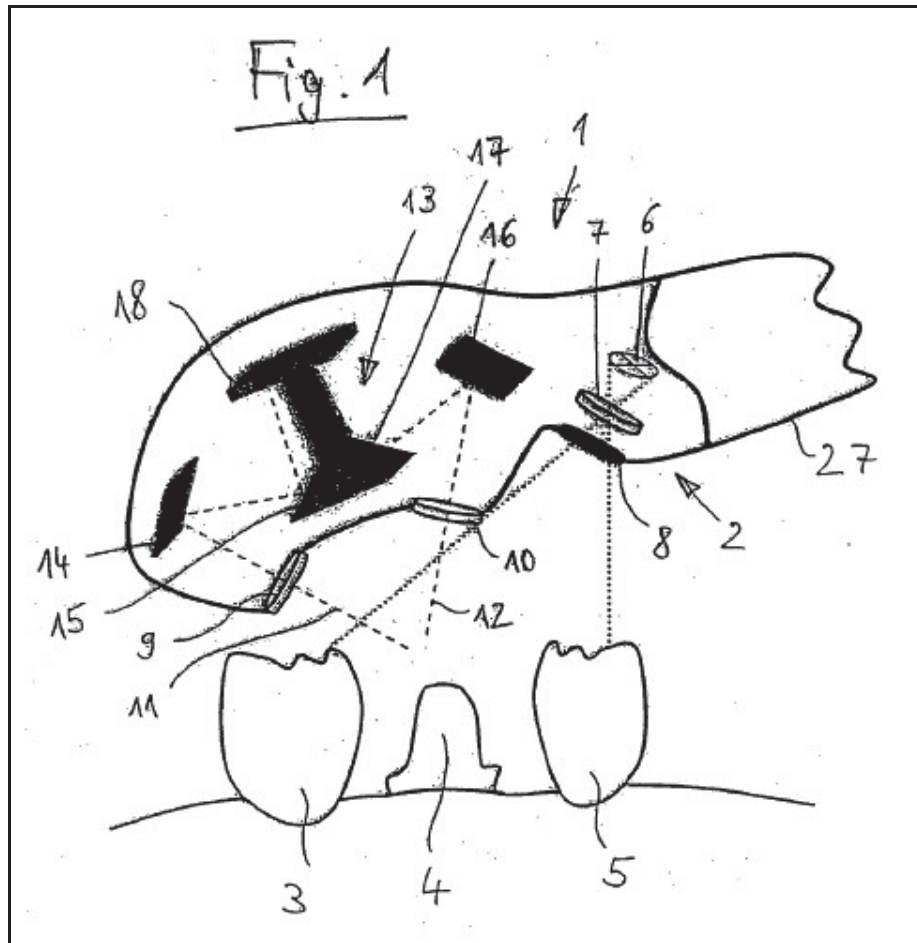


Id., FIG. 6.

46. Hanson explains that having the multiple A/D converters 123 allows for the image sensor to be high speed. *Id.*, [0017], [0028], [0030]-[0037].

F. Gandyra

47. Gandyra is yet another reference that discloses an intraoral scanner for scanning teeth and also teaches the use of a time-variable illumination pattern for the scanning. EX1009, Abstract, [0001], [0030], [0038], FIG. 1. An example of the intraoral scanner is shown in FIG. 1:



48. Gandyra teaches that the pattern can be any graphical pattern such as lines, and further teaches that the pattern can be produced using a pattern transparency, which is a transparent pattern element. *Id.*, [0030], [0038]. Gandyra also teaches that the time-varying pattern can be produced using a transmitted-light

LCD or a DLP projection. *Id.*, [0030], [0038].

V. INVALIDITY OF THE '146 PATENT

A. Ground 1: Claims 21, 23-27, and 29 Are Obvious Over Babayoff and Zhang and Knighton

1. Claim 21

[preamble] “21. A method for determining the 3D geometry and color of at least a part of the surface of an object in an oral cavity, said method comprising the steps of:”

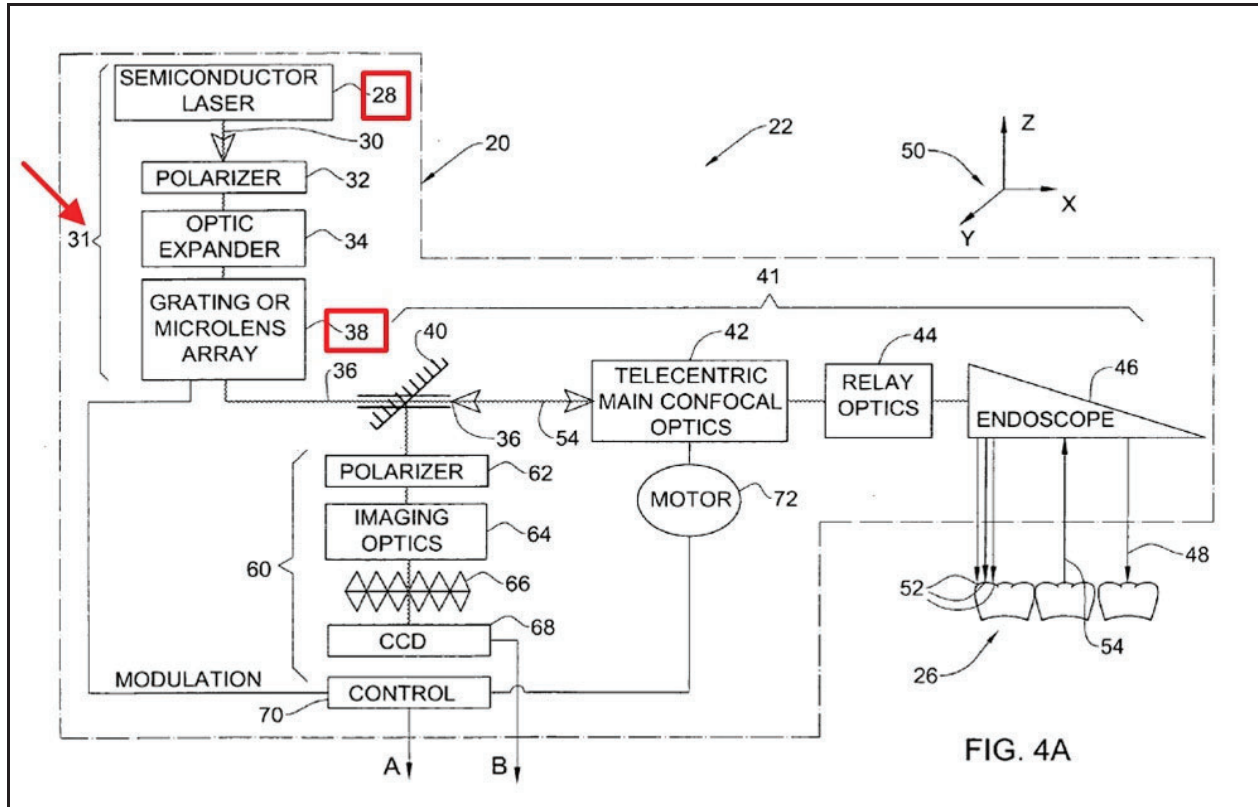
49. In my opinion, to the extent that the preamble of claim 21 is limiting, Babayoff discloses the features of the preamble. Babayoff discloses a method for determining the surface topology and associated color of a structure, such as a teeth segment in an oral cavity. EX1005, Abstract, [0009], [0021], [0023]. Babayoff shows an example structure to be scanned as the object 26 in FIGS. 4A, 5C, and 8, which is explained by Babayoff to be one or more teeth in an intraoral cavity. *Id.*, Abstract, [0009], [0129], [0183], FIGS. 4A, 5C, 8. Babayoff states that the surface topology that is determined of the object is a 3D surface topology, which provides the 3D geometry of the object. *Id.*, Abstract, [0010], [0020]-[0022], [0129], [0131], [0143], FIGS. 2A, 2B. Babayoff discloses that the color of the object is also determined and is associated with the 3D geometry of the object to provide a 3D digital representation of the object including color. *Id.*, Abstract,

[0001], [0009], [0020]-[0022], [0028], [0129]-[0131].

[a] “using a light source and a pattern generator to generate a probe light with a plurality of configurations in the form of a time-varying illumination pattern;”

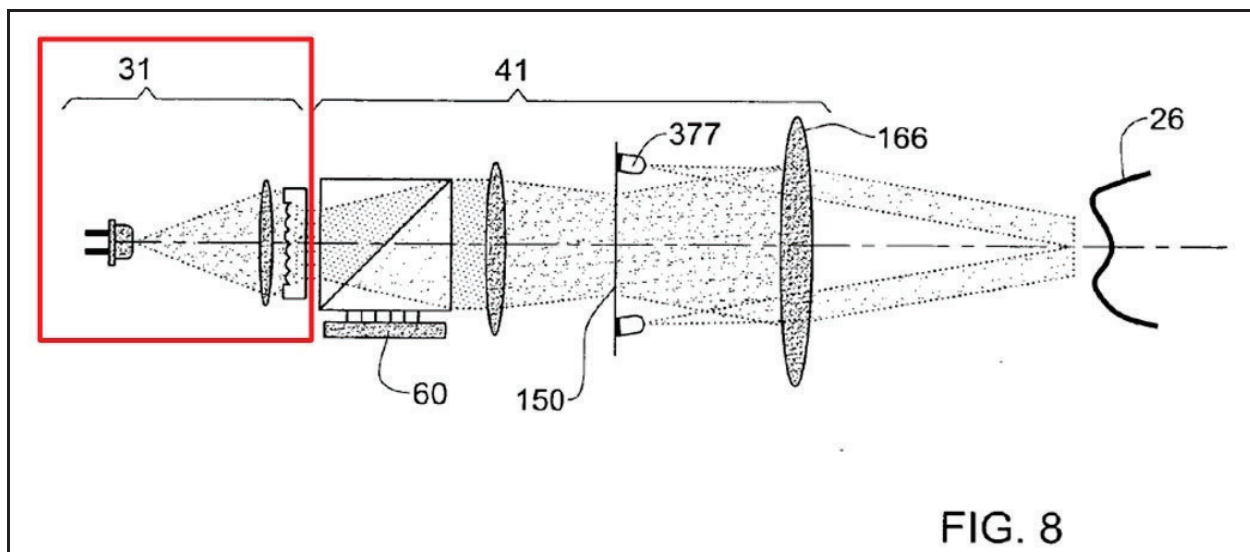
50. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 21. The light source in Babayoff is part of the illumination source 31, which is also called the illuminating unit 31, as shown for example in the embodiments of FIGS. 4A and 8. EX1005, [0030], [0134], [0135], [0139], [0156]-[0157], FIGS. 1, 4A, 8. Namely, FIG. 4A of Babayoff shows the light source as the semiconductor laser unit 28, and FIG. 8 of Babayoff shows a light as the light source. *Id.* The pattern generator in Babayoff is also part of the illumination source 31, and is shown in FIGS. 4A and 8 as a grating or micro-lens array called the module 38. *Id.*, [0135], FIGS. 4A, 8. Babayoff explains that the module 38 splits the parent light beam 30 into a plurality of incident light beams 36. *Id.* The plurality of incident light beams 36 travel through the main optics 41 to provide the incident light beams 48, which are an array of light beams and therefore form a pattern on the surface of the object 26. *Id.*, [0135]-[0139], FIGS. 1, 4A, 8. The incident light beams 36 that become the incident light beams 48 are a probe light. EX1005, [0135]-[0139], FIGS. 1, 4A, 8.

51. FIG. 4A of Babayoff is annotated in red below to show the illumination source 31 that includes the semiconductor laser unit 28 as well as the module 38 that is a grating or micro-lens array, which provides the incident light beams 36 that become the incident light beams 48.



EX1005, FIG. 4A (annotated).

52. FIG. 8 of Babayoff is annotated in red below to similarly show the illumination source 31.



Id., FIG. 8 (annotated).

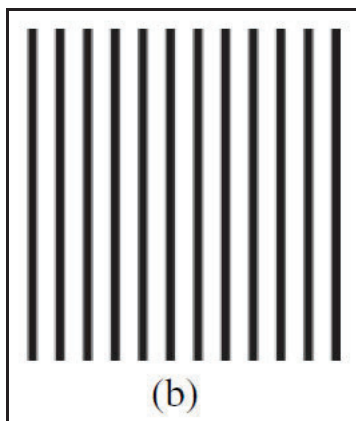
53. Babayoff discloses a technique for determining a Z or depth coordinate for each location on the object 26 for the 3D representation. *Id.*, [0010]-[0015], [0139]-[0143]. In particular, Babayoff provides motor 72 that is linked to the telecentric confocal optics 42 for changing the relative location of the focal plane of the optics 42 along the Z-axis. *Id.*, [0142], FIG. 4A. As explained in paragraph [0142] of Babayoff, the motor 72 displaces the optical element 42 to change the focal plane location and then an image is captured by the image-capturing module 80 for that focal plane location. *Id.* This process is repeated for different focal plane locations with an image taken for each focal plane location, and the motor 72 is used to change between the focal plane locations. *Id.*, [0011], [0032], [0139]-[0142]. Babayoff then determines the Z-axis depth coordinate for each (X, Y) location by analyzing the light intensity at the location in the captured

images. *Id.*, [0012]-[0015], [0139], [0143]. For determining the depth coordinates, therefore, Babayoff takes an image at each focal plane position using the light pattern as created by the illumination source 31. *Id.*, [0011], [0032], [0139]-[0142], FIGS. 4A, 8.

54. As discussed above, for determining the depth coordinates, Babayoff takes an image at each focal plane position using the light pattern as created by the illumination source 31. *Id.*, [0011], [0032], [0139]-[0142], FIGS. 4A, 8. Babayoff does not explicitly disclose that the light pattern is time-varying. However, Zhang is in the same field as Babayoff because Zhang also discloses a confocal or coaxial imaging system like Babayoff for obtaining 3D shape information, and Zhang also discloses to use a light source and a pattern generator to generate a probe light with a plurality of configurations in the form of a time-varying illumination pattern. EX1011, pp. 907-910, Figs. 1, 2. As discussed above, Babayoff employs at least in part a camera defocus method for determining the depth coordinates. EX1005, [0011], [0032], [0139]-[0142], FIGS. 4A, 8. Zhang discloses that an alternative to a camera defocus method for determining the depth coordinates is a projection defocus method in which an illumination pattern is shifted across the object being imaged to measure depth. EX1011, pp. 907-910, 914-915, Figs. 1, 2. Whereas Babayoff captures a single image at each focus setting, Zhang discloses the projection defocus method in which the illumination pattern is shifted across the

object being imaged to measure depth at each focus setting, and multiple images are captured, one for each shift.

55. Zhang provides an example of the illumination pattern as a periodic stripe pattern that is shifted across the scene and can be formed, for example, by a Digital Light Processing (DLP) or Liquid Crystal Display (LCD) projector. *Id.*, pp. 907, 909, Fig. 2. An example of the illumination pattern that is shifted across the scene is shown in Figure 2(b) of Zhang as follows:



Id., Fig. 2(b).

56. As discussed above in the section on Claim Construction, the '146 patent states that a time varying pattern can be created by moving a pattern across the object being scanned by translating a pattern element EX1001, 3:11-14, 8:54-57, 10:57-59. The illumination pattern of Zhang that is shifted across the scene at time intervals, therefore, is a time-varying illumination pattern. EX1011, p. 909, Fig. 2(b). The DLP or LCD projector of Zhang is the light source and pattern generator to generate the probe light with the plurality of configurations in the

form of the time-varying illumination pattern. *Id.*, pp. 907, 909, Figs. 1, 2. The plurality of configurations are the stripes being translated across the scene. *Id.*

57. Zhang provides the motivation for using a projection defocus method with a shifting illumination pattern as an alternative to a camera focus/defocus method by explaining that the projection defocus method for obtaining 3D shape information is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and texture, which makes it superior to camera defocus for depth estimation. *Id.*, 907-908, 914. It would have been obvious to a POSA, therefore, to replace the illumination source 31 in Babayoff with the DLP or LCD projector of Zhang to create a time-varying illumination pattern and to determine depth using the projection defocus method of Zhang, because Zhang's projection defocus method with a time-varying pattern is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and textures.

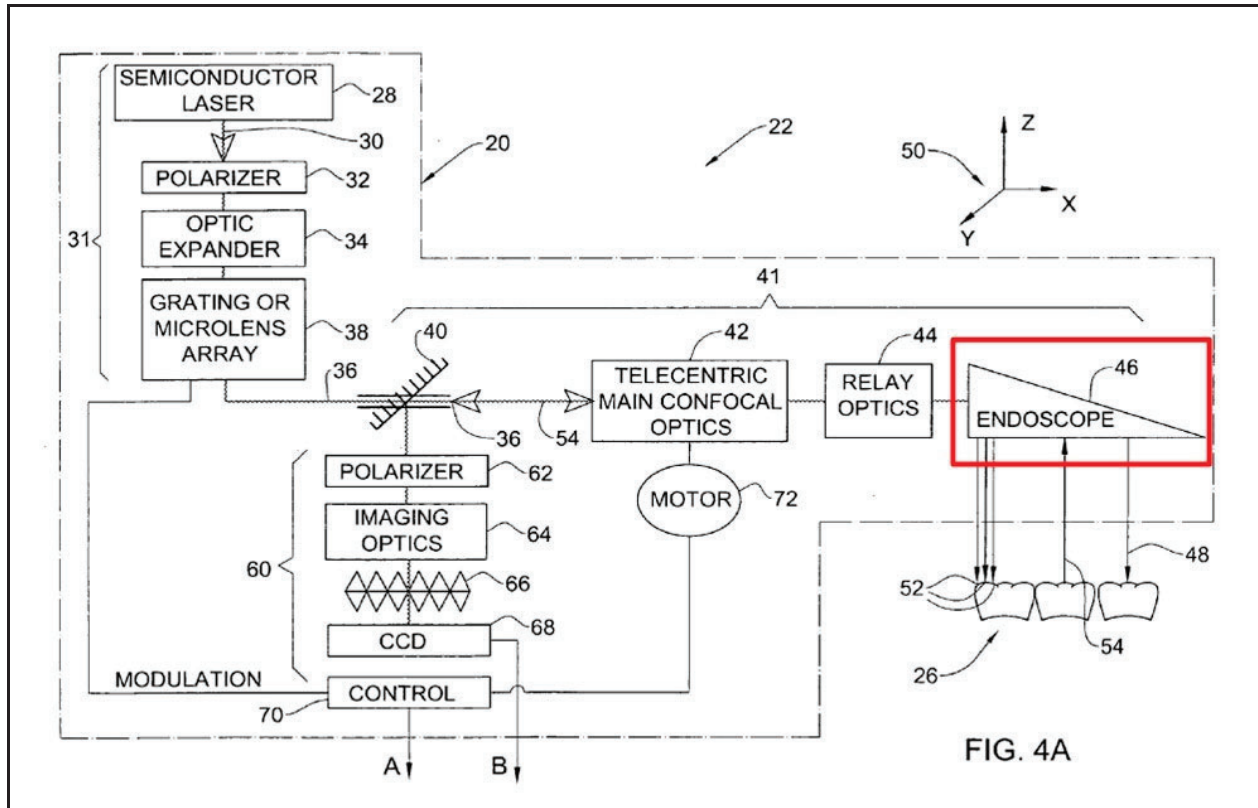
58. A POSA would have expected such a combination to work for its intended purpose because Zhang already applied the time-varying illumination pattern technique to structures that are on the same geometric scale as parts of teeth, so it would be expected to work for imaging teeth. Further, the modification to the Babayoff device to include a DLP or LCD projector as taught by Zhang in

place of the illumination source 31 would have been straightforward for a POSA to implement because it is just the substitution of one known element for another. A POSA would have understood how to size the projector to fit within a hand-held device as is exemplified by Gandyra. EX1009, [0030], [0038].

[b] “transmitting the probe light, through a tip of intraoral scanner inserted into the oral cavity, towards the object along an optical path, thereby illuminating at least a part of the object with the time-varying illumination pattern;”

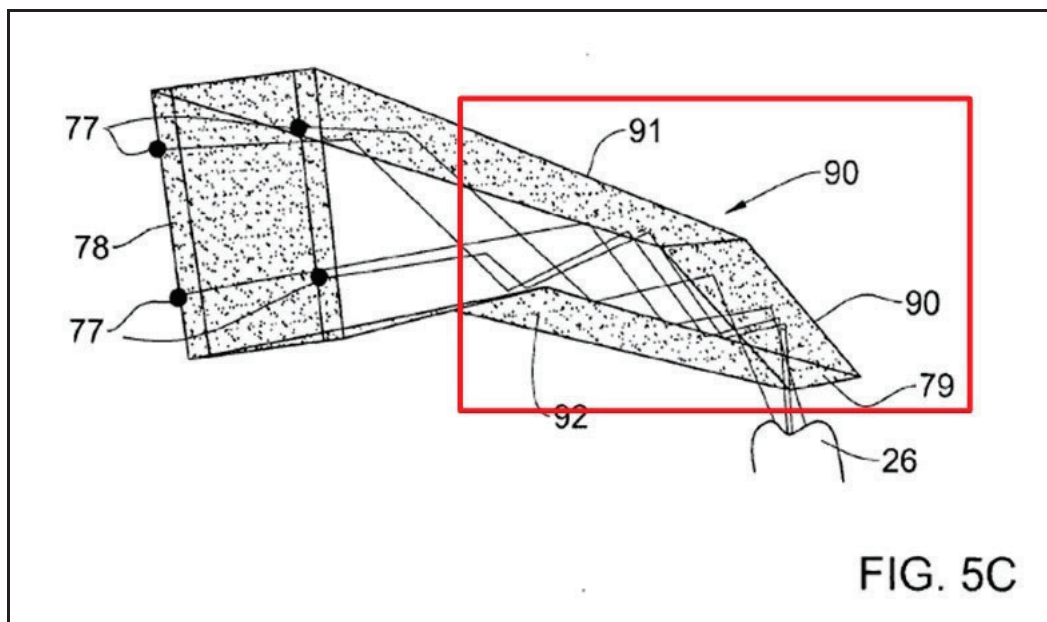
59. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 21. As discussed *supra*, the illumination source 31 in Babayoff is modified with the DLP or LCD projector as taught by Zhang, which provides the probe light with the time-varying illumination pattern. EX1005, FIGS. 1, 4A, 8; EX1011, pp. 907-909. Babayoff explains that the scanner in Babayoff is used for scanning an intraoral cavity, and shows in FIGS. 4A, 5C, and 8 that the scanned object can be one or more teeth in an intraoral cavity. EX1005, Abstract, [0001], [0021], [0183]. Babayoff teaches that the probe light is transmitted through a tip of the intraoral scanner that is inserted into the oral cavity, such as part of the endoscope 46 that can be in the form of a probing member 90. *Id.*, [0137], [0146], FIGS. 4A, 5C.

60. The below annotated version of FIG. 4A highlights the endoscope 46:



Id., FIG. 4A (annotated).

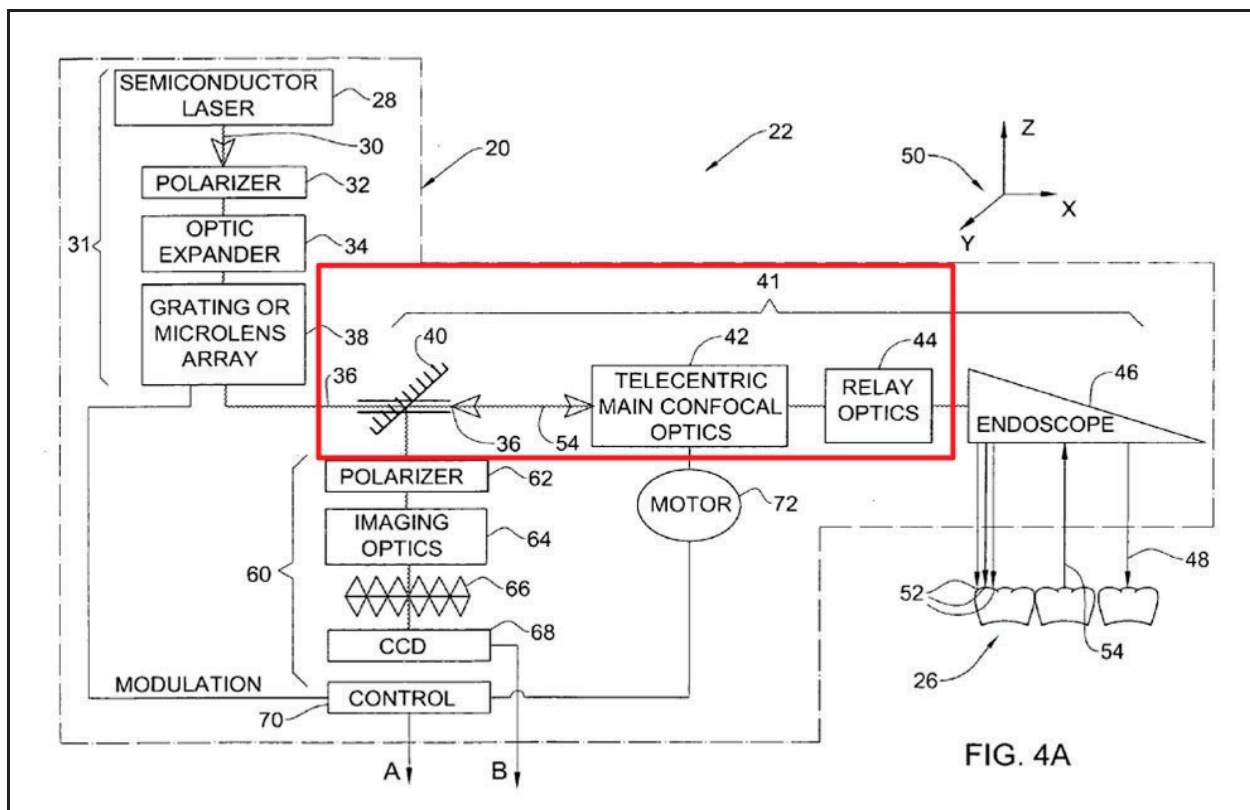
61. The below annotated version of FIG. 5C highlights an example of an end of the probing member 90:



Id., FIG. 5C (annotated).

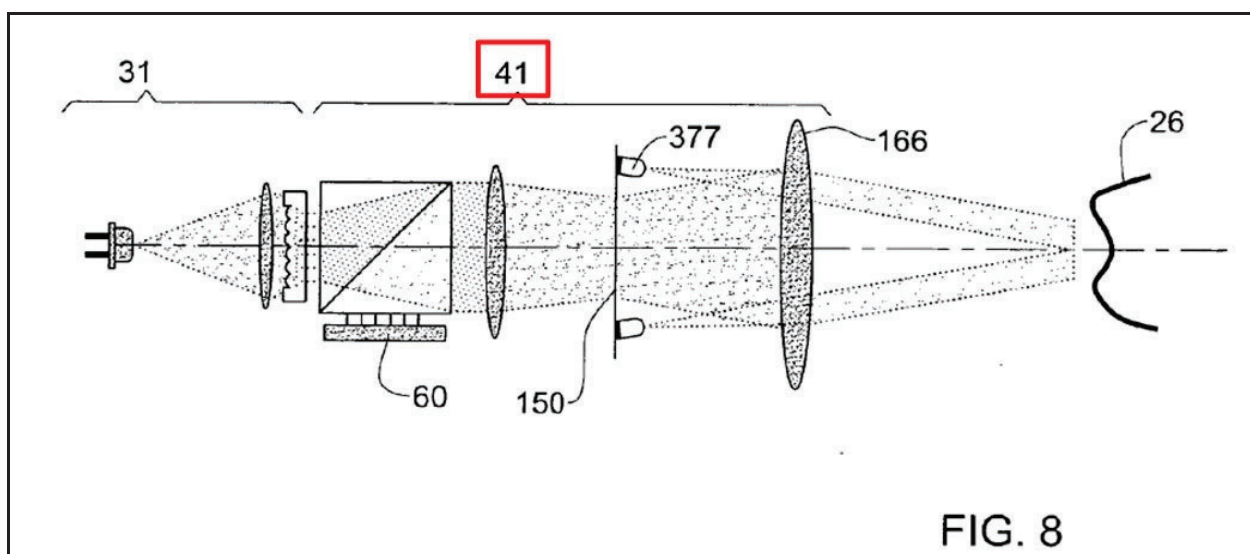
62. The optical path for the probe light in Babayoff includes at least part of the main optics 41, such as the confocal optics 42 and the relay optics 44. *Id.*, [0137]-[0139], FIGS. 4A, 8. Babayoff shows that the light from the illumination source 31 is transmitted toward the object 26 along the optical path provided by the main optics 41 and goes through the tip such as part of the endoscope 46. *Id.*, [0134]-[0139], FIGS. 4A, 5C, 8.

63. The below annotated version of FIG. 4A highlights part of the main optics 41 through which the light is transmitted:



Id., FIG. 4A (annotated).

64. Similarly, the below annotated version of FIG. 8 highlights part of the main optics 41 through which the light is transmitted:



Id., FIG. 8.

65. The embodiment in FIG. 8 would also be understood to have a probing member for insertion into the oral cavity.

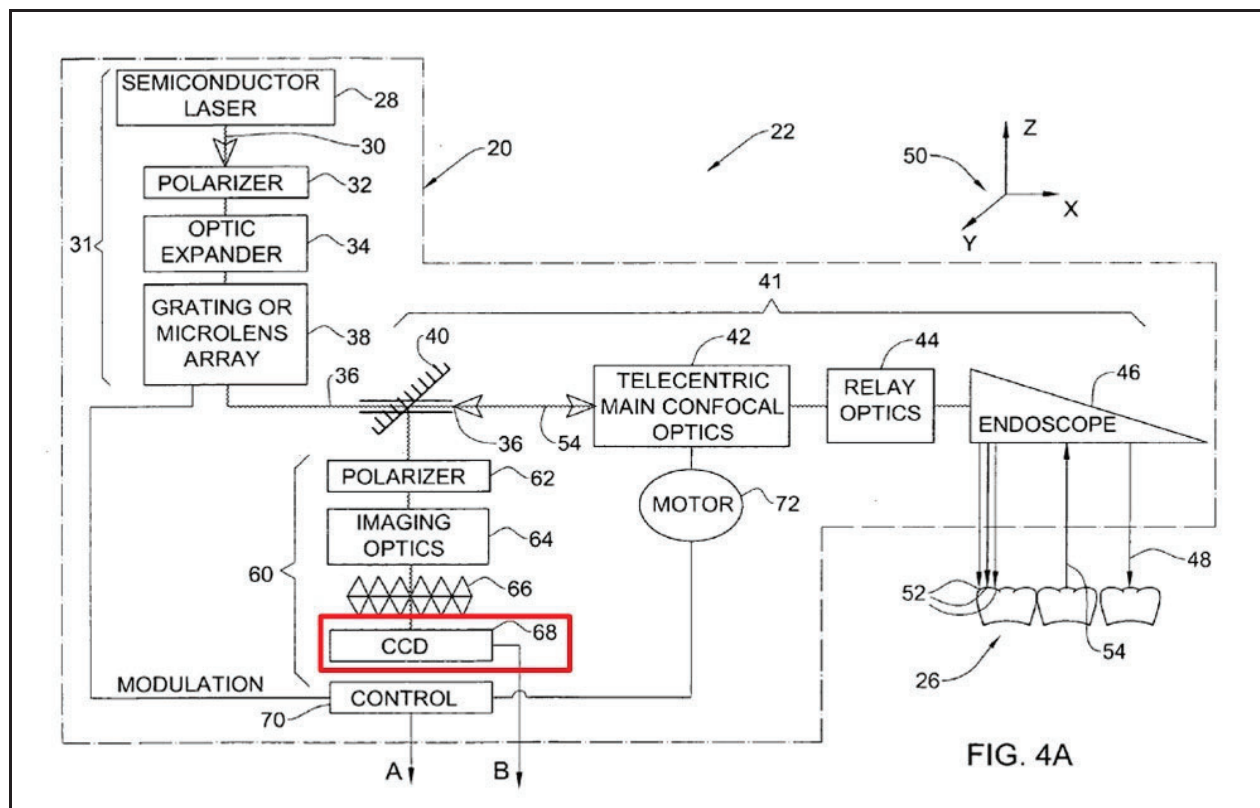
66. By having the illumination source 31 of Babayoff modified by the teaching of Zhang with the projector to provide the probe light with the time-varying illumination pattern, at least part of the object 26 in Babayoff would thereby be illuminated with the time-varying illumination pattern.

[c] “transmitting at least a part of the light returned from the object to at least one camera accommodating an array of sensor elements to form a plurality of 2D images,”

67. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 21. As discussed *supra*, the probe light with the time-varying illumination pattern would be provided by the illumination source 31 of Babayoff modified by the teaching of Zhang with the projector. Babayoff shows that at least part of the light returned from the object 26 is transmitted to an image sensor, which is part of the detection optics 60. EX1005, [0002], [0011], [0033], [0042], [0129], [0134]-[0141], [0145], FIGS. 1, 4A, 8. The image sensor in Babayoff is called a camera that accommodates an array of sensor elements, which Babayoff explains could be, for example, an array of charge coupled devices (CCD) 68. *Id.*,

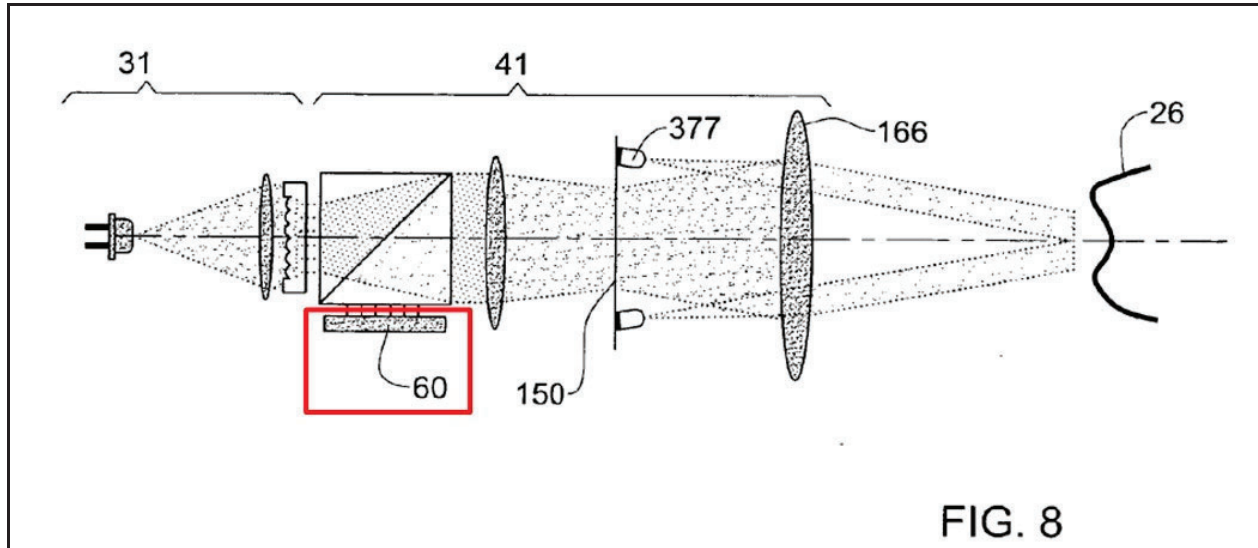
[0042], [0129], [0140]-[0141], [0145], FIG. 4A. Babayoff explains in paragraph [0140] that the returned light beams 54 from the object 26 travel initially along the opposite direction of the optical path traveled by the incident light beams and are then reflected by the mirror 40 in the direction of the detection optics 60 where the camera uses the array of sensing elements to form the 2D image, and the process is repeated a plurality of times as discussed in paragraph [0011] of Babayoff, which would result in a plurality of 2D images. *Id.*, [0011], [0139]-[0143], FIGS. 4A, 8.

68. The below annotated version of FIG. 4A highlights the CCD 68 camera in red:



Id., FIG. 4A (annotated).

69. Similarly, the below annotated version of FIG. 8 highlights the detection optics 60 in red, which includes the image sensor:



Id., FIG. 8 (annotated).

70. Just as in Babayoff, Zhang also uses a camera with a plurality of pixels, so the combination would work with the camera of Babayoff. EX1011, pp. 907-909.

[d] “wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern;”

71. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 21. As discussed *supra*, the device 100 of Babayoff as modified by Zhang would use the projector of Zhang to shift the time-varying illumination pattern across the object being imaged and would capture a plurality

of 2D images with the camera. EX1005, [0011], [0142], FIG. 4A; EX1011, pp. 907-910, 915, Fig. 1. Then, the projection defocus method described in Zhang would be used to determine the Z or depth coordinate for each (X, Y) position based on plurality of 2D images and knowledge of the time-varying illumination pattern. EX1011, pp. 907-910. The result is the 3D geometry for the object. *Id.* Zhang explains that the determination of the depth values is based on both the scene radiance as captured in the 2D images and on the projection illumination pattern, which allows for the equations in Zhang to be valid for estimating depth. *Id.*, 909. The 3D geometry, therefore, is determined based on the plurality of 2D images and the time-varying illumination pattern. *Id.* For a particular illumination pattern, the determination can be made using a pre-computed lookup table, or simple analytic computations, which are valid for the pattern, and the plurality of 2D images as described in Zhang. *Id.*, 910.

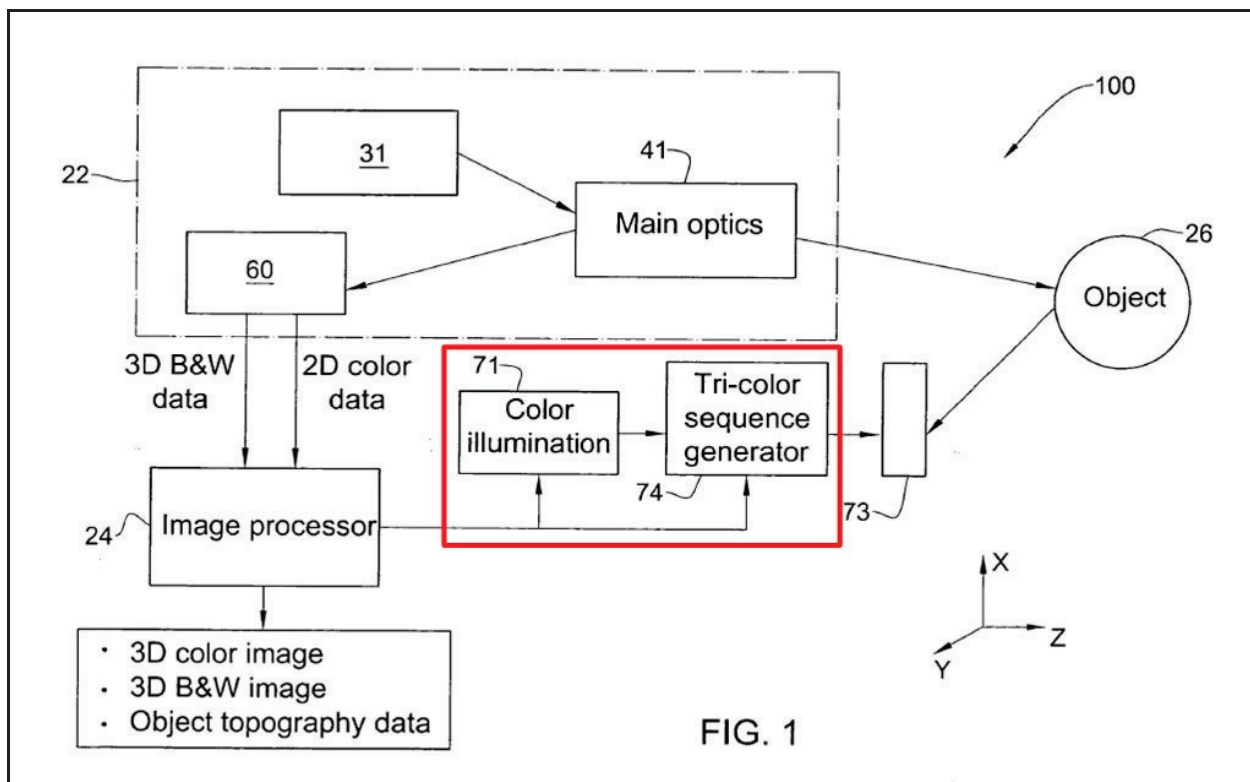
72. It would have been obvious to a POSA to determine the 3D geometry using the projection defocus method of Zhang in the device of Babayoff because Zhang explains that the projection defocus method is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and texture. *Id.*, 907-908, 914. A POSA would have had an expectation of success with the combination because it uses the projection defocus method of Zhang with the time-varying illumination

pattern for determining depth in place of the method of Babayoff, which is exactly what Zhang taught to do to obtain the noted advantages.

**[e] “selectively switching a color of the probe light,
thereby illuminating the object with different colors
at different times;”**

73. In my opinion, Babayoff discloses these limitations of claim 21. Babayoff teaches use of a tri-color sequence generator 74 to selectively switch among three differently colored illumination radiations to illuminate the object 26 with different colors at different times. EX1005, [0044], [0063]-[0064], [0079], [0130]-[0131], [0145]-[0151], [0155]-[0157], FIG. 1.

74. FIG. 1 of Babayoff is annotated below in red to highlight the tri-color light sources 71 and the tri-color sequence generator 74:



Id., FIG. 1 (annotated).

75. Babayoff explains that the tri-color light sources 71 are one or more light sources that provide illumination to the object 26 in a plurality of different colors such as red, green, and blue. *Id.*, [0145]. The tri-color sequence generator 74 is controlled to provide the three-color illuminations in a predetermined sequence. *Id.* [0130], [0145]. FIGS. 5A and 5C of Babayoff show exemplary locations of tri-color LED's 77 for providing the light in the different colors. *Id.*, FIGS. [0146], 5A, 5C. FIG. 8 similarly shows another exemplary location for the tri-color light sources 377. *Id.*, [0157], FIGS. 8, 9.

[f] “recording different images by the at least one camera at the different times, thereby recording images of the object with the different colors;”

76. In my opinion, Babayoff discloses these limitations of claim 21. Babayoff teaches to illuminate the object 26 sequentially with the three different colored lights such as red, green, and blue, and to capture a monochromatic image corresponding to each color via the detection optics 60 that includes the camera such as the CCD 68 camera. EX1005, [0044]-[0045], [0079], [0092], [0130], [0145], FIGS. 1, 4A, 8. Babayoff, therefore, teaches how to record different images by the camera at the different times, which are the times at which each of the colors illuminate the object 26, and thereby how to record images of the object 26 with the different colors. *Id.*

[g] “combining the different colors from the different images to obtain the color of the surface of the object; and”

77. In my opinion, Babayoff discloses these limitations of claim 21. Babayoff teaches that the processor 24 processes the three differently colored monochromatic images and combines the same to provide a full color image of the object 26. EX1005, [0046], [0063], [0079], [0092], [0130], [0145], FIG. 1. Babayoff explains that the processor 24 aligns the color image with the 3D entity

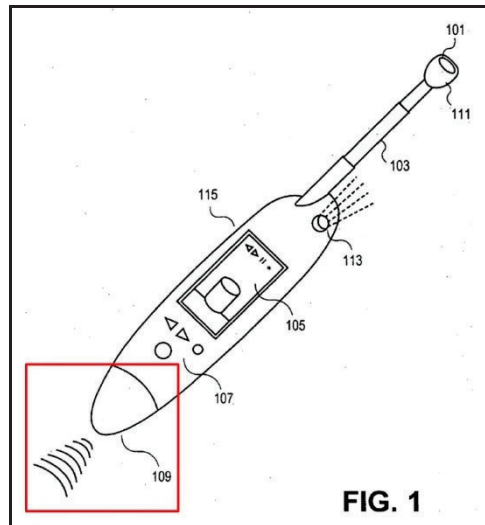
previously created to provide color values to the entity by mapping the color values to the entity, which provides the color of the surface of the object 26 for the 3D representation. *Id.*, [0009], [0065], [0131], FIG. 1.

[h] “wirelessly transmitting the data for the 3D geometry.”

78. In my opinion, Babayoff in combination with Zhang and Knighton satisfies this limitation of claim 21. Babayoff discloses that the device can be a hand-held device in which the hand-held device includes the endoscope 46, the illumination unit 31, the main optics 41, color illumination 71, tri-color sequence generator 74, and detector optics 60. EX1005, [0179], FIGS. 1, 4A, 8. Babayoff does not explicitly disclose that the hand-held device uses wireless transmission, but does provide a modem 88 for transmission of the 3D data. *Id.*, [0065], [0093], [0180]. Knighton is in the same field as Babayoff and teaches to have the hand-held scanner wirelessly transmit data for the 3D geometry of an object. EX1007, Abstract, [0024]-[0025], [0033], [0038], [0045], [0049], [0093], FIGS. 1, 3. It would have been obvious to modify the hand-held device of Babayoff based on the teaching of Knighton to process data for the 3D geometry in the device and wirelessly transmit the data for the 3D geometry. A POSA would have expected such a modification to be successful because the wireless transmission would be done in the manner taught by Knighton.

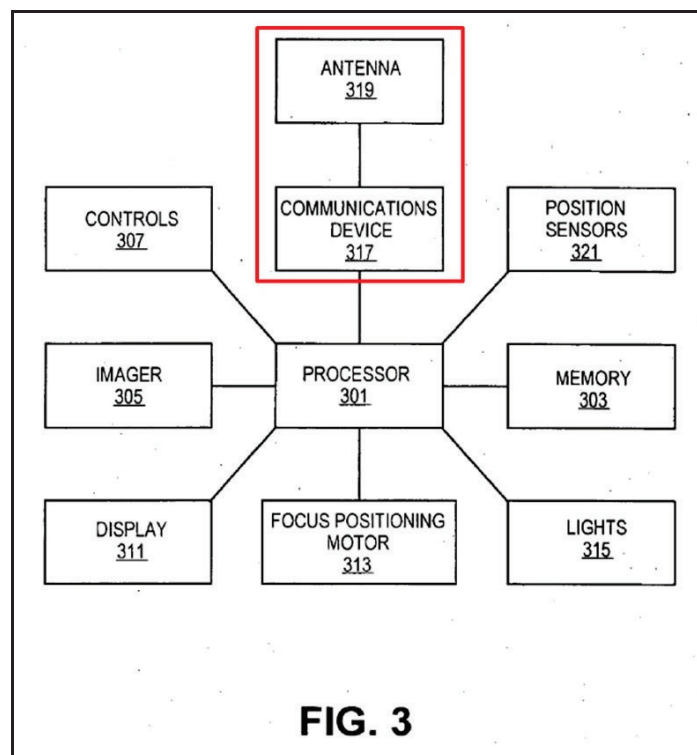
79. The processing performed in Knighton is similar to the processing performed in Babayoff and Zhang because Knighton similarly discloses to capture multiple images at distinct focus positions and then to produce a depth map for three-dimensional data based on the light intensities from the captured images. EX1007, [0026]-[0027], [0047]-[0053], FIG. 4. Knighton teaches that the processor 301 for performing the processing can be included in the hand-held device such that the processing is performed locally at the hand-held device to generate the 3D geometry data. *Id.*, [0025], [0029], [0038]-[0039], [0041], [0049], [0054], [0093], FIG. 3. Knighton explains that the hand-held device can include the communications device 317 and the antenna 319 for wirelessly transmitting the data for the 3D geometry. *Id.*, [0033], [0038], [0045], [0049], [0054], [0093], FIGS. 1, 3.

80. An annotated version of FIG. 1 of Knighton is shown below with the wireless communication device 109 and wireless communication symbol highlighted in red:



Id., FIG. 1 (annotated).

81. FIG. 3 of Knighton is annotated below to show in red the communications device 317 and the antenna 319 of the hand-held scanner device for the wireless transmission.



Id., FIG. 3 (annotated).

82. It would have been obvious to a POSA to include the processor in the hand-held device of Babayoff as is done in Knighton, and to include the communications device 317 and the antenna 319 of Knighton in the hand-held device of Babayoff so that the device of Babayoff would be wireless and, therefore, easier to carry around with improved usability in that the device would be more maneuverable with respect to an object being imaged.

2. Claim 23

“23. The method according to claim 21, wherein the method further comprises a step of locally processing, on the intraoral scanner, raw 3D data into data for the 3D geometry, such that the data for the 3D geometry is wirelessly transmitted instead of the raw 3D data, and wherein the raw 3D data is based on the plurality of 2D images.”

83. In my opinion, Babayoff in combination with Zhang and Knighton satisfies these limitations of claim 23. Babayoff discloses that the processor 24 determines the depth Z values for each (X, Y) point illuminated on the object 26 based on the plurality of 2D images obtained for the focal plane locations. EX1005, [0011]-[0015], [0129]-[0131], [0142]-[0143], FIGS. 1, 4B. In the

combination of Babayoff with Zhang, the processor 24 of Babayoff would use the projection defocus method described in Zhang to determine the Z or depth coordinate for each (X, Y) position based on plurality of 2D images and knowledge of the time-varying illumination pattern. EX1011, pp. 907-910.

84. Babayoff further discloses that the processor 24 provides the entity E that comprises the array of (X, Y, Z) points and is a 3D geometry of the surface topology of the object 26. EX1005, [0129], [0131], [0143], [0183]. This 3D geometry representation in terms of the array of (X, Y, Z) points is called a “3D point cloud,” and is a standard representation of 3D surface topology in commercial 3D scanners. Babayoff further discloses that a modem 88 is used to transmit the determined 3D surface topology data. *Id.*, [0180]. Babayoff does not explicitly disclose that the processor 24 is local on the intraoral scanner or that the transmission by the modem 88 is wireless.

85. Knighton, however, performs similar processing as Babayoff and Zhang—determining depth values based on a plurality of 2D images and producing a 3D geometry representation of the surface of the object. EX1007, [0024]-[0025], [0029], [0033], [0038]-[0041], [0045], [0049], [0052], [0054], [0093], FIGS. 1, 3, 4. Knighton further teaches that the processing can be performed by the processor 301 that is local to the hand-held scanning device, and that the transmission of the data can be performed wirelessly using the communications device 317 and the

antenna 319 of the hand-held scanning device. *Id.*

86. In particular, Knighton teaches that the processing to determine the 3D geometry can be performed local to the hand-held scanning device using the processor 301 that is internal to the hand-held scanning device. *Id.*, [0025], [0029], [0049], [0054], [0093], FIG. 3. Knighton uses the 2D images to produce a component depth map with 3D information, and the component depth map is then meshed to create the 3D model of the surface of the object. *Id.*, [0052], [0054], [0094]. Knighton explains that the processing to generate the 3D model data can be done locally on the hand-held scanning device and that the transmission of the data from the hand-held scanning device can be done wirelessly using a wireless communications device. *Id.*, [0033], [0045], [0049], [0051], [0054], [0093]. Knighton explains that the scanning device may store raw data, intermediate data, or processed data. *Id.*, [0093]. This allows for the hand-held scanning device in Knighton to wirelessly transmit the processed 3D model data instead of the raw data. *Id.*, [0045], [0049], [0051], [0093]. Knighton explains that rather than offloading all the captured data to a host processor, the processing can be performed locally to the hand-held scanning device so that it would not be necessary to transmit the raw data. *Id.*, [0049], [0051]. The 3D point cloud representation can be computed from the raw captured 2D images via a processor that is either local to the scanner itself, or the processor could be off the scanner, in

which case the raw images can be transmitted from the scanner to the processor using any of the number of transmission protocols (wired or wireless). The approach of performing local processing to avoid transmitting all the raw data has been well-known to be more efficient in terms of lowering computation and data transfer, and thus overall power consumption.

87. Therefore, it would have been obvious to a POSA to perform the processing for the 3D geometry as taught by Zhang locally on the hand-held device in Babayoff as is done in Knighton because it would reduce the amount of data that needs to be transmitted so as to improve power efficiency, and it would have also been obvious to use wireless transmission for the data for the 3D geometry in Babayoff as is done in Knighton because it allows for the hand-held device to be wireless and easier to move around, and Babayoff and Zhang are concerned with generating the 3D representation of an object just as is Knighton. A POSA would have expected the modification of the hand-held scanner in Babayoff to be successful because the hand-held scanning device in Knighton is used for the same purpose and already shows how to do the local processing and wireless transmission.

3. Claim 24

“24. The method according to claim 21, wherein the method further comprises a step of locally processing,

on the intraoral scanner, raw 3D data into data for the 3D geometry, such that the data for the 3D geometry is wirelessly transmitted at a reduced data rate in comparison with transmission of raw 3D data, and wherein the raw 3D data is based on the plurality of 2D images.”

88. Claim 24 of the '146 patent is the same as claim 23 of the '146 patent, except it changes the recitation of “instead of the raw 3D data” to “at a reduced data rate in comparison with transmission of raw 3D data” in the claim language. In my opinion, Babayoff in combination with Zhang and Knighton satisfies these limitations of claim 24, therefore, for the same reasons provided above with reference to claim 23. The approach of performing compression on the 3D data (e.g., by using point-cloud compression algorithms) to lower the required data transmission bandwidth has been a standard approach used in handheld and mobile devices, and forms the motivation for on-chip compression methods, and is described in detail in Knighton as well.

89. Regarding the added limitation in claim 24 of “the data for the 3D geometry is wirelessly transmitted at a reduced data rate in comparison with transmission of raw 3D data,” In my opinion, Babayoff in combination with Zhang and Knighton also satisfies this limitation of claim 24. Knighton notes that it is

possible to perform the processing to create the 3D representation of the object either externally from the scanning device, internally to the scanning device, or partially externally and internally. EX1007, [0093].

90. In the case where all the processing is done externally in Knighton, all the captured 2D images are transmitted to an external host processor for further processing. *Id.*, [0049]. In the case where all the processing is performed internally in Knighton, the internal processor to the scanning device would perform all the processing including creating the depth map of the 3D model locally on the scanning device from the captured 2D images, and then the finished 3D geometry would be transmitted from the scanning device. *Id.*, [0049], [0054], [0093].

91. Knighton explains that a composite image generated from the 2D images is a much smaller data set than the total pixels captured. *Id.*, [0052]. The depth map and 3D coordinates for the 3D geometry would also represent a smaller data set. *Id.*, [0052]. By performing processing locally at the scanning device in Knighton, therefore, the amount of data that would need to be wirelessly transmitted from the scanning device is reduced, which allows for a reduced data rate for transmission of the data resulting from the processing as compared to the raw data before processing. *Id.*, [0033], [0045], [0049], [0051]-[0054], [0093]. There are several processing steps starting from the raw input images to the end 3D representation. In some instances, all these steps can be performed off the scanning

device, which will require transmitting all the raw data. In some other instantiations, most or all the steps could be performed on the scanner itself. Since the “processed” information requires lower amount of data, performing the processing on the scanner device lowers the required data bandwidth, which in turn lowers power consumption – a consideration for handheld battery-operated devices.

92. It would have been obvious to a POSA to perform the processing for the 3D geometry at taught by Zhang locally on the hand-held device in Babayoff as is done in Knighton because it would reduce the amount of data that needs to be transmitted and, thus, the require data rate for transmission, and it would have also been obvious to use wireless transmission for the data for the 3D geometry in Babayoff as is done in Knighton because it would allow for the hand-held device to be wireless and easier to move around, and both Babayoff and Zhang are concerned with generating the 3D representation of an object just as is Knighton.

4. Claim 25

“25. The method according to claim 23, wherein the step of wirelessly transmitting the data for the 3D geometry is to a workstation.”

93. In my opinion, Babayoff in combination with Knighton satisfies this limitation of claim 25. Babayoff discloses that the data for the 3D geometry is

transmitted through a communication medium to a recipient. EX1005, [0065], [0093], [0180]. Knighton shows that the transmission can be a wireless transmission, and also explicitly states that the transmission can be to an external computing device such as a “workstation.” EX1007, [0033], [0045]. It would have been obvious to a POSA to use the wireless transmission to a workstation from Knighton for the hand-held device of Babayoff because Knighton specifically states to transmit data like the 3D data of Babayoff wirelessly to a workstation, which would allow for displaying the data at the workstation for further viewing the data.

5. Claim 26

“26. The method according to claim 23, wherein the step of locally processing is in real time.”

94. In my opinion, Babayoff in combination with Zhang and Knighton satisfies this limitation of claim 26. As discussed above for claim 23, it would have been obvious to a POSA to have local processing for the device of Babayoff as is done in Knighton. Knighton further discloses that the calculation of the depth map and the three-dimensional representation may be accomplished during a scan of the target object. EX1007, [0081]. By performing the processing to calculate the depth map and 3D representation “during” a scan of the target object, the processing is being done in real time. *Id.* Also, as discussed above, the processing in Knighton

can be done locally on the hand-held scanning device. *Id.*, [0049], [0054], [0093]. Zhang explains that the determination of the 3D data could be done using a pre-computed lookup table. EX1011, p. 910. It would have been obvious to a POSA to employ the local processing in real time as taught by Knighton in the hand-held device of Babayoff using the pre-computed lookup table of Zhang because it would have allowed for fast processing of the data so that the results would be available in real time. Real-time processing allows for real-time feedback and interactivity for adapting a 3D scan.

6. Claim 27

“27. The method according to claim 21, where the method further comprises a step of computing a temporal correlation measure with sensor signals, in the at least one camera, recorded at different times while the plurality of configurations in the form of a time-varying illumination pattern are changed.”

95. In my opinion, Babayoff in combination with Zhang and Knighton satisfies these limitations. Zhang computes scene depths by projecting a time-varying illumination pattern on the scene. EX1011, pp. 908-909. Specifically, a pattern with periodic vertical stripes is shifted across the scene, one (projector) pixel at a time in the horizontal direction. *Id.* For each shift of the pattern, an image

is captured. Consider the set of intensities captured at a given camera image pixel as the pattern is shifted. We call these intensities the temporal radiance profile of that pixel. The scene points at different distances to the projector exhibit different amounts of blur in their temporal radiance profile. For example, for a scene point that is perfectly in focus, the temporal profile will have minimal blur, and will appear like a perfect square wave (since the projected pattern is a square wave). On the other hand, for a scene point that is out of focus, the temporal profile will be blurred. This blur in the temporal profile can be used for depth recovery. The blur can be estimated by computing the correlation of the temporal radiance profile with the projected pattern (a square wave). Zhang performs this estimation by computing the Fourier transform of the temporal radiance profile. *Id.*, pp. 908-909. The rate at which the Fourier coefficients diminish is a measure of the amount of defocus. *Id.* Therefore, Zhang measures the ratio of the second and third coefficients and uses it as a measure of depth. *Id.* The exact mapping from the ratio to depth is determined via a one-time calibration procedure. *Id.*, p. 910.

96. Knighton teaches that correlation calculations may occur local to the image capture device. EX1007, [0058]. Knighton also explains that correlation calculations may be accomplished during a scan of the target, which would be while the plurality of configurations in the form of a time-varying illumination pattern are changed. *Id.*, [0081]. It would have been obvious to a POSA, therefore,

to compute a temporal correlation measure as the correlation of the temporal radiance profile (which is a sensor signal) with the projected pattern as is done in Zhang locally at the camera and during a scan as taught by Knighton because it would reduce the amount of data that needs to be transmitted as explained by Knighton. *Id.*, [0049], [0051].

97. As another example, Knighton discloses in FIG. 10 a method for aligning image data to a three-dimensional representation that includes computing a correlation measure. *Id.*, [0079]-[0082], FIG. 10. The method includes generating a depth map from image data, which are sensor signals. *Id.*, [0079]. Knighton teaches that correlation calculations may occur local to the image capture device. *Id.*, [0058]. The image data for determining the depth map would be captured at different times by moving the pattern of Zhang while capturing the images as discussed *supra* in the analysis for claim 21. The depth map determined from the images is correlated to a three-dimensional representation, which is the correlation measure. *Id.*, [0080]. Knighton explains that the calculation may be accomplished during a scan of the target, which would be while the plurality of configurations in the form of a time-varying illumination pattern are changed. *Id.*, [0081]. It would have been obvious to a POSA to use the correlation of Knighton in the scanner of Babayoff to generate the three-dimensional representations with greater accuracy and to do the calculations during a scan of the target as in Knighton to speed up the

calculations.

7. Claim 29

“29. The method according to claim 27, wherein the temporal correlation measure is based on a reference signal that is based on knowledge or on calibration of the plurality of configurations of the time-varying illumination pattern.”

98. In my opinion, Babayoff in combination with Zhang and Knighton satisfies these limitations of claim 29. As discussed *supra*, the blur in Zhang can be estimated by computing the correlation of the temporal radiance profile with the projected pattern (a square wave), and Zhang performs this estimation by computing the Fourier transform of the temporal radiance profile. EX1011, pp. 908-909. That correlation is a temporal correlation measure and is based on a reference signal, which is specified by the discrete-time Fourier series, that is based on knowledge of configurations of the time-varying illumination pattern. *Id.*, p. 909.

B. Ground 2: Claims 1, 3-6, 8-13, 15, 20, and 22 Are Obvious Over Babayoff and Zhang and Knighton and Hanson

1. Claim 1

[preamble] “1. An intraoral scanner for determining the 3D geometry and color of at least a part of the

**surface of an object in an oral cavity, the intraoral
scanner comprising:”**

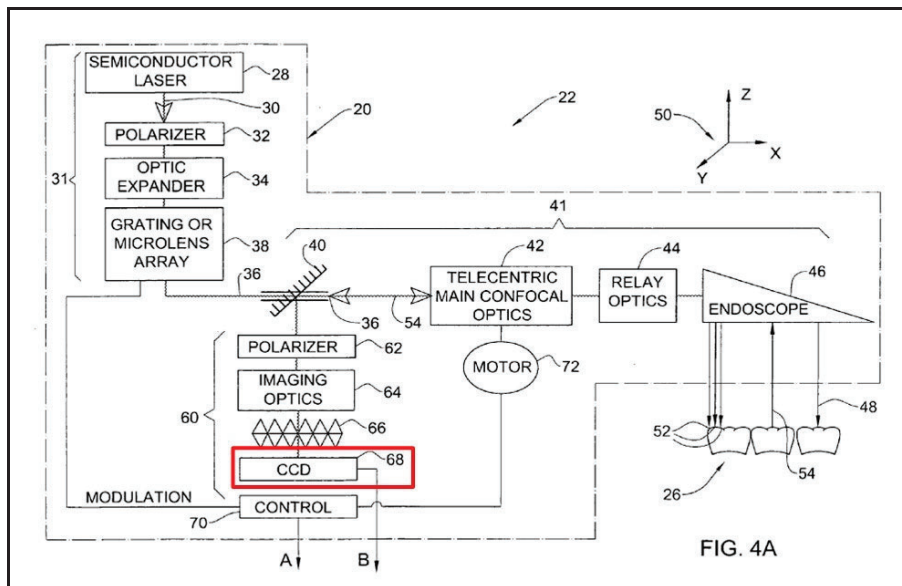
99. In my opinion, to the extent that the preamble of claim 1 is limiting, Babayoff discloses the features of the preamble. The intraoral scanner in Babayoff is the device 100 shown in FIG. 1. EX1005, Abstract, [0001], [0009], [0128]-[0149], [0179], FIG. 1. Example embodiments for parts of the device are shown in FIGS. 4A and 8 of Babayoff. *Id.*, FIGS. 4A, 8.

100. Babayoff discloses that the device 100 is for determining the surface topology and associated color of a structure, such as a teeth segment in an oral cavity. EX1005, Abstract, [0009], [0021], [0023], [0129]. Babayoff shows an example structure to be scanned as the object 26 in FIGS. 4A, 5C, and 8, which is explained by Babayoff to be one or more teeth in an intraoral cavity. *Id.*, Abstract, [0009], [0129], [0183], FIGS. 4A, 5C, 8. Babayoff states that the surface topology that is determined of the object is a three-dimensional (3D) surface topology, which provides the 3D geometry of the object. *Id.*, Abstract, [0010], [0020]-[0022], [0129], [0131], [0143], FIGS. 2A, 2B. Babayoff discloses that the color of the object is also determined and is associated with the 3D geometry of the object to provide a 3D digital representation of the object including color. *Id.*, Abstract, [0001], [0009], [0020]-[0022], [0028], [0129]-[0131].

[a] “at least one camera accommodating an array of sensor elements;”

101. In my opinion, Babayoff discloses these limitations of claim 1. The at least one camera in the device of Babayoff is an image sensor that is part of the detection optics 60. EX1005, [0002], [0011], [0033], [0042], [0129], [0134]-[0141], [0145], FIGS. 1, 4A, 8. The image sensor in Babayoff is called a camera and is described as having an array of sensor elements, which Babayoff explains could be, for example, an array of charge coupled devices (CCD) 68. *Id.*, [0042], [0129], [0140]-[0141], [0145], FIG. 4A.

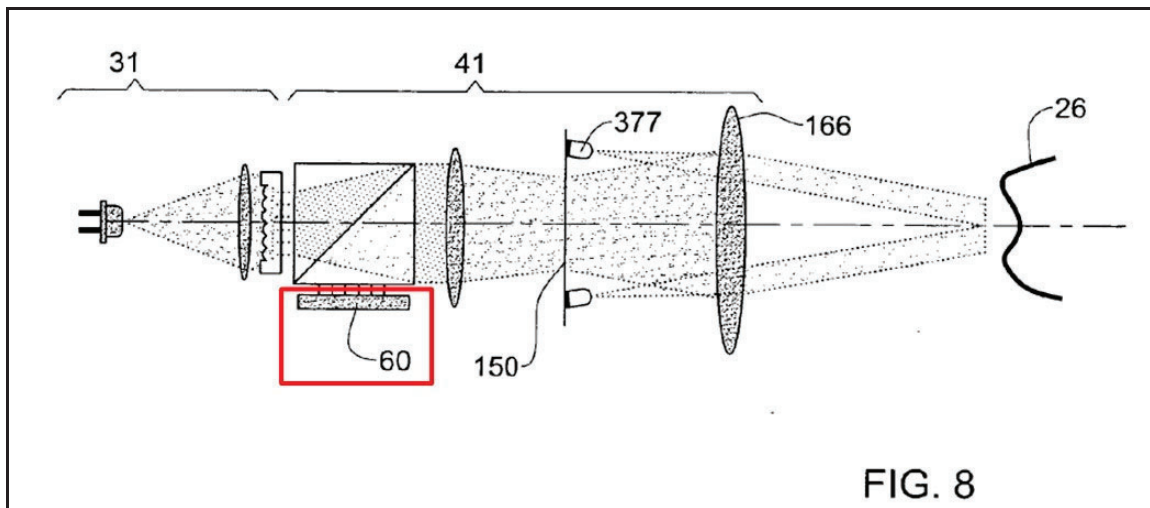
102. The below annotated version of FIG. 4A highlights the CCD 68 camera in red.



Id., FIG. 4A (annotated).

103. Similarly, the below annotated version of FIG. 8 highlights the

detection optics 60 in red, which includes the image sensor that is the camera.



Id., FIG. 8 (annotated).

104. While Babayoff discloses the limitation, Knighton also discloses the limitation because in the same type of hand-held three-dimensional scanner as Babayoff, Knighton points out that the image sensor could be one of a charge coupled device (CCD) type or could be one of a complementary metal oxide semiconductor (CMOS) type. EX1007, [0005], [0024]. Knighton points out that in either type (*i.e.*, CCD or CMOS), there would be an array of sensor elements each representing a pixel. *Id.* It would have been obvious to a POSA to use a CMOS image sensor in the device of Babayoff in place of the CCD image sensor of Babayoff because Knighton demonstrates that a CMOS image sensor was a known available substitute for a CCD image sensor in this same context. *Id.* CMOS image sensors have been routinely used instead of CCD due to their lower costs, higher resolution, and high-speeds. Therefore, it would have been obvious for any POSA

to use a CMOS sensor instead of CCD in the intraoral 3D scanner.

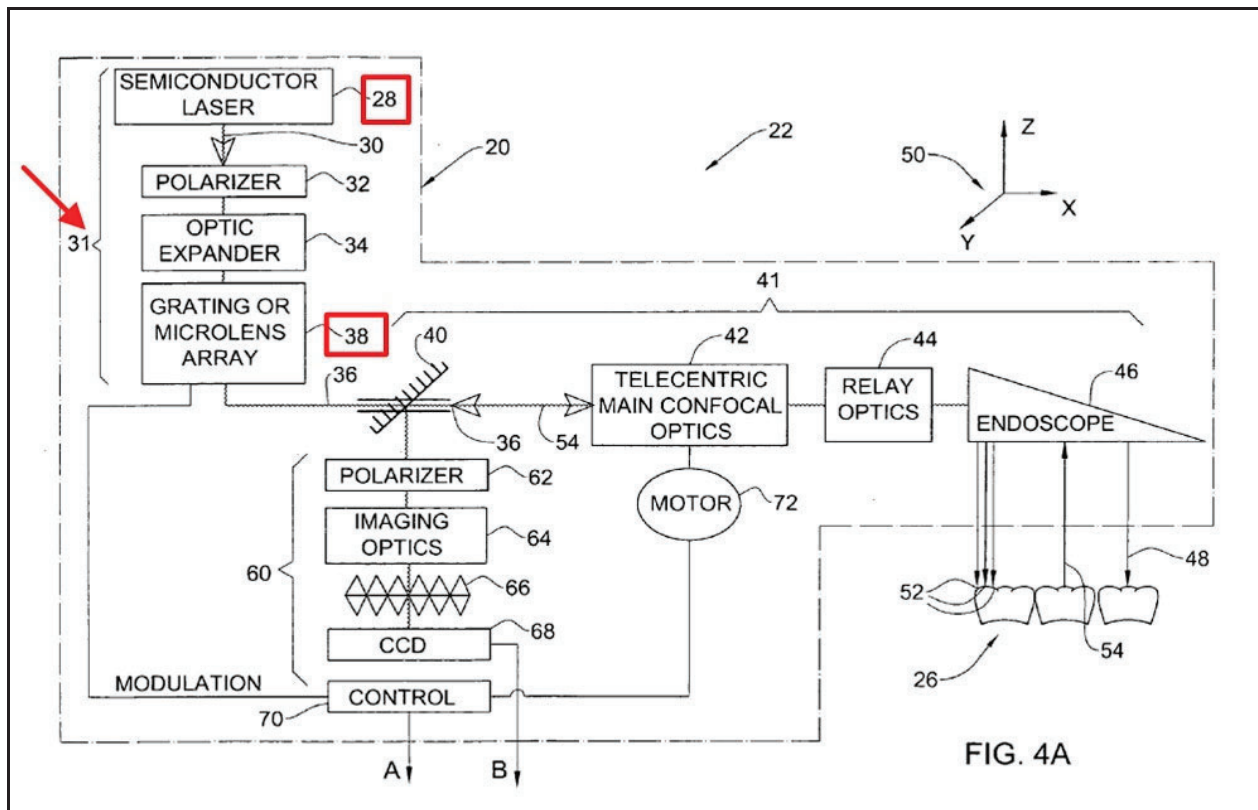
**[b] “a pattern generator configured to generate, using
a light source, a probe light with a plurality of
configurations in the form of a time-varying
illumination pattern;”**

105. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 1. The light source in Babayoff is part of the illumination source 31, which is also called the illuminating unit 31, as shown for example in the embodiments of FIGS. 4A and 8 of Babayoff. EX1005, [0030], [0134], [0135], [0139], [0156]-[0157], FIGS. 1, 4A, 8. In the embodiment of FIG. 4A, Babayoff shows the light source as the semiconductor laser unit 28, and in the embodiment of FIG. 8 Babayoff shows a light as the light source. *Id.*

106. The pattern generator in Babayoff is also part of the illumination source 31, and is shown in FIGS. 4A and 8 as a grating or micro-lens array called the module 38. *Id.*, [0135], FIGS. 4A, 8. Babayoff explains that the module 38 splits the parent light beam 30 into a plurality of incident light beams 36. *Id.* The plurality of incident light beams 36 travel through the main optics 41 to provide the incident light beams 48, which are an array of light beams and therefore form a pattern on the surface of the object 26. *Id.*, [0135]-[0139], FIGS. 1, 4A, 8. The incident light beams 36 that become the incident light beams 48 are a probe light.

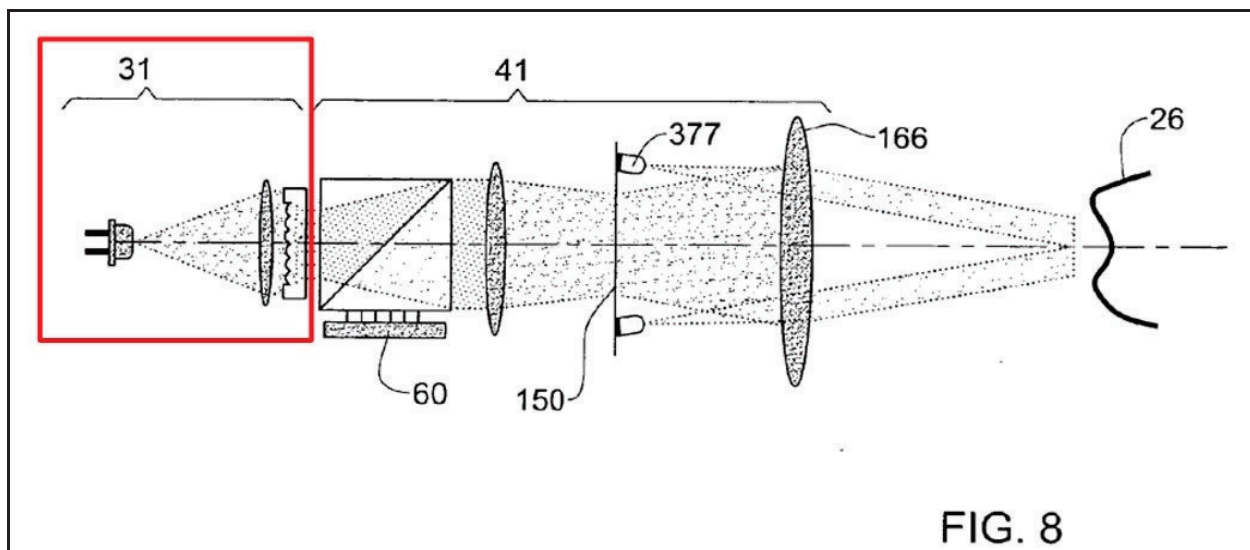
EX1005, [0135]-[0139], FIGS. 1, 4A, 8.

107. FIG. 4A of Babayoff is annotated in red below to show the illumination source 31 that includes the semiconductor laser unit 28 as well as the module 38 that is a grating or micro-lens array, which provides the incident light beams 36 that become the incident light beams 48.



EX1005, FIG. 4A (annotated).

108. FIG. 8 of Babayoff is annotated in red below to similarly show the show the illumination source 31.



Id., FIG. 8 (annotated).

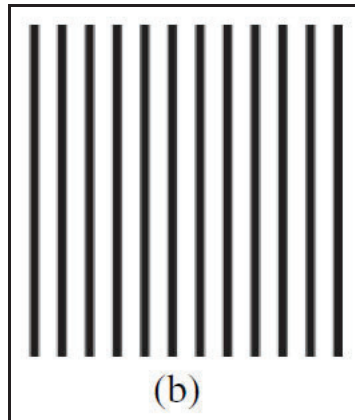
109. Babayoff discloses in paragraphs [0010]-[0015] and [0139]-[0143] a technique for determining a Z or depth coordinate for each location on the object 26 for the 3D representation. *Id.*, [0010]-[0015], [0139]-[0143]. In particular, Babayoff provides the motor 72 that is linked to the telecentric confocal optics 42 for changing the relative location of the focal plane of the optics 42 along the Z-axis. *Id.*, [0142], FIG. 4A. As explained in paragraph [0142] of Babayoff, the motor 72 displaces the optical element 42 to change the focal plane location and then an image is captured by the image-capturing module 80 for that focal plane location. *Id.* This process is repeated for different focal plane locations with an image taken for each focal plane location, and the motor 72 is used to change between the focal plane locations. *Id.*, [0011], [0032], [0139]-[0142]. Babayoff then determines the Z-axis depth coordinate for each (X, Y) location by analyzing

the light intensity at the location in the captured images. *Id.*, [0012]-[0015], [0139], [0143]. For determining the depth coordinates, therefore, Babayoff takes an image at each focal plane position using the light pattern as created by the illumination source 31. *Id.*, [0011], [0032], [0139]-[0142], FIGS. 4A, 8.

110. Babayoff does not explicitly disclose that the light pattern is time-varying. However, Zhang is in the same field as Babayoff because Zhang also discloses a confocal or coaxial imaging system like Babayoff for obtaining 3D shape information, and Zhang discloses to use a light source and a pattern generator to generate a probe light with a plurality of configurations in the form of a time-varying illumination pattern. EX1011, pp. 907-910, Figs. 1, 2. As discussed above, Babayoff employs a camera focus/defocus method for determining the depth coordinates. EX1005, [0011], [0032], [0139]-[0142], FIGS. 4A, 8. Zhang discloses that an alternative to a camera focus/defocus method for determining the depth coordinates is a projection defocus method in which an illumination pattern is shifted across the object being imaged to measure depth. EX1011, pp. 907-910, 914-915, Figs. 1, 2.

111. Zhang provides an example of the illumination pattern as a stripe pattern that is shifted across the scene and can be formed, for example, by a Digital Light Processing (DLP) or Liquid Crystal Display (LCD) projector. *Id.*, pp. 907, 909, Fig. 2. An example of the illumination pattern that is shifted across the scene

is shown in Figure 2(b) of Zhang as follows:



Id., Fig. 2(b).

112. As discussed above in the section on Claim Construction, the '146 patent states that a time-varying pattern can be created by moving a pattern across the object being scanned by translating a pattern element EX1001, 3:11-14, 8:54-57, 10:57-59. The illumination pattern of Zhang that is shifted across the scene at time intervals, therefore, is a periodic time-varying illumination pattern. EX1011, p. 909, Fig. 2(b). The DLP or LCD projector of Zhang is the light-source and pattern generator to generate the probe light with the plurality of configurations in the form of the time-varying illumination pattern. *Id.*, pp. 907, 909, Figs. 1, 2. The plurality of configurations are the stripes being translated across the scene. *Id.*

113. Zhang provides the motivation for using a projection defocus method with a shifting illumination pattern as an alternative to a camera focus/defocus method by explaining that the projection defocus method for obtaining 3D shape information is more accurate near depth discontinuities, is simple, has lower

computational complexity, is not subject to local minima, and is independent of scene geometry and texture, which makes it superior to camera defocus for depth estimation. *Id.*, 907-908, 914. It would have been obvious to a POSA, therefore, to replace the illumination source 31 in Babayoff with the DLP or LCD projector of Zhang to create a time-varying illumination pattern and to determine depth using the projection defocus method of Zhang, because the projection defocus method is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and texture.

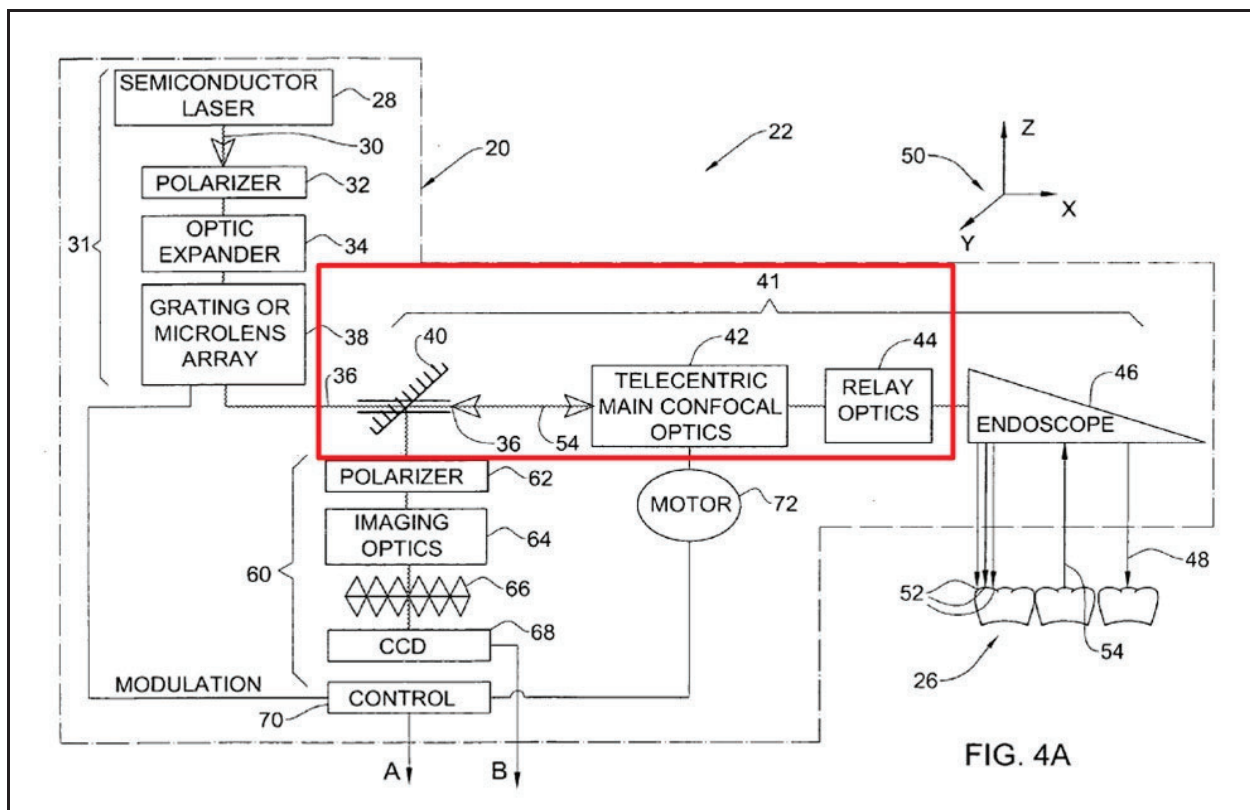
114. A POSA would have expected such a combination to work for its intended purpose because Zhang already applied the time-varying illumination pattern technique to structures that are on the same scale as parts of teeth, so it would be expected to work for imaging teeth. Further, the modification to the Babayoff device to include a DLP or LCD projector as taught by Zhang in place of the illumination source 31 would have been straightforward for a POSA to implement because it is just the substitution of one known element for another. A POSA would have understood as to how to size the projector to fit within a hand-held device as is exemplified by Gandyra. EX1009, [0030], [0038].

**[c] “an optical system for transmitting the probe light
towards the object along an optical path thereby**

illuminating at least a part of the object with the time-varying illumination pattern, and for transmitting at least a part of the light returned from the object to the at least one camera to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern;”

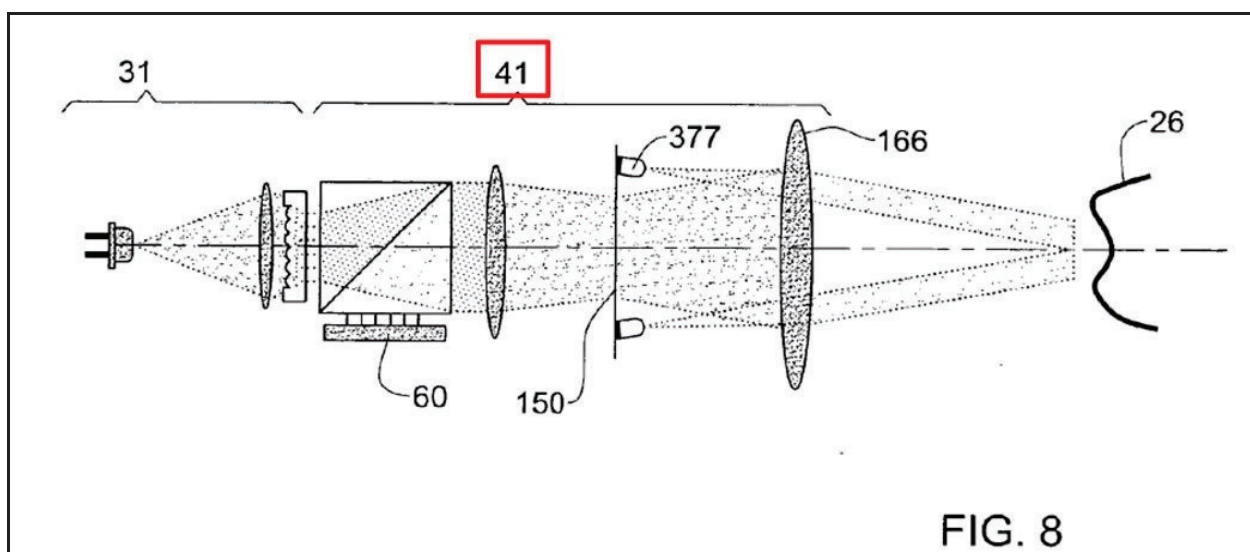
115. In my opinion, Babayoff in combination with Zhang satisfies these limitations of claim 1. The optical system in Babayoff includes at least part of the main optics 41, such as the confocal optics 42 and the relay optics 44, which form an optical path. *Id.*, [0137]-[0139], FIGS. 4A, 8. Babayoff shows that the light from the illumination source 31 is transmitted toward the object 26 along the optical path provided by the main optics 41. *Id.*, [0134]-[0139], FIGS. 4A, 5C, 8.

116. The below annotated version of FIG. 4A highlights part of the main optics 41 through which the light is transmitted.



Id., FIG. 4A (annotated).

117. Similarly, the below annotated version of FIG. 8 highlights part of the main optics 41 through which the light is transmitted.



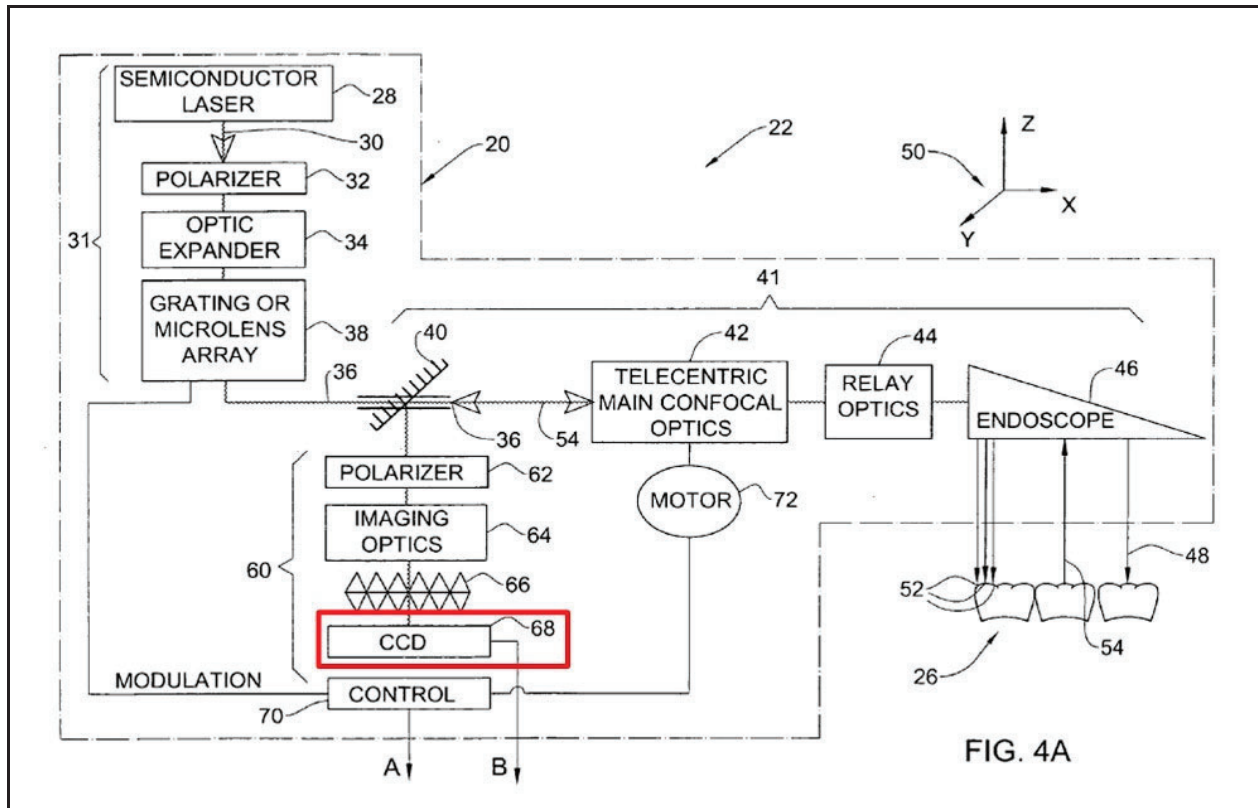
Id., FIG. 8.

118. As discussed *supra*, the illumination source 31 in Babayoff is modified is modified with the DLP or LCD projector of Zhang which provides the probe light with the time-varying illumination pattern. EX1005, FIGS. 1, 4A, 8; EX1011, pp. 907-909. By having the illumination source 31 of Babayoff modified by the teaching of Zhang to provide the probe light with the time-varying illumination pattern, at least part of the object 26 in Babayoff would thereby be illuminated with the time-varying illumination pattern.

119. Babayoff further shows that at least part of the light returned from the object 26 is transmitted to an image sensor, which is part of the detection optics 60. EX1005, [0002], [0011], [0033], [0042], [0129], [0134]-[0141], [0145], FIGS. 1, 4A, 8. The image sensor in Babayoff is called a camera that accommodates an array of sensor elements, which Babayoff explains could be, for example, an array of charge coupled devices (CCD) 68. *Id.*, [0042], [0129], [0140]-[0141], [0145], FIG. 4A. Babayoff explains in paragraph [0140] that the returned light beams 54 from the object 26 travel initially along the opposite direction of the optical path traveled by the incident light beams and are then reflected by the mirror 40 in the direction of the detection optics 60 where the camera uses the array of sensing elements to form the 2D image, and the process is repeated a plurality of times as discussed in Babayoff in paragraph [0011], which would result in a plurality of 2D

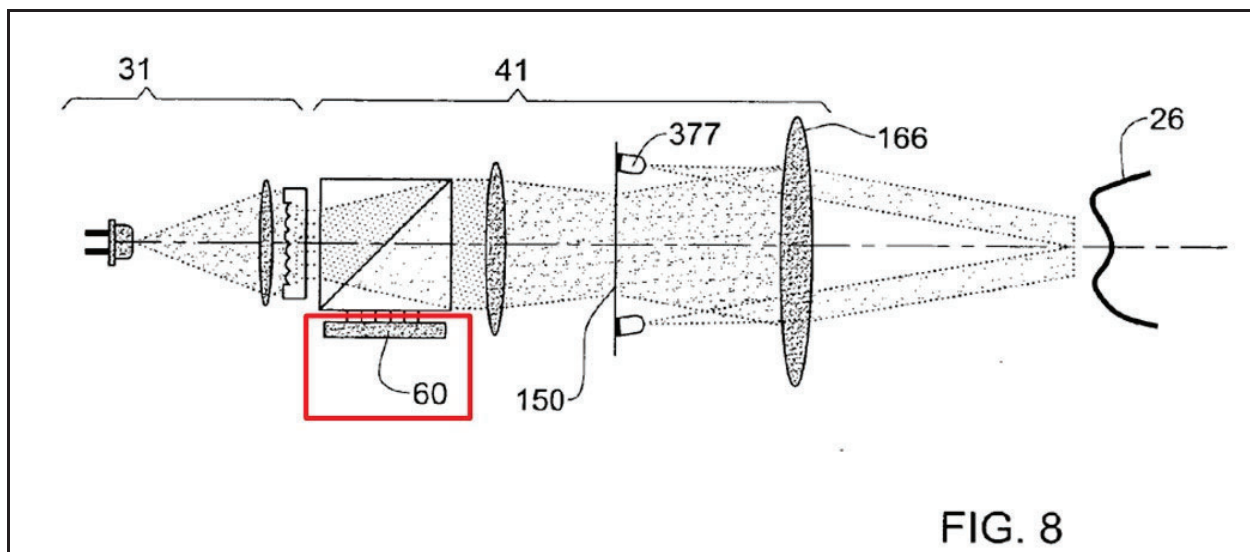
images. *Id.*, [0011], [0139]-[0143], FIGS. 4A, 8.

120. The below annotated version of FIG. 4A highlights the CCD 68 camera in red.



Id., FIG. 4A (annotated).

121. Similarly, the below annotated version of FIG. 8 highlights the detection optics 60 in red, which includes the image sensor.



Id., FIG. 8 (annotated).

122. Just as in Babayoff, Zhang also uses a camera with a plurality of pixels, so the combination would work with the camera of Babayoff. EX1011, pp. 907-909.

123. As discussed *supra*, the device 100 of Babayoff as modified by Zhang would use the projector of Zhang to shift the time-varying illumination pattern across the object being imaged and would capture a plurality of 2D images with the camera. EX1005, [0011], [0142], FIG. 4A; EX1011, pp. 907-910, 915, Fig. 1. Then, the projection defocus method described in Zhang would be used to determine the Z or depth coordinate for each (X, Y) position based on plurality of 2D images and knowledge of the time-varying illumination pattern. EX1011, pp. 907-910. The result is the 3D geometry for the object. *Id.* Zhang explains that the determination of the depth values is based on both the scene radiance as captured

in the 2D images and on the projection illumination pattern, which allows for the equations in Zhang to be valid for estimating depth. *Id.*, 909. The 3D geometry, therefore, is determined based on the plurality of 2D images and the time-varying illumination pattern. *Id.* For a particular illumination pattern, the determination can be made using a pre-computed lookup table or simple analytic computations, which are valid for the pattern, and the plurality of 2D images as described in Zhang. *Id.*, 910.

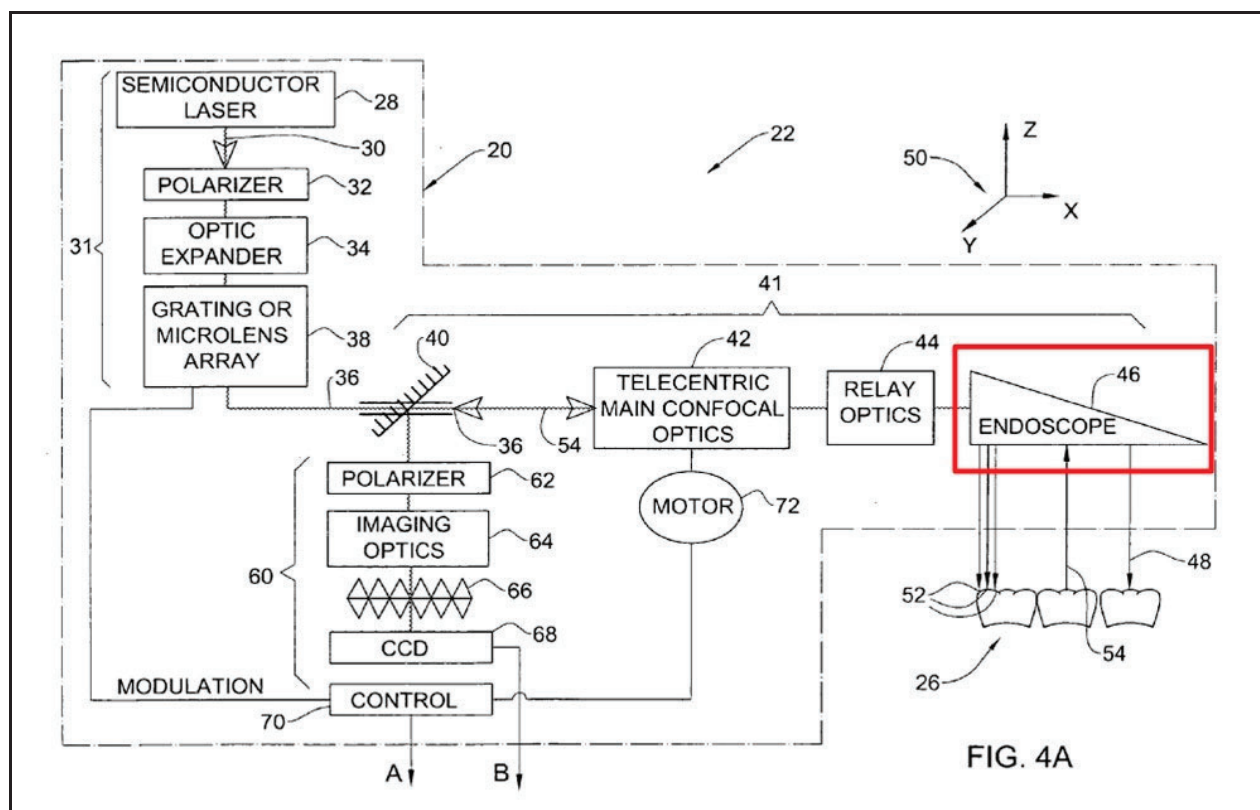
124. It would have been obvious to a POSA to determine the 3D geometry using the projection defocus method of Zhang in the device of Babayoff because Zhang explains that the projection defocus method is more accurate near depth discontinuities, is simple, has lower computational complexity, is not subject to local minima, and is independent of scene geometry and texture. *Id.*, 907-908, 914. A POSA would have had an expectation of success with the combination because it uses the projection defocus method of Zhang with the time-varying illumination pattern for determining depth in place of the method of Babayoff, which is exactly what Zhang taught to do to obtain the noted advantages.

[d] “a tip configured to be inserted into the oral cavity; and”

125. In my opinion, Babayoff discloses this limitation of claim 1. The tip in Babayoff is the endoscope 46 that can be in the form of a probing member 90.

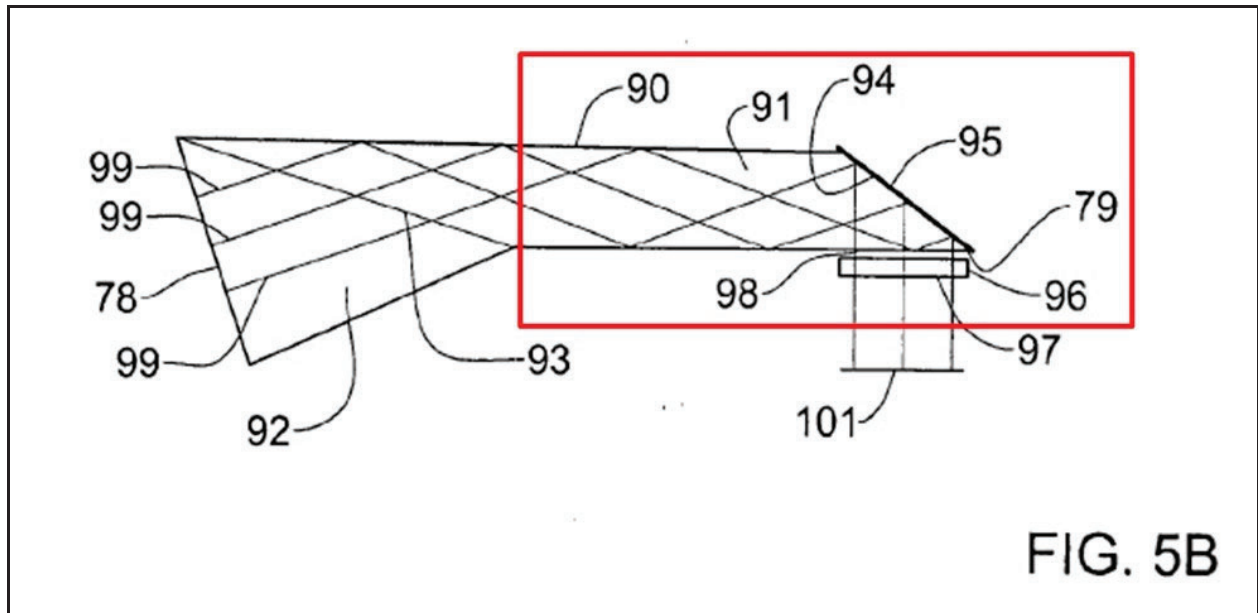
EX1005, [0137], [0146], FIGS. 4A, 5A, 5B, 5C. An endoscope is a structure that is designed to be inserted into a body cavity, which in Babayoff is the mouth. *Id.*, Abstract, [0001], [0021], [0183], FIGS. 4A, 5C, 8. Babayoff explains that the scanner in Babayoff is used for scanning an intraoral cavity, and shows in FIGS. 4A, 5C, and 8 that the scanned object 26 can be one or more teeth in an intraoral cavity. *Id.* Babayoff shows that the probe light is transmitted through the tip of the intraoral scanner that is inserted into the oral cavity. *Id.*, [0137], [0146], FIGS. 4A, 5C, 8.

126. The below annotated version of FIG. 4A highlights the endoscope 46.



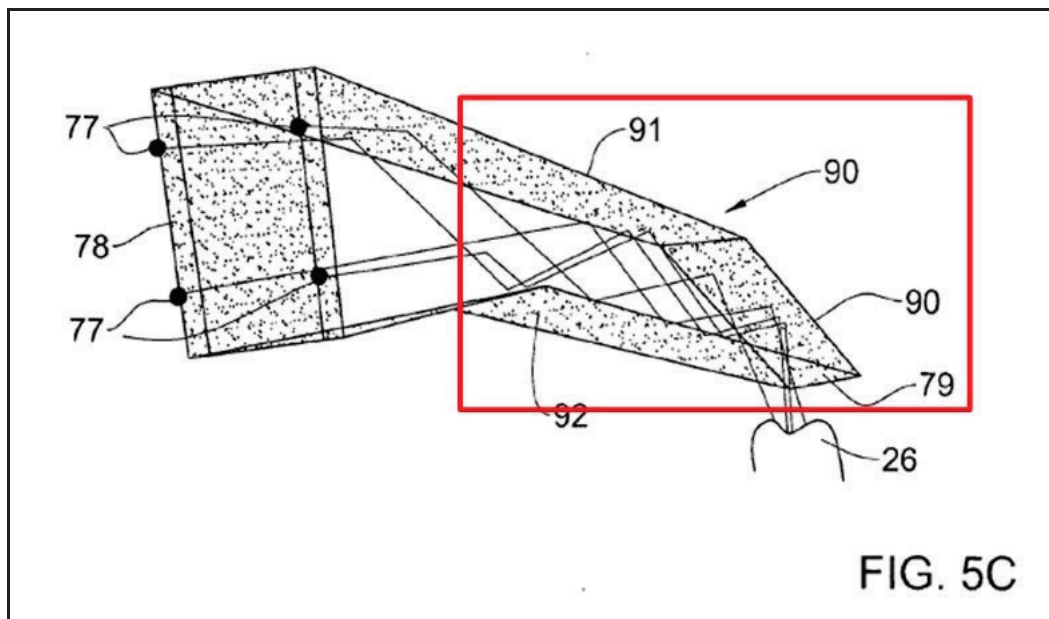
Id., FIG. 4A (annotated).

127. The below annotated version of FIG. 5B highlights an example of an end of the probing member 90.



Id., FIG. 5B (annotated).

128. The below annotated version of FIG. 5C highlights another example of an end of the probing member 90.

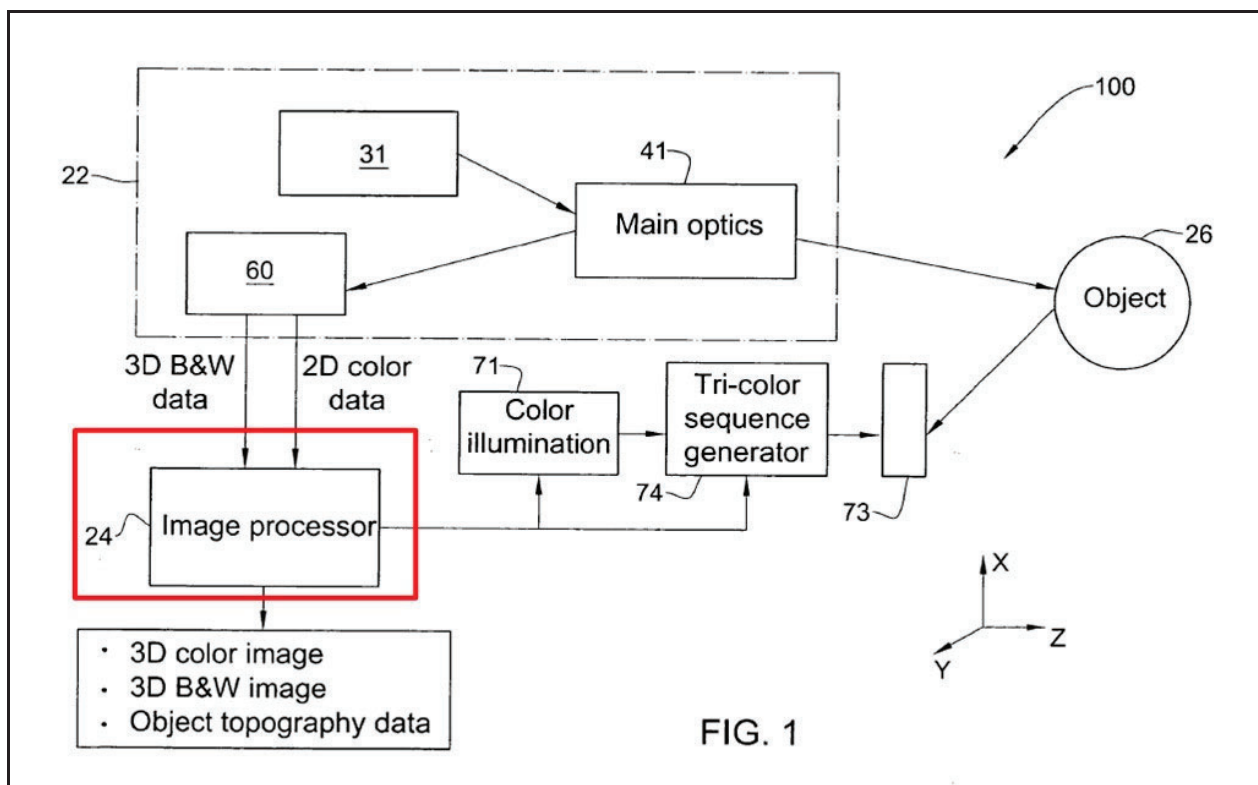


Id., FIG. 5C (annotated).

129. The embodiment in FIG. 8 of Babayoff would also be understood to have a probing member for insertion into the oral cavity.

[e] “a hardware processor configured to:”

130. In my opinion, Babayoff discloses this limitation of claim 1. The hardware processor in Babayoff is the processor 24. EX1005, [0129]-[0131], [0133], [0141], [0145], FIG. 1, 4B. An annotated version of FIG. 1 of Babayoff is provided below that highlights the processor 24.



Id., FIG. 1 (annotated).

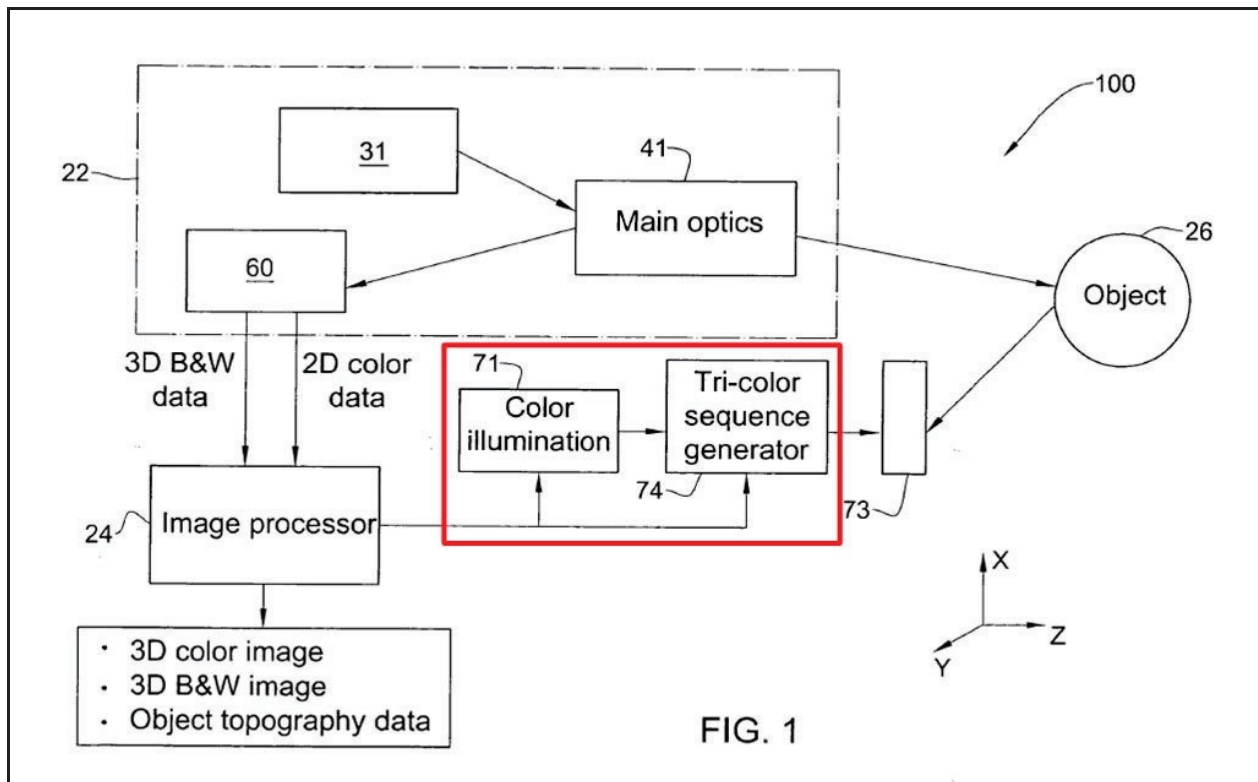
131. Babayoff explains that the processor 24, also called the processing unit 24, controls the tri-color sequence generator 74 to provide the three different

colored illuminations of the object 26. *Id.*, [0145]. Babayoff also explains that the processor 24 uses the CCD camera to grab the images for processing by the processor 24. *Id.*, [0141]. Babayoff further explains that the processor 24 combines the three differently colored monochromatic images to provide a full color image of the surface of the object 26. *Id.*, [0130].

**[e][1] “selectively switch a color of the probe light,
thereby illuminating the object with different colors
at different times;”**

132. In my opinion, Babayoff satisfies these limitations of claim 1. Babayoff teaches to use a tri-color sequence generator 74 to selectively switch among three differently colored illumination radiations to illuminate the object 26 with different colors at different times. EX1005, [0044], [0063]-[0064], [0079], [0130]-[0131], [0145]-[0151], [0155]-[0157], FIG. 1. Babayoff explains that the processor 24, also called the processing unit 24, controls the tri-color sequence generator 74 to provide the three different colored illuminations of the object 26. *Id.*, [0145].

133. FIG. 1 of Babayoff is annotated below in red to highlight the tri-color light sources 71 and the tri-color sequence generator 74:



Id., FIG. 1 (annotated).

134. Babayoff explains that the tri-color light sources 71 are one or more light sources that provide illumination to the object 26 in a plurality of different colors such as red, green, and blue. *Id.*, [0145]. The tri-color sequence generator 74 is controlled to provide the three-color illuminations in a predetermined sequence. *Id.* [0130], [0145]. FIGS. 5A and 5C of Babayoff show exemplary locations of tri-color LED's 77 for providing the light in the different colors. *Id.*, FIGS. [0146], 5A, 5C. FIG. 8 similarly shows another exemplary location for the tri-color light sources 377. *Id.*, [0157], FIGS. 8, 9. Using light sources with multiple colors sequentially has been a standard approach used for creating color images of objects and scenes.

[e][2] “record different images by the at least one camera at the different times, thereby recording images of the object with the different colors; and”

135. In my opinion, Babayoff satisfies these limitations of claim 1. As described above, Babayoff teaches to illuminate the object 26 sequentially with the three different colored lights such as red, green, and blue, and to capture a monochromatic image corresponding to each color via the detection optics 60 that includes the camera such as the CCD 68 camera. EX1005, [0044]-[0045], [0079], [0092], [0130], [0145], FIGS. 1, 4A, 8. Babayoff also explains that the processor 24 uses the CCD camera to grab the images for processing by the processor 24. *Id.*, [0044]-[0045], [0063], [0141], [0145]. Babayoff, therefore, teaches how to record different images by the camera at the different times, which are the times at which each of the colors illuminate the object 26, and thereby how to record images of the object 26 with the different colors. *Id.*

[e][3] “combine the different colors from the different images, thereby obtaining the color of the surface of the object,”

136. In my opinion, Babayoff satisfies these limitations of claim 1. Babayoff teaches that the processor 24 processes the three differently colored monochromatic images and combines the same to provide a full color image of the

object 26. EX1005, [0046], [0063], [0079], [0092], [0130], [0145], FIG. 1. Babayoff explains that the processor 24 aligns the color image with the 3D entity previously created to provide color values to the entity by mapping the color values to the entity, which provides the color of the surface of the object 26 for the 3D representation. *Id.*, [0009], [0065], [0131], FIG. 1. Combining several monochromatic images into a single color image has been a standard procedure.

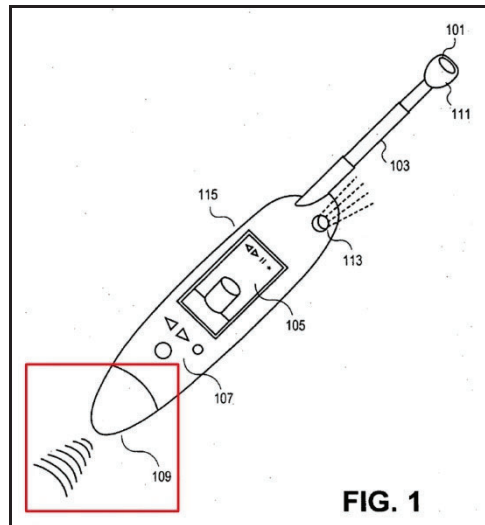
**[f] “wherein the intraoral scanner is wireless, and
wherein the at least one camera is a high-speed
camera.”**

137. In my opinion, Babayoff in combination with Knighton and Hanson satisfies these limitations of claim 1. Babayoff discloses that the device can be a hand-held device in which the hand-held device includes the endoscope 46, the illumination unit 31, the main optics 41, color illumination 71, tri-color sequence generator 74, and detector optics 60. EX1005, [0179], FIGS. 1, 4A, 8. Babayoff does not explicitly disclose that the hand-held device uses wireless transmission, but does provide a modem 88 for transmission of the 3D data. *Id.*, [0065], [0093], [0180]. Knighton is in the same field as Babayoff and teaches to have the hand-held scanner wirelessly transmit data for the 3D geometry of an object. EX1007, Abstract, [0024]-[0025], [0033], [0038], [0045], [0049], [0093], FIGS. 1, 3. It would have been obvious to modify the hand-held device of Babayoff based on the

teaching of Knighton to process data for the 3D geometry in the device and wirelessly transmit the data for the 3D geometry. A POSA would have expected such a modification to be successful because the wireless transmission would be done just as taught by Knighton.

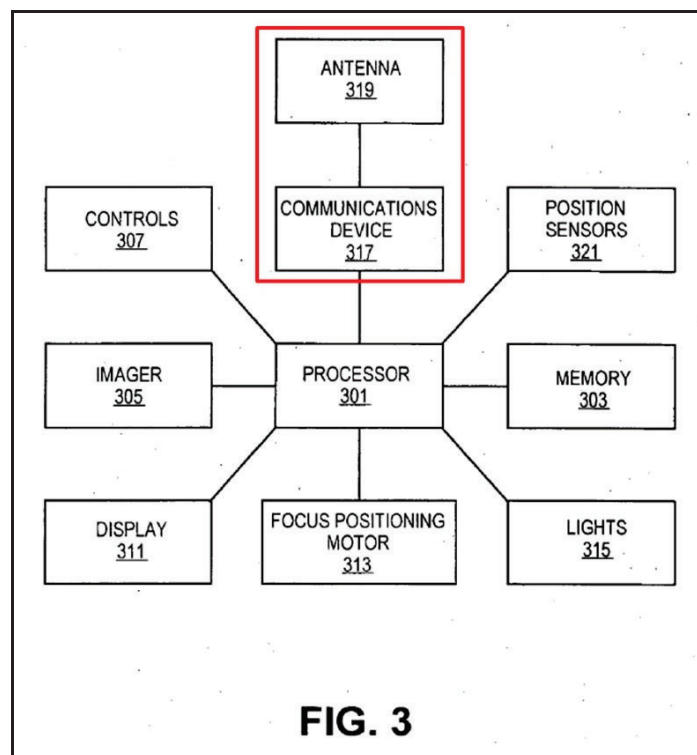
138. The processing performed in Knighton is similar to the processing performed in Babayoff and Zhang because Knighton similarly discloses to capture multiple images and then to produce a depth map for three-dimensional data based on the light intensities from the captured images. EX1007, [0026]-[0027], [0047]-[0053], FIG. 4. Knighton teaches that the processor 301 for performing the processing can be included in the hand-held device such that the processing is performed locally at the hand-held device to generate the 3D geometry data. *Id.*, [0025], [0029], [0038]-[0039], [0041], [0049], [0054], [0093], FIG. 3. Knighton explains that the hand-held device can include the communications device 317 and the antenna 319 for wirelessly transmitting the data for the 3D geometry. *Id.*, [0033], [0038], [0045], [0049], [0054], [0093], FIGS. 1, 3.

139. An annotated version of FIG. 1 of Knighton is shown below with the wireless communication device 109 and wireless communication symbol highlighted in red:



Id., FIG. 1 (annotated).

140. FIG. 3 of Knighton is annotated below to show in red the communications device 317 and the antenna 319 of the hand-held scanner device for the wireless transmission:



Id., FIG. 3 (annotated).

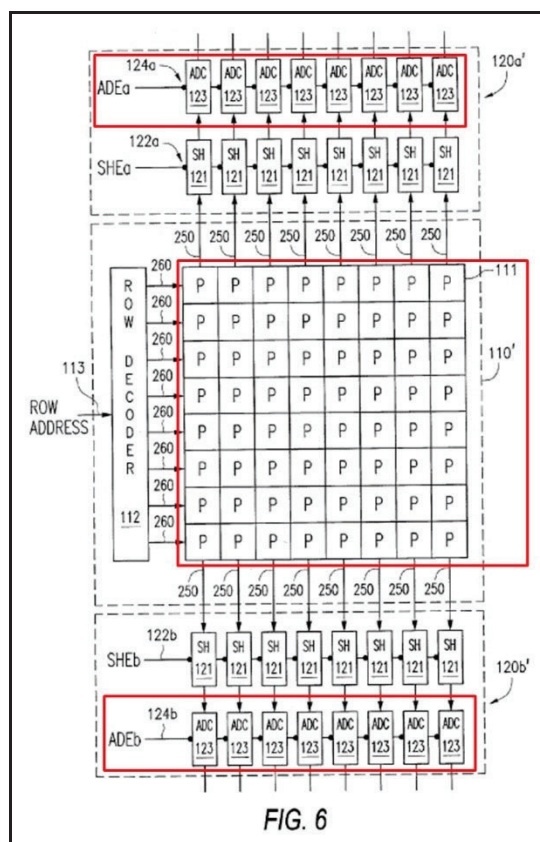
141. It would have been obvious to a POSA to include the processor in the hand-held device of Babayoff as is done in Knighton, and to include the communications device and the antenna of Knighton in the hand-held device of Babayoff so that the device of Babayoff would be more power efficient and also wireless and, therefore, easier to carry around.

142. Regarding the camera being a high-speed camera, Babayoff teaches that the camera must be high-speed to keep the time interval between acquisition of images to a minimum amount of time. EX1005, [0027], [0072], [0145]. In particular, Babayoff teaches that the time interval between acquisition of images by the camera is preferably between about 0 and 20 milliseconds. *Id.* To have such a low time interval between acquisitions, the camera is high-speed. *Id.*

143. To the extent that the phrase “high-speed camera” in the ’146 patent is interpreted to mean that the camera must have multiple analog-to-digital (A/D) converters per line of pixels in the camera, the use of multiple A/D converters per line of pixels for the camera in Babayoff would have also been obvious to a POSA. As discussed *supra*, in the same type of hand-held three dimensional scanner as Babayoff, Knighton points out that the image sensor could be one of a charge coupled device (CCD) type or could be one of a complementary metal oxide semiconductor (CMOS) type. EX1007, [0005], [0024]. It would have been obvious

to a POSA to use a CMOS image sensor in the device of Babayoff in place of the CCD image sensor of Babayoff because Knighton demonstrates that a CMOS image sensor was a known available substitute for a CCD image sensor in this same context. *Id.* Furthermore, Hanson discloses that a CMOS image sensor can have multiple A/D converters per line of pixels in a pixel array to increase the speed of the image sensor. EX1008, Abstract, [0017], [0028], [0030]-[0037], FIGS. 3, 5, 6.

144. FIG. 6 of Hanson is annotated below in red to highlight the pixel array 110' as well as the analog processing and digitizing circuits 120a', 120b', which each include a plurality of A/D converters 123:



Id., FIG. 6 (annotated).

145. As shown in FIG. 6 of Hanson, the CMOS image sensor has multiple A/D converters 123 per line of pixels P in the pixel array 110'. Hanson explains that having the multiple A/D converters 123 allows for the CMOS image sensor to be "high speed." *Id.*, [0017], [0028], [0030]-[0037]. It would have been obvious to a POSA to use a high-speed CMOS image sensor as shown in Hanson as the image sensor for the camera in Babayoff, because Babayoff indicates that it is preferable to have a short time interval, in the range of about 0 to 20 milliseconds, between image acquisitions, and Hanson shows an example of an image sensor that would provide that benefit for high-speed capture of images. The speed of a method that requires capturing multiple images (e.g., due to projecting and imaging a time-varying pattern) can be limited by the frame rate of the camera used. Thus, it would be obvious to a POSA to use as high-speed a camera as possible to minimize the capture time and make the overall 3D scanning as real-time as possible. A POSA would have expected the use of Hanson's CMOS image sensor in Babayoff to be successful because it applies a straightforward insertion of the image sensor of Hanson in place of the image sensor of Babayoff that performs the same function of capturing images. *Id.*

2. Claim 3

“3. The intraoral scanner according to claim 1, wherein the pattern generator is based on a projector such as a liquid crystal display (LCD) projector or a digital light processing (DLP) projector.”

146. In my opinion, claim 3 is obvious based on the combination provided for claim 1. As discussed *supra* in the analysis for claim 1, the pattern generator in Babayoff as modified by Zhang is the projector of Zhang, which Zhang explicitly states could be a digital light processing (DLP) or liquid crystal display (LCD) projector. EX1011, pp. 907, 909.

3. Claim 4

“4. The intraoral scanner according to claim 1, wherein the different colors are provided by at least three monochromatic light sources of the light source.”

147. In my opinion, Babayoff discloses this limitation of claim 4. Babayoff discloses that the different colors can be provided by LEDs, and states that each LED can provide illumination in one of at least three colors, such that some of the LEDs provide a blue illumination, while other LEDs provide green illumination, and while yet other LEDs provide red illumination. EX1005, [0057], [0149],

[0157]. The LEDs in Babayoff, therefore, are at least three monochromatic light sources of the light source and provide the different colors. *Id.*, [0044], [0048], [0057], [0145], [0149], [0157].

4. Claim 5

“5. The intraoral scanner according to claim 4, wherein the at least three monochromatic light sources are light-emitting diodes (LEDs) or a segmented LED.”

148. In my opinion, Babayoff discloses this limitation of claim 5. Babayoff discloses that the at least three monochromatic light sources in Babayoff are light-emitting diodes (LEDs). EX1005, [0057], [0149], [0157].

5. Claim 6

“6. The intraoral scanner according to claim 4, wherein the hardware processor is configured to selectively switch the color of the probe light by switching on and off the at least three monochromatic light sources.”

149. In my opinion, Babayoff discloses this limitation of claim 6. Babayoff explains that the processor 24, also called the processing unit 24, controls the tri-color sequence generator 74 to provide the three different colored illuminations of

the object 26. EX1005, [0145]. The tri-color sequence generator 74 is controlled by the processor 24 to selectively switch the color of the probe light by switching on and off the LEDs, which are the at least three monochromatic light sources. *Id.*, [0044]-[0045], [0048], [0057], [0063]-[0064], [0079], [0130], [0145], [0149], [0157]. Switching the colors of the light sources programmatically using a hardware processor allows for a small switching time.

6. Claim 8

“8. The intraoral scanner according to claim 1, wherein the probe light is directed towards the object in a direction substantially parallel with the longitudinal axis of the tip, and wherein the probe light is further reflected towards the object by a single reflective mirror located in the tip.”

150. In my opinion, Babayoff in combination with Zhang discloses the limitations of claim 8. As discussed *supra*, Babayoff as modified by Zhang provides the probe light. The tip is part of the endoscopic probing member 46 of Babayoff. EX1005, [0138], FIGS. 4A. As shown in FIG. 4A of Babayoff, the probe light, which would be on the path of the incident light beams 36, is directed towards the object 26 in a direction substantially parallel with the longitudinal axis of the endoscopic probing member 46. *Id.*, [0135], [0138], FIG. 4A. The probe

light is then further reflected towards the object 26 by a single reflective mirror located in the endoscopic probing member 46 as described in paragraph [0138] of Babayoff and shown by FIG. 4A. *Id.*, [0138], FIG. 4A. Babayoff also shows an example of the endoscope in the form of a probing member 90 in FIG. 5B in which the light rays 99 travel down the probing member and bounce on the mirror 95 such that they are reflected out through the sensing face 97. *Id.*, [0146], FIG. 5B.

7. Claim 9

“9. The intraoral scanner according to claim 1, wherein the hardware processor is further configured to locally process raw 3D data into data for the 3D geometry, such that the data for the 3D geometry is wirelessly transmitted instead of the raw 3D data, and wherein the raw 3D data is based on the plurality of 2D images.”

151. In my opinion, Babayoff in combination with Zhang and Knighton satisfies the limitations of claim 9. Claim 9 is a device claim with limitations similar to the method claim 23 and, therefore, is obvious for the same reasons provided above with reference to claim 23 under Ground 1.

8. Claim 10

“10. The intraoral scanner according to claim 1, wherein the hardware processor is further configured to locally process raw 3D data into data for the 3D geometry, such that the data for the 3D geometry is wirelessly transmitted at a reduced data rate in comparison with transmission of raw 3D data, and wherein the raw 3D data is based on the plurality of 2D images.”

152. In my opinion, Babayoff in combination with Zhang and Knighton satisfies the limitations of claim 10. Claim 10 is a device claim with limitations similar to the method claim 24 and, therefore, is obvious for the same reasons provided above with reference to claim 24 under Ground 1.

9. Claim 11

“11. The intraoral scanner according to claim 9, wherein the data for the 3D geometry is wirelessly transmitted to a workstation.”

153. In my opinion, Babayoff in combination with Knighton satisfies this limitation of claim 11. Claim 11 is a device claim with limitations similar to the method claim 25 and, therefore, is obvious for the same reasons provided above

with reference to claim 25 under Ground 1.

10. Claim 12

**“12. The intraoral scanner according to claim 9,
wherein the hardware processor processes the raw 3D
data into data for the 3D geometry in real time.”**

154. In my opinion, Babayoff in combination with Zhang and Knighton satisfies this limitation of claim 12. Claim 12 is a device claim with limitations similar to the method claim 26 and, therefore, is obvious for the same reasons provided above with reference to claim 26 under Ground 1.

11. Claim 13

**“13. The intraoral scanner according to claim 1,
wherein a temporal correlation measure is computed
with sensor signals, in the at least one camera,
recorded at different times while the plurality of
configurations in the form of a time-varying
illumination pattern are changed.”**

155. In my opinion, Babayoff in combination with Zhang and Knighton satisfies these limitations. Claim 13 is a device claim with limitations similar to the method claim 27 and, therefore, is obvious for the same reasons provided above with reference to claim 27 under Ground 1.

12. Claim 15

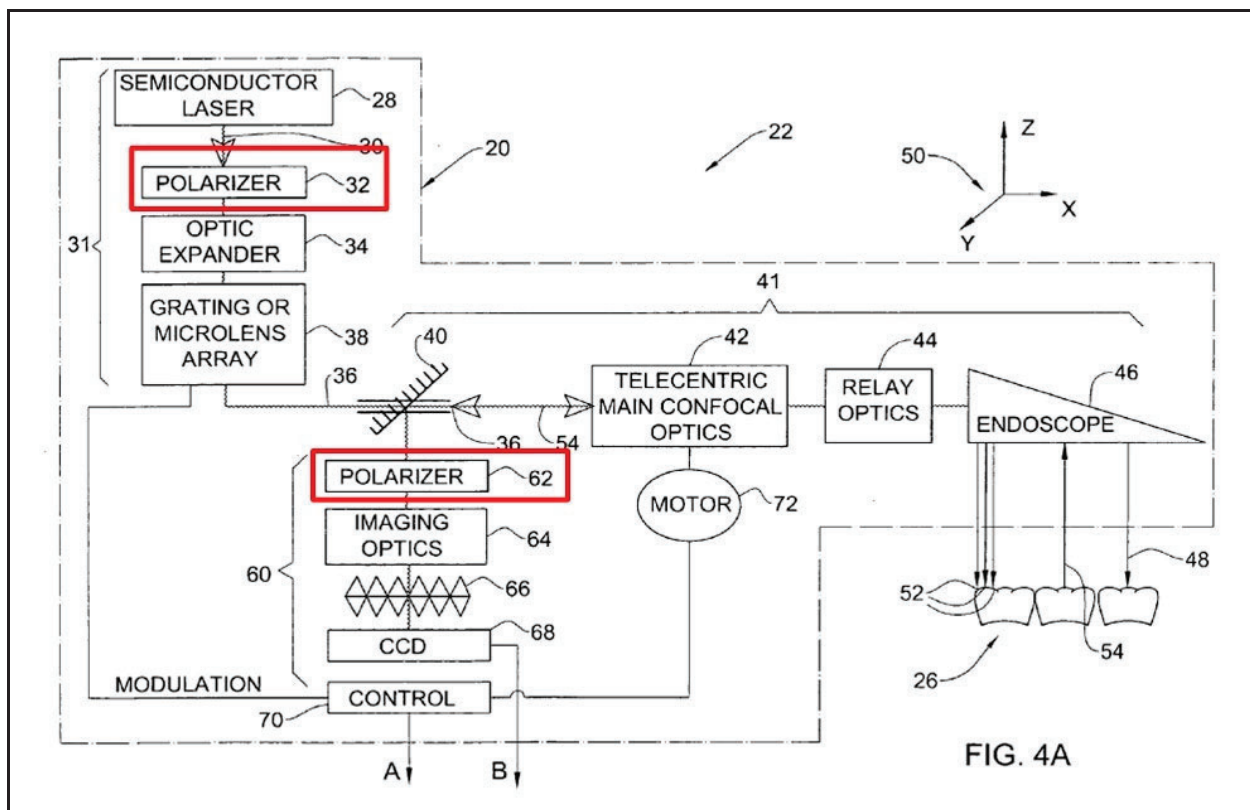
“15. The intraoral scanner according to claim 13, wherein the temporal correlation measure is based on a reference signal that is based on knowledge or on calibration of the plurality of configurations of the time-varying illumination pattern.”

156. In my opinion, Babayoff in combination with Zhang and Knighton satisfies the limitations of claim 15. Claim 15 is a device claim with limitations similar to the method claim 29 and, therefore, is obvious for the same reasons provided above with reference to claim 29 under Ground 1.

13. Claim 20

“20. The intraoral scanner according to claim 1, wherein the intraoral scanner further comprises polarization optics.”

157. In my opinion, Babayoff discloses this limitation of claim 20. The intraoral scanner in Babayoff includes the polarizer 32, which gives rise to polarization of the light passing through it, and also includes the polarizer 62. EX1005, [0135], [0140], FIG. 4A. An annotated version of FIG. 4A of Babayoff is shown below with the polarizer 32 and the polarizer 62 highlighted, which are polarization optics:



Id., FIG. 4A (annotated).

158. Babayoff also shows and describes further exemplary uses of polarization optics in the device of Babayoff. *Id.*, [0037], [0051]-[0054], [0087]-[0090], [0168], FIG. 11. Polarization optics can be used to mitigate the adverse effects of multiple scattering in translucent objects that can lead to errors in the recovered 3D shape.

14. Claim 22

“22. The method according to claim 21, wherein the plurality of 2D images is recorded using a high-speed camera.”

159. In my opinion, Babayoff in combination with Knighton and Hanson discloses this limitation of claim 22. The limitation in this method claim 22 is similar to the last limitation in the device claim of independent 1 and, therefore, is obvious for the same reasons provided above with respect to limitation [f] of claim 1 under Ground 2. Hanson discloses that a CMOS image sensor can have multiple A/D converters per line of pixels in a pixel array and is “high speed.” EX1008, Abstract, [0017], [0028], [0030]-[0037], FIGS. 3, 5, 6. It would have been obvious to a POSA to use a high-speed CMOS image sensor as shown in Hanson as the image sensor for the camera in Babayoff, because Babayoff indicates that it is preferable to have a short time interval (about 0 to 20 milliseconds) between image acquisitions, and Hanson shows an example of an image sensor that would provide that benefit. EX1005, [0027], [0072], [0145].

C. Ground 3: Claim 2 Is Obvious Over Babayoff and Zhang and Knighton and Hanson and Gandyra

1. Claim 2

“2. The intraoral scanner according to claim 1, wherein the pattern generator includes at least one translucent and/or transparent pattern element.”

160. In my opinion, claim 2 is obvious based on the combination provided for claim 1 in Ground 2 above further in combination with Gandyra. As discussed *supra* in the analysis for claim 1 in Ground 2, Zhang shows the use of a projector

to make the pattern for the time-varying illumination pattern. EX1011, pp. 907-909. Gandyra discloses an intraoral scanner for scanning teeth and also teaches in paragraph [0038] the use of a time-variable illumination pattern for the scanning. EX1009, Abstract, [0001], [0030], [0038], FIG. 1. Gandyra teaches that the pattern can be any graphical pattern such as lines, and further teaches that the pattern can be produced using a DLP projection or, alternatively, using the pattern transparency 7, which is a transparent pattern element. *Id.*, [0030], [0038]. It would have been obvious to a POSA to use the pattern transparency of Gandyra to modify the device noted in the combination discussed in the analysis of claim 1 in place of the projector to produce the time-varying illumination pattern because Gandyra shows that the use of such a transparency is a known alternative to a projector for producing the time-varying illumination pattern in the context of scanning teeth. Using a transparency consisting of several translucent elements with different levels of opacities has been a standard technique for displaying patterns, both in mechanical projection devices (e.g., slide projectors, transparencies with piezos) as well as opto-electronic devices such as liquid crystal display (LCD) projectors. Using such a transparency-based projection device would have been obvious to a POSA building a 3D scanning device based on a pattern principle.

161. I am of the opinion that Claims 1-6, 8-13, 15, 20-27, and 29 of the '146 patent are invalid for at least the reasons given above.

I hereby declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. § 1001).

Executed on 10/26, 2022



MOHIT GUPTA, Ph.D