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**Geng**

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(54) **SANITARY SLEEVE OR TIP FOR INTRA-ORAL THREE-DIMENSIONAL CAMERA**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 358 days.

This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
***G06F 19/00*** (2006.01)

(52) **U.S. Cl.** ..... **700/117**; 433/29

(58) **Field of Classification Search** ..... 700/97, 700/98, 117, 118; 353/7, 42, 8, 123; 707/104.1; 433/29, 2, 30; 356/197, 121, 123, 445; 313/113, 313/501
See application file for complete search history.

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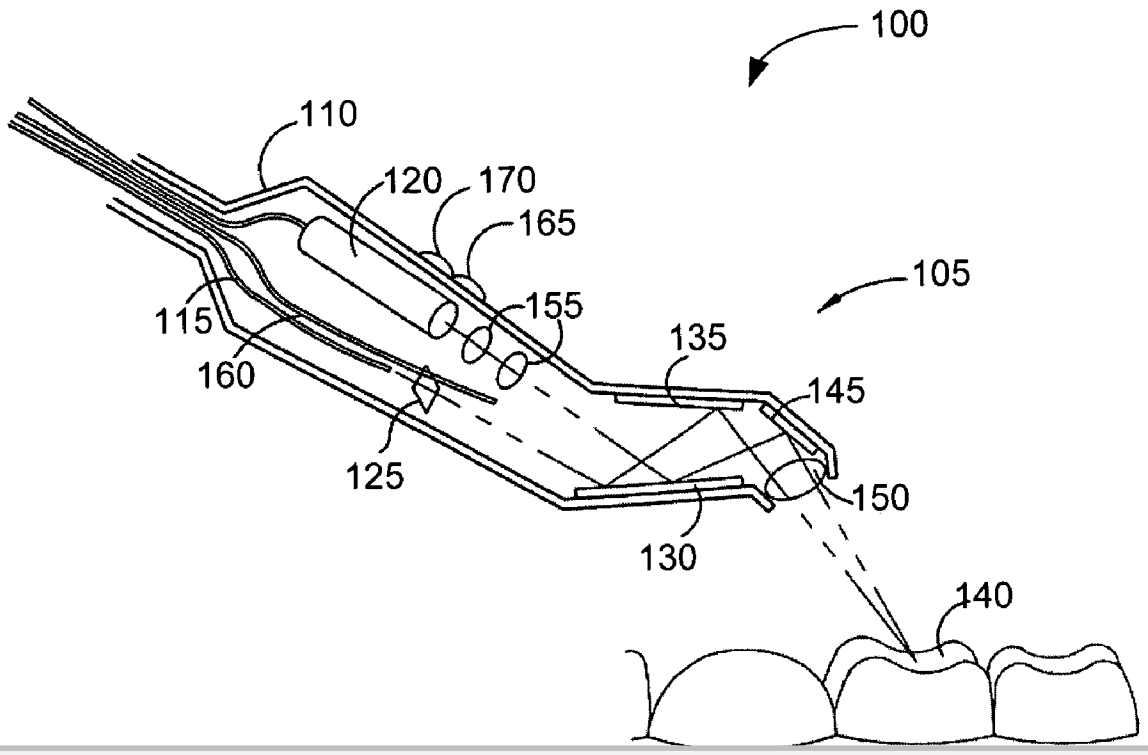
(57) **ABSTRACT**

An intra-oral imaging system includes an optical conduit, a light source generating light rays, at least a portion of which are transmitted through the optical conduit to illuminate a dental surface, a device for converting the light rays into radiation illumination with spatially varying wavelengths prior to illuminating the dental surface, a reflector that directs the light rays from the light source to a selected point; and an imager for receiving the light rays when the light rays are reflected from the dental surface.

**29 Claims, 2 Drawing Sheets**



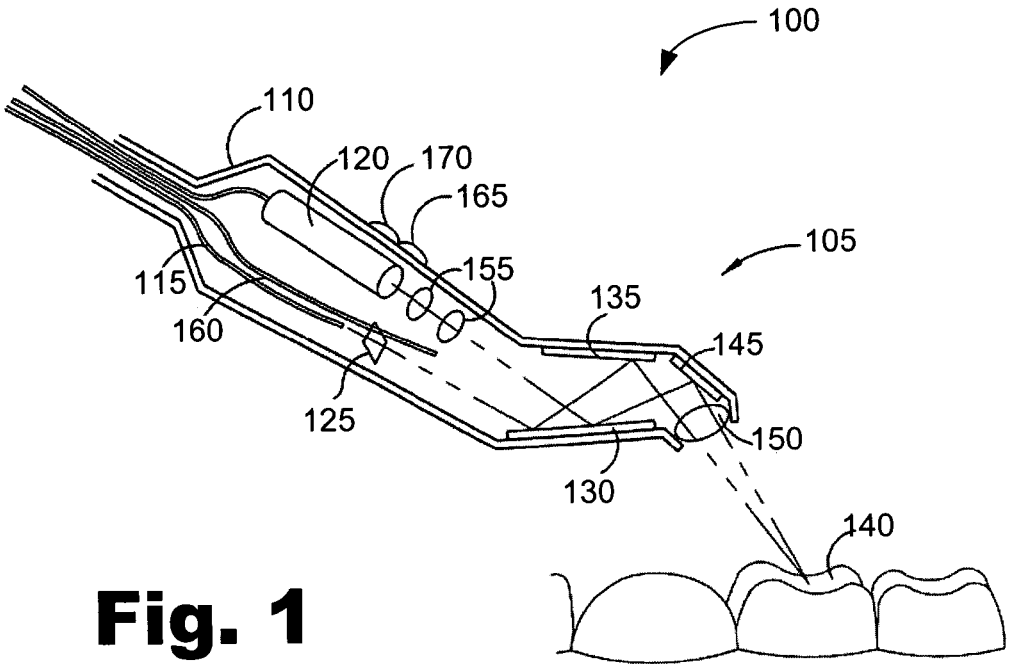



Fig. 1

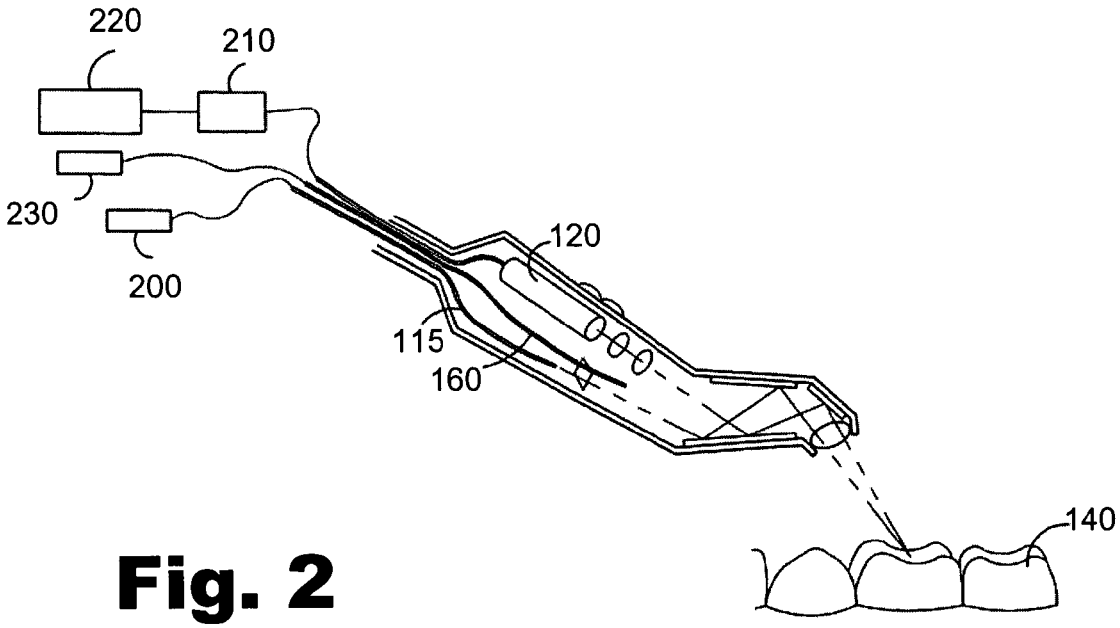



Fig. 2

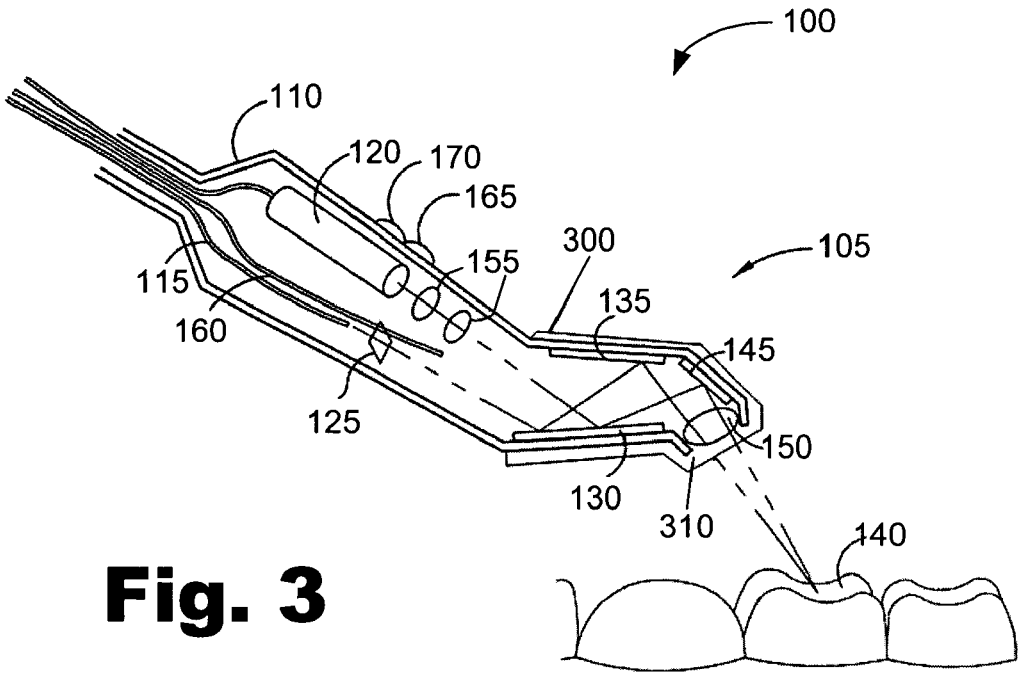



Fig. 3

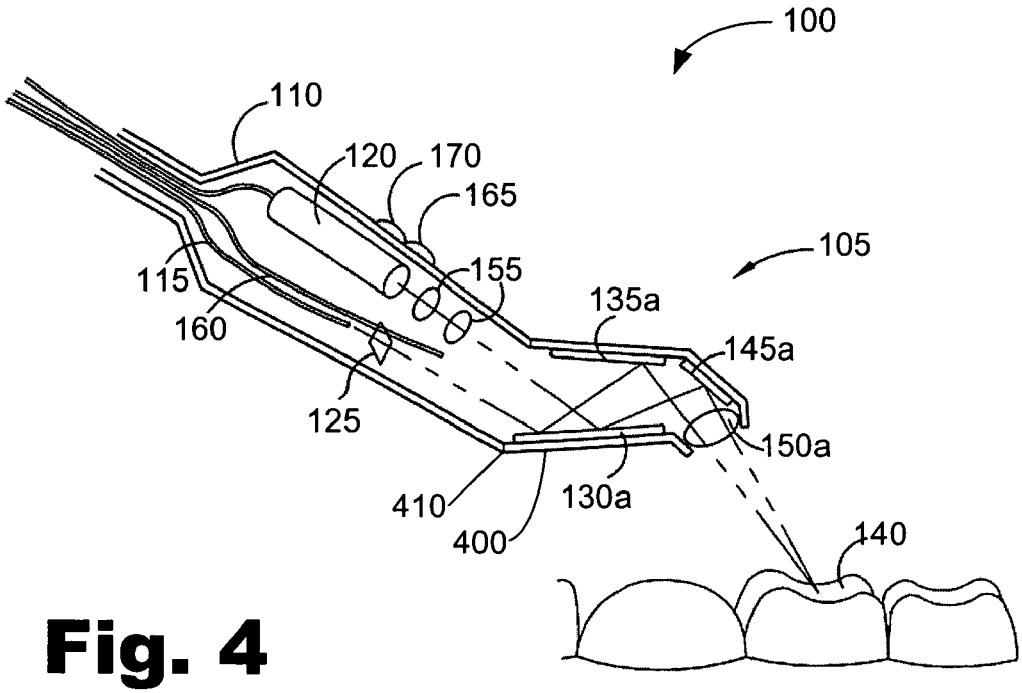



Fig. 4

# SANITARY SLEEVE OR TIP FOR INTRA-ORAL THREE-DIMENSIONAL CAMERA

## RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. § 119(e) from the following previously-filed Provisional Patent Applications, U.S. Application No. 60/408,040, filed Sep. 3, 2002 by Geng, entitled "Sanitary Sleeve or Tip for Intra-Oral Three-Dimensional Camera" which is incorporated herein by reference in its entirety.

The present application is related to U.S. application Ser. No. 09/616,723 by Geng entitled "Three-Dimensional Dental Imaging Method and Apparatus Having a Reflective Member." application Ser. No. 09/616,723 is a Continuation-in-Part of U.S. application Ser. No. 09/616,723 by Geng entitled, "Three-Dimensional Dental Imaging Method and Apparatus." Application Ser. No. 09/616,723 claims priority from U.S. Provisional Application. No. 60/144,010, filed Jul. 15, 1999. All three of these previous applications are hereby incorporated by reference in their entireties.

The present application is also related to (1) U.S. Provisional Patent Application No. 60/375,934, "Method and Apparatus for Generating Structural Pattern Illumination" filed Apr. 26, 2002; (2) U.S. Provisional Patent Application No. 60/178,695, "Improvement on the 3D Imaging Methods & Apparatus" filed Jan. 28, 2000; (3) U.S. patent application Ser. No. 09/770,124, "3D Surface Profile Imaging Method & Apparatus Using Single Spectral Light Condition" filed Jan. 26, 2001; (4) PCT Patent Application No. PCT/US01/18644, "3D Surface Profile Imaging Method & Apparatus Using Single Spectral Light Condition" filed Jun. 11, 2001; and (5) U.S. patent application Ser. No. 09/771,531, "Method & Apparatus for 3D Imaging Using Light Pattern Having Multiple Sub-Patterns" filed Jan. 29, 2001. All of these previous applications are hereby incorporated by reference in their entireties.

## FIELD OF THE INVENTION

The present invention relates to intra-oral imaging of dental surfaces and to methods and apparatus for such imaging. The present invention also relates to the field of sanitary measures taken for dental instruments.

## BACKGROUND

The accurate and rapid intra-oral measurement of dental surfaces for many purposes including the production of prosthodontics or dental parts has been a goal of Dental Science for some time.

A system developed by Francois Duret et al. combines holographic moire techniques to produce an array of three dimensional points that represent a single-view image of a tooth. The hand held optical probe consists primarily of a laser diode and a CCD photo sensor in order to capture dental images. The spatial resolution of the dental images produced with this technique is about 20 μm. Images from different views are then interactively combined, and a rigid theoretical tooth is fitted to the points in order to reconstruct the tooth analytically. With this system, a dental practitioner can personalize the anatomy of a tooth. Further, this system allows design of a custom crown for a particular tooth as



can produce a posterior crown in less than an hour. However, as mentioned this system requires the use of a laser in the vicinity of a patient's eyes.

U.S. Pat. No. 4,575,805 describes a system called CEREC (Ceramic Reconstruction). According to this patent, the intra-oral scanner incorporates a light emitting diode and lens system to illuminate the cavity of the tooth. The light rays pass through a set of ruled lines, casting stripe patterns on the prepared cavity. A CCD camera is used to record the stripe pattern in a 12.8 $mm^3$ volume. Due to the limitations on the width of the ruled lines, spatial resolution is quite low. To increase the spatial resolution, a mechanism was introduced that requires multiple frame images. Using a piezo motor, the ruler is moved to four fixed and offset locations, allowing the CCD camera to take an image at each of the four locations. The number of measurements is thus quadrupled. In this arrangement, the system loses the capability of taking a complete 3 dimensional measurement in a single snapshot, and the design of the system becomes fairly complicated.

Rekow developed a system known as the Minnesota System. The raw image of a tooth is acquired using a standard 35 mm camera through a 10 mm diameter single rod lens magnifying laryngopharyngoscope. A prism system at the distal end of the rod lens permits the field of view to be 90 degrees. A number of views are used to ensure that complete information is obtained and to minimize the likelihood of blur caused by patient movement. Fiber optics provides the illumination necessary to capture the stereos images, or slides, that are taken on standard photographic film. The slides are then digitized in 4096×4096 resolution. Stereo correspondence algorithms are used to produce three dimensional measurement data. The aim of this system was to produce a low cost high resolution three dimensional measurement. It does not, however, take advantage of the rapid advances in the field of machine vision and analysis.

While each of the above prior art systems has merit in the measurement of dental structure, each have shortcomings of one type or another. Most require multiple imaging which in turn requires that the patient maintain a fixed position for a long period of time. In addition, most of the above systems lack adequate resolution or expose the patient to undesirable radiation such as a laser.

U.S. Pat. No. 5,675,407 to Geng issued Oct. 7, 1997 describes a novel three-dimensional surface profile measuring technique that is able to acquire full frame, dynamic 3-D images of objects with complex surface geometries at high speed. By "full frame 3-D image" is meant that the value of each pixel (i.e. picture element) in an acquired digital image represents the accurate distance from the camera's focal point to the corresponding point on the object's surface. The (x,y,z) coordinates for all visible points on the object surface are supplied by a single 3-D image. By "acquiring dynamic 3-D images at high speed" is meant, that a camera of the type described in U.S. Pat. No. 5,675,407 is able to capture a full frame 3-D image in one snapshot, i.e. within one exposure time of its imager device (for example, within one millisecond), and can obtain a stream of such 3-D images at a sustainable speed of at least 30 frames per second.

## SUMMARY

An intra-oral imaging system includes an optical conduit, a light source generating light rays, at least a portion of which are transmitted through the optical conduit to illumi-

lengths prior to illuminating the dental surface, a reflector that directs the light rays from the light source to a selected point; and an imager for receiving the light rays when the light rays are reflected from the dental surface.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate various embodiments of the present apparatus and method and are a part of the specification. The illustrated embodiments are merely examples of the present apparatus and method and do not limit the scope of the disclosure.

FIG. **1** is a schematic representation of the intra-oral camera of the present invention.

FIG. **2** is a schematic representation of the combined camera, image processing and CAD/CAM system of the present invention.

FIG. **3** is a schematic representation of an intra-oral camera with a sanitary sleeve according to a first embodiment of the present invention.

FIG. **4** is a schematic representation of an intra-oral camera with a sanitary sleeve according to a second embodiment of the present invention.

Throughout the drawings, identical reference numbers designate similar, but not necessarily identical, elements.

## DETAILED DESCRIPTION

An intra-oral imaging system includes an optical conduit, a light source generating light rays, at least a portion of which are transmitted through the optical conduit to illuminate a dental surface, a device for converting the light rays into radiation illumination with spatially varying wavelengths prior to illuminating the dental surface, a reflector that directs the light rays from the light source to a selected point; and an imager for receiving the light rays when the light rays are reflected from the dental surface.

In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present method and apparatus. It will be apparent, however, to one skilled in the art that the present method and apparatus may be practiced without these specific details. Reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearance of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

### Improved Intra-Oral Dental Probe and Camera

FIG. **1** illustrates an intra-oral imaging system (**100**) that produces both 3-D and color 2-D images of dental structure. The intra-oral imaging system (**100**) generally includes an intra-oral probe (**105**) that is surrounded by an appropriately shaped housing (**110**) that encompasses a fiber optic bundle (**115**) and a CCD imaging device (**120**). A linear variable wavelength filter or LVWF (**125**) is disposed at the outlet of fiber optic bundle (**115**). The purpose, composition and utility of this device are described in detail in aforementioned U.S. Pat. No. 5,675,407 and such description will not be repeated herein.

Light projected from fiber optic bundle (**115**) passes through LVWF (**125**) and is then reflected from a first mirror surface of dental structure (**140**) is then conducted by reflection from a third mirror (**145**) to the first mirror (**130**) and onto the CCD imagining device (**120**). Appropriate lenses or lens pairs (**150**, **155**) maybe incorporated to obtain appropriate focus of the image and protection of the interior of housing (**110**). The particular shape or configuration of CCD imaging device (**120**) and housing (**110**) is not critical to the successful practice of the invention; so long as the configuration of the housing allows for maintenance of a substantially fixed relationship between an output end of the fiber optic bundle (**115**) and the receiving end of the CCD imaging device (**120**) during imaging. A configuration in which the parts of the probe (**105**) remain in a substantially fixed relationship with respect to one another within the housing (**110**) facilitates generation of a three-dimensional image. In such a configuration, the projection angle θ, described in the '407 patent, remains substantially constant, such that it can be readily related to the different spectral wavelengths produced by a light source which serves to define the x,y,z, coordinates of the three-dimensional image.

A second fiber optic bundle (**160**) may act as a second independent diverging white light source to permit probe (**105**) to be used to obtain intra-oral images with accurate color representation for shading, color shadings and shadows. The image is obtained in a similar manner as the three-dimensional image described above. Correct color shading may be important to both the patient and the dentist. Since different parts of the tooth may have different shading and reflection, it is presently an "art" to obtain to obtain a "natural" effect, requiring subtleties in shading and intensity of coloration as well as thickness of materials. Switches (**165**, **170**) permit the selective switching between activation of the fiber optic bundles (**115**, **160**) facilitates the use of the same probe (**105**) to obtain virtually simultaneously both 3-D and 2-D colored images.

Housing (**110**) may be fabricated from any suitable material such as a metal or a plastic material, however, for patient comfort plastic or polymeric materials such as polyethylene or polypropylene are preferred as the material of construction. Similarly, fiber optic conduit (**115**) may comprise a single monolithic light conductor or a bundle of fiber optic fibers. The latter configuration is generally preferred on a cost basis. Suffice it to say for the instant purposes, that LVWF devices are commercially available and well known to the skilled optical artisan. Their operation and the effects they produce are discussed in detail in the foregoing patent. The color ranging principle is not at all restrained by nor does it rely on the LVWF to produce the required radiation. In fact, any means that can provide registered spatial distribution of an energy projection ray that can be related to the wavelength of the ray may be used in the system. Additionally, although the LVWF (**125**) is depicted as being at the exit of fiber optic bundle (**115**), it could just as readily be incorporated at the light source described hereinafter.

### Improved Intra-Oral Imaging and Dental Fixture Manufacturing System

FIG. **2** illustrates the components external to probe (**105**) in more detail. A light source (**200**) is connected to fiber optic bundle (**115**). Such a light source as described in the '407 patent generates a sheet of white light that passes through a cylindrical lens (not shown) to form a "fan beam" light source. This fan beam light then passes through an LVWF located either ahead of or behind fiber optic bundle

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