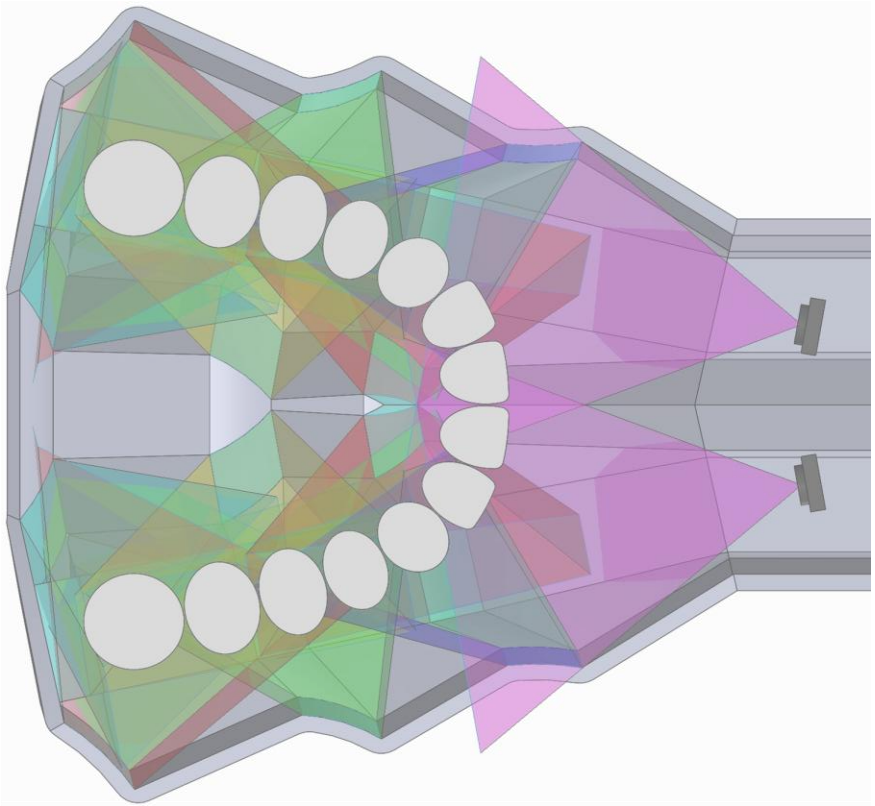

Eyes of AI Pty Ltd
EAI Intraoral Scanner (IOS)

OAU EAI 260201.1

# Stage 1
# 3D CAD Development &
# Proof of Principle Prototype Testing

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# Contents

# Stage 1

3D CAD Development & Proof of Principle Prototype Testing

# Introduction

## Background to Stage 1

This Structured Light 3D scanning system Concept was first developed in 3D CAD to facilitate calculation of light paths, Camera and Structured Light triangulation and overall geometry for the final device. The Concept incorporates a Mirror Array of multiple convex mirrors. The Mirror Array simultaneously directs multiple viewpoints of the dental arch back to two Cameras. The Mirror Array also projects a Structured Light Pattern & white LED illumination onto all areas of the teeth simultaneously. Additionally, the mirror array

Once the design had been developed sufficiently in 3D CAD, a Proof of Principle prototype was produced to evaluate the practicality of the Concept.

The prototype was built to confirm that the geometry of the mirrors and camera position would function as calculated and as required. The requirement being that all surfaces of the full arch of the teeth (top or bottom arch) would be visible and able to be scanned virtually simultaneously, i.e. all surfaces could be mapped with a single pass of the scanner, in a short period of time.

The prototype was designed to test both the visible light illuminated image return (via a white LED), plus a Structured Light projection onto the surfaces of the teeth and gums. The Structured Light projection was facilitated using a green Laser projecting through a Diffraction Grating. The Diffraction Grating created a regular grid of laser light points, which are projected onto the teeth from multiple angles, via the convex Mirror Arrays. Two additional lighting systems were tested within the bounds of the system - Ultraviolet Fluorescence LED and Near Infrared Reflectance Technology LEDs, which highlight additional functionality that can be easily incorporated into the same base system.

In the final product, the combination of structured light projection, captured via two Cameras which are offset from the Structured Light Projectors, allows for positional triangulation. This positional triangulation is then used to calculate the exact geometry of the surfaces of the teeth and gums.

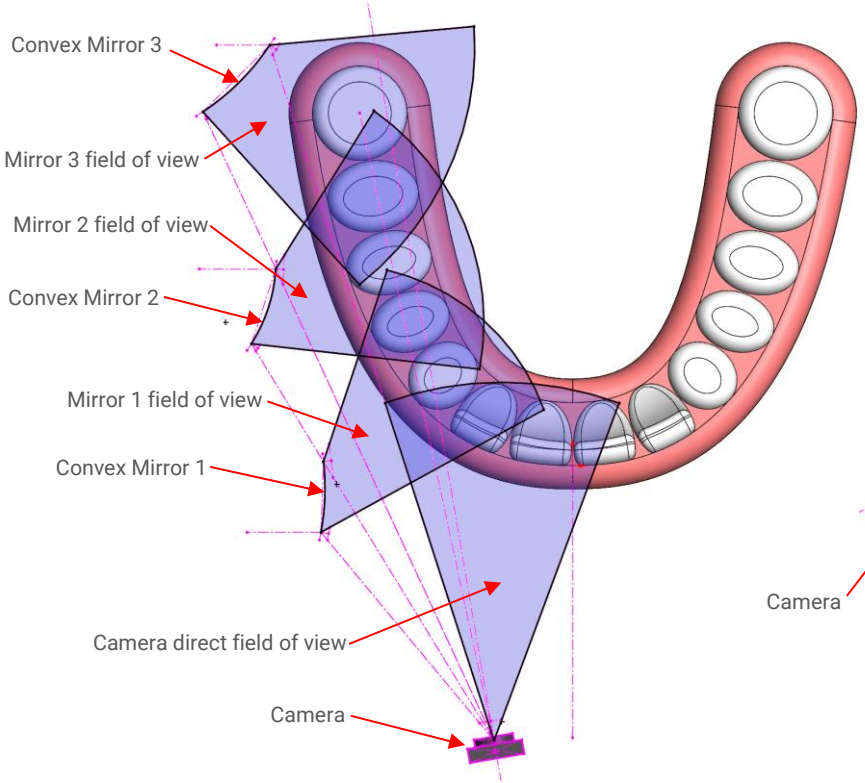
Note: The concept prototype was built with the mirrors, projectors and cameras only implemented on one side. In the final product, there would be 2 sets of mirrors, cameras and structured light projectors, i.e. one camera, one set of mirrors & projectors per side.

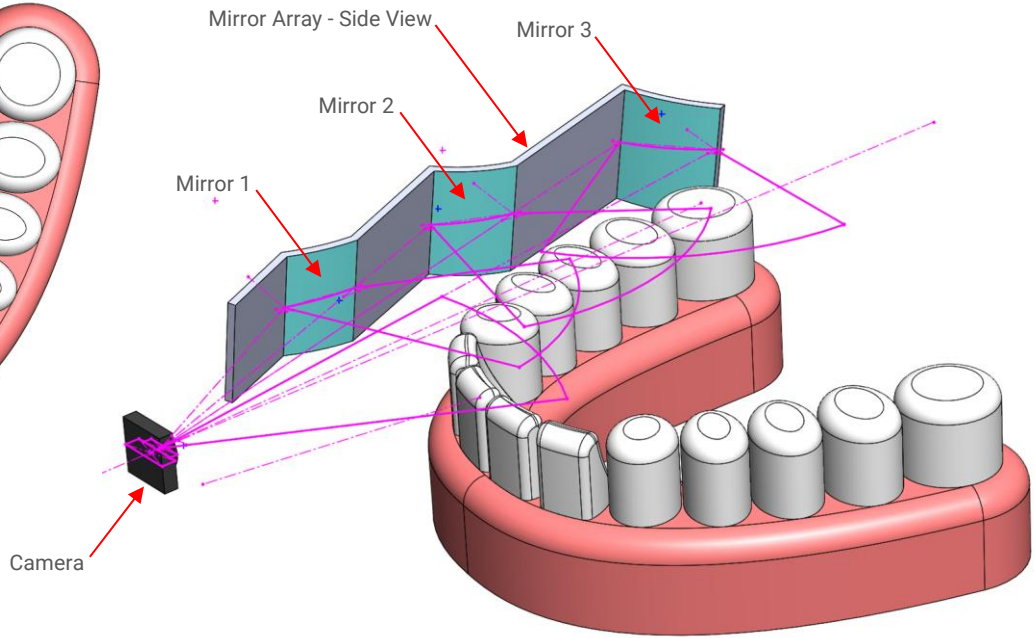
# CAD Design

## Mirror Array Geometry 1

The Mirror Array fields of views shown for a single array of 3 convex mirrors, plus a single direct view of the front teeth to the Camera.

The full device would have 6 arrays of mirrors - 3 per side.

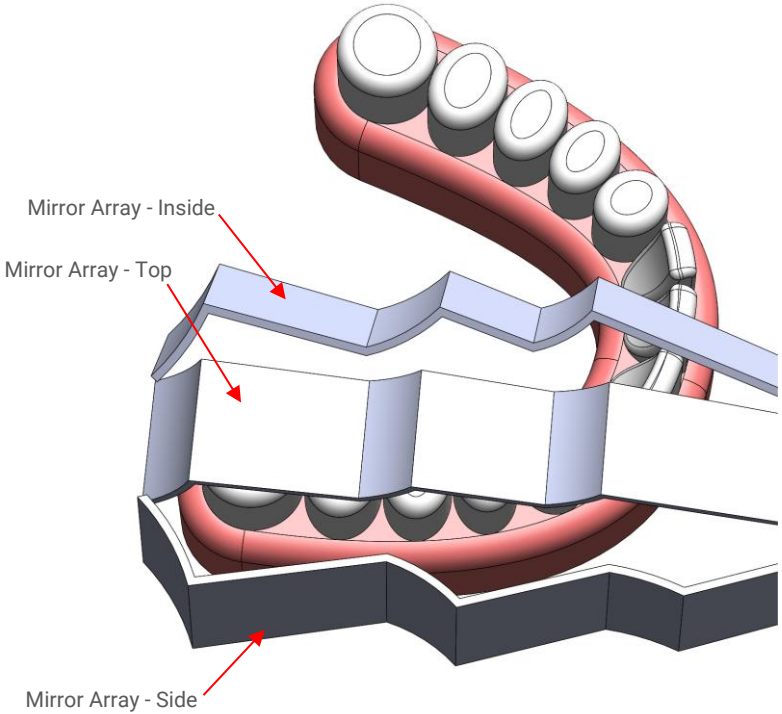


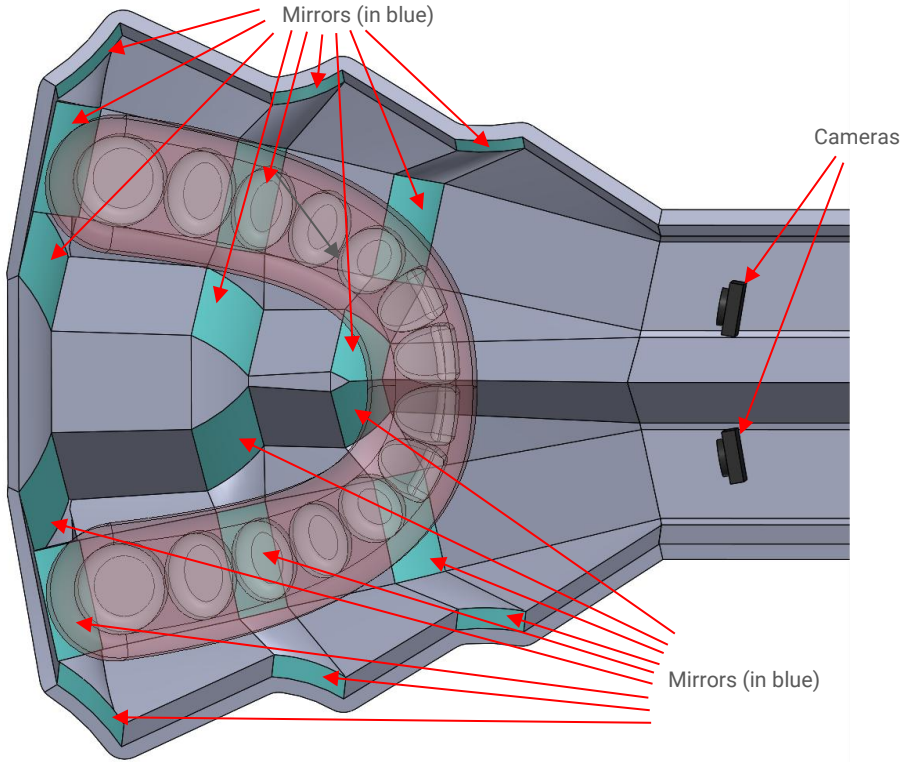



# CAD Design

## Mirror Array Geometry 2

Each side of the device frame has 3 x Mirror Arrays with 3 convex mirrors each.
The full 6 arrays of mirrors shown in blue below (18 mirrors in total).



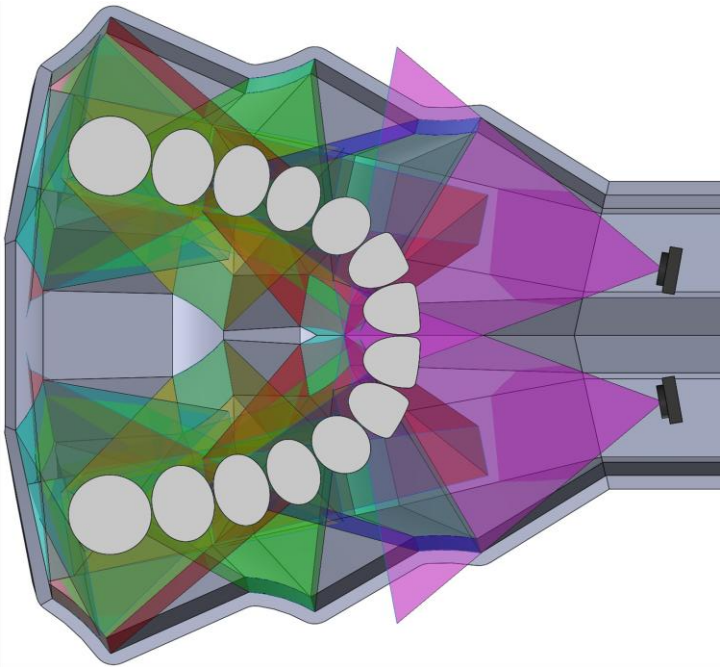



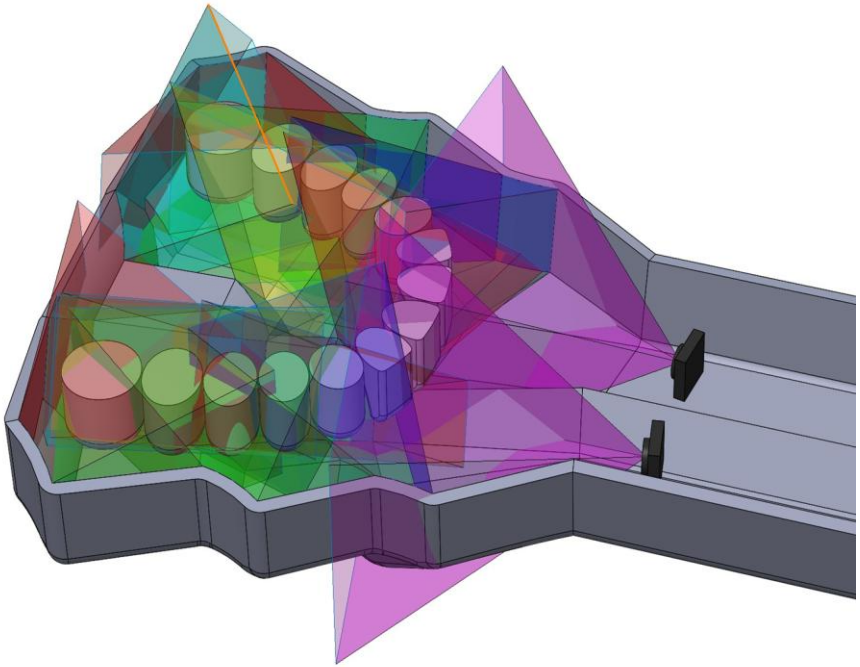
# CAD Design

## Cameras & Mirrors - Fields of View 1

Total Mirror Array fields of views shown.
18 mirrors, plus the 2 x direct views from the Cameras of the front teeth (shown in purple).

Every surface of every tooth is theoretically covered. However it may be necessary to move the device slightly in order to view hard to see areas, for example between individual teeth. This would be particularly true if the teeth are misaligned and overlapping (see next slide).

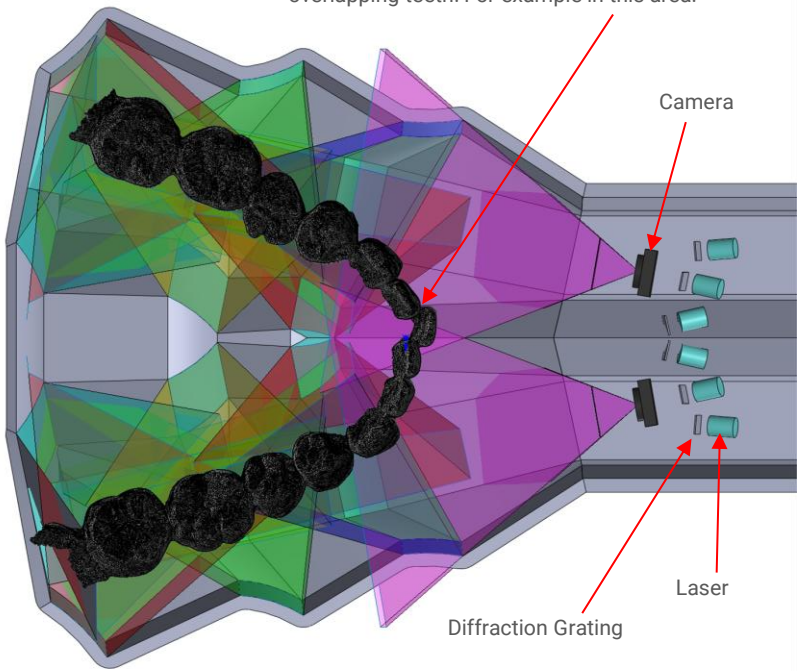




# CAD Design

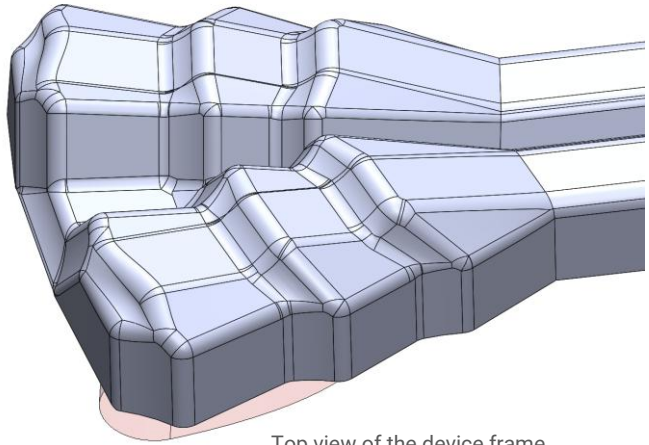
## Cameras & Mirrors - Fields of View 2

It may be necessary to move the device frame slightly, to view tooth surfaces hidden behind overlapping teeth. For example in this area.




Using actual 3D dental scanning data it can be seen that it may be necessary to move the device slightly in order to view hard to see areas, between individual teeth. Particularly if the teeth are misaligned and overlapping (see below).

Also shown below are the Laser Projectors and Diffraction Gratings, which produce the Structured Light. The Structured Light is reflected off the convex mirrors and onto all surfaces of the teeth, in a similar way, but opposite in direction, to visible images going back to the cameras.

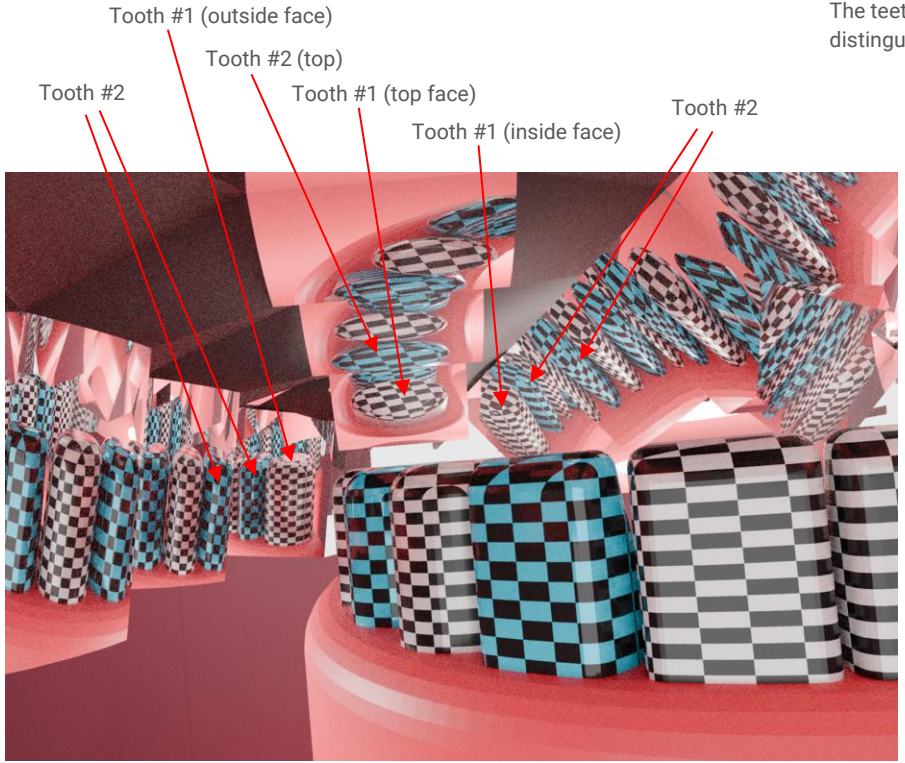


Top view of the device frame

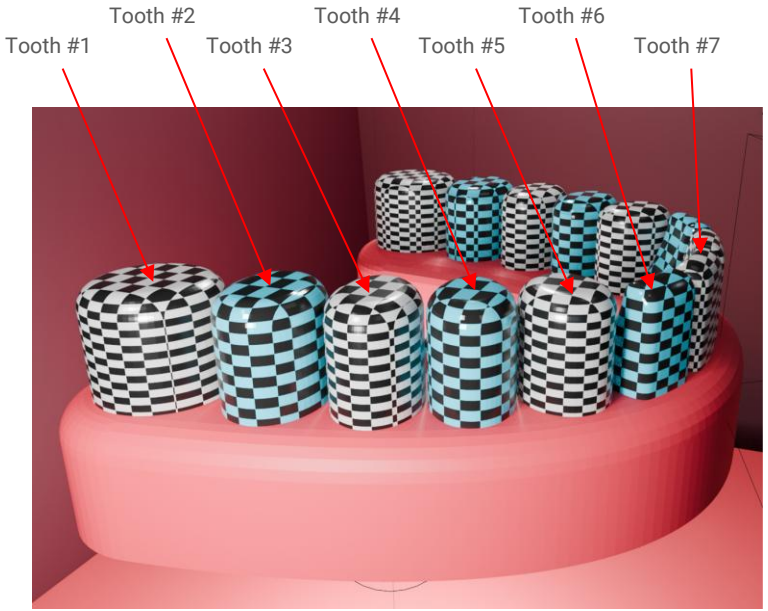
# CAD Design

## CAD Render of Camera View

Below is a 3D CAD render of the image which would be captured from one of the two Cameras (left side camera). Also shown is the teeth model, with checkerboard pattern, for reference.
The render shows the overlapping fields of view of individual teeth. Overlapping fields of view are critical to stitching together multiple images into a unified 3D model of the full palette.
The teeth have been given a checkerboard appearance & alternating blue and white colouring, to help distinguish each individual tooth in the rendering (teeth numbered below).



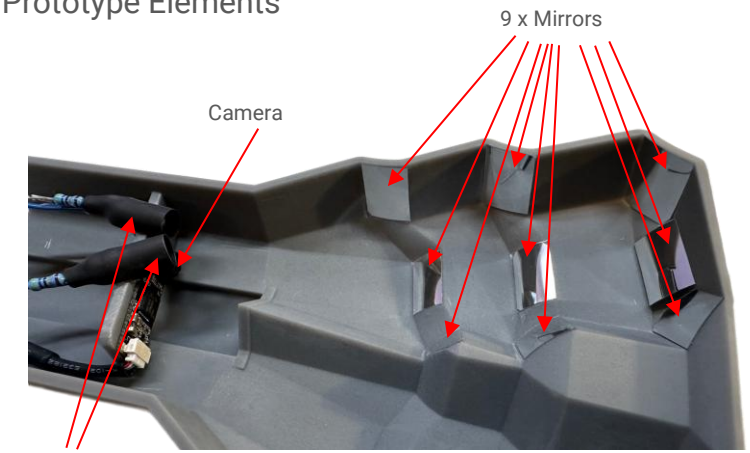

Each individual tooth can be viewed from multiple perspectives in multiple mirrors




Full set of lower jaw teeth modelled

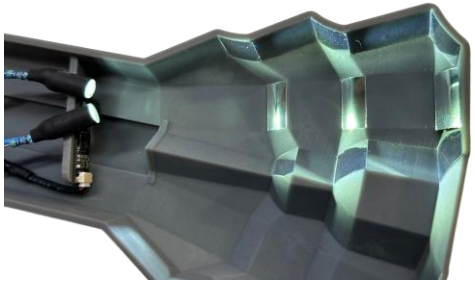
# Proof of Principle Prototype

## Prototype Elements

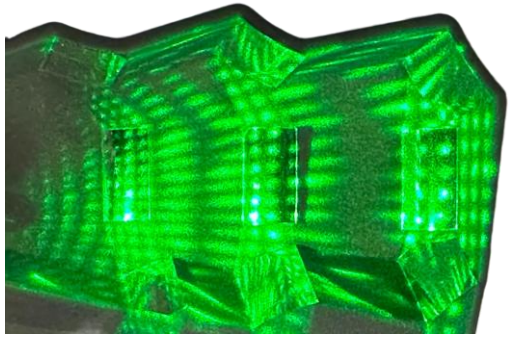



Left side Mirror Array

A Proof of Principle prototype was constructed from the 3D CAD model, as an FDM rapid prototype. The prototype incorporated a mini camera, functional mirrors, LED illumination and structured light projection (produced using a green laser and a diffraction grating).

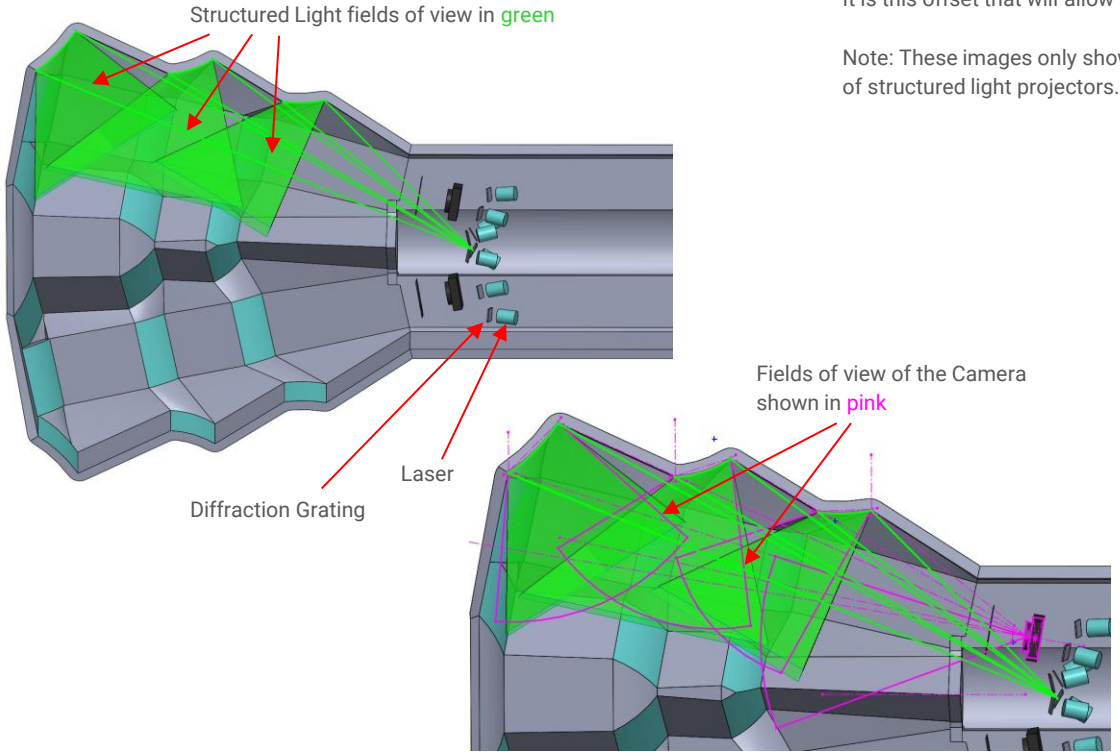
White LEDs projecting light onto the Mirror Array shown. The mirrors then reflect this light (visible, UV and infrared light) from multiple sources (each of the convex mirrors) onto the teeth, illuminating the teeth from every angle.



Above is a green Laser projecting light through a Diffraction Grating and onto the Mirror Array. This creates an array of Structured Light sources, each projecting onto a different area of the teeth.

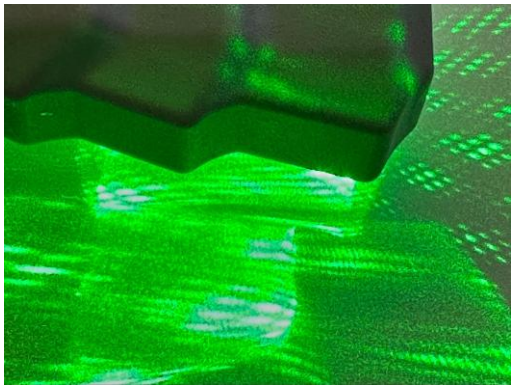
# Proof of Principle Prototype

## Structured Light - Fields of View & Triangulation




The two CAD images below show the calculated Structured Light projection (in green) from the 3 x side Mirror Array. The second CAD image includes the field of view of the Camera (in pink) via the same mirrors. This illustrates the triangulated offset between the projected laser light pattern and the Camera view.
It is this offset that will allow calculation of the tooth surface geometry.

Note: These images only show light tracing for 1 off the 6 sets of proposed mirrors & 1 off the 8 sets of structured light projectors.

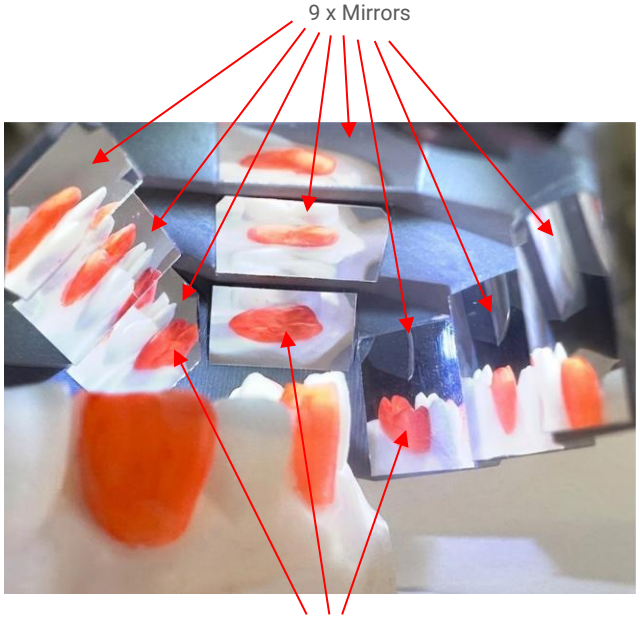


Shown above is a photo of the Proof of Principle Prototype producing a structured light pattern of green dots and stripes.
The structured light shown is reflected off the array of 9 convex mirrors and onto all surfaces of the teeth.
In the photo the structured light is illuminating the bench top, to illustrate the reflected light dispersion.

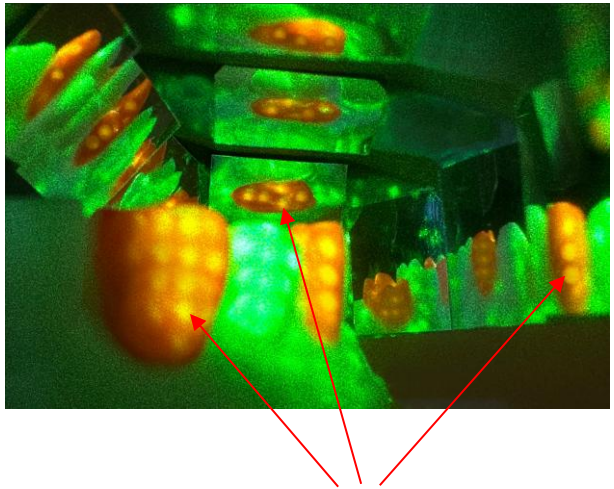
# Proof of Principle Prototype
## Camera View

Below are images taken by the Camera in the Proof of Principle prototype.
The image on the left shows the teeth and their reflected images shown in the mirrors. The rear tooth (orange) can be seen in all 3 rear mirrors, from different angles.

The image on the right shows the Structured Light pattern projected onto the teeth via the mirrors. It can be seen that the Structured Light pattern is visible on the top, outside and inside faces if the teeth simultaneously, as required.




Rear orange tooth visible from different perspectives in all 3 rear mirrors.

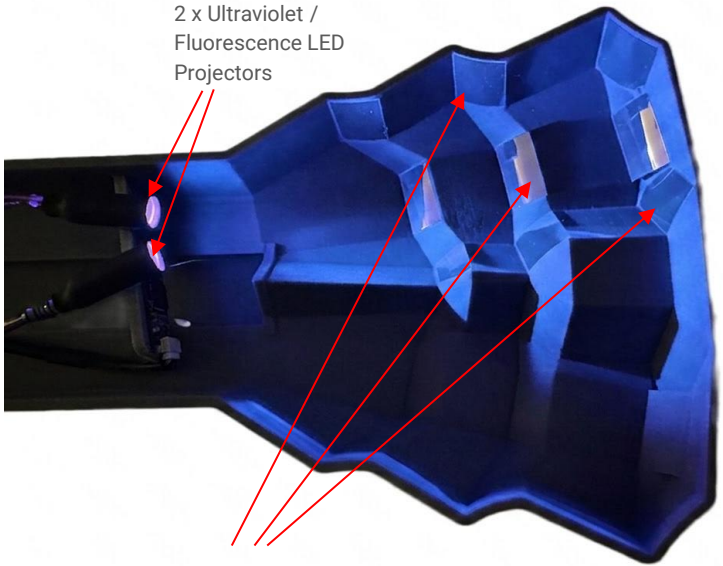


Structured Light pattern projected onto the teeth vis the Mirror Array.

The teeth used in the CAD model were printed and coloured, to allow for easy differentiation of individual teeth in the captured images.

# Proof of Principle Prototype

## Fluorescence Plaque Biofilm Mapper Technology

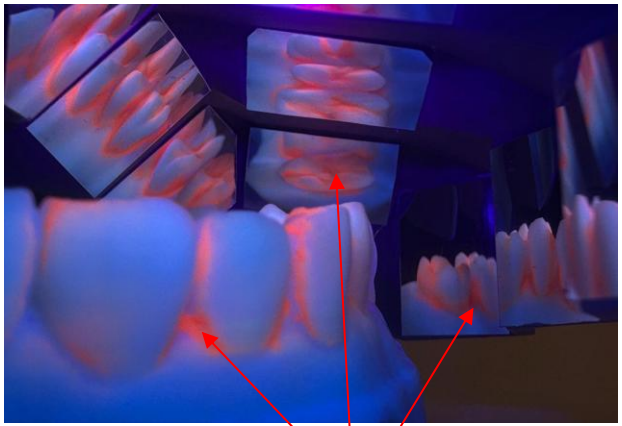



Ultraviolet / Fluorescence light is projected onto all surfaces of the teeth simultaneously from different perspectives through all 9 rear mirrors per side.

Plaque Biofilm Mapper Technology (often referred to as biofluorescence or 3D digital mapping) is an advanced diagnostic and educational tool used to visualize and measure bacterial buildup on teeth.

How it works: Instead of using traditional physical disclosing tablets that stain your teeth, this tech uses specific wavelengths of light (like Ultraviolet / Fluorescence) to illuminate the mouth. The metabolic byproducts of living plaque bacteria naturally absorb this light and emit a bright, distinct color (such as orange).

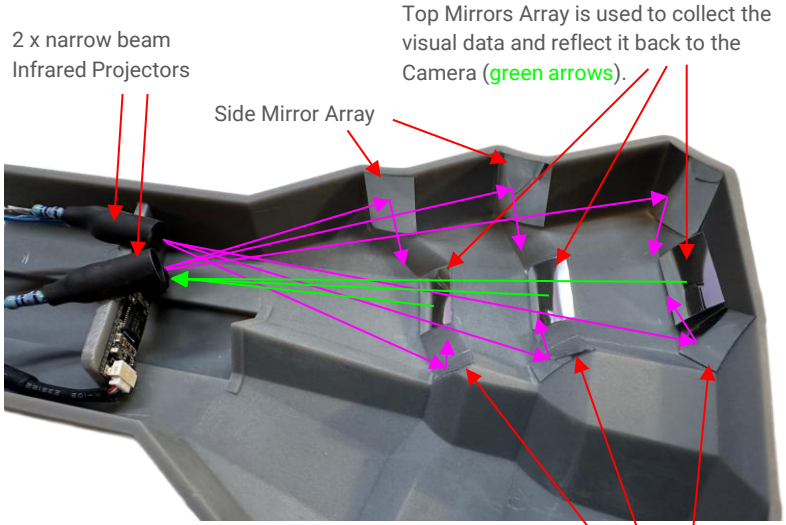
We have incorporated a visualization of Plaque Biofilm Mapper Technology into the Proof of Principle prototype. The image on the left shows the 2 x UV LED Projectors and their reflected light shown in the mirrors. The image below shows a simulation of the easily identified glowing plaque and biofilm between, and within the cavities of the teeth. All surfaces of the teeth can be simultaneously illuminated and mapped.



Simulation of plaque and biofilm shown glowing on all surfaces of the teeth. All teeth are simultaneously illuminated and mapped.

# Proof of Principle Prototype

## Near-Infrared Reflectance Technology (NIRT)

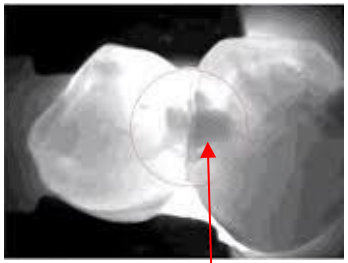



Near-Infrared Reflectance Technology (NIRT) is a dental inspection method that uses invisible, near-infrared light to see inside the semi transparent material of the teeth. It safely detects subsurface defects, internal voids (such as dental caries), delaminations, cracks and structural weaknesses of the teeth without the health risks associated with X-ray technologies.

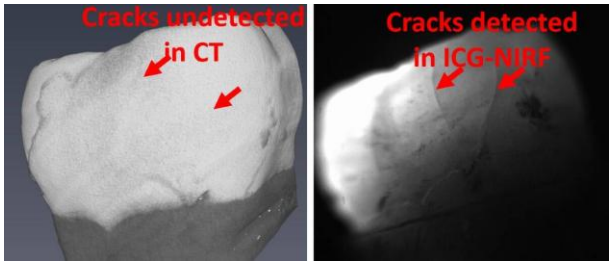
We have incorporated a visualization of NIRT implementation into the Proof of Principle prototype. The device is ideally suited for NIRT, as it can utilise the 2 x Side Mirror Arrays to direct the IR light into the teeth from both sides simultaneously. The Top Mirror Array captures the visual data of the illuminated teeth as seen from above, and reflects those images back to the Camera. The diagram on the left shows the light path of the 2 x narrow beam Infrared Projectors (pink arrows) and the reflected light path from within the teeth being directed back to the Camera (green arrows).

The Top Mirror Array is not used to project any near-infrared light into the teeth, it is only used to collect the visual data and direct it back to the camera.

Camera view of teeth from above



Dark area is dental caries




Cracks detected using NIRT, which were undetected with CT scan

# Conclusion

## Stage Summary

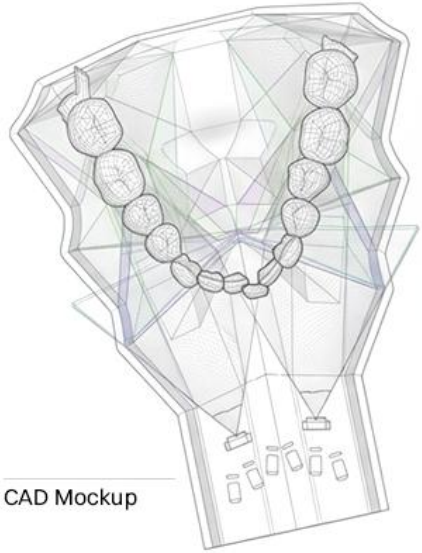
**Design and Testing:**
The Concept's 3D CAD Development and Proof of Principle Prototype Testing have validated that the required Camera and Structured Light triangulation for determination of the 3D surface geometry, is possible. The testing has validated that the use of an array of convex mirrors to project Structured Light and white LED light onto the teeth and gums is practical. Additionally it has been verified that the overall geometry for the final device is both ergonomic - it can fit within the mouth easily, and practical - when in use the Mirror Array can function as required, and is not obscured by the teeth or gums.

**Plaque Biofilm Mapper Technology** - It was determined that incorporation of this technology into the device has been easily implemented, practical in use and is highly beneficial from the perspective of patient health. This could add another layer of utility to the device, without the need for complex modifications to the overall design, due to the existing light projection and image capturing functionality of the Camera and Mirror Array.

**Near-Infrared Reflectance Technology (NIRT)** - This technology was also easily implemented into the device. It would be practical in use and again be highly beneficial from the perspective of patient health. As with Plaque Biofilm Mapper Technology, this would add an additional layer of utility to the device, again without the need for complex modifications to the overall design.

Note: The prototype was tested to see if it could be easily inserted into the mouth. Once in the mouth it was then moved around, relative to the teeth, to see if scanning of hidden areas was possible (overlapping teeth etc.).

The conclusion was that the device in its current configuration can be quite easily placed in the mouth, without patient discomfort, and once inside the mouth it can be easily moved around as required.



CAD Mockup

Benchtop
Prototype


Conceptual
Illustration

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