White Paper

Digital Light-Field for Vision Care

Author
Malcolm Paterson

Contact
malcolm.paterson@creal.com

Confidentiality
This document is confidential and intended solely for the use by the recipient and its affiliates.

CREAL SA
Chemin de la Dent d'Oche, 1A
1024 Ecublens
Switzerland

February 2023

Summary

CREAL has developed unique technology for the digital near-eye light-field projector. The device projects a genuine/true 3D image, and can place virtual images at any optical distance or respectively apply arbitrary spherical, astigmatic or prismatic power to the displayed virtual image.

Unlike existing devices, such as phoropters, change of content or applied correction is instantaneous. Furthermore, images with different corrections at different distances can be applied and displayed simultaneously. The device built on such technology could be also made "intelligent" and controlled by a simple touch screen, allowing for an unassisted procedure carried out by the eye care practitioner and, if appropriate, the patient.

Therefore, CREAL believes that digital near-eye light-field projector could bring a revolution to numerous optometric, optical and ophthalmological applications, especially in subjective diagnostics.

We think this is a great opportunity for industry and the profession to be involved in bringing 21st century technology to vision care.

1. CREAL's Digital Light-Field Technology

1.1 CREAL

CREAL is a Swiss startup founded in 2017 with the mission to develop a near-eye light-field display. Such a device creates an image where the eye can focus naturally on virtual objects in different optical distances, experiencing their realistic blur, micro-parallax and breathtaking image quality.

1.2 Digital Light-Field

Light-field imagery is a genuine representation of how light exists in the real world. Light-field displays provide imagery with entirely natural focal depth. Thus, light-field allows the human eye to focus at virtual objects at correct distances, to perceive all monocular depth cues and to blend the real and virtual objects without visual conflicts.

Following is a simple schematics of our digital light-field projector. It performs sequential pin light illumination of a Spatial Light Modulator which reflects a sequence of "always-in-focus" light-field components into an array of pinhole-like viewpoints at the exit pupil, forming a discretized light-field.

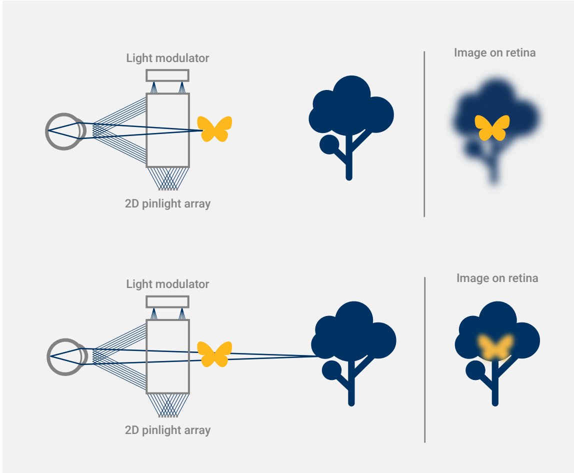


Fig. 1.1 More detailed technical information on light-field technology is available on request.

1.3 Other Applications

CREAL's digital light-field technology is also suitable for displaying graphically rich content in VR and AR. CREAL already embeds it in its patented light-field headset evaluation kits.

Fig. 1.2 Existing VR digital light-field headset

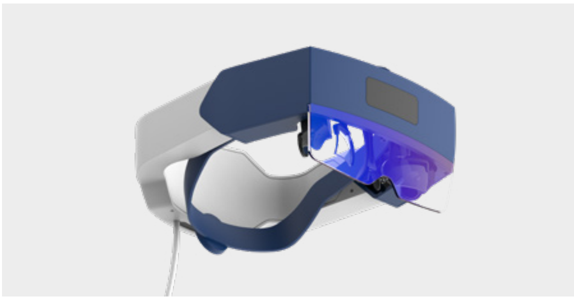


Fig. 1.3 Existing AR digital light-field headset

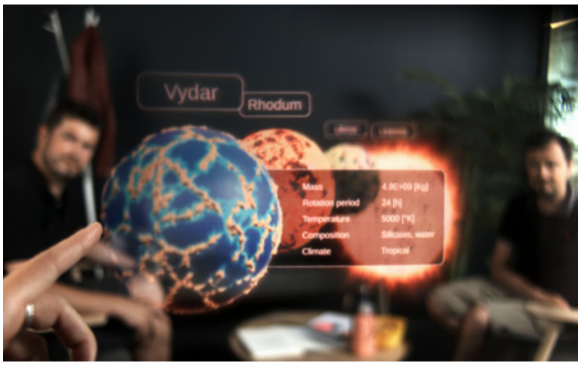


Fig. 1.4 Authentic see-through footage from existing AR headset

The above image showcases CREAL's ability to create any 3D image at any distance and dioptric correction.

2. Benefits of Digital Light-Field Technology for Optometry

Current eye examination procedures have not changed much in over 100 years; with eye care practitioners (ECPs) still using physical lenses and test charts in refraction.

Optometry products based on CREAL's digital light-field technology can bring a significant change to the industry and can offer following advantages.

The industry is ripe for CHANGE and DISRUPTION to bring it into the 21st century.

2.1 Self Contained and Space Efficient

The device based on our digital light-field technology is fully self-contained. The displayed image originates directly in the device itself with optical distance reconstructed fully digitally. The size required can be minimised and it can be a small, effective tabletop instrument or even a head-mounted VR headset.

Space is always a consideration in optical retail.

2.2 Different Spherical & Astigmatic Powers Displayed Simultaneously

Objects with different optical power applied can be shown simultaneously next to each other in a single image. See the examples below:

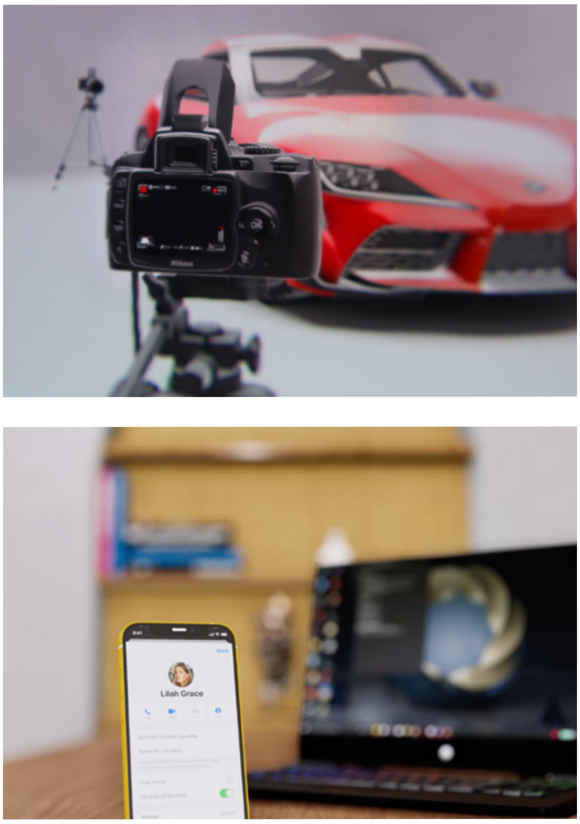


Fig. 2.1 & 2.2: Sample of real-life objects projected with different optical power simultaneously

This brings 2 very significant benefits:

1. Faster and precise subjective measurement:

- The user can easily compare which one is seen best, because the user sees them simultaneously next to each other.
- For example letters with a range of diopters are shown simultaneously. (Fig.2.4)
- User identifies which is seen best, picks it and quickly moves to a finer selection.
- Comparing different powers next to each other allows for faster assessment than comparing one after another in traditional devices.
- This could remove the need for initial measurement with an autorefractor.

2. The user is shown real-world images:

- Can see relevant imagery such as computer screen, mobile phone, television.
- Images are seen at the appropriate distances at the same time.

Simultaneous or comparative images at the same time (especially for astigmatic evaluation) give the user more confidence in their answer. Currently most refractions end with “I am not sure”.

2.3 Shown Content Can Be Changed Digitally

Permutation of symbols in a Snellen chart can be randomised for position and prescription for each measurement.

This prevents users from learning the chart leading to more reliable testing procedures. Each patient and each measurement will be unique.

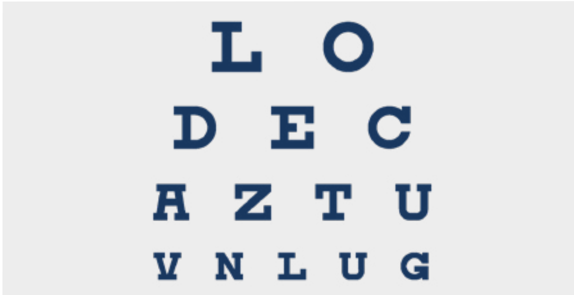


Fig. 2.3 Snellen chart in typical layout

Fig. 2.4 New chart with CREAL simultaneous display. The patient does the selection by clicking.

This is a key step-change. With a click by the patient or ECP new and specific images can be instantly changed taking the eye test along a defined and automated route to determine the refraction.

2.4 Flexible Spherical Power and Astigmatic Power

The optical power is generated digitally, it is not tied to a set of pre-existing lenses, so its range and fineness is not limited by a set of physical lenses or historical processes.

- Spherical power steps can be adjusted in increments: <0.1 D.
- Spherical power range is large.
- Same range applies for astigmatic power.
- Prismatic powers can be applied.
- Presbyopic prescriptions can be evaluated easily with near field imagery.

A major benefit is that any prescription (or comparative prescriptions) can be generated rapidly and not limited by physical lens combinations.

2.5 Multiple Types of Digital Content

Any flat image, 3D object or even animation can be displayed.

- More relevant and recognisable scenarios can be displayed to evaluate refraction.
- Variety of different symbols or images, including 3D objects can be used for children or adult patients for whom standard symbols might be hard to recognize/name.
- Application specific symbols can be designed.
- The device can display information to guide the user through the procedure.

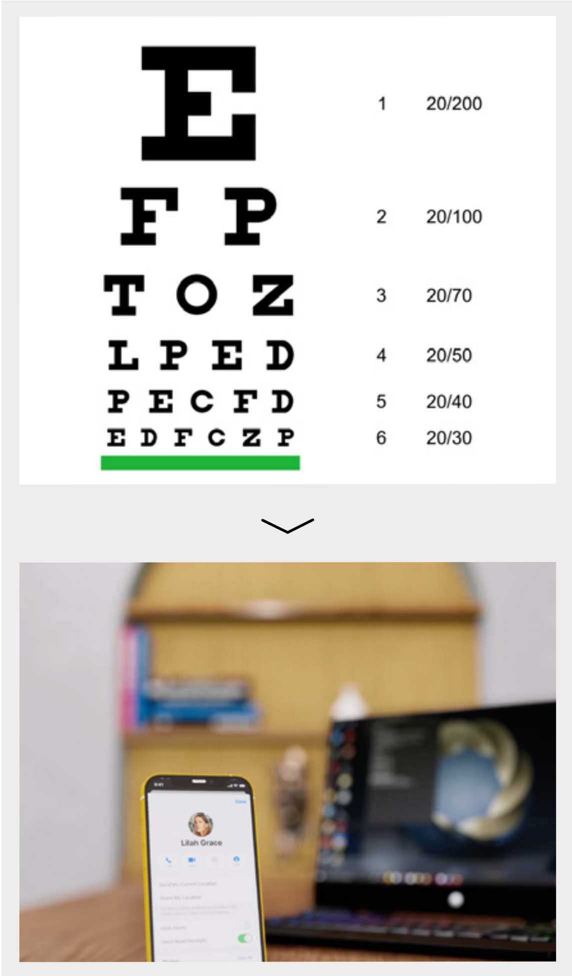


Fig. 2.5. Change to a 3D virtual library of real world imagery

Who does not want something different from the 1862 Snellen Chart? Welcome to the 21st century.

2.6 Change of Spherical Power or Displayed Content Is Instant

The change of content is instant (<1/30 s), similar to a change of picture on the screen of a mobile phone. The same applies to the change of spherical or astigmatic power.

Procedures can be completed much faster. No time-consuming changing of lenses or rotation of phoropter wheels.

2.7 Procedure Can Be Interactive and Fully User Controlled and/or Automated

Since the device is based on the digital light-field technology, it can be controlled through a tablet or similar interface. This allows us to design an interface that fully guides the user through the entire procedure.

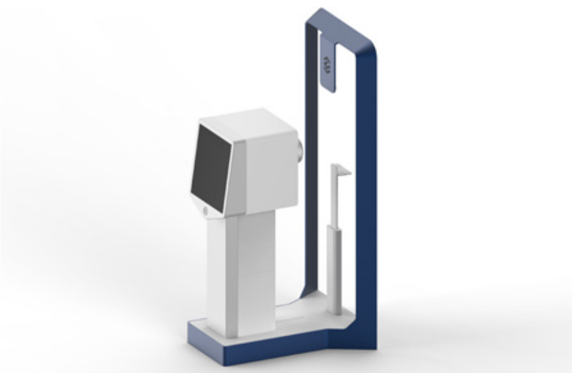


Fig. 2.6 Future light-field refraction

- Automated procedures: no need for lengthy subjective assessments during the normal procedure.
- One staff member can supervise multiple devices and act as an assistant in case of problems or questions.
- Multiple procedures can be combined.
- The procedures can be more entertaining (e.g. for children or patients with special needs).
- The measurement procedure can be updated over the internet, allowing immediate deployment of new procedures through the retail network without costly and time intensive staff retraining.
- Specific tailor made procedures can be designed for niche customers and markets.
- Other device input (autorefractor, lensometer) can be incorporated.

2.8 New Classes of Devices and Use Cases

Not much more needs to be said here: new, participative, flexible and engaging.

All of above and future development / imagination can allow for development of completely new test procedures or even treatment procedures; for example:

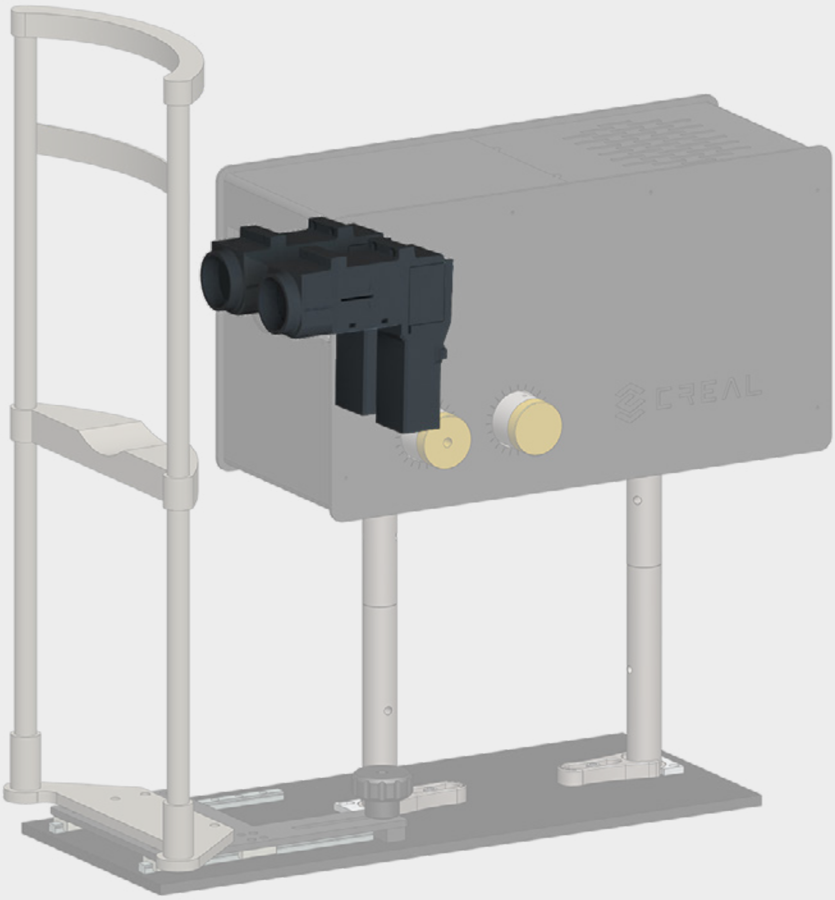
- Interactive games to stimulate development focusing abilities
  Such as treating amblyopia/lazy eye.
- Gamified examination procedures.
- Pilot/driver training procedures.
- Colour vision screening.
- Binocular vision testing.
- Visual Fields.

Future potential is not limited to simple refraction.

As you know we are looking for industry partners to further explore these possibilities and new projects for the ECP and vision care world.

Who knows what we can create?

Why wait - let’s do something now!



Internal optical engine highlighted

3. Technical Specifications

3.1 Dimensions & General Specifications

Dimensions shown below (fig. 3.1) are for one of our current prototype devices. Actual optical engines can be made smaller and adjusted for integration into the units of the customer.

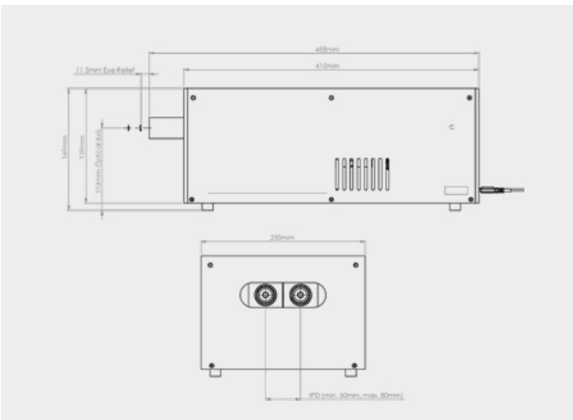


Fig. 3.1 Current tabletop prototype dimensions

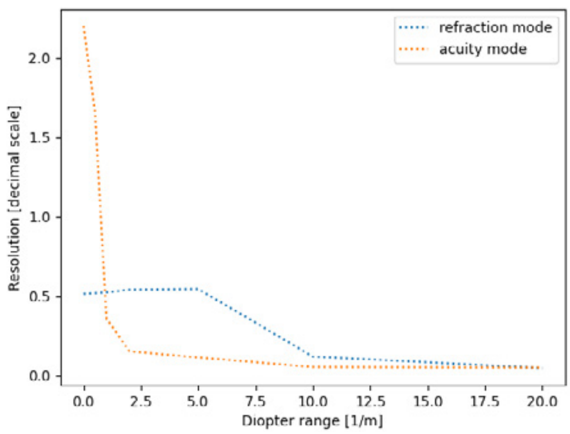
3.2 Optical Specifications [1]

Property	Value
Resolution (Modulator)	1024 x 1024 px
Resolution (Image)	<0.66' (at infinity in acuity mode) [2], <2' refraction mode
Optical Power	-15.00D to +12.00D (affects resolution, see [2]) with 0.05D step
Astigmatic Power	-5.00D to +5.00D with 0.125D step, for resolution see [2]
Cylinder Axis	0 - 180° with 1° step
Prismatic Power	-6Δ to +6Δ with 0.01Δ step
Field of View Diagonal	14º (single eye)
Field of View Horizontal	10º (single eye)
Field of View Vertical	10º (single eye)
Eye box	5 × 5 mm^2
Number of viewpoints	32 viewpoints
Brightness	Up to 290 cd/m^2 (full white)

[1] Latest tabletop prototype

[2] Machine operates in 2 modes: acuity mode and refraction mode. The resolution depends on the digitally applied dioptric power in each mode and is denoted in the chart below.

The 0-point of the chart can be shifted in the range of -8 to +5 D optically; in this range, the machine operates in full specs in both modes. The range of -15 to +12 D is achieved only in the refraction mode. Operation in wider dioptre range is possible, but resolution drops below specs.



3.3 Colours

The device is calibrated for D65 white point (x_ch, y_ch) = (0.31271, 0.32902) in the XYZ colour space (Y normalised to 1), using CIE 1931 standard 2° observer colour matching function. The charts below show a calibrated RGB spectrum and CIE 1931 chromaticity diagram.

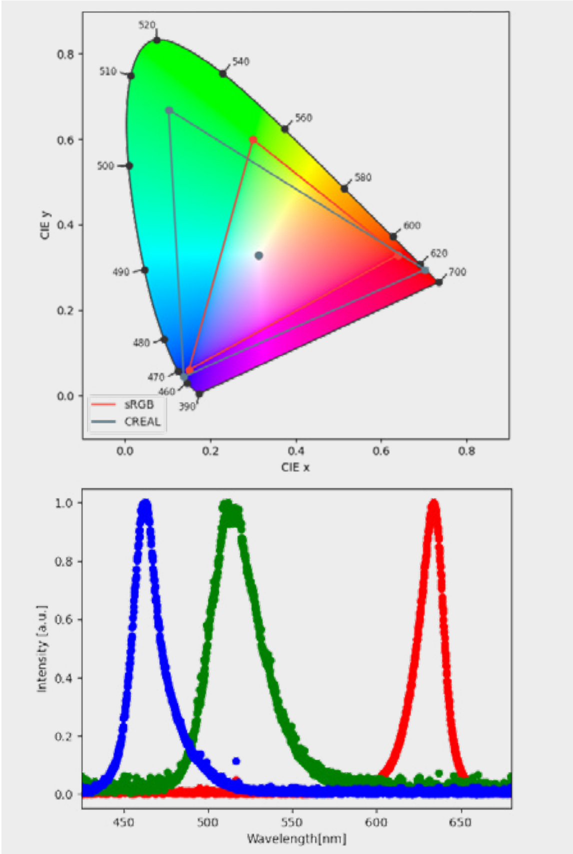


Fig. 3.2 Gamut and spectrum diagrams

CREAL.com/vision-care | visioncare@creal.com | EPFL Innovation Park, Switzerland