White Paper
Digital light field for vision care

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Summary

CREAL has developed a light field display technology that enables a healthy and natural visual experience of digital imagery, by supporting the natural behaviour of the human eye. The display projects a highly efficient, high-fidelity digital representation of how light exists in the real world. This radically new type of display system provides correct focal depth to the digital content, and can place it at any optical distance and/or respectively apply arbitrary spherical, astigmatic or prismatic power to the projected 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. Any 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 display could bring a revolution to numerous optometric, optical and ophthalmological applications, especially in subjective diagnostics.

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 3D display that takes care of the user's eyes. CREAL's light field display projects virtual images at any focal distance, enabling the user's eye to focus naturally on virtual objects within arm's reach distance up to infinity.

1.2 Digital light field display

Light field imagery is a genuine representation of how light exists in the real world. It therefore provides highly realistic digital imagery with natural focal depth, enabling the digital content to blend seamlessly with the real world, and removing any visual conflict causing eyestrain and nausea.

CREAL's light field display technology projects a sequence of slightly different perspectives of a digital scene (the light field) to the eye. Each perspective/image is projected through its corresponding virtual viewpoint placed by the user's pupil. By sending more than 6000 in-focus images per second, the full 3D digital scene is recreated in front of the user's eyes.

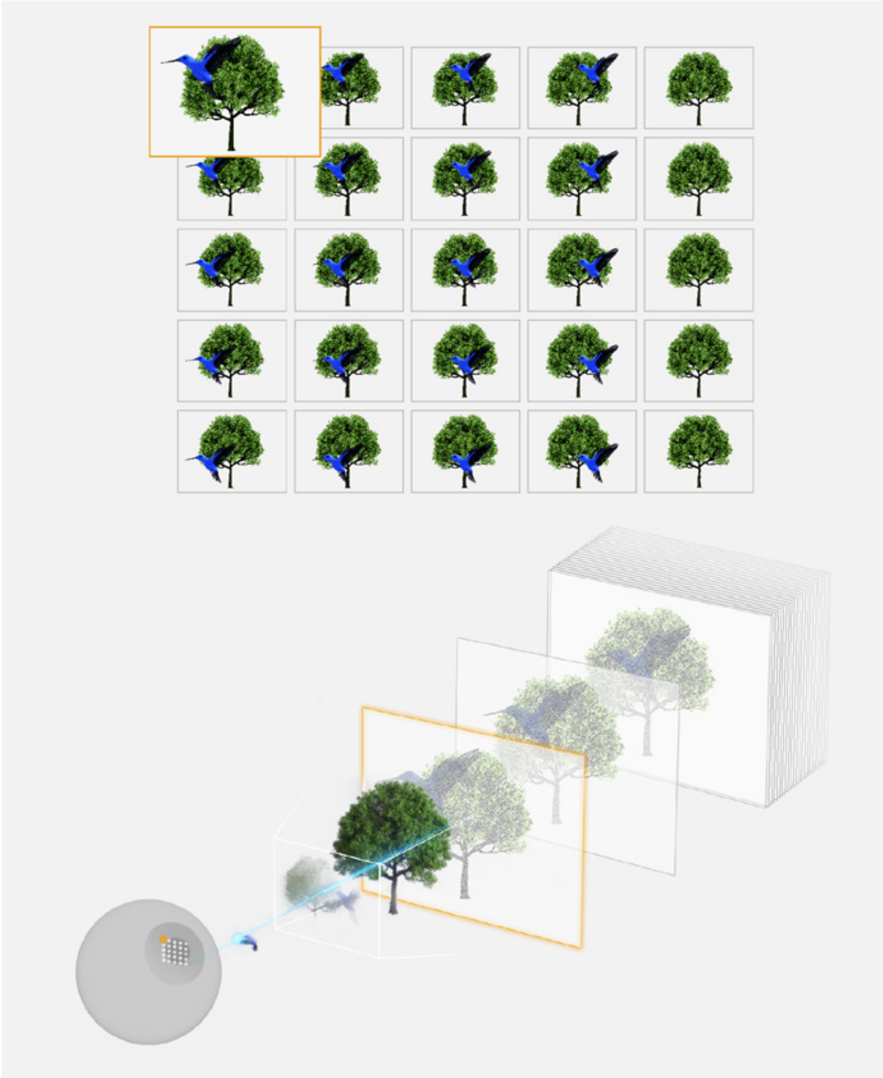


Fig. 1.1 Each perspective of the light field is projected to its corresponding viewpoint on the eye.

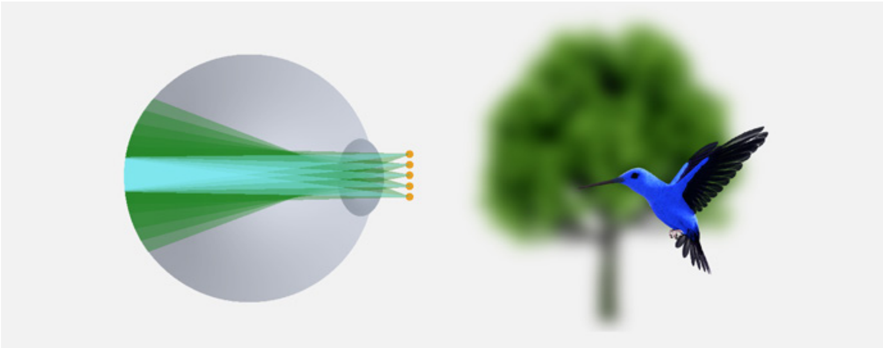


Fig. 1.2 Image perceived by the eye when the eye accommodates close (bird's light rays combine on the retina)

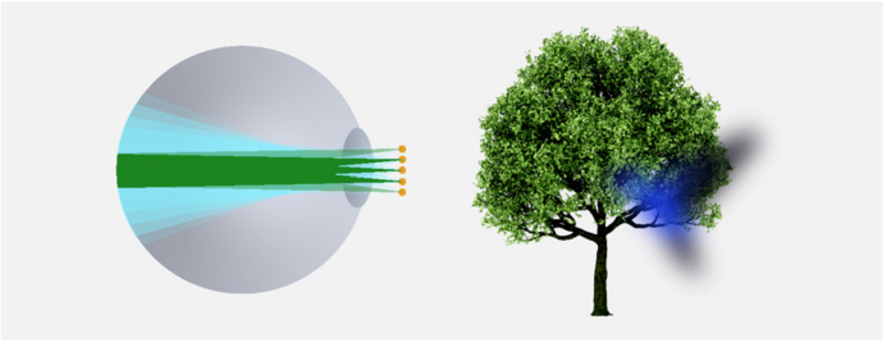


Fig. 1.3 Image perceived by the eye when the eye accommodates far (tree's light rays combine on the retina)

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. 1.4 Existing VR digital light field headset and see-through the lens image

Fig. 1.5 Existing AR digital light field headset and see-through the lens image

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 the following advantages.

Fig. 2.1: Eye examinations yesterday, today, tomorrow and in the future.

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 device's size is actually the one of the optical engine (p.13). It can be further minimized, resulting in a small, effective tabletop instrument or even a head-mounted VR headset.

2.2 Different spherical & astigmatic powers displayed simultaneously

Objects or images with different optical power applied can be shown simultaneously next to each other in a single screen.

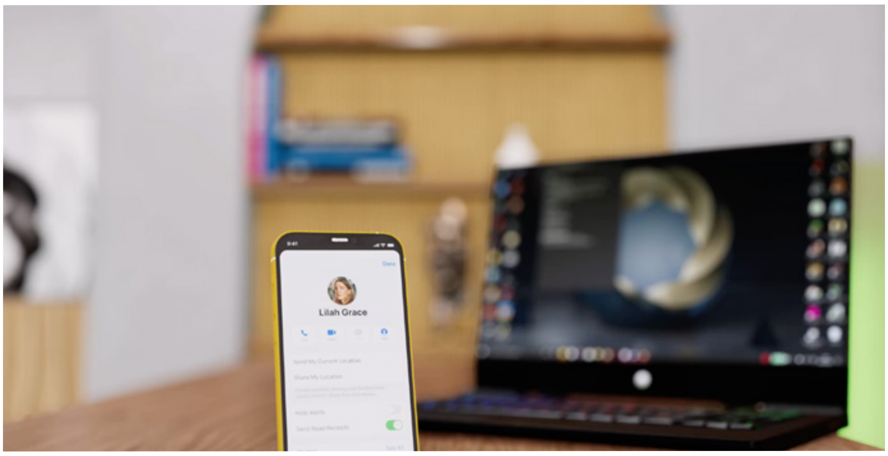


Fig. 2.2: Sample of real-life objects projected with different optical power simultaneously

This brings 2 very significant benefits:

1. The measurement is faster and precise:

- The user can easily compare which image 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)
- The user can identify which is seen best, picks it and quickly moves to a finer refraction selection. (Fig.2.4)
- The comparison between different powers next to each other allows for faster assessment than comparing one after another in traditional devices.
- The process can 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, all at the same time.

Simultaneous or comparative images projected 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

CREAL’s device enables randomized permutation of Snellen chart letters’ 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. Therefore, its range and fineness are 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. (p.14)
- Same range applies to 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 recognizable 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.
- Information can be displayed to guide the user through the procedure.

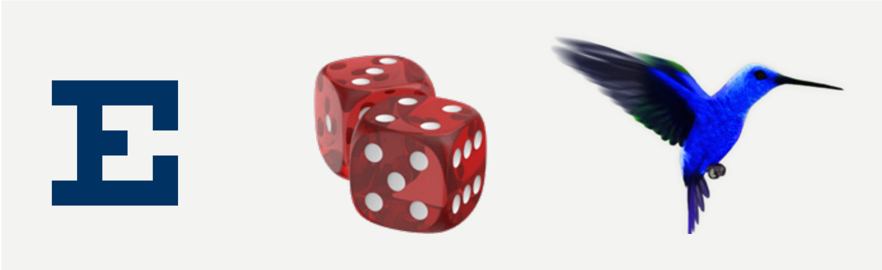


Fig. 2.5. Possibility to project any type of content, from 2D to 3D and animated content.

2.6 Instantaneous change of spherical power and displayed content

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 Interactive and fully user-controlled and/or automated procedures

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

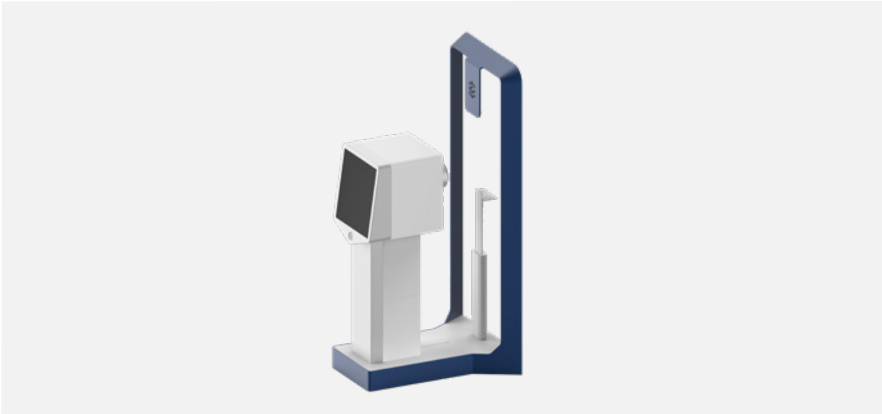


Fig. 2.6 Future light field refraction prototype

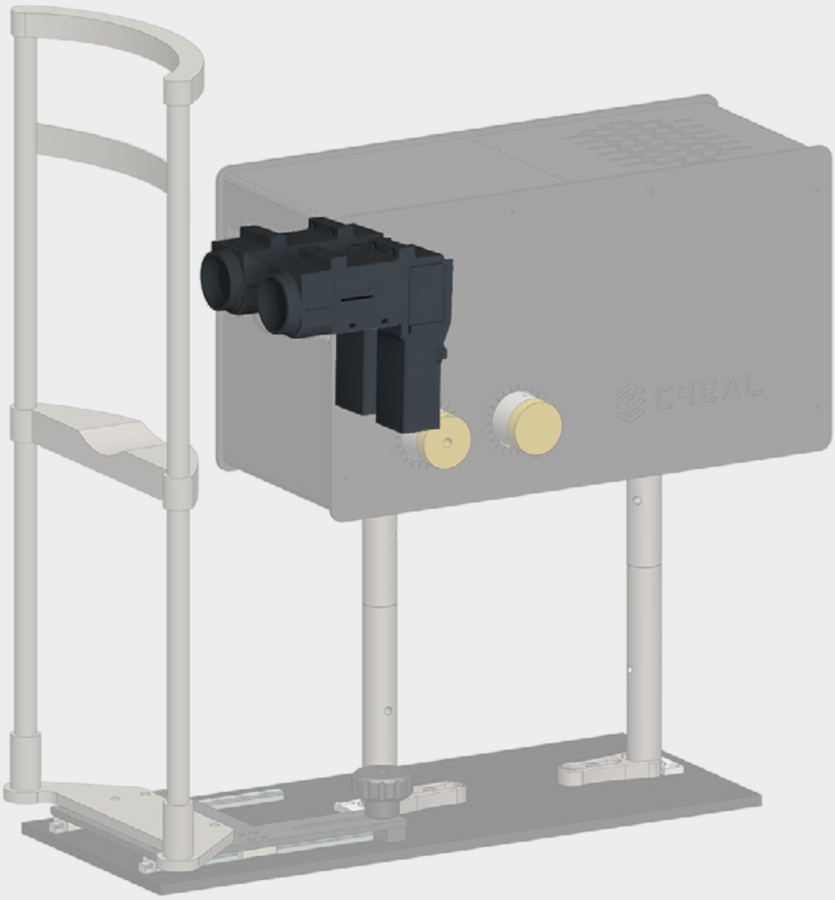
- Automated procedures: no need for lengthy subjective assessments during the normal procedure.
- Multiple devices supervision by one staff member.
- Multiple procedures can be combined.
- Procedures can be entertaining (e.g. for children or patients with special needs).
- Measurement procedures can 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 inputs (autorefractor, lensometer) can be incorporated.

2.8 New classes of devices and use cases

All of the above and future advancements 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.



Internal optical engine highlighted

3. Technical specifications

3.1 Dimensions & general specifications

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

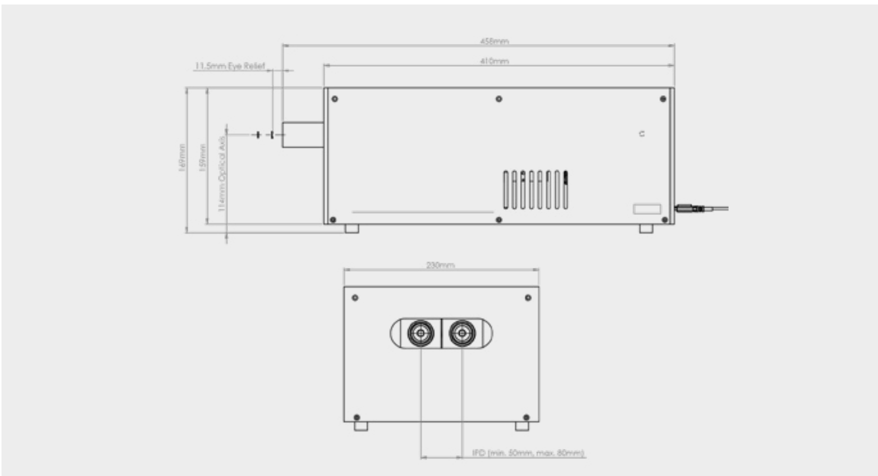


Fig. 3.1 Current tabletop prototype dimensions

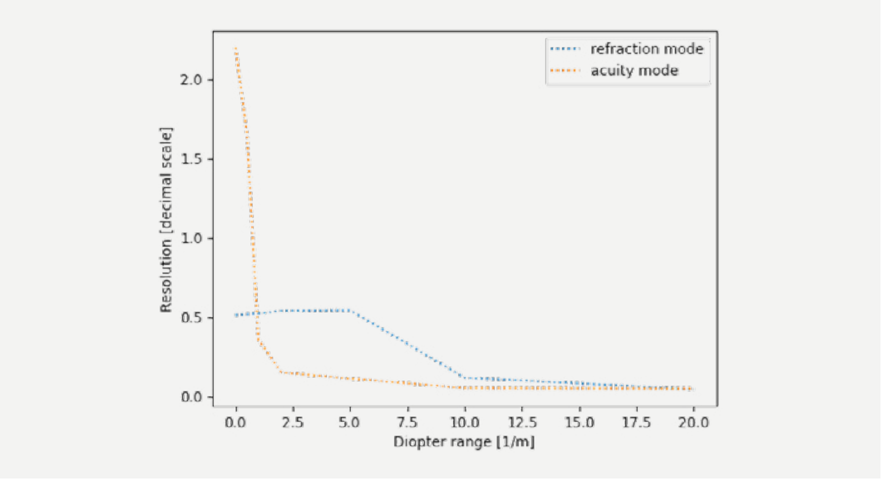
3.2 Optical specifications [1]

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 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 color space (Y normalized to 1), using CIE 1931 standard 2° observer color matching function. The charts below show a calibrated RGB spectrum and CIE 1931 chromaticity diagram.

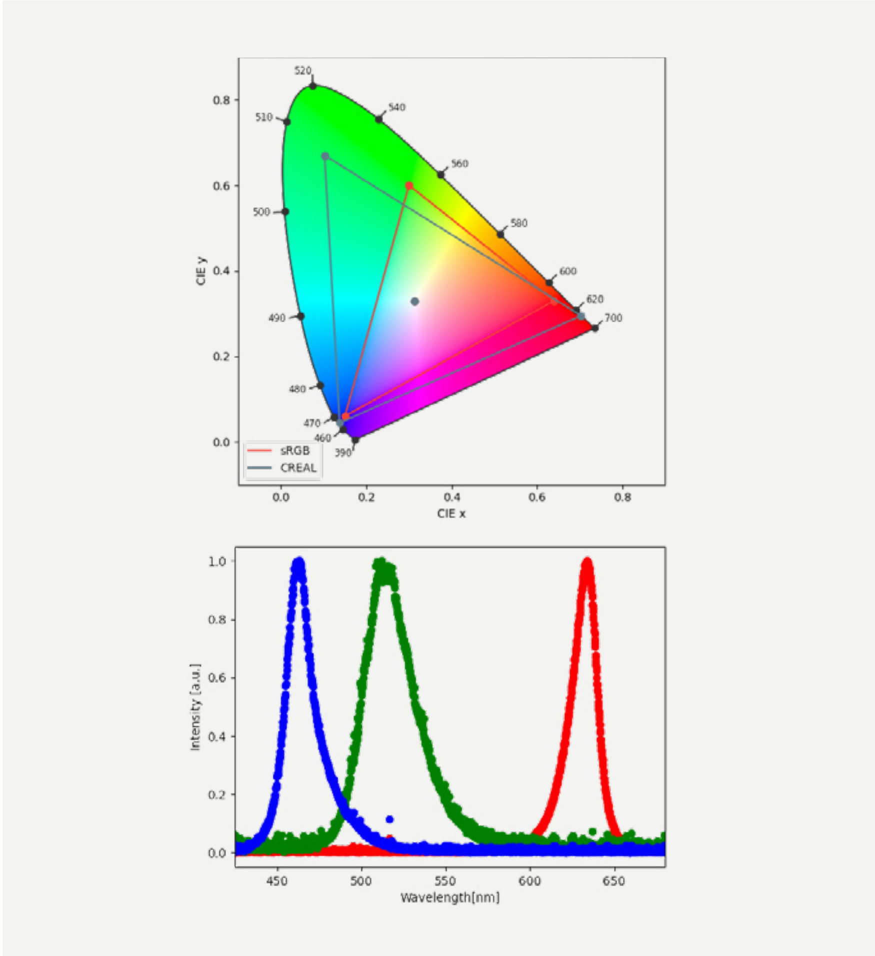


Fig. 3.2 Gamut and spectrum diagrams