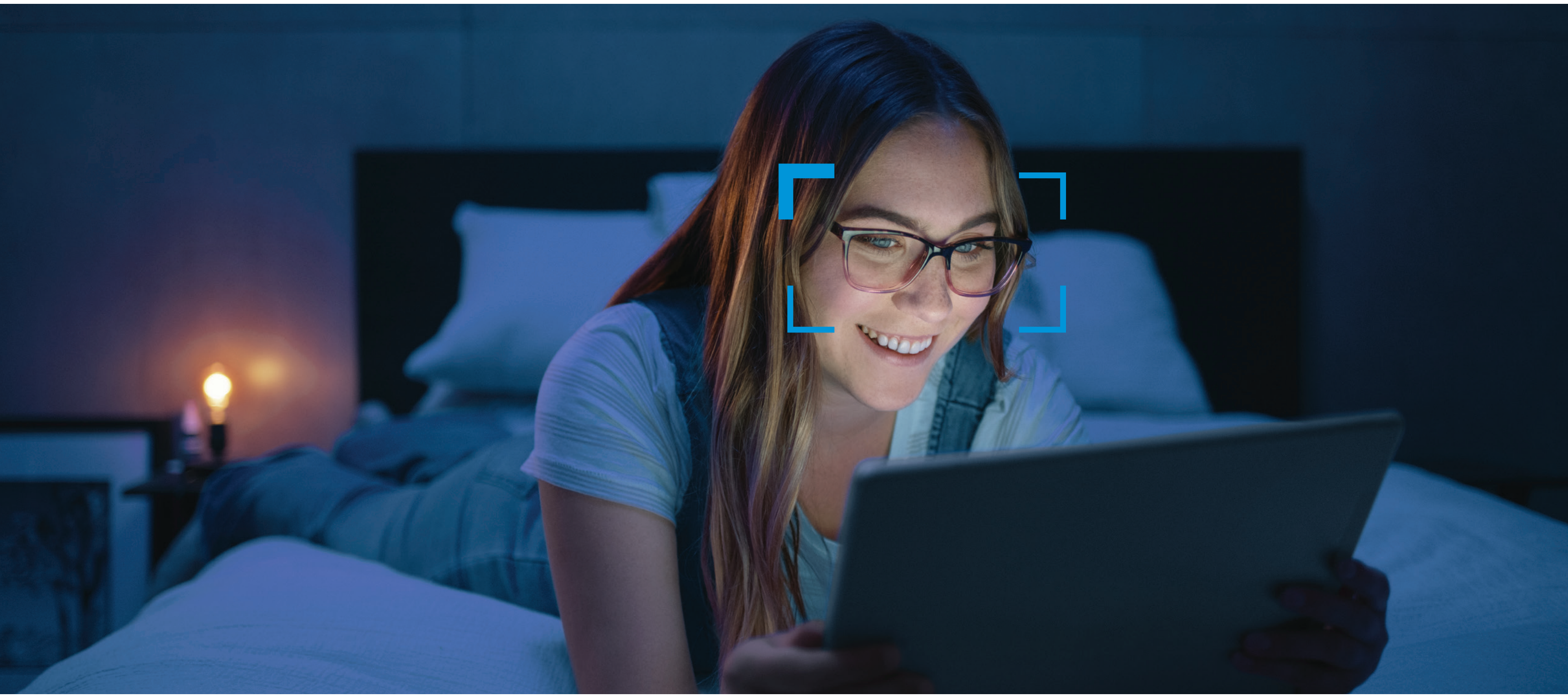
White Paper

ZEISS BlueGuard™ Lenses

Easy on the eyes. More protection, less reflection.



ZEISS BlueGuard Lenses are the latest in blue light protection, providing comfortable vision and excellent clarity and aesthetics, while blocking up to 40% of potentially harmful and irritating blue light and providing full UV protection.

PERFORMANCE EXCELLENCE COLTS™ Laboratories TESTED & VERIFIED

ZEISS BlueGuard** has been **awarded** the **COLTS Performance Seal** for **Blue Light blocking.

ZEISS

Seeing beyond

ZEISS BlueGuard Lenses

ZEISS BlueGuard Lenses are the latest in blue light protection. Now that we're spending more time in front of screens, increasing our blue light exposure, our eyes are facing new challenges. ZEISS BlueGuard Lenses are engineered to balance protection, clarity and aesthetics to mitigate the potential challenges of digital light sources. Using the latest organic-chemical technology, ZEISS BlueGuard Lenses provide an "in-material" solution, block up to 40% of potentially harmful blue light and providing full UV protection up to 400 nm.

While longer wavelength blue light can help us stay alert, shorter wavelengths are irritating and potentially harmful to the eyes. ZEISS BlueGuard Lenses are designed to partially block the bad blue light while maximizing the transmission of the good blue light.

As we spend more time in virtual meetings, where we are exposed to digital blue light, the aesthetics of blue blocking lenses become even more relevant. People are increasingly conscious of the prominent blue-purple reflections from blue light coatings. With their in-material blocking function, ZEISS BlueGuard Lenses solve this problem, producing up to 50% less visible blue light reflections of digital blue light compared to blue light coatings. The result is blue light protection, full UV blocking, comfortable vision, excellent lens clarity and superb aesthetics.

The New Online Lifestyle

Increased digitalization and modern artificial light sources are increasing our eyes' exposure to artificial or digital blue light. The last few years have accelerated this trend, changing the way we work, learn and socialize. Since the pandemic began, worldwide smartphone usage has increased by 70%, while laptop usage has increased by 40%.[1]

A peer-reviewed article in the Indian Journal of Ophthalmology showed that 94% of participants had increased their screen time during lockdowns. On average, screen time increased from 4.8 to 8.6 hours per day.[2]
Device usage has become an integral part of our daily lives and is likely here to stay, even after the pandemic subsides.

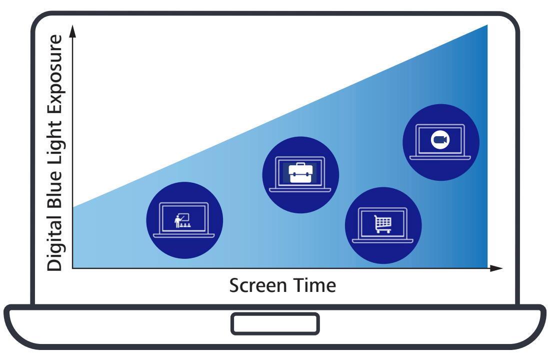


Figure 1. Increased exposure to digital blue light based on-screen time.

Blue Light

Blue Light Fundamentals

Both the eye care industry and the scientific community are recognizing increased exposure to artificially-generated blue light. Blue light can have both negative and positive impacts on our eyes – the dualism of blue light. For example, it is scientifically accepted that blue light is essential for our vision, but also for our alertness and mood, wellbeing and the sleep-wake cycle.

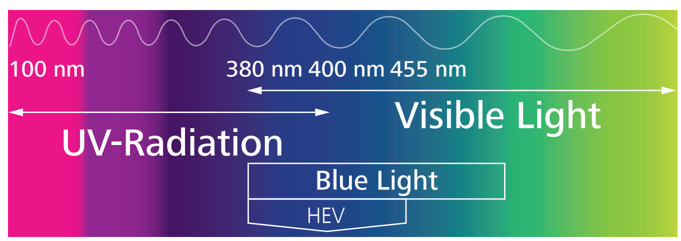


Figure 2. Cutout of the electro-magnetic light spectrum.

The visible light range for the human eye is between 380 and 780 nm. The blue light band (Figure 2), between 380 and 500 nm, is an essential part of the spectrum that is relevant for proper vision performance and some physiological processes.

Our vision evolved under sunlight, the most intense natural blue light source (solar blue light). However, LEDs and digital devices have dramatically increased our daily exposure to artificial and digital blue light.

Potentially Harmful Blue Light

Blue light can be potentially harmful to our eyes. High-energy visible (HEV) light can cause retinal damage. Shorter wavelengths within the blue light spectrum have higher energy and greater potential to damage eye tissue.
The blue light band between 380 and 500 nm can be divided into two sub-bands:

I. HEV or blue-violet light, 380-450 nm
II. Blue-turquoise light, 450-500 nm

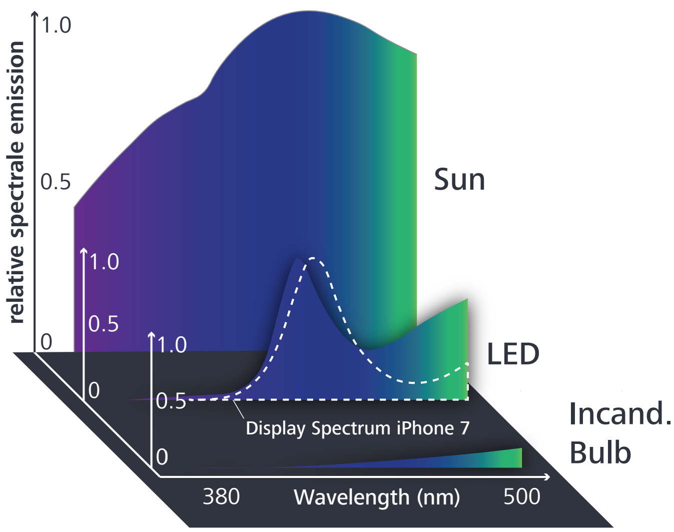


Figure 3. Relative spectral emissions, between 380-500 nm, of an incandescent bulb, a white light LED and the sun. The dotted line shows a smartphone's typical display spectrum. The graph shows the relatively high spectral intensity of blue light emitted by LEDs and digital displays compared to older light sources.

When it comes to photo-induced eye health risks and longterm retinal damage like age-related macular degeneration (AMD) related to blue light exposure, High Energy Visible light (HEV) in the spectral range of blue-violet light has been identified to be the cause.[3] The photons with high energy can interact with biological tissue on a molecular level, and there is a general relation between higher photon energy and increased possibility of detrimental effects on eye health.

HEV has the potential to cause oxidative damage to receptive ocular structures of the retina. Unlike UV radiation, blue light reaches the retina and interacts with macular pigment epithelium and photoreceptors. One study found blue light can be more damaging to the retina than other spectral colors.[4]

Scientists have established the blue light hazard (BLH) function, which highlights blue light risks at each wavelength in the range between 390 and 500 nm. BLH is derived from *in vitro* and animal studies and describes the weighting function for calculated risk of damage at a given wavelength along the blue light spectrum. The data is also included in various industry norms, standards and publications.

It is appropriate to weigh the potential risks to retinal tissue associated with bright light sources, such as the sun or arc welders. However, according to the CIE International Commission on Illumination[5], BLH does not govern common artificial light sources, such as LEDs or digital devices.
As a result, BLH is not particularly relevant to blue light lenses. The latest ISO blue light report (ISO/ TR20772:2018) notes that blue light up to 455nm delivers the greatest phototoxic risk to retinal pigment epithelium. The report suggests minimizing blue light up to 455nm and maximizing longer wavelengths to avoid interfering with the circadian rhythm and other functions. As a result, ZEISS BlueGuard Lenses were designed to partially block blue light between 400 and 455 nm but allow transmission of longer wavelengths.

At present, there is no scientifically established action spectrum to specifically weigh the ocular risk from digital or artificial blue light. As a result, ZEISS does not use any action spectrum calculations to quantify blue light blocking.

The Blue Violet Block metric – to quantify the blocking of potentially harmful blue light

Blue-violet block (BVB) measures the percentage of potentially harmful blue-violet light, between 400 and 455 nm, being blocked to minimize HEV exposure and still allow beneficial blue light. ZEISS introduced this simple metric because there is no industry standard to quantify blue light blocking in spectacle lenses.

$$Blue\ Violet\ Block = 100\% - \frac{\int_{400}^{455} T(\lambda)d(\lambda)}{\int_{400}^{455} d(\lambda)}$$

T = spectral transmittance of the lens (%) at each single nm

Some alternative formulas incorporate a solar spectral weighting factor. This approach is not appropriate because these lenses are designed and used predominantly for using digital screens that have a very different spectral emission profile from the sun.

Beneficial Blue Light

Blue light has a good side, triggering physiological processes that control our body clocks and maintain general wellbeing.

Rods and cones are photoreceptors that enable vision under photopic (daylight) and scotopic (nighttime) conditions. Another class of photoreceptors, the intrinsically photosensitive retinal ganglion cells (ipRGCs), do not contribute to vision but detect light intensity, drive pupil aperture control and other physiological and psychological mechanisms.

Retinal ganglion cells play a key role in circadian rhythm, contributing to our well-being and sleep-wake cycle. Retinal blue light exposure modulates the hormone melatonin, which is associated with the sleep-wake cycle. The peak sensitivity for melatonin suppression in the blue light band is around 464-490 nm.[6], [7] As a result, blue light-blocking lenses should ideally transmit beneficial blue light in this range, while blocking potentially harmful blue light wavelengths.

Digital Eye Strain

With excessive screen use, many people experience digital eye strain. DES symptoms include: glare/dazzle, discomfort, blurred vision, accommodation stress and dysfunction, fixation disparity, pain in or around the eyes, dryness and eye fatigue.[8], [9]

The Vision Council's Digital Eye Strain Report, and other sources, show that more than two-thirds of adults in the US who regularly use digital devices experience symptoms associated with Digital Eye Strain.[10]

Formerly known as Computer Vision Syndrom (CVS), the more contemporary term of digital eye strain includes the plethora of eye and vision-related symptoms and asthenopic challenges associated with the extensive use of computers and digital displays, intense reading and other extensive near vision tasks. Digital eye strain can occur when the visual demand exceeds the capacity of the accommodation and vergence system to maintain clear and comfortable vision, resulting in an overload of our visual system, leading to eye strain and visual discomfort.

Blue Light and Digital Eye Strain

Blue light is thought to contribute to digital eye strain, causing symptoms like blurry vision and visual discomfort.[11] Shorter wavelength blue light can induce opto-physical effects while entering the eye on its path through the ocular media to the retina.

The two main effects are wavelength-dependent light scatter and longitudinal chromatic aberration.[12], [13]

The first is linked to increased scattering propensity of short wavelength blue light by the ocular media (Figure 4). This effect generates increased "visual noise" on the retina, which can cause perceived dazzle, reduced contrast and contribute to digital eye strain.

Longitudinal chromatic aberration is also caused by short wavelength blue light. Because ocular media's refractive index varies with the wavelength, induced optical dispersion effects, can cause longitudinal and lateral chromatic aberrations. The shorter the wavelength, the higher the refraction angle, giving diverse colors different focal points. The difference between blue and red light can be up to 2 diopters. As a result, the image can look blurred or have noticeably colored edges.

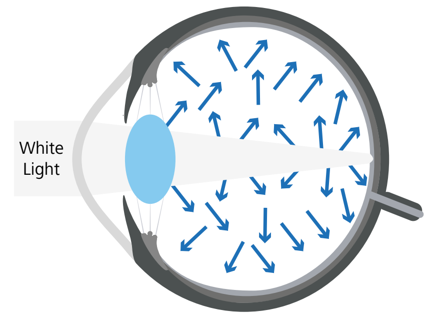
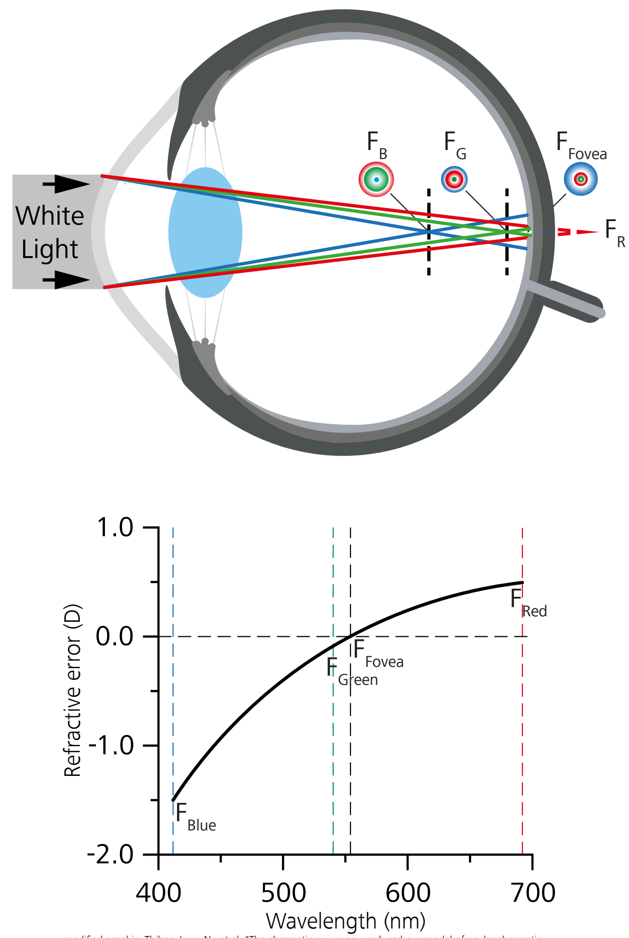


Figure 4. Schematic visualization of blue light scatter in the eye.

ZEISS BlueGuard Lenses are designed to reduce digital eye strain by minimizing exposure to the problematic shorter wavelength blue light.



modified graphic: Thibos, Larry N., et al. "The chromatic eye: a new reduced-eye model of ocular chromatic aberration in humans." Applied Optics 31.19 (1992): 3594-3600.

Figure 5. Different focal points for blue, green and red light (F_B, F_G and F_R). The blue light focal point, 1.5 diopters in front of the fovea, creates aberrations. Because it is not focused on the fovea, the sharpest point of vision, this aberration can lead to blurry vision, discomfort and impaired retinal image quality.

ZEISS BlueGuard Lenses

The Next Generation of Blue Light Blocking Lenses

ZEISS BlueGuard is an in-material blue light blocking solution that addresses the complex challenges of balancing the positive and negative side of blue light and comes with hardcoat or with ZEISS DuraVision Platinum coating. It blocks up to 40% of the blue-violet spectrum[14], 400 to 455 nm, while transmitting beneficial wavelengths, 455 to 500 nm. By blocking blue light in the material, ZEISS BlueGuard reduces digital blue light reflections up to 50% compared to typical blue light coatings.[15]

ZEISS BlueGuard uses the latest benzotriazole and enzophenone technology to support UV and blue light absorption, delivering excellent color fidelity and spectral coverage. The ZEISS 1.50 index BlueGuard material uses state-of-the-art pigments to perfectly balance clarity and protection. ZEISS uses its global network to deliver ZEISS BlueGuard materials for all common plastic lenses, indexes 1.50 to 1.74.

ZEISS BlueGuard Lenses Block up to 40% of Potentially Harmful Blue Light

As measured by BVB, ZEISS BlueGuard Lenses block up to 40% of potentially harmful blue light.[14] All ZEISS BlueGuard materials offer similar BVB levels, from 38% to 42% (Figure 7), and are available in 1.50, 1.56, 1.60, 1.67, 1.74, Trivex® (1.53) and Polycarbonate (1.59) in many regions.

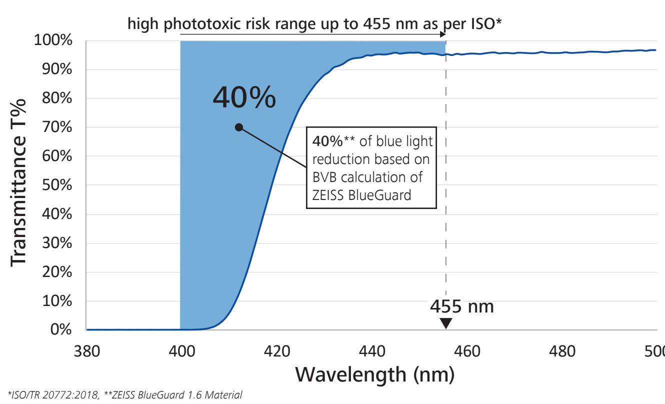


Figure 6. Transmittance curve of ZEISS BlueGuard 1.60 index lenses with DuraVision Platinum UV anti-reflective coating. The blue shaded area indicates blue light reduction based on the BVB calculation from 400 to 455 nm. The spectral curve demonstrates high transparency above 455 nm, an important factor when considering circadian rhythm.

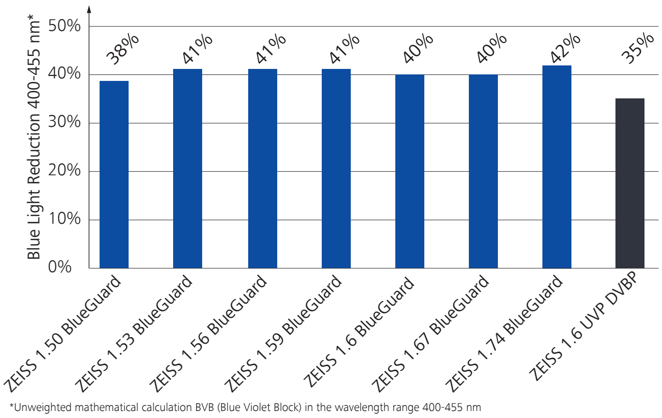


Figure 7. ZEISS BlueGuard (blue bars) blue light protection in available lens index materials calculated by BVB. Black bar illustrates a ZEISS 1.6 UVP DVBP as a comparison lens.

Full UV Protection to 400 nm

International regulatory bodies agree that UV is harmful to the human eye and surrounding tissues. Ultraviolet radiation ranges between 100 to 400 nm. While UV is mostly invisible, it can still damage eyes and other structures.

In addition to partially blocking potentially harmful blue light, ZEISS BlueGuard Lenses provide full UV protection, blocking harmful UV radiation up to 400 nm. This protection is standard for ZEISS UVProtect and ZEISS BlueGuard Lenses.

The Digital Blue Light Reflection metric

During video calls, lenses with blue blocking coatings show annoying blue and violet reflections. Because ZEISS BlueGuard Lenses provide in-material blocking, no blue light reflective coating is required, minimizing visible reflections.(Figure 8).

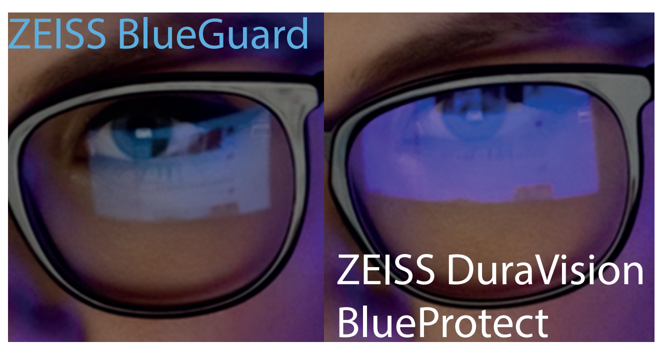


Figure 8. Reduced reflectance on lens surface for ZEISS BlueGuard lenses compared to ZEISS DuraVision BlueProtect.

DBR_{LED} calculates the intensity of blue light reflected by the lens front surface seen by the human eye when the light source is in a common digital spectrum. ZEISS developed the DBR_{LED} metric, as there is no industry or scientific standard for this effect.
Most digital displays produce peak intensity between 380 and 500 nm. ZEISS used the display spectrum for the world's most popular smartphone to create the DBR_{LED} calculation.

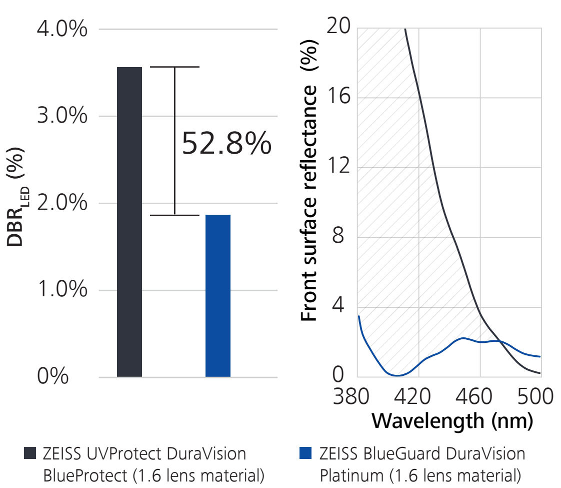
$$\mathrm{DBR}_{\mathrm{LED}} = \frac{\int_{380}^{500} R(\lambda)\, L(\lambda)\, LED(\lambda)\, d(\lambda)}{\int_{380}^{500} d(\lambda)}$$

Based on digital blue reflectance (DBR_{LED}), ZEISS BlueGuard Lenses exhibit up to 50% less digital blue light reflection compared to ZEISS DuraVision BlueProtect, as shown in Figure 9.[15]

- R(λ) is the spectral reflectance of the front side of the spectacle lens
- L(λ) is the Luminous efficiency function for a 10° observer (http://www.cvrl.org/ciepr.htm- CIE 2006)[16]
- LED(λ) is the spectral distribution of most popular smartphone of the world 2020[17]

Because blue light is blocked in-material, ZEISS BlueGuard is ideally combined with ZEISS DuraVision Platinum UV coating – the premium AR coating with outstanding anti-reflective qualities throughout the visible spectrum.

A ZEISS quantitative survey found that 72% of participants felt ZEISS BlueGuard Lenses showed less intense reflections than ZEISS DuraVision BlueProtect.[18]



50 pieces of ZEISS UV Protect 1.6 with DuraVision Blue Protect coating; 50 pieces of ZEISS BlueGuard 1.6 with DuraVision Platinum coating were measured[14]

Figure 9. Percentage change of ZEISS BlueGuard Lenses compared to a previous ZEISS UVProtect DuraVision BlueProtect lens based on the DBR_{LED} metric.

Outstanding Clarity and High Transmission

Previous in-material blue light lenses showed discolorations from grey/blue color additives, reduced lens transmittance and a grey or bluish colour hue.

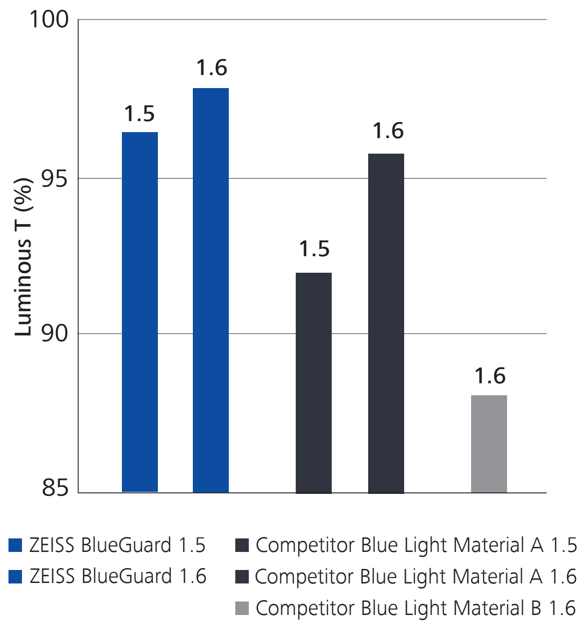


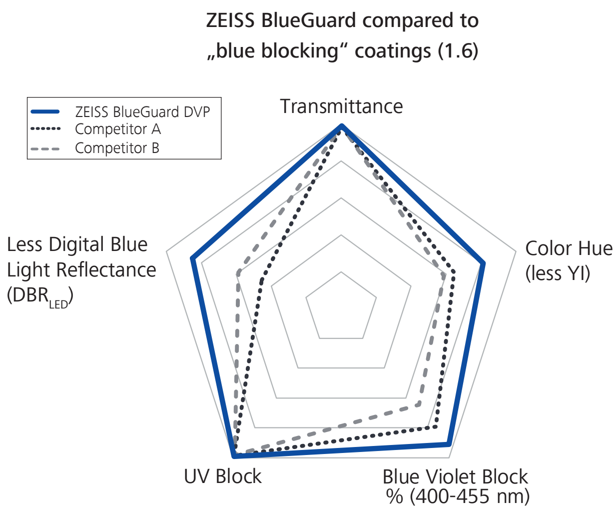
Figure 10. Luminous transmittance of ZEISS BlueGuard 1.5 and 1.6 index lenses combined with ZEISS DuraVision Platinum UV compared to two competitors' blue light blocking materials. All three lens types have blue light blocking (BVB) values between 30% and 42%, but ZEISS BlueGuard maintain the highest transmittance values. ZEISS BlueGuard 1.6 lens material has 2% more transmittance compared to Competitor A (95.8%), and far more than Competitor B at 88.1%.[14]

ZEISS chemists have found the best balance between clarity and transmission. ZEISS BlueGuard Lenses are engineered to achieve the best clarity and achieve up to 97.8% luminous transmittance.[14]

As a result, 90% of wearers are very satisfied with the clarity of ZEISS BlueGuard Lenses.[18]

Combining protection, visual comfort and aesthetics

Blue Light lenses are prolific in the market – over 100 new product launches have been identified in this space over the last years. Blue light reflecting coatings are a common industry approach, while more recently in-material solutions have been released. Amongst this suite of products, ZEISS BlueGuard Lenses provide an optimal balance between blue light blocking, focused on the spectral range that matters, allowing good blue light through, minimizing reflections and providing excellent clarity (Figure 11).



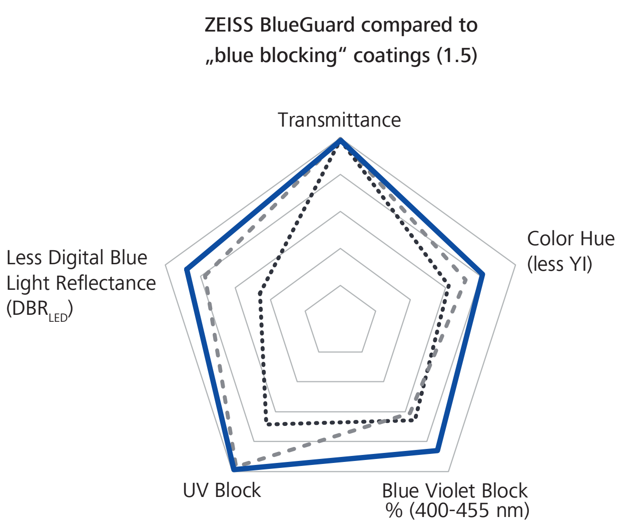


Figure 11. ZEISS BlueGuard lens material 1.6 and 1.5 compared to two competitors, with both a blue light coating, and an alternate in-material blue light blocking lens. ZEISS's BlueGuard provides the optimal balance.

Comparing ZEISS BlueGuard Lenses to ZEISS DuraVision BlueProtect

The biggest difference between ZEISS BlueGuard Lenses and ZEISS DuraVision BlueProtect is the blue blocking approach – absorption vs. reflection. ZEISS BlueGuard Lenses have an in-material solution, in which the blue light is absorbed. ZEISS DuraVision BlueProtect uses a coating, reflecting the light. ZEISS BlueGuard Lenses are designed to deliver more protection with less reflection and better clarity.

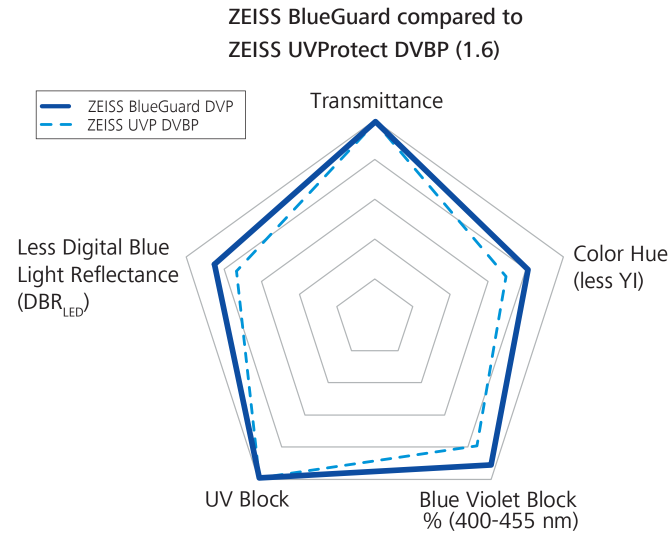


Figure 12. ZEISS BlueGuard 1.6 material with the ZEISS DuraVision Platinum UV coating compared to a ZEISS UVProtect 1.6 material with the ZEISS DuraVision BlueProtect UV coating. Both products have excellent transmittance and UV Block profiles. But reflectance and blue-violet block show the advantages of an in-material solution. In addition, the in-material solution has less of a color hue (YI).

Customer Acceptance

In an external consumer acceptance study[19] conducted by ZEISS, 182 participants tested ZEISS BlueGuard Lenses, compared to their habitual lenses. Almost 6 out of 10 (59.6%) of the study participants were already experienced wearers of various blue filter lenses. The feedback:

- **Result 1:** 96% (9 out of 10) of spectacle lens wearers are satisfied with the clarity of ZEISS BlueGuard lenses.
- **Result 2:** 93% (9 out of 10) of wearer say they feel less digital eyestrain with ZEISS BlueGuard lenses.
- **Result 3:** 92% (9 out of 10) of lens wearers state they experience less symptoms, like tired eyes, with ZEISS BlueGuard lenses.

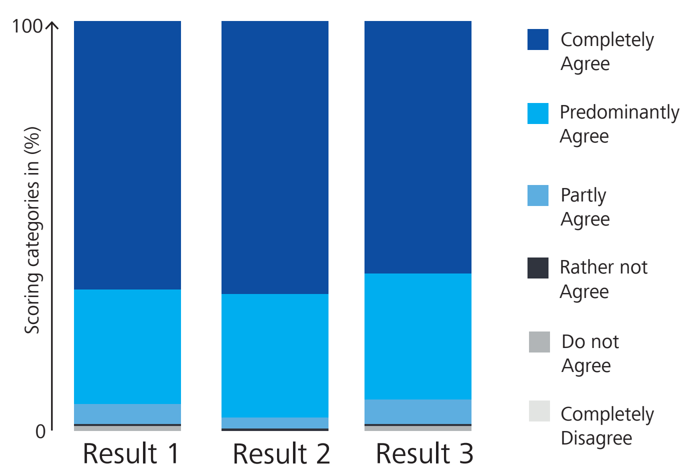


Figure 13. Evaluation of three main results out of external consumer acceptance test on the ZEISS BlueGuard Lenses. ZEISS Vision Care, DE, 2021.

The Solution - ZEISS BlueGuard Lenses

- Designed to address digital eye strain by blocking blue light.
- Blocks up to 40% of potentially harmful blue light.
- Full UV protection to 400nm.
- Beneficial blue light is not blocked
- In-material blue blocking solution, reduces unwanted digital blue light reflections off the lens surface by up to 50% compared to typical blue light coatings.
- Optimally balanced for clarity and protection.

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Carl Zeiss Vision Inc.

USA 1-866-596-5467

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Seeing beyond