WHITEPAPER

MISSION SUCCESS –

GOING BEYOND GLASS FOR NIGHT VISION

EXPLORE HAWKAI™ LGRIN OPTICS

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HAWKAI™

peak

HAWKAI LGRIN - OVERMATCH OPTICS FOR MISSION OBJECTIVES

SEEING THE SOLUTION

Normal human night vision
Limited Visibility
low-situational awareness

Green phosphor night vision
Better visibility
Improved situational awareness

Fused phosphor night vision
Excellent visibility
Optimal situational awareness

Our senses play an elemental role when shaping our perception of the world. Our brains receive critical input from what we see, hear, smell, touch, and taste. Our brains combine these data points with our memories and experiences, offering information to address problems and challenges to accomplish missions in our professional and personal lives. As we increase awareness and available intelligence, we improve the probability of success and lower risks. This is why warfighters have sought better visibility and intelligence for centuries. Governments, intellgence agencies, and militaries invest billions of Dollars, Euros, and Yen annually in developing and deploying next-generation systems for improved visibility, identification, and targeting. We all know that the human eye haslimited night visibility, dramatically reducing situational awareness. Adding night vision capabilities and fused thermal imaging dramatically changes night vision capabilities and optimizes situational awareness.

In the book Accidental Empires by Robert X. Cringely, about the history and development of Silicon Valley, he emphasizes the enduring leadership created by investments in pure research and development beyond mere product solutions.

> **"Nearly all companies do research and development, but only a few do basic research. The companies that can afford to do basic research (and can't afford not to) are ones that dominate their markets. Most basic research in industry is done by companies that have at least a 50 percent market share. They have both the greatest resources to spare for this type of activity and the most to lose if, by choosing not to do basic research, they eventually lose their technical advantage over competitors."[1]**

This principle is one of the main reasons the U.S. continues to lead in most facets of military technology. The funding of DARPA, The Naval Research Lab, The National Science Foundation, and Case Reserve Western University has led to the development of LGRIN (Layered Gradient Refractive Index) optics. LGRIN is one of the most significant innovations that help our warfighters combine what they see in the field with the overall team plans to find the right solutions to accomplish their missions.

[1]https://techratchet.com/2021/04/28/book-summary-accidental-empires-how-silicon-valley-make-their-millions-by-robert-x-cringely/awareness.

OPTIMIZING OPTICS - LGRINS GENESIS STORY

The DARPA BOSS Program
GRIN Optics

CWRU Ballistics Visor Research
Nanolayered materials

The Reece's Peanut Butter
Cup moment of Inspiration

In 2002, DARPA initiated the Bio-Optic Synthetic Systems (BOSS) program, which aimed to synthesize the components of a biologically inspired vision system and demonstrate a level of performance beyond that of standard optical imaging systems (i.e., with reduced size and complexity). Four of more than a dozen exploratory efforts were selected for further development and demonstration: fluidic adaptive zoom lenses, foveated imaging, photon sieves, and nanolayer lenses. Case Western Reserve University (CWRU) and the Naval Research Laboratory (NRL) collaborated on the nanolayer lens effort to create a synthetic lens that would mimic the structure and capabilities of an octopus eye. The CWRU/ NRL team used a forced assembly nanolayer coextrusion process to form films with a tailored refractive index consisting of thousands of nanolayers of two different polymers with different refractive indices. The films were stacked to create a refractive index range (Δn) and formed into hemispheres, which were combined to form the synthetic bi-convex octopus lens[2].

The eyes of an octopus, the development of ballistic visors, and a Reese's Peanut Butter Cup share a common thread – they represent the genesis story of LGRIN technology as we know it today.

Research conducted for the DARPA BOSS program determined a critical insight: biological optics can adapt to various circumstances and visual demands by moving thin films of proteins over the eyeball. These films are utilized to alter the optical properties of the eyes and, at times, reshape the cornea to optimize vision capabilities. However, they lacked a material that could be translucent across multiple layers and deliver the required refractive indexes to create specific optics capabilities. In 2010, the BOSS team went to a conference where they met a Case Western Reserve University team working on developing a translucent nanolayered material for ballistic visors. At the end of the presentation, the two teams realized that if they combined GRIN optics principles, the research on biological optics, and the nanolayered metamaterials, like a Reese's Peanut Butter Cup Commercial, they could create LGRIN technology, fundamentally changing how we see and perceive the world.

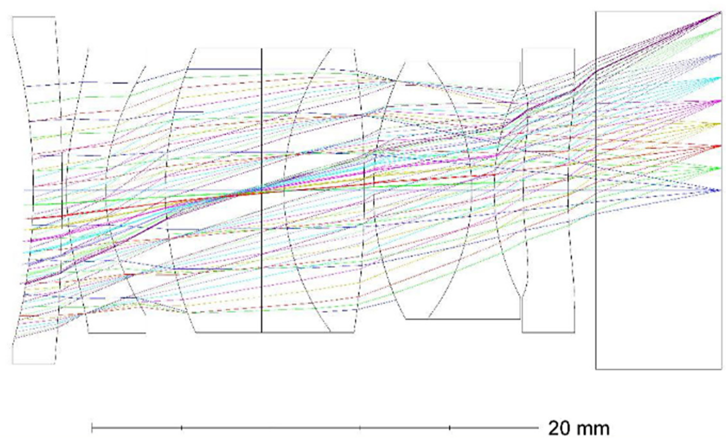
[2]https://apps.dtic.mil/sti/citations/ADA606263

REIMAGINING CLARITY - THE FUTURE OF OPTICS

FUSED THERMAL IMAGING

Archaeologists have unearthed optical instruments like lenses and mirrors dating back thousands of years from ancient Egypt, Greece, and Rome. The invention of eyeglasses in the thirteenth century began the first widespread use of glass lenses as we know them today. The next major step in optics development was in the seventeenth century with the invention of the microscope and the telescope. Since then, there have been very few significant changes in glass lenses. Most lens systems remained homogeneous, multi-element designs with spherical glass surfaces and fixed optical properties. Traditional glass lenses have many well-documented limitations:

- **Color and Clarity Aberrations** - The most notable issue with glass lenses is aberration. Different wavelengths or colors of light don't converge at the same point after passing through a lens. As a result, complex multi-lens systems are used to correct these aberrations and achieve sharp images.



- **Weight and Size** - High-performance optical systems usually require multiple lenses, making them bulkier and heavier. The excess weight and size of glass lenses adversely impact applications like night vision, fire control systems, cameras, and unmanned aircraft systems.
- **Material Limitations** - Glass has inherent physical constraints, such as fragility, weight, and the inability to be easily manipulated at the nano-scale to create specific optical properties.
- **Hazardous Substances** - Many glass optics include known hazardous substances such as lead and nickel, reducing options for optics development. The combination of the EPAs, Toxic Substances Control Act (TSCA), and The European Union REACH regulation (Registration, Evaluation, Authorization, and Restriction of Chemicals) have significantly impacted the optics industry.

FIVE WAYS HAWKAI LGRIN OPTICS CREATE OVERMATCH CAPABILITIES

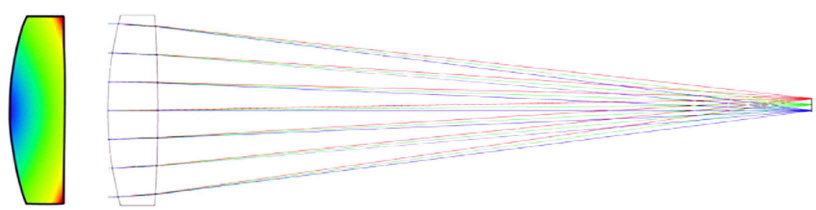
UP TO **2x**

THINNER

LENSES

The world of glass lenses is ripe for disruption, and the advent of LGRIN optics lenses is the beginning of this disruption within the optics industry. Glass lenses can only change light twice per lens: When the light enters and exits the lens. LGRIN lenses comprise hundreds or thousands of refractive index layers, enabling our designers to create lenses with a wide range of capabilities and properties optimized for specific applications.

1. **Optimize Clarity with Superior Color** - Peak's LGRIN optics are manufactured using our NanoPlex™ metamaterial, featuring a heterogeneous design of multiple refractive index layers. This design enables our lenses to significantly reduce color aberration and better manage the wavelengths of light compared to glass lenses



2. **Wider Field Of View FOV** - The ability to manage the composition of the LGRIN lens with different refractive indexes from the middle of the lens to the edge can enable our lens to achieve more expansive FOV compared to similarly sized glass lenses.
3. **Enhanced Distances** - Similar to our abilities to manage FOV, we can adjust the composition of LGRIN refractive indexes to be optimized for distance to improve target identification over longer distances than similar-sized glass lenses.
4. **Up to 50% Lighter Weight** - LGRIN optics leverage Peak's NanoPlex polymer metamaterial, which is up to 50% lighter than glass optics. LGRIN lenses can provide significant weight reductions in optics systems.
5. **Optimized Form Factors** - LGRIN optics can reduce/eliminate glass lenses required in optics systems, making them more compact and lighter. LGRIN can improve ergonomics to reduce warfighter burdens and reduce operation issues like equipment snags.

[3]Kaloia, D. S. (2022). Business model innovation in marine engine maintenance. https://core.ac.uk/download/548496413.pdf
[4]Carroll, J. (1972). Materials and devices: A close interactive system. Electronics and Power. https://doi.org/10.1049/ep.1972.0287

HAWKAI LGRIN OPTICS
DESIGN PLATFORM

IMPROVED
FOV

Today, Peak's HawkAI design platform creates LGRIN optics by combining over 800 versions of our NanoPlex refractive metamaterial for our lens prescriptions. No other company has our machine learning design software. Our advanced manufacturing and lens diamond-turning technology produce lenses that will disrupt the glass-based optics markets.

1. **Unparalleled Optics Performance** - Layered Gradient Refractive Index (LGRIN) technology improves the field of view (FOV), color clarity, and distance of optics for night vision goggles, fire control systems, and UAS reconnaissance.
2. **Machine Learning Optics Design** - Peak invented a new class of mathematics based on Maxwell's equations and created patented design software.
3. **Machine Learning Optics Design** - The core metamaterial of our LGRIN lenses is our patented translucent NanoPlex. Our manufacturing processes and systems are the most advanced and precise in the optics industry.
4. **Lens Shaping and Diamond Turning** - Our diamond-turning process can remove layers as small as two molecules of thickness.
5. **U.S.-based IP and Manufacturing** - Over 20 global patents protect Peak's LGRIN optics, NanoPlex metamaterials, and manufacturing processes. The research and engineering teams and manufacturing facilities are U.S.-based.

LGRIN APPLICATIONS

LGRIN technology is being applied primarily in the defense industries, driven by the original funding for research and development. There is significant potential for marketing opportunities in commercial and medical applications.

Applications for LGRIN Optics

Defense

Night vision
Fire control
Drones
Satellites

Commercial

Cameras
Sunglasses
Sporting goods
Automotive glass

Medical

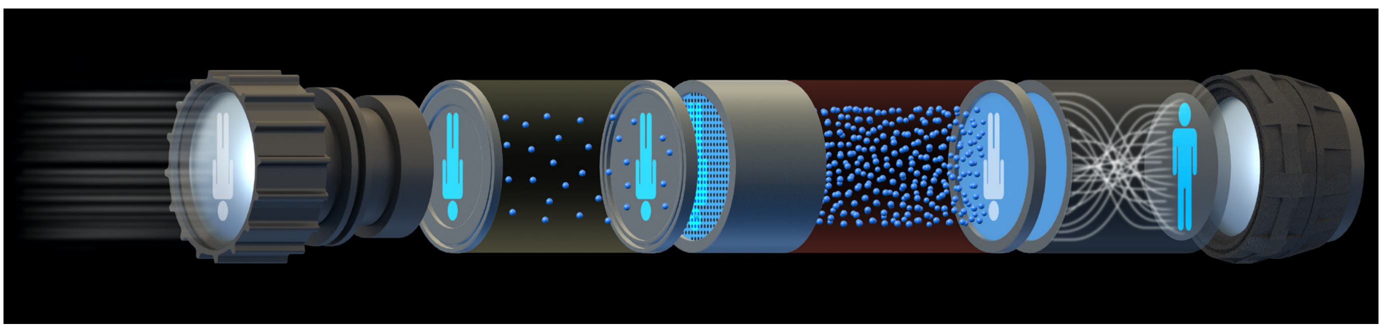
Endoscopy
Glasses/contacts
Vision testing
Medical equipment

HAWKAI LGRIN - CREATING OVERMATCH CAPABILITIES FOR NIGHT VISION

One of the first implementations of Peak's HawkAI LGRIN optics was in the night vision space. Let's review how night vision works and is deployed today and discuss the advantages of implementing LGRIN versus glass optics for night vision devices.

HOW NIGHT VISION WORKS

Night vision technology uses image intensifier tubes that capture and enhance ambient light, illuminated light, or thermal sensors to create an enhanced image that is visible to the human eye even if the light source is not natively visible.



Here is a quick overview of the night vision process that enables our warfighters to operate with precision in very low/no light environments:

1. **Capture Ambient Light** - Light photons from ambient light (moon, starlight, and other sources) enter the night vision device. The optic objective at the front of the night vision device inverts the image and directs the light photons to the image intensifier (I2) tube, which hits the photocathode plate.

2. **Photocathode Converts the Light Photons to Electrons** - When the light photons hit the photocathode. The photocathode converts the light photons into electrons with the exact positioning of the photon from the source image. The electrons are released from the back of the photocathode tube into an electrically charged vacuum, accelerating them toward the microchannel plate.

1000x

BRIGHTER

IMAGE

3 **The Microchannel Plate Intensifies the Image** - As accelerated electrons progress toward the microchannel plate, they enter slightly angled tubes (at an angle of 4-5°) within the plate, causing them to hit the side of the tube coated with gallium arsenide. This process adds more electrons to the image pattern, which will cause the image to become up to 1000X brighter than the ambient light. As the larger image-patterned electron clusters exit the microchannel plate, they accelerate again toward the phosphor screen (white or green) to be converted back into photons so warfighters can see the intensified image.

4 **Intensified Image Converted Back to Visible Photons** - The accelerated image-patterned electron clusters hit the phosphor screen and convert back into photons. On the backside of the phosphor screen, over 20 million optic fibers again invert the image, making it visible to the human eye.

5 **Intensified Image is Visible to the Warfighter** - The intensified image is visible to the warfighter in real-time so they can make the right decisions at the right time to accomplish their mission.

A crucial aspect of this technology is its sensitivity to a wide range of light, including parts of the spectrum that are not visible to the human eye, such as near-infrared. This capability further enhances its effectiveness in very low-light conditions. However, it's important to note that image intensifier tubes require some light and cannot operate in absolute darkness. Other types of night vision technology, such as thermal imaging[5], are used for situations devoid of light.

[5]The Advantages of Digital Display Night Vision Accessories for Hunting – Clarity Scopes. https://clarity-scopes.com/blogs/news/the-advantages-of-digital-display-night-vision-accessories-for-hunting

CHALLENGES OF GLASS OPTICS IN NIGHT VISION

Using glass optics in night vision presents two classes of challenges. The first is in the optical performance of the night vision device. Second is the increased soldier burden that impacts ergonomics and operational tempo. These are the primary challenges for glass optics:

Challenges for Glass Optics in Night Vision	
Field of View	Glass optics grow in size and weight as they increase the field of view, limiting the range of FOV in smaller optics.
Image Clarity	Glass optics have challenges correcting the different wavelengths or converging simultaneously after passing through a lens, reducing image clarity.
Target Identification	The same color correction issues hamper clarity in glass optics and create limits in target identification at a distance.
Edge Distortion	Glass optics cannot adjust their composition at the edge of the lens to provide complete image clarity, which creates the "O-Ring" effect on many night vision devices.
Neck Torque	Glass optics and image intensifier tube length increase neck torque for warfighters due to the distance weight being positioned away from the head with helmet-mounted NVDs.
Warfighter Safety	Many glass optics are made or contain hazardous substances such as lead and nickel. Repeated long-term exposure to these substances can endanger warfighters' health.

Glass optics have primarily stayed the same for hundreds of years, reducing our warfighters' overmatch capabilities today. It is time for a change.

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HAWKAI LGRIN - THE OVERMATCH FUTURE OF NIGHT VISION OPTICS

Using glass optics in night vision presents two classes of challenges. The first is in the optical performance of the night vision device. Second is the increased soldier burden that impacts ergonomics and operational tempo. These are the primary challenges for glass optics:

HawkAI LGRIN Optics Optimize Night Vision	
Optimize Situation Awareness	▪ LGRIN lens can provide up to 25% wider FOV than glass optics in the same form factor. ▪ LGRIN optics make images sharper and increase understanding of your operating environment
Increased Operational Tempo	▪ LGRIN optics are up to 50% lighter than similar glass optics
Faster Target Identification	▪ See and identify targets faster and at greater distances with LGRIN's increased optic clarity
Level Up Lethality	▪ Optimize target identification in battlefield conditions & light levels ▪ Enhanced accuracy in degraded environments (smoke, fog, & debris)
Improve Survivability	▪ React faster with lighter-weight optics ▪ Reduce required head movements with increased FOV ▪ Decreased target acquisition and engagement times
Reduce Soldier Burden	▪ LGRIN will reduce optics weight, which is the farthest away from the helmet, thereby reducing neck torque ▪ Reduce total deployment kit weight ▪ Reduce required head movement to see your environment with a wider FOV ▪ Optimized diopter eyepieces enable warfighters with differing visual acuity
Increase Warfighter Safety	▪ LGRIN lenses do not contain known hazardous substances, including heavy metals like lead or nickel.

HAWKAI LGRIN - COMPLETE MISSIONS AND GET HOME SAFELY

At the end of the day, night vision, fire control, and other optics systems are deployed to complete missions and get people home safely. Peak believes that LGRIN optics offer the overmatch capabilities our warfighters need to do this every time they leave home. HawkAI optics can change how we and our partners innovate, design, and build night vision and other optics systems to improve performance, reduce soldier burden, and help our warfighters complete missions and come home safely.