Application Note

IR Optics for Automotive Night Vision and Advanced Driver-Assistance Systems (ADAS)

PROBLEM Poor visibility is a leading cause of traffic collisions worldwide[1], especially during night time hours and harsh weather conditions like fog, smoke, heavy rain and snow. Night vision systems are often used to provide increased vehicle and pedestrian safety, especially in these challenging conditions. When it comes to developing optics for these systems, there must be high thermal imaging quality, and long distance object detection, to minimize collision risk and provide maximum performance.

BACKGROUND Studies into the causes of traffic collisions have long researched into the times of day and weather conditions associated with traffic collisions and fatalities. Statistics have shown that 44% of fatal collisions happened during the night time[2]. Poor visibility is clearly a major factor in traffic collisions and resulting fatalities. In order to prevent situations in which drivers experience poor visibility, vehicles are increasingly including Night Vision systems that enable drivers to anticipate potential hazards even in low lighting conditions such as darkness, smoke, or fog. This is part of the trend towards ADAS (Advanced Driver-Assistance Systems), with many major vehicle manufacturers investing billions of dollars into such systems. Such systems provide a range of features, including semi or fully autonomous driving, collision avoidance, and alert systems.

ADAS can be passive or active. A passive system alerts the driver of potential hazards, allowing time for the driver to respond. Active safety systems take direct action in response to a hazard.

The systems are designed to increase road safety and minimize collisions that result from human limitations or error. One such limitation is an inability to see in poor visibility, a situation which can only be resolved through a Night Vision system.

Figure 1:
Night Vision - Visible vs. Thermal Imaging

Standard vision systems, using visible-light cameras, rely on light from the sun, or street lighting, limiting their use in low-lighting conditions. Thermal Imaging Night Vision Systems, in contrast, use the thermal energy (heat) emitted by all objects to allow for 'sight', even in complete darkness.

A recent study into Automatic Emergency Braking (AEB) systems highlights the necessity for thermal imaging cameras in vehicles equipped with ADAS.[3] Performed by the AAA, the study found that AEB systems with pedestrian detection were completely ineffective at night. The four car models evaluated had radar and visible cameras, but not thermal imaging cameras. During the day, these vehicles were able to detect and avoid a proportion of collisions with adult pedestrians (~40% when the vehicle was travelling at 20mph). However, during the night, the AEB system failed to detect even one adult pedestrian,

at any vehicle speed. Without thermal imaging, such a system is limited to use only in the day.

Having a Night Vision System with thermal imaging is not enough in itself. For Night Vision systems to be effective, they must be equipped with high sensitivity, high performance athermalized (i.e., stay in focus at all temperatures) lenses, that allow for long distance hazard detection, and even object classification, to provide the driver with sufficient response time and information about the type of hazard ahead. These optics must also maintain high image quality and full operability in the harshest environmental conditions.

PROBLEM Developing high performance optics for the automotive industry involves many challenges.

High image quality ADAS and AV (autonomous vehicle) systems are based on AI (artificial intelligence) algorithms, which analyze captured images in real time and identify potential obstacles and humans, in order to take action and avoid collisions. Obviously, to be effective, these systems must recognize and identify the objects from large distances, so that the system can take action in a timely manner, and with extremely high reliability, with no false alarms. To achieve these goals, the images must have the highest quality available, i.e. diffraction limited. This means that both the IR detector and lens must be of the highest level of performance. When using the most advanced IR detectors, an improvement in lens quality is necessary to take full advantages of advances in detector performance. In other words – lens quality is essential. An inferior lens will produce an inferior image, even with the best detector. In order to match high performance detectors, lower F#s and tighter tolerances are required, forming lenses with minimal aberrations.

Optics must also feature:

- Compact size
- Athermalization – essential for the continuous full operation of the system at any temperature during driving.
- Full operation in all environmental conditions - including extreme temperatures, high humidity, severe shock and vibrations, thermal shock, impact resistance, as well as exposure to chemicals, salt spray and blowing sand.
- Low cost – the challenge is to design and manufacture a lens with both high quality and low cost, for cost-effectiveness for the mass market.

SOLUTION In order to meet the requirements of thermal imaging night vision systems, Ophir utilizes its vast knowledge and experience in designing and manufacturing lenses for the automotive industry for many years. Starting with several innovative optical and mechanical design alternatives, Ophir analyzes the tradeoffs of each alternative, and select the most cost effective design, taking into account both performance and cost.

When selecting the final design concept, multiple considerations are taken into account: nominal performance, tolerance sensitivity, manufacturability, raw material costs and availability, manufacturing and assembly costs, testability, and risks.

Aspheric and diffractive surfaces are often used in Ophir's optical designs, in order to reduce aberrations and improve image quality, while minimizing the number of optical elements. This reduces size, weight and cost. Diamond turning technology can produce these aspheric and diffractive surfaces, with exceptional levels of accuracy and quality. Aspheric lens surfaces are desirable, particularly when it comes to infrared optics, showing significant increases in optical performance over their spherical

counterparts. Aspheric-Diffractive lens surfaces allow for the integration of multiple functions, such as chromatic and spherical aberration corrections.

Product features

When it comes to optics for night vision and ADAS systems, Ophir's range of products feature the following capabilities:

- High MTF
- Up to 51.1° HFOV
- QVGA or VGA resolution availability, at 12, 17 and 25 µm pixel pitch
- High volume manufacturing

After design selection, Ophir moves on to prototype production, using cutting-edge equipment and manufacturing processes to produce the highest quality IR optical components.

Following the production of the optical elements, lens assembly and testing is preformed by utilizing an advanced and fully equipped R&D lab. The whole process ensures a high quality, cost-effective product for the automotive market.

Figure 2:
NV3 | 12.8mm f/1

Ophir has delivered hundreds of thousands of automotive lenses to the market to date. Starting from the second generation of products – Night Vision 2 (NV2) for 320x240 25µm FPA, moving to the current third generation – Night Vision 3 (NV3) – for 320x240 17µm FPA, and looking towards the next generation – Night Vision 4 (NV4) for 640x480 12µm FPA.

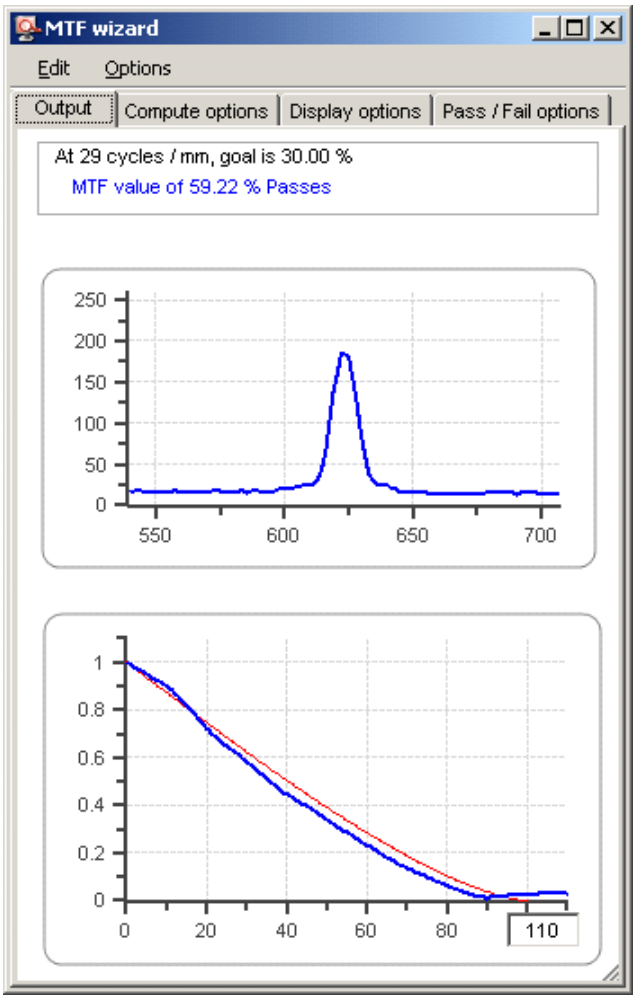

Figure 3: NV3, 12.8mm f/1 optical performance measurements
Top graph: Measured line spread function
Bottom graph: Measured MTF vs. spatial frequency (cy/mm)

Figure 3 illustrates the impressive optical performance of the 680177 – NV3, 12.8mm f/1, that is close to maximum theoretical limit (diffraction limit).

CONCLUSION

Automotive night vision systems using thermal imaging are critical for the future of ADAS (Advanced Driver Assistance Systems) and AV (Autonomous Vehicles) markets. The high-quality, low-cost lenses that are needed for such systems are extremely challenging, from both design and manufacturing aspects. The lenses must allow for high quality thermal imaging performance in the lowest lighting conditions, so that the Night Vision system can detect and identify potential hazards from a distance.

Based on years of experience and cutting-edge technology, Ophir is the worldwide leading supplier for automotive night vision systems, with an installed base of hundreds of thousands of lenses, and the most advanced next generation design – the Night Vision 4 (NV4) - suitable for 640x480 12µm pixel FPA.

REFERENCES

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