Protective window in the optical path of a LIDAR system

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Protective windows in an automotive LIDAR system have to provide an almost lossless transmission of the NIR radiation. Thus, low wavefront distortion and haze-free surfaces are key, because long-range objects can only be detected when even faintest reflections can reach the sensor. Additionally, there are mechanical, chemical and cosmetic requirements to be satisfied.

1 Introduction

Autonomous driving and automated driver assistance systems (ADAS) are using LIDAR for the 3D detection of the surroundings among camera based imaging, ultrasonic sensing and RADAR. LIDAR is a key technology that bridges the gaps of RADAR, visible imaging and ultrasonic sensing. The optical system needs to have high accuracy and reliability to gauge the surroundings and perspectively the velocity of moving objects. This results in specific requirements for the window that protects the sensitive optics from harsh road & traffic conditions.

2 Principle function of LIDAR

There are several LIDAR technologies using the same principle: A NIR laser source emits radiation at either 905 nm or 1550 nm which is focused into the scenery around the car. The reflection from any object is imaged onto a detector, which provides the ADAS system's algorithms with the object's exact direction, distance and perspectively velocity. See figure 1.

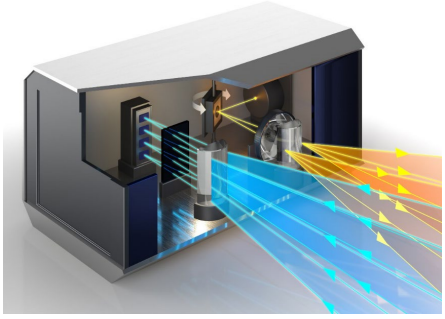

Fig. 1 *Principle of LIDAR optics: a laser source emits radiation (orange) and the faint reflection (blue) of any object is being detected precisely.*

A LIDAR system used in autonomous driving or in ADAS is relevant for the passenger safety and therefore, focus is on reliability and functionality. Any type of obstacles, that might influence the driving of the car, has to be recognized early enough. I.e., a black tire lying in the middle of the path of travel must be detected far ahead when driving at high speed. However, such a black tire has very low reflectance, resulting in only a few photons returning to the LIDAR sensor for detection.

The optics of the LIDAR system are covered with a black protective window, that represents the exit window for the laser radiation and the entrance window for the reflected photons.

3 Optical effects of the outside window

The laser beam (or multiple beams) leaving the LIDAR system can be distorted by variations of flatness or internal quality of the protective window. Such distortion could be a deflection, which is expected to be negligible for a local wedge of e.g., 3 µm. However, a defocus of the collimated beam will result in a divergent beam that will lose its intensity for long distances. This will cause a much smaller reflection, having less photons reaching back to the detector. Therefore, a low wavefront distortion is required in the optically effective area of the window.

For a system which relies on the detection of low intensity radiation there are several critical factors that limit the detection of the photons in the receiving path:

- Striae can reduce contrast and photons getting lost.
- Surface roughness will cause stray light, and those photons will not reach the detector.
- Scratches and digs cause local stray light areas which limit the detection in certain sectors of the field of view.
- Internal defects can cause losses due to stray light or could even block a solid angle of the field of view.

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4 Protective function

Another main purpose of the window is its protective function. It protects the sensitive electronics and optics from gravel, rain, snow and ice. The window shall withstand sandstorms, car wash and all other stresses and forces of an automotive lifetime. Therefore, materials and coatings shall be easy to clean and shall have a high strength against bending, gravel and impact. The window requires a high chemical durability and good temperature resistance for defrosting, therefore, a glass window is recommended. The hardness of glass and its invariance of optical properties with temperature changes makes it the ideal material choice.

5 Transmittance and color

A window for automotive LIDAR shall be black for the observer's eyes but highly transparent in the NIR range. The black color is a cosmetic requirement and it adds to the laser safety for human eyes. The material selection for such windows is limited due to special automotive requirements on the glass composition. Glass types with perfect blocking in the visible and high transmittance at 905 nm contain some amount of Cadmium ions, prohibited by the automotive industry [1]. The development of Cadmium free glasses has some challenges. Figure 2 displays the typical spectra of those glass types: A Cadmium free glass like RG905 has a black appearance when mounted in front of a LIDAR sensor, but the optical density for a Cadmium glass is several orders higher. For Cadmium free glasses that are suited for the wavelength of 1550 nm, the steepness of the transmission edge is lower and the maximum transmittance is slightly lower.

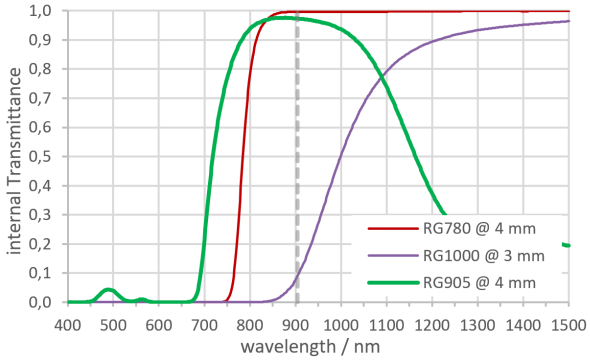

Fig. 2 *Examples of spectra of internal transmittance. The red curve is a typical spectrum of a Cadmium containing glass; the green and black curves show Cadmium free formulations.*

In order to enhance the transmittance at the laser wavelength, anti-reflection coatings are used on the inside and on the outside of the window.

Due to the cosmetic requirement of the customer, the outside coating has to be optimized for visible appearance as well. Figure 3 depicts an AR coating for the outside surface of the window with a neutral color appearance over a wide range of angles of incidence.

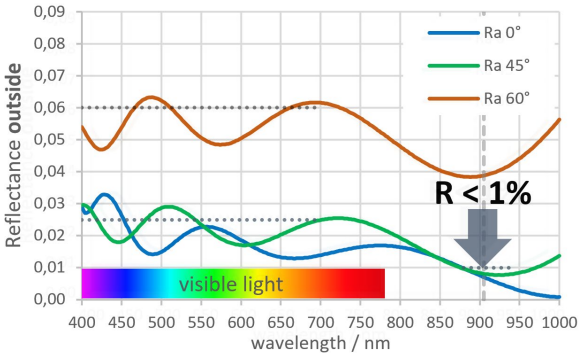

Fig. 3 *Reflection spectra of an outside coating at three different angles of incidence. The visible color appearance of the residual reflection is almost neutral for all angles.*

6 Conclusion

Cadmium-free glasses with high transmission at 905 nm and 1550 nm are available. They meet both the protective requirements of the automotive industry as well as the needs of designers. In addition, they ensure a high optical performance of the LIDAR system due to their excellent internal quality and robustness.

References

[1] Automotive EU regulation 2000/53/EG

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