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Agenda item [[2]](#footnote-3) 3.1

Technical Domain / Task Number 2 Task 2

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Three Interesting Lenses

# Summary

Three different narrow beam unidirectional lenses usable for large rotating beacons or range lights are presented. This paper is for information only.

# Background

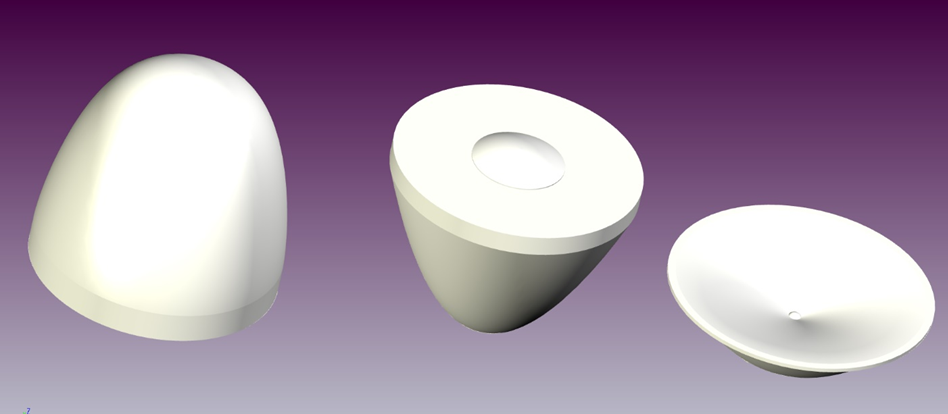
A project was executed to evaluate lens designs suitable for use in large rotating beacons or range lights. Primary design goals were for lenses with fixed intensity of 500,000 candelas and divergence at 50% of 1.5 degrees using a single LED for the light source. The input parameters are summarized in the following table:

Table Project Parameters

|  |  |  |
| --- | --- | --- |
| Target Intensity | 500,000 | Candela |
| Target Divergence at 50% | 1.5 | Degrees |
| LED Chosen | Cree XQ-E Plus HD | 1.6 mm square emitter; 4500K |
| LED Electrical Power Chosen | 3 | Watts |
| LED Luminous Flux Chosen | 250 | Lumens |

Weight and manufacturability were considered and are described in Section 4 Concluding Remarks below.Three different lens geometries were chosen for study - Aspheric, Parabolic and Free Form:

Figure Left to Right: Aspheric, Parabolic, Free Form



The three lenses are shown at the same scale.

# The three lenses

## Introduction to the Lenses

The three lenses use a single LED with a narrow beam to give long range performance. They were designed using the same diameter, LED choice and LED power for comparison purposes.

Using the project parameters with the chosen LED and by applying conservation of etendue, the lens diameter of 150 mm was calculated and chosen.

1. A traditional aspheric (cylindrical with rounded end) lens. The lens is quite heavy and cannot be moulded. It is typically formed on a lathe using single point diamond tool.
2. A parabolic reflector lens. The lens uses total internal reflection on the parabolic surface. The lens is slightly shorter and lighter than the aspheric but is also too heavy to be moulded. It is typically formed on a lathe using a single point diamond tool.
3. A free form flat-bowl-shaped lens. The lens is much shorter and lighter than the other two lenses. The lens has sections thin enough that is could possibly be moulded. It can also be formed on a lathe using a single point diamond tool.

The three lenses were designed and simulated. Please note that simulations were for ideal lenses – second order effects (surface reflections, scattering, manufacturing and assembly tolerances, etc.) were not considered. Further, as this was done as a study, none of the lens designs were optically optimized. Some performance improvements may be gained through optimization.

A ten-million random ray set was built using luminous intensity data provided by the manufacturer of the LED. The ray set was used as the light source for simulations.

## Divergence Plots and Section Drawings

Figure Aspheric Divergence Plot and Section Drawing

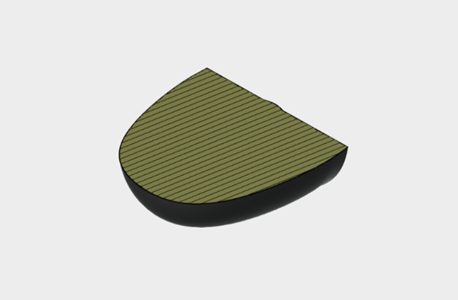
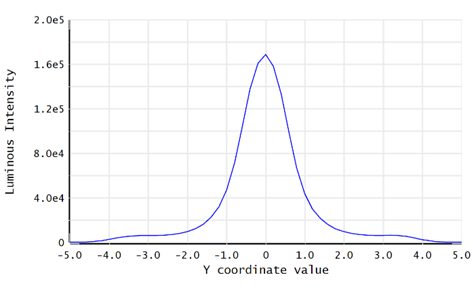


Figure Parabolic Divergence Plot and Section Drawing

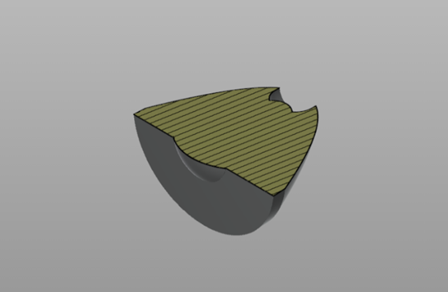
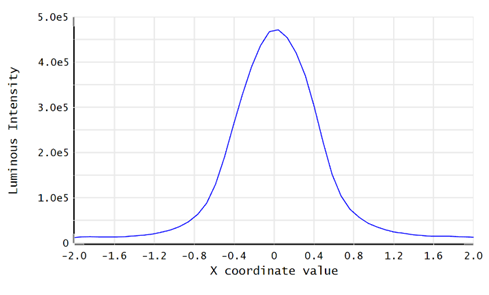
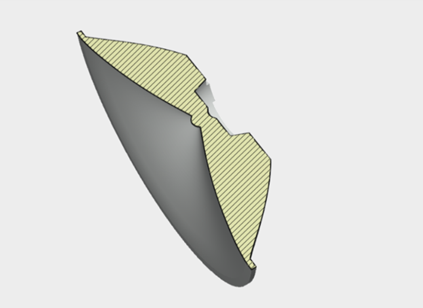
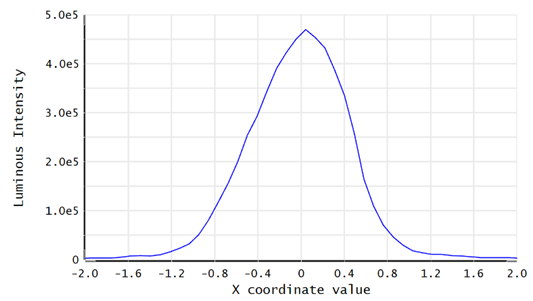


Figure Free Form Divergence Plot and Section Drawing



## Lens Performance Data

Table Lens Performance Data

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lens | Diameter (mm) | Length (mm) | Weight (kg) | Divergence at 50% (degrees) | Divergence at 10% (degrees) | Fixed Intensity (cd) | Range at 10-Mile Meteorologic Visibility (NM) |
| Aspheric | 150 | 142 | 2.1 | 1.6 | 3.2 | 182000 | 21 |
| Parabolic | 150 | 121 | 1.4 | 1.0 | 1.8 | 472000 | 23 |
| Free Form | 150 | 41 | 0.4 | 1.0 | 1.9 | 470000 | 23 |

## How the Lenses Work

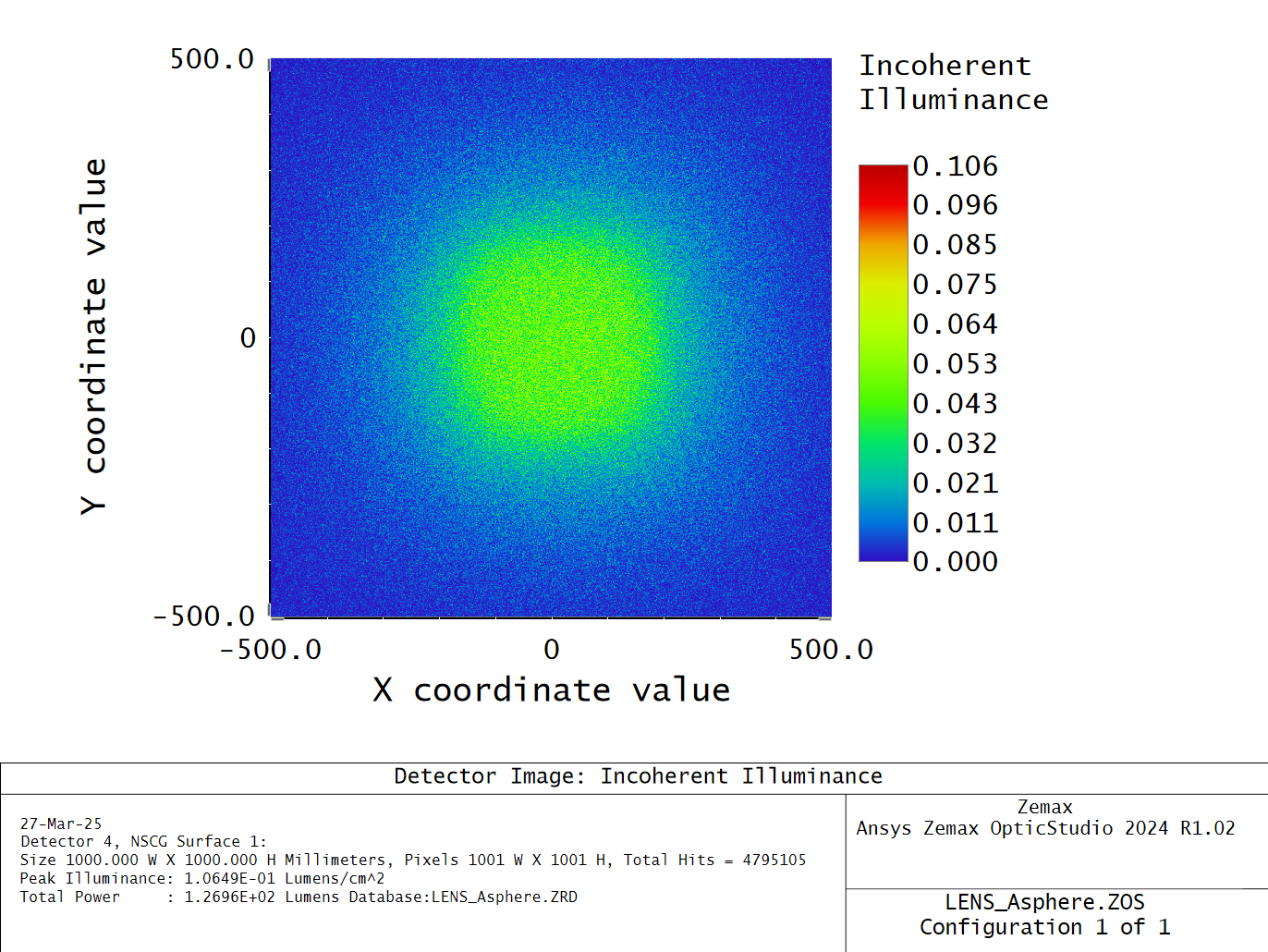
Shown are three images for each lens that illustrate how each lens works. The first image shows a ray trace through a cross section of the lens. The second image shows detector response in the near field at 1 meter in front of the lens. The third image slide shows detector response in the far field at 20 meters from the lens.

### Aspheric

Figure Aspheric Ray Trace; Near Field; Far Field

A blue lines around a grey object

AI-generated content may be incorrect.A screen shot of a graph

AI-generated content may be incorrect.

### Parabolic

Figure Parabolic Ray Trace; Near Field; Far Field

A blue lines in a blue background

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AI-generated content may be incorrect.A screen shot of a computer screen

AI-generated content may be incorrect.

### Free Form

Figure Free Form Ray Trace; Near Field; Far Field

A diagram of a bridge

AI-generated content may be incorrect.A screen shot of a computer

AI-generated content may be incorrect.A screen shot of a computer

AI-generated content may be incorrect.

# CONCLUDING REMARKS

The traditional aspheric lens is clearly superseded by the other lenses in terms of light gathering and output. Only about ±40 degrees of the LED emissions are usable by the aspheric lens. The weight and thus cost of material of the lens are working against the practicality of the aspheric lens. The lens is simple to design. Looking at the ray trace, a significantly smaller diameter lens might work as well as the one designed.

The parabolic lens has clearly better performance compared to the aspheric lens. Almost all the LED emissions are usable, and this shows in the fixed intensity. The parabolic is a bit lighter than the aspheric, and but still has the high cost of material compared to the aspheric lens. The lens is easy to design.

The free form lens is equivalent to the parabolic lens in performance. The lens is expensive to design as specialized software for the Miñano-Benítez Simultaneous Multiple Surfaces (SMS) design method needs to be written to calculate the surfaces. The lens requires the least amount of material to make. The metallic coating on the reflective surface adds cost. It may be possible to injection mould the lens, making cost of production in large quantities very favourable.

It is expected that diamond lathe turning costs for each of the three lenses would be similar.

# Acknowledgements

The author thanks Orion Maritime Systems for the opportunity to execute this project, and for providing a licence to Ansys Zemax OpticStudio for the optical simulations.

# Action requested of the Committee

The Committee is requested to accept this paper for information only.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-2)
2. Leave open if uncertain [↑](#footnote-ref-3)