Functional integration for additively manufactured reflectors

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This work investigates the possibilities of functional integration for reflective optics that are manufactured via Selective Laser Melting. A method for identifying a broad range of technical functions and concepts that are suitable for functional integration is presented. Using a flashlight and a bicycle headlamp, selected concepts are realized.

1 Introduction

The demand for custom designed optical components such as integrated waveguides or free form lenses with specific light distributions have risen sharply in recent years in several industrial sectors [1]. Individualized designs offer benefits through miniaturization and lightweight concepts, which result in a more efficient usage of resources and lower energy consumption [2]. In order to manufacture such individualized optics, Additive Manufacturing is becoming increasingly important due to the large number of design options available. In addition to the possibility of realizing free-form optics, Additive Manufacturing offers the potential for functional integration and optimization [3]. However, there is still a lack in methodology for identifying possible functions that can be integrated. Additionally, there is no guideline how to realize the design of functionally integrated optical components. The objective of this work is to close the mentioned gap in methodology. Furthermore the functional integration is demonstrated using integrated reflectors manufactured with Additive Manufacturing.

2 Identification of additional functions

First, a methodology is developed to find as many additional functions as possible. For this purpose, three different approaches are performed. A Bottom-Up method as used by Crull is adapted, which allows the analysis of functions of reflectors and their adjacent components without investigating an existing system. In addition a specially developed Top-Down method is used that evaluates existing reflector systems regarding their implemented functions. Additional functions can therefore be determined with an opposite analysis direction and can be added to the variety of integrable functions. An extensive literature review supports the two methods to identify the widest possible range of additional functions for functional integration. Although having three different approaches for identifying the possibilities of functional integration, the success of the methods are determined by the thoroughness of the operator.

3 Design catalogue

In order to systematically prepare and classify the results from the function identification, a design catalogue is created. The catalogue resembles a supporting tool for a designer to pick suitable functions for the reflector. An excerpt from the design catalogue with concepts from various physical areas is shown in figure 1. A total of 27 functions are catalogued, which can be viewed using the link at the end of this paper.

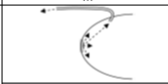
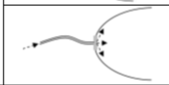
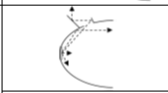
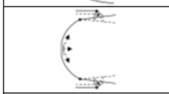
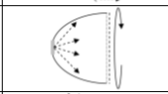
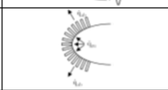
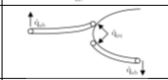
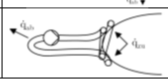
Index Structure		Application sample	Selection characteristics			
Subfield of physics	Functional component	Schematic view	Suitable Additive Manufacturing technique		Function extension	Component reduction
			SLM	FDM		
I	II	III	IV	V	VI	VII
Optics	Waveguide		✓	✓	✓	x
			✓	✓	x	x
	Reflector		✓	✓	✓	✓
			✓	✓	✓	x
			✓	✓	✓	x
	Filter		✓	✓	✓	x
Thermal dynamics	Heat sink		✓	x	✓	✓
	Heat pipe		✓	x	✓	✓
	Active cooling		✓	x	✓	✓

Fig. 1: Excerpt from the design catalogue for functional integration

It is evaluated whether additional functions implemented on the reflector (function extension) and thus other components that originally had these functions can be omitted (component reduction).

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Since several functions need specific material properties, i.e. high thermal conductivity for sufficient heat flux, different material classes may be utilized. For this purpose the design catalogue also evaluates the usage of Selective Laser Melting (processes metals) and Fused Deposition Modelling (processes polymers) for manufacturing parts with different functionality.

4 Design approach

The design approach shown in figure 2 is based on an existing flashlight reflector. Using the possibilities given by the design catalogue, heatsinks for passive air cooling, clip mountings (that can be used as waveguides) for an additional lens and protection window and the integration of the reflector in the electrical circuit have been realized. One component is removed, since the reflector also resembles the housing. All in all, six new functions are added compared to the already existing model.

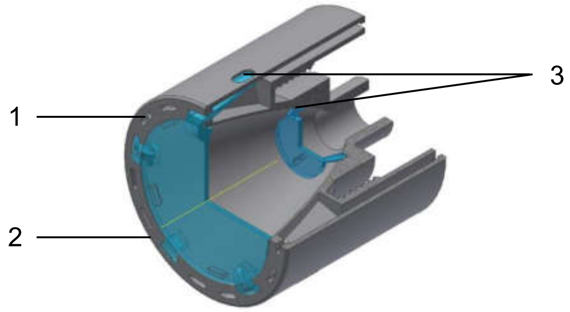

Fig. 2: Functionally integrated reflector with heatsinks (1), housing (2) and lens mounts (3)

Figure 3 shows an entirely new design for a bicycle headlamp in which the idea of real time measurement of the light source is implemented. Therefore a mounting for an optical fibre is designed, which guides a percentage of light to a sensoring element. Anomalies in power or spectrum can be directly recorded and counter measures can be taken. There are also retro reflective elements at the end of the reflector for improved visibility and cooling elements for more powerful light sources.

When designing functionally integrated components, the order in which the functions are implemented must be taken into account, because certain implementations can also create new disturbances. Highly complex cooling elements can achieve better heat flux, but may also reduce the simplicity of mounting the reflector.

5 Conclusion

The advantages of Additive Manufacturing can be used profitably for the realization of optical components.

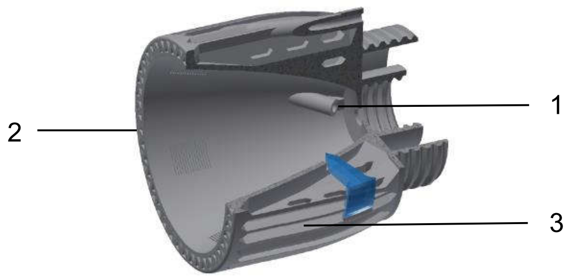

Fig. 3: Reflector with fibre mounting (1), retro reflective elements (2) and cooling elements (3)

In summary, functional integration offers a lot of potential to systematically and quickly innovate due to high competitive pressure and scarcer resources to develop products or to save material and weight. Functional integration benefits from the freedom in design of Additive Manufacturing. Thus the functional integration for single parts or small series products is becoming increasingly interesting a competitive environment.

In the development of functionally integrated components, especially methods in the early phase, when designing the component is not finished, are relevant. Since the suggested methodology offers a rather general approach on functional integration, here the implementations can often be difficult. Applying the methods in later development phases offer more accessible ways to get from existing products to more innovative solutions. However, these tools require experience and skill to find and implement new functions.

Acknowledgements

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Link to design catalogue:

https://www.ipeg.uni-hannover.de/konstrkat

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