# Synopsis of a published paper

## "Optical design and engineering: lessons learned"

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## Abstract

This report gives a synopsis of a published paper [1], entitled "Optical design and engineering: lessons learned " by Pantazis Mouroulis. This paper contains some recommendations for the optics curricula that seek to serve students intent on a career in optical engineering,  and also gives suggestions for the young professional embarking on such a career. By giving several examples, It also illustrates the suggestions of actual optical systems.

## Introduction

Having studied and then taught optics for a number of years, the author eventually found himself in the position of having to produce optical systems and designs for a living. There arose then an interesting opportunity for assessing how much of the theoretical knowledge was actually useful in practice, as well as what was missing from it that could have made a difference had it been taught. While one person's view and experience is undoubtedly limited, it is hoped that a few of the lessons learned will be of more general interest. Three themes are examined in this paper: 1) the incorporation of a 'systems' outlook as an inherent part of optical design and engineering, 2) the uses of optical design software, and 3) concepts found very useful or not so useful in optical design or engineering practice.

## Suggestion for the optics curricula

An optical engineering curriculum needs to instill a systems outlook. While it is necessary and useful to master the basics of individual areas within optics, there is usually no place in the curriculum where a complete system is analyzed. There are two distinct aspects to this outlook:

1) the interaction between optics and the other disciplines that go into making a complete system.The closest relative of optical design is opto-mechanics, where the optical engineer needs not only an appreciation of lens mounting techniques but also an understanding of the principles of minimizing thermal or mounting stresses and distortion. The principle of kinematic mounting should be discussed theoretically and demonstrated in the laboratory. Same thing with electronic detector.

2) the incorporation into the optical design of considerations that relate to the manufacturability and performance of the system in its intended environment. Including a better understanding of what is a good design, reducing the aberration to very low level, tolerancing, fabrication, alignment, assembly, and performance testing.

Many of these topics are normally taught in an optics curriculum, but they are taught separately. The author believe that there is significant value in bringing them all together and showing how they all interact in order to build a successful instrument.

## Suggestion for the entering optical engineer

1) S*implify is the most important thing*. A simpler design will generally be easier to align and will have a better chance of maintaining performance in the field.

2) *Design with cost in mind from the beginning*. Even if you are told that cost is not an issue, cost is still an issue.

3) *Eliminate the middleman or at least strive to reduce the need for one*. Attempt to understand the customer requirements and translate them into optical design metrics.

4) *Forget "first-cut" designs* even if you are asked to produce one. Insert complete system considerations into the design from the beginning.

5) *Question "impossible" specifications*. Probe relentlessly into the customer's "impossible" requirements.

6) *Think on the customer' s behalf,* and try to solve the problems that s/he does not know s/he has.

7) *Try to keep up with developments by reading the current literature*. Optical engineers, perhaps no more so than any other engineers, tend to think that engineering is mostly a matter of employing sound practices while only the researchers need to keep up with the research literature.

## Some issues specific to optical design

It is impossible for optics curricula to cover everything. The engineer will have to figure out many details on his or her own after graduation. For this reason, the topics in this subsection are only the few most important ones.

1) *Reflective systems, especially unobscured*.

2) *Zernike polynomials*

3) *Stray light*.

4) *Optical design for the thermal infrared*.

5) *Ray aiming*.

Also, there are several material that is rarely used but they are not useless, they are just topics that this engineer has had no reason to use until now.

1) *High order aberration theory*.

2) *Coddington's equations, Conrady's D-d chromatic sum, offence against the sine condition, and other similar formulas*.

3) *Third order correction by hand computation and thin lens pre-design*.

4) *Ray fans*.

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## Tremendously useful topics

The topics below are those that have been found useful not just once or twice but practically all the time. While they may appear to be rather elementary, they are also endless in their application and not as fully appreciated as they should be, sometimes even by practicing engineers. Certainly, any time spent in an optics curriculum trying to instill a deeper understanding and more detailed knowledge of these few topics is time well spent.

1) *A clear understanding of pupils and stops and pupil matching*.

2) *The process of first order system layout using the marginal and pupil rays*.

3) *The Lagrange invariant and its relation to resolution and throughput*.

4) *A detailed knowledge of wavefront and PSF shapes as a function of various aberrations*.

5) *An understanding of how certain aberrations may arise within any particular system* (e.g., due to symmetry or lack thereof).

6) *Computational principles and issues regarding diffraction calculations*.