Laser Systems Engineering

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Preface

How did it happen that more than 50 years after the invention of the laser, almost all of the books that have the word "laser" in their title emphasize the design of the lasers themselves, rather than the development of optical systems that incorporate these unique sources of light? A quick web search reveals thousands of books that focus on laser design; very few books, however—*Building Electro-Optical Systems* by Hobbs, *Laser Communications in Space* by Lambert and Casey, *Field Guide to Lidar* by McManamon, and *Electro-Optical Instrumentation* by Donati, for example—address aspects of the design and engineering of laser systems.

As a result, and aside from the many books available for fiber-optic communication systems, the design of laser systems that use free-space optics—manufacturing, biomedical systems, laser radar, laser displays, and so on—is still a hit-or-miss proposition, with little systematic guidance available. The purpose of this book is to take an initial step in addressing this gap.

The perspective taken to do this—that of the laser systems engineer—is sometimes thought of as "designing the right laser" versus "designing the laser right." Unfortunately, this approach is both incomplete and overly centered on the laser designer's goal of designing the laser right. Designing (or selecting) the right laser—i.e., one that meets system-level requirements—is certainly key, but designing the right optical, scanning, and detector subsystems is equally important.

Starting with a description of what the "right" laser might look like, this book addresses all of these topics. Laser selection will depend on the application, with Chapter 2 reviewing the available laser types (semiconductor, solid-state, fiber, and gas) in the context of what makes them uniquely suited to meet specific requirements such as average power, peak power, linewidth, power consumption, cost, size, and so on.

Chapter 3 then looks at Gaussian beam propagation and associated non-idealities for aberrated and higher-order beams; Chapter 4 uses these concepts to develop the details of the optical subsystem, including the unique properties of Gaussian-beam focusing, as well as truncation, aberrations, surface figure, surface ripple, surface roughness, surface quality, material absorption, back-reflections, optical coatings, and laser damage threshold.

In addition to the laser and optical subsystems, scanning and beam control are required for directing photons onto a biomedical specimen, manufacturing workpiece, projection screen, or target. The scanning technologies, optical components, and system trades for these subsystems are covered in Chapter 5.

Finally, many laser systems require the use of a detector—single-pixel or focal plane array—to collect an image or otherwise obtain information about the beam. Before we can measure photons, however, we first need to understand how many are expected, their wavelengths, and their spatial distribution. This is reviewed in Chapter 6, where we examine the notion of laser brightness, and then use the concept to estimate the power collected by the optical and detector subsystems. Chapter 7 then ties everything together from the point of view of photon detection, including detector types, geometries, sensitivities, and selection.

The emphasis in all chapters is on real-world design problems and the first-order equations and commercial off-the-shelf components used to solve them. As with any book, not every topic can be included; however, readers may also find my previous books useful for understanding the many differences between lasers and incoherent sources [*Optical Systems Engineering* (McGraw-Hill, 2011)] or obtaining additional details on the optomechanical aspects of building laser systems [*Optomechanical Systems Engineering* (John Wiley & Sons, 2015)].

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