Sources and gain in photonic random media
El-Dardiry, R.G.S.

Citation for published version (APA):
El-Dardiry, R. G. S. (2012). Sources and gain in photonic random media

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: http://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
## Contents

1 **Introduction**  
1.1 Sources of electromagnetic radiation  
1.1.1 Radiating point dipole  
1.1.2 Spontaneous emission and vacuum fluctuations  
1.1.3 Non-radiative decay: quantum efficiency and spectral broadening  
1.1.4 Stimulated emission, absorption, and elastic scattering  
1.1.5 Lasers  
1.2 Random photonic media  
1.2.1 Single scattering  
1.2.2 Multiple scattering and random walks  
1.2.3 Particle diffusion  
1.2.4 Wave diffusion  
1.2.5 Anderson localization  
1.3 Interaction between sources and random media  
1.3.1 Random lasers  
1.3.2 $C_0$-correlation  
1.4 Outline of this thesis  

2 **Classification of light sources and their interaction with active and passive environments**  
2.1 Light sources in the natural sciences  
2.2 Random laser experiment  
2.3 Random laser model  
2.4 A classical dipole source in a complex environment  
2.4.1 Generalized expression for a source  
2.5 Numerical example: 1D localization  
2.6 Conclusion and discussion  

3 **Probing the dynamics of Anderson localization through spatial mapping**  
3.1 Transverse localization  
3.2 Experimental methods
3.2.1 Measurement characterization ........................................... 51
3.3 Results on disordered samples ............................................. 53
  3.3.1 Ensemble averaged data .................................................. 54
  3.3.2 Single realizations of disorder ......................................... 55
3.4 Model .............................................................................. 56
3.5 Conclusion and discussion .................................................. 58

4 Spatial threshold in amplifying random media 59
  4.1 Transport of light inside random media ................................. 59
  4.2 Experimental methods ...................................................... 60
  4.3 Experimental results and analysis ....................................... 62
  4.4 Diffusion theory with gain ................................................ 63
    4.4.1 Numerical solution to diffusive random laser equations ... 64
  4.5 Numerical results and analysis .......................................... 66
  4.6 Conclusion and discussion ................................................ 68

5 Tuning random lasers by engineered absorption 69
  5.1 Emission wavelength of a random laser ............................... 69
    5.1.1 Exploiting absorption .................................................. 70
  5.2 Samples ......................................................................... 70
  5.3 Experimental results ........................................................ 71
    5.3.1 Mode competition ........................................................ 72
  5.4 Model .............................................................................. 72
  5.5 Conclusion and discussion ................................................ 75

6 Narrow spectral features in random lasers 77
  6.1 A short history of spikes: a scattered field ........................... 77
  6.2 Systematically studying narrow spectral features .................... 78
  6.3 The spatial structure of random laser modes ......................... 80
    6.3.1 Sample fabrication and configuration ............................. 80
    6.3.2 Apparatus for spatially resolved spectral measurements ... 81
    6.3.3 Results on GaP random laser ....................................... 82
    6.3.4 Influence of dye surface layer on random laser emission ... 87
    6.3.5 Conclusion on random lasing in and around porous GaP ... 88
  6.4 Constructing a random laser phase diagram ......................... 89
    6.4.1 Sample fabrication ...................................................... 89
    6.4.2 Data analysis and spike detection ................................ 90
    6.4.3 Results on dispersive systems ..................................... 90
  6.5 Two-mode model with gain competition ............................... 92
  6.6 Conclusion and discussion ................................................ 94

7 Outlook and applications 97
  7.1 A new tool for studying paint ............................................. 97
  7.2 Turbidimeter based on the method of extrapolation ............... 100
  7.3 Controlling random lasers by wavefront shaping .................... 101
  7.4 Sinks in random media: the black shades of white ................ 102

Summary 105
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samenvatting</td>
<td>107</td>
</tr>
<tr>
<td>Context of discovery</td>
<td>111</td>
</tr>
<tr>
<td>Dankwoord</td>
<td>117</td>
</tr>
<tr>
<td>Bibliography</td>
<td>119</td>
</tr>
</tbody>
</table>