Scattering and absorption in 2D optics

Mariani, F.

Scattering and absorption in 2D optics

PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C. J. J. M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 6 maart 2018
klokke 13:45 uur

door

Flavio Mariani

geboren te Foligno, Italië
in 1983

Promotores:	Prof. dr. M. P. van Exter	Universiteit Leiden
	Prof. dr. E. R. Eliel	Universiteit Leiden
Promotiecommissie:	Prof. dr. M. A. G. J. Orrit	Universiteit Leiden
	Prof. dr. W. L. Vos	Technical University of Twente
	Prof. dr. L. M. Moreno	Universidad de Zaragoza, Spain
	Dr. M. J. A. de Dood	Universiteit Leiden
	Prof. dr. C. U. Keller	Universiteit Leiden

Casimir PhD series, Delft-Leiden 2017-48

ISBN: 978-90-8593-332-8

An electronic version of this dissertation is available at:
https://openaccess.leidenuniv.nl

The research described in this thesis was conducted at the 'Leids Instituut voor Onderzoek in de Natuurkunde' (LION). This work is part of the research program of the Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organization for Scientific Research (NWO).

Cover image: light reflected by a thin-film silicon solar cell illuminated with linearly polarized coherent light. The co-polarized and depolarized reflected intensity are shown in red and green, respectively. A portion of the surface illuminated with incoherent light is visible on the back cover. The width of the name on the cover is equivalent to 10 μm.

Science is more than a body of knowledge, it's a way of thinking.
A way of skeptically interrogating the universe
with a fine understanding of human fallibility.

Carl Sagan

Contents

1 Introduction **1**

1.1 Scattering of light: an intuitive picture . . . 2
1.2 Two dimensional optics . . . 2
1.3 Random scattering . . . 3
1.4 Overview of this thesis . . . 4

2 Scattering of guided light by a hole in a dielectric slab **9**

2.1 2D optics in dielectric slabs . . . 10
2.2 Simulation method and scattering parameters . . . 11
2.3 2D scattering in the slab and 3D losses . . . 13
2.4 Relevance in modelling 2D random media . . . 19
2.5 Conclusions . . . 20
Appendix 2.A FDTD simulations . . . 21
Appendix 2.B Results for higher index contrast (GaAs) . . . 22

3 Angle resolved transmission through metal hole arrays **27**

3.1 Introduction . . . 28
3.2 Hole arrays and setup . . . 29
3.3 Theoretical model of spectral and angular transmission . . . 30
3.4 Experimental results . . . 33
3.5 Discussion . . . 37
3.6 Conclusions . . . 39

4 Scattering media characterization with phase-only wavefront modulation **43**

4.1 Complex scattering media . . . 44
4.2 From diffusion theory to speckles fluctuations . . . 45
4.3 Experimental setup and samples . . . 47
4.4 Results . . . 51
4.5 Discussion . . . 54
4.6 Conclusions . . . 56

5 Light propagation in rough thin-film solar cells **61**
5.1 Introduction . . . 62
5.2 Thin-film Si solar cell . . . 64
5.3 Experimental Setup . . . 65
5.4 Polarization resolved reflection . . . 67
5.5 Angular reflection properties . . . 70
5.6 Light-transport measurement . . . 76
5.7 Guided modes in the layered structure . . . 82
5.8 Summary . . . 84
5.9 Concluding discussion . . . 86
5.10 Acknowledgments . . . 87
Appendix 5.A Depolarization for specular reflections . . . 88
Appendix 5.B Objective shift to reduce interfacial reflection . . . 90

Samenvatting **97**

Curriculum Vitæ **101**

List of publications **103**

Acknowledgements **105**