



Universiteit  
Leiden  
The Netherlands

## Photon detection at subwavelength scales

Wang, Q.

### Citation

Wang, Q. (2015, October 27). *Photon detection at subwavelength scales*. Retrieved from <https://hdl.handle.net/1887/35972>

Version: Not Applicable (or Unknown)

License: [Leiden University Non-exclusive license](#)

Downloaded from: <https://hdl.handle.net/1887/35972>

**Note:** To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/35972> holds various files of this Leiden University dissertation.

**Author:** Wang, Qiang

**Title:** Photon detection at subwavelength scales

**Issue Date:** 2015-10-27

# **Photon Detection at Subwavelength Scales**



# **Photon Detection at Subwavelength Scales**

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 27 oktober 2015  
klokke 11:15 uur

door

Qiang Wang

geboren te Dezhou (China)  
in 1985

Promotor:	Prof. dr. E. R. Eliel
Co-promotor:	Dr. M. J. A. de Dood
Promotiecommissie:	Prof. dr. A. Fiore (Technische Universiteit Eindhoven )
	Prof. dr. A. F. Koenderink (FOM-Instituut voor Atoom- en Molecuulfysica & Universiteit van Amsterdam)
	Prof. dr. M. Dogterom (Technische Universiteit Delft & Universiteit Leiden)
	Dr. J. J. A. Baselmans (Ruimteonderzoeksinstituut SRON & Technische Universiteit Delft)
	Prof. dr. E. J. J. Groenen
	Prof. dr. J. Aarts
	Prof. dr. M. P. van Exter

Casimir PhD series Delft-Leiden 2015-21  
ISBN 978-90-8593-229-1

The work described in this thesis is part of the research programme of the Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organization for Scientific Research (NWO).  
Cover design by Jieke Lei.

*To my family and Lu Xun*



# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Single photons and single-photon detection . . . . .	1
1.2	Superconducting single-photon detectors . . . . .	3
1.3	Quantum detector tomography . . . . .	5
1.4	Photon detection mechanism of SSPDs . . . . .	7
1.5	Subwavelength microscopy with nano SSPDs . . . . .	9
<b>2</b>	<b>How Noise Affects Quantum Detector Tomography</b>	<b>13</b>
2.1	Introduction . . . . .	13
2.2	Experiment . . . . .	16
2.3	Quantum detector tomography . . . . .	17
2.4	Overall noise and tomography results . . . . .	20
2.5	Uncertainty budget . . . . .	24
2.6	Conclusions . . . . .	32
<b>3</b>	<b>Position-Dependent Detection Efficiency of a Single NbN Nanowire SSPD</b>	<b>35</b>
3.1	Introduction . . . . .	35
3.2	Separation of fit parameters . . . . .	37
3.3	Polarization-dependent IDE . . . . .	38
3.4	Optical absorption . . . . .	40
3.5	Position-dependent LDE . . . . .	43
3.6	Conclusions . . . . .	47
3.7	Appendix I: Photon detection mechanism . . . . .	48
3.8	Appendix II: Fit to visibility . . . . .	52
<b>4</b>	<b>Optimal Design of NbN Superconducting Single-Photon Detectors</b>	<b>55</b>
4.1	Introduction . . . . .	55
4.2	Photon detection process in SSPDs . . . . .	57
4.3	Optical absorption and detector response . . . . .	59

4.4	Results . . . . .	63
4.5	Conclusions . . . . .	68
<b>5</b>	<b>An Absorption-Based Superconducting Nanodetector as a Near-Field Optical Probe</b>	<b>71</b>
5.1	Introduction . . . . .	71
5.2	Scattering and absorption . . . . .	72
5.3	Dipole and nanodetector interaction . . . . .	76
5.4	Influence on the emitter . . . . .	80
5.5	Conclusions . . . . .	84
<b>6</b>	<b>Near-Field Single-Photon Detection in a Scattering SNOM</b>	<b>85</b>
6.1	Introduction . . . . .	86
6.2	Absorption spectrum . . . . .	88
6.3	<i>E</i> -field enhancement by the bare tip . . . . .	89
6.4	Absorption of the nanowire with the tip . . . . .	91
6.5	Conclusions . . . . .	92
<b>7</b>	<b>Local Detection Efficiency of a NbN SSPD Explored by a Scattering SNOM</b>	<b>93</b>
7.1	Introduction . . . . .	93
7.2	Simulation configuration . . . . .	95
7.3	Enhanced electric field and absorption . . . . .	98
7.4	Local detection efficiency . . . . .	102
7.5	Detector response in an s-SNOM . . . . .	105
7.6	Conclusions . . . . .	109
<b>Bibliography</b>		<b>111</b>
<b>Summary</b>		<b>123</b>
<b>Samenvatting</b>		<b>127</b>
<b>List of publications</b>		<b>131</b>
<b>Curriculum vitae</b>		<b>133</b>
<b>Acknowledgement</b>		<b>135</b>