Efficient Terahertz-Range Beam Control Using Flat Optics

by

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## Contents

### Contents

Abstract ............................................. ix

Statement of Originality ............................. xi

Acknowledgments .................................... xiii

Conventions ........................................ xv

Publications ....................................... xvii

List of Figures .................................... xxi

List of Tables .................................... xxv

I Context ........................................ xxvii

**Chapter 1. Introduction** ........................ 1

1.1 Terahertz range ................................... 2

1.1.1 Terahertz gap .................................. 3

1.1.2 Applications of terahertz waves .......... 5

1.2 Motivation for efficient beam control ........ 9

1.3 Application concepts ............................. 11

1.3.1 Public data shower ............................ 13

1.3.2 Indoor communications ....................... 14

1.3.3 Defence and secure communications ...... 15

1.4 Outline of thesis ................................ 16

1.5 Summary of original contributions .......... 18
## Chapter 2. Theory

<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction</td>
</tr>
<tr>
<td>2.2 The Huygens-Fresnel principle of diffraction</td>
</tr>
<tr>
<td>2.2.1 Historical background of scalar diffraction theory</td>
</tr>
<tr>
<td>2.2.2 Mathematical formulation</td>
</tr>
<tr>
<td>2.2.3 Relevance to array theory</td>
</tr>
<tr>
<td>2.3 Wavefront engineering</td>
</tr>
<tr>
<td>2.3.1 Magnitude-based beam control</td>
</tr>
<tr>
<td>2.3.2 Phase-based beam control</td>
</tr>
<tr>
<td>2.4 Techniques</td>
</tr>
<tr>
<td>2.4.1 Path-length techniques</td>
</tr>
<tr>
<td>2.4.2 Phased arrays</td>
</tr>
<tr>
<td>2.4.3 Guided-wave techniques</td>
</tr>
<tr>
<td>2.4.4 Passive arrays</td>
</tr>
<tr>
<td>2.5 Passive resonators</td>
</tr>
<tr>
<td>2.5.1 Passive resonators in reflectarray design</td>
</tr>
<tr>
<td>2.6 Conclusion</td>
</tr>
</tbody>
</table>

## Chapter 3. Background

<table>
<thead>
<tr>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
</tr>
<tr>
<td>3.2 Amplitude-blocking for diffractive optics</td>
</tr>
<tr>
<td>3.3 Path-length optics</td>
</tr>
<tr>
<td>3.4 Phased arrays</td>
</tr>
<tr>
<td>3.5 Guided-wave and plasmonic techniques</td>
</tr>
<tr>
<td>3.6 Transmitarrays</td>
</tr>
<tr>
<td>3.7 Reflectarrays</td>
</tr>
<tr>
<td>3.7.1 Beam-shaping operation of 1 THz reflectarrays</td>
</tr>
<tr>
<td>3.7.2 Fabrication of metallic resonators for 1 THz reflectarrays</td>
</tr>
<tr>
<td>3.7.3 Isotropic deflection reflectarray</td>
</tr>
<tr>
<td>3.7.4 Polarising beam splitter</td>
</tr>
<tr>
<td>3.7.5 Polariser-based reflectarray</td>
</tr>
<tr>
<td>3.8 Challenges and opportunities</td>
</tr>
</tbody>
</table>
II Metallic resonators 85

Chapter 4. Doped polymer for efficient metallic resonators 87
4.1 Introduction .................................................... 88
4.2 Fabrication ..................................................... 88
4.3 Experiment ..................................................... 90
4.4 Results ......................................................... 91
4.4.1 Effective medium theory ................................. 92
4.5 Resonator efficiency ......................................... 94
4.6 Conclusion ..................................................... 95

Chapter 5. Polarisation-converting transmitarray for flat lens 97
5.1 Introduction ..................................................... 98
5.2 Design .......................................................... 98
5.3 Fabrication ..................................................... 101
5.4 Characterisation of focal spot .............................. 103
5.5 Efficiency ....................................................... 107
5.6 Conclusion ..................................................... 107

III Silicon-on-gold microstructures 109

Chapter 6. Fabrication and characterisation of dielectric resonator antennas 111
6.1 Introduction ..................................................... 112
6.2 Terahertz dielectric resonator antenna design .......... 114
6.3 Comparison with metallic resonators ..................... 117
6.4 Fabrication ..................................................... 119
6.5 Experiment ..................................................... 121
6.6 Results ......................................................... 122
6.7 Conclusion ..................................................... 124

Chapter 7. Dielectric-resonator-based reflectarray 125
7.1 Introduction ..................................................... 126
## Contents

7.2 Unit-cell design ................................................................. 126  
7.3 Array-level design ............................................................. 128  
7.4 Fabrication of terahertz reflectarray ........................................ 132  
7.5 Characterisation of focal spot ................................................. 133  
  7.5.1 Broadband performance ................................................. 136  
7.6 Efficiency .................................................................................. 137  
7.7 Antenna gain ............................................................................. 138  
7.8 Conclusion .................................................................................. 139  

IV Non-resonant techniques ................................................................. 141  

Chapter 8. Characterisation of 3D-printed metal for terahertz optics  
8.1 Introduction ................................................................................. 144  
8.2 Characteristics of 3D-printed metal .............................................. 146  
  8.2.1 Fabrication of 3D-printed metal .............................................. 146  
  8.2.2 Terahertz properties of 3D-printed metal ............................... 149  
  8.2.3 Modelling of reflection characteristics .................................... 150  
8.3 3D-printed zone plate ............................................................... 154  
  8.3.1 Required phase distribution .................................................. 154  
  8.3.2 Characterisation and modelling of zone plate ......................... 156  
8.4 Conclusion .................................................................................. 159  

Chapter 9. Hole lattice zone plate ................................................... 161  
9.1 Introduction ................................................................................ 162  
9.2 Unit cell .................................................................................... 162  
9.3 Array-level design ...................................................................... 165  
9.4 Fabrication ................................................................................. 168  
9.5 Experimentation ......................................................................... 169  
9.6 Conclusion .................................................................................. 170  

V Conclusion ................................................................................. 171  

Chapter 10. Thesis summary ........................................................... 173  

---

Page vi
# Contents

10.1 Part I—Context .................................................. 174
  10.1.1 Chapter 1—Introduction ............................... 174
  10.1.2 Chapter 2—Theory ...................................... 175
  10.1.3 Chapter 3—Background ............................... 175

10.2 Part II—Metallic resonators .............................. 175
  10.2.1 Chapter 4—Doped polymer for efficient metallic resonators .......................... 176
  10.2.2 Chapter 5—Polarisation-converting transmitarray for flat lens .................. 176

10.3 Part III—Silicon-on-gold microstructures .............. 177
  10.3.1 Chapter 6—Fabrication and characterisation of dielectric resonator antennas ........................................ 177
  10.3.2 Chapter 7—Dielectric-resonator-based reflectarray ..................................... 178

10.4 Part IV—Non-resonant techniques ....................... 178
  10.4.1 Chapter 8—Characterisation of 3D-printed metal for terahertz optics ............. 178
  10.4.2 Chapter 9—Hole lattice zone plate .................................................. 179

10.5 Executive summary of original contributions .......... 180

10.6 Outlook ...................................................... 180

10.7 Concluding remarks ......................................... 182

Appendix A. Miscellaneous relations ........................ 183
  A.1 Cartesian and polar axes .................................. 184
  A.2 Fundamentals of wave propagation ..................... 185
  A.3 Properties of homogeneous, isotropic media ......... 186
  A.4 Drude model ................................................. 187

Appendix B. Full-wave simulations .......................... 189
  B.1 General concept ............................................. 190
  B.2 Boundary conditions ...................................... 191
  B.3 Port de-embedding ......................................... 192

Appendix C. THz-TDS systems ................................. 195
  C.1 Terahertz time-domain spectroscopy ................. 196
  C.2 Automated scanning ....................................... 198
<table>
<thead>
<tr>
<th>Contents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliography</td>
<td>203</td>
</tr>
<tr>
<td>Glossary</td>
<td>223</td>
</tr>
<tr>
<td>Index</td>
<td>237</td>
</tr>
<tr>
<td>Biography</td>
<td>241</td>
</tr>
</tbody>
</table>
The terahertz range, which spans 0.1 to 10 THz of the electromagnetic spectrum, has significant potential for numerous diverse uses including high-volume short-range communications, non-invasive and non-destructive sub-dermal medical imaging, and safe imaging of personnel and postal items for security applications. These capabilities are identified due to the unique properties of terahertz radiation; terahertz waves are of high carrier frequency relative to conventional wireless communications, are able to transmit through dry, non-polar substances, and yet are non-ionising. However, owing to factors including a lack of available power and significant atmospheric attenuation, it is challenging to maintain sufficient signal power over a realistic propagation distance for terahertz waves. For this reason, the terahertz range is presently lacking in practical applications, and hence it occupies an under-utilised portion of the electromagnetic spectrum. As unused spectrum is a valuable resource, the development of technologies to exploit the terahertz range is a highly desirable goal.

Beam-control techniques—the capacity to shape and steer electromagnetic radiation—can prevent radiated power from being lost to undesired directions. Thus, techniques of this variety have the capacity to address the aforementioned obstacles to the realisation of practical terahertz technologies. This thesis is therefore centred around the development of terahertz beam-control devices that satisfy two criteria. Firstly, the beam manipulation operation must be highly efficient, as much of the motivation of this work is to mitigate the constraints upon power. Secondly, planar devices are preferable, as this is a requirement for compact systems. With these restrictions in mind, various techniques are explored for their viability in future applications of terahertz technology, including various forms of metallic and dielectric resonators, 3D printing, and composite materials with effective properties. The advantages and drawbacks of each approach are evaluated.
Statement of Originality

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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15/05/2017

Signed

Date
Acknowledgments

To my wonderful wife, Véra Daye, I am extremely grateful for your support. Without it, this would not have been possible.

I would like to thank my parents, Michael Headland and Meera Verma, for supporting and educating me throughout my formative years, and well beyond. That they both hold higher degrees has no doubt inspired my pursuit of a PhD. My older brother, Matthew Headland, also played a large role in fostering my interest in engineering in particular, as well as shaping my values and world-view.

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Lastly, I would like to extend my gratitude to The University of Adelaide for providing The George Fraser Scholarship, which has supported me throughout this endeavour.
Conventions

Typesetting

This thesis is typeset using the \LaTeX\textsuperscript{2e} software. Vim build 7.4 was used as an effective interface to \LaTeX{}.

Referencing

Harvard style is employed for referencing and citation in this thesis.

System of units

The units comply with the international system of units recommended in an Australian standard: AS ISO 1000-1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

Spelling

Australian English spelling is adopted, as defined by the Macquarie English Dictionary (Delbridge 2001).

Terminology

Where applicable, recent terminology is employed for this thesis, in accordance with that which is seen to be used most frequently in the interested academic community. For instance, the frequency range in which these investigations are undertaken could validly be classified as either the sub-mm or the terahertz range, but most recent work at similar frequencies employs the latter terminology, and hence this is adopted for this thesis.
Publications

Journal publications


*These authors contributed equally to this work.

DH performed unit-cell modelling, array-level design and modelling, experimentation, and lead the writing and publication of the manuscript.


DH lead the writing of the manuscript of this review article.


DH performed design and modelling of the devices in this work, conducted all experiments and analysis, and lead the writing of the article.


DH performed modelling of the device presented in this work, conducted all experiments and analysis, and lead the writing of the article.


DH performed modelling of the device presented in this work, conducted all experiments and analysis, and lead the writing of the article.


DH conducted all experiments and analysis, and lead the writing of the article.
Publications


DH performed modelling and analysis.


DH conducted experiments.


DH conducted experiments.

Conference publications


List of Figures

For images taken from published work, the appropriate reference is included in each case. In cases in which no such reference is provided, the illustration is by the author.

1.1 Electromagnetic spectrum ................................................. 2
1.2 Overview of sources ..................................................... 3
1.3 Atmospheric absorption .................................................. 4
1.4 Terahertz applications .................................................. 6
1.5 Cisco forecast .............................................................. 7
1.6 Dish antenna ............................................................... 10
1.7 FAST radio telescope .................................................... 10
1.8 Public terahertz access point ........................................... 12
1.9 Terahertz indoor communications ..................................... 14
1.10 Terahertz VLPI communications ...................................... 15

2.1 Phenomenology of Huygens-Fresnel principle ........................ 23
2.2 Huygens-Fresnel formulation .......................................... 24
2.3 Array theory’s equivalence to scalar diffraction theory ............. 26
2.4 Beam operations .......................................................... 28
2.5 Magnitude-based beamforming ........................................ 30
2.6 Phase-based beamforming .............................................. 32
2.7 Effects of phase quantisation on beamforming ....................... 35
2.8 Path-length optics ......................................................... 37
2.9 Phased array .............................................................. 41
2.10 Guided-wave beam-control techniques ............................... 44
2.11 Reflectarrays and transmittarrays ..................................... 47
2.12 Patch resonator theory .................................................. 50
2.13 Reflectarray design ..................................................... 53
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Optically-controlled magnitude-blocking mask</td>
<td>58</td>
</tr>
<tr>
<td>3.2</td>
<td>Stone terahertz lens</td>
<td>59</td>
</tr>
<tr>
<td>3.3</td>
<td>All-metal artificial dielectric lens</td>
<td>61</td>
</tr>
<tr>
<td>3.4</td>
<td>Variable-focus liquid lens</td>
<td>62</td>
</tr>
<tr>
<td>3.5</td>
<td>Electronically-controlled switched-beam device</td>
<td>63</td>
</tr>
<tr>
<td>3.6</td>
<td>Pump beam-tilt terahertz beam scanning</td>
<td>64</td>
</tr>
<tr>
<td>3.7</td>
<td>Terahertz CMOS phased array</td>
<td>65</td>
</tr>
<tr>
<td>3.8</td>
<td>Parallel-plate leaky-wave antenna</td>
<td>67</td>
</tr>
<tr>
<td>3.9</td>
<td>Plasmonic Bessel beamformer</td>
<td>68</td>
</tr>
<tr>
<td>3.10</td>
<td>Complementary “V”-shaped resonators</td>
<td>70</td>
</tr>
<tr>
<td>3.11</td>
<td>Reflectarray at 650 GHz</td>
<td>71</td>
</tr>
<tr>
<td>3.12</td>
<td>Realisation of terahertz metallic resonators</td>
<td>74</td>
</tr>
<tr>
<td>3.13</td>
<td>Isotropic deflection reflectarray</td>
<td>75</td>
</tr>
<tr>
<td>3.14</td>
<td>Polarising beam splitter reflectarray</td>
<td>78</td>
</tr>
<tr>
<td>3.15</td>
<td>Stripline polariser-based reflectarray</td>
<td>81</td>
</tr>
<tr>
<td>4.1</td>
<td>Doped PDMS samples</td>
<td>89</td>
</tr>
<tr>
<td>4.2</td>
<td>Properties of doped PDMS</td>
<td>91</td>
</tr>
<tr>
<td>4.3</td>
<td>Effective medium theory</td>
<td>93</td>
</tr>
<tr>
<td>4.4</td>
<td>Doped PDMS-based resonator</td>
<td>94</td>
</tr>
<tr>
<td>5.1</td>
<td>Unit cell of transmitarray</td>
<td>99</td>
</tr>
<tr>
<td>5.2</td>
<td>Array-level design of transmitarray</td>
<td>101</td>
</tr>
<tr>
<td>5.3</td>
<td>Fabricated transmitarray</td>
<td>102</td>
</tr>
<tr>
<td>5.4</td>
<td>Incident beam</td>
<td>104</td>
</tr>
<tr>
<td>5.5</td>
<td>Focal spot of transmitarray</td>
<td>105</td>
</tr>
<tr>
<td>5.6</td>
<td>Efficiency of tri-layer transmitarray</td>
<td>106</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>6.1</td>
<td>Illustration of dielectric resonator antennas</td>
<td>113</td>
</tr>
<tr>
<td>6.2</td>
<td>Long’s resonant cylindrical dielectric cavity antenna</td>
<td>114</td>
</tr>
<tr>
<td>6.3</td>
<td>DRA unit cell</td>
<td>115</td>
</tr>
<tr>
<td>6.4</td>
<td>DRA comparison with metallic resonator</td>
<td>118</td>
</tr>
<tr>
<td>6.5</td>
<td>Fabrication of terahertz DRAs</td>
<td>120</td>
</tr>
<tr>
<td>6.6</td>
<td>Characterisation of DRA-based AMC</td>
<td>122</td>
</tr>
<tr>
<td>6.7</td>
<td>Measured response of AMC sample</td>
<td>123</td>
</tr>
<tr>
<td>7.1</td>
<td>Parametric analysis of DRA</td>
<td>127</td>
</tr>
<tr>
<td>7.2</td>
<td>Beam-shaping operation of DRA-based reflectarray</td>
<td>129</td>
</tr>
<tr>
<td>7.3</td>
<td>Accounting for divergent incident beam</td>
<td>130</td>
</tr>
<tr>
<td>7.4</td>
<td>Reflectarray layout</td>
<td>131</td>
</tr>
<tr>
<td>7.5</td>
<td>Fabricated terahertz reflectarray design</td>
<td>132</td>
</tr>
<tr>
<td>7.6</td>
<td>Characterisation of terahertz reflectarray</td>
<td>133</td>
</tr>
<tr>
<td>7.7</td>
<td>Measured focal spot of DRA-based reflectarray</td>
<td>135</td>
</tr>
<tr>
<td>7.8</td>
<td>Measured focal spots at other frequencies</td>
<td>136</td>
</tr>
<tr>
<td>7.9</td>
<td>Efficiency of DRA-based reflectarray</td>
<td>137</td>
</tr>
<tr>
<td>7.10</td>
<td>Antenna gain of DRA-based reflectarray</td>
<td>138</td>
</tr>
<tr>
<td>8.1</td>
<td>3D-printed featureless disk</td>
<td>147</td>
</tr>
<tr>
<td>8.2</td>
<td>EDX characterisation of titanium alloy surface</td>
<td>148</td>
</tr>
<tr>
<td>8.3</td>
<td>Reflective efficiency of 3D-printed metal</td>
<td>149</td>
</tr>
<tr>
<td>8.4</td>
<td>Transmission-line model of oxide layer</td>
<td>151</td>
</tr>
<tr>
<td>8.5</td>
<td>Results of modelling procedure</td>
<td>153</td>
</tr>
<tr>
<td>8.6</td>
<td>3D-printed zone plate</td>
<td>155</td>
</tr>
<tr>
<td>8.7</td>
<td>Focal spot at operating frequency</td>
<td>156</td>
</tr>
<tr>
<td>8.8</td>
<td>Measured focal spots at other frequencies</td>
<td>158</td>
</tr>
<tr>
<td>9.1</td>
<td>Hole lattice unit cell</td>
<td>163</td>
</tr>
</tbody>
</table>
List of Figures

9.2 Transmission-line modelling of hole lattice .......................... 163
9.3 Hole lattice zone plate .................................................. 166
9.4 Hole lattice zone plate simulation .................................. 167
9.5 Non-ideal geometry with DRIE process ............................. 168
9.6 Hole lattice zone plate sample ...................................... 169
9.7 Focal spot of hole lattice zone plate ................................. 170

A.1 Illustration of axes ....................................................... 184

B.1 Simulation and meshing ................................................. 190
B.2 Unit-cell analysis ....................................................... 191
B.3 Port de-embedding ..................................................... 192

C.1 Photoconductive antenna ............................................... 196
C.2 THz-TDS system ......................................................... 197
C.3 Fibre-coupled THz-TDS system .................................. 198
C.4 Goniometer ............................................................... 199
C.5 Raster scanner .......................................................... 199
C.6 Automated-scan duplex .............................................. 200
C.7 Example of raster-scanning setup .................................. 201
## List of Tables

1.1 Thesis structure .................................................. 17

2.1 Comparison of beam-control techniques ............................. 47

3.1 Optimised birefringent patch dimensions ............................. 80

4.1 Thickness of doped PDMS samples .................................. 90

4.2 Properties of doped PDMS ........................................... 92