



Universiteit
Leiden
The Netherlands

Silicon pore optics for high-energy optical systems

Girou, D.A.

Citation

Girou, D. A. (2022, June 14). *Silicon pore optics for high-energy optical systems. Casimir PhD Series*. Retrieved from
<https://hdl.handle.net/1887/3420652>

Version: Publisher's Version

[Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

License: <https://hdl.handle.net/1887/3420652>

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

SILICON PORE OPTICS FOR HIGH-ENERGY OPTICAL SYSTEMS

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op dinsdag 14 juni 2022
klokke 16.15 uur

door

David Alain Girou

geboren te Saint-Michel d'Entraygues (France)
in 1989

Promotor: Prof. dr. M.W. Beijersbergen
Copromotor: Prof. dr. M.A.G.J. Orrit

Promotiecommissie: Dr. M. Baudaz (ESA-ESTEC, Noordwijk, The Netherlands)
Dr. D.D.M. Ferreira (DTU, Kgs. Lyngby, Denmark)
Prof. dr. J. Aarts
Prof. dr. E.R. Eliel
Prof. dr. ir. T.H. Oosterkamp



Universiteit
Leiden
The Netherlands



Casimir PhD series, Delft-Leiden 2022-14

ISBN 978-90-8593-525-4

An electronic version of this thesis can be found at:

<https://openaccess.leidenuniv.nl>

The present work is financially supported by cosine Research B.V.:
<https://cosine.nl/>

The front and back cover show stacks of thirty-five silicon plates directly bonded on top of each other, forming a pore-like structure. High-energy photons enter these pores at low grazing angles, where they are reflected on the reflective side of each plate, and exit the stack at the opposite end. Images are courtesy of cosine Research B.V.

CONTENTS

| | | |
|----------|--|-----------|
| 1 | Introduction | 1 |
| 1.1 | Silicon Pore Optics (SPO) concept | 2 |
| 1.2 | The astrophysics case | 3 |
| 1.3 | Thesis outline | 6 |
| | References | 8 |
| 2 | Silicon Pore Optics realization | 11 |
| 2.1 | Introduction | 12 |
| 2.2 | Production of SPO mirror plates | 12 |
| 2.3 | Development of coatings | 13 |
| 2.4 | Cleaning and activation | 16 |
| 2.5 | Stacking of mirror plates | 16 |
| 2.6 | Stacking robots | 17 |
| 2.7 | Mirror modules | 19 |
| 2.8 | Ruggedisation | 20 |
| 2.9 | X-ray characterization | 24 |
| 2.9.1 | SPO stack characterization | 24 |
| 2.9.2 | X-ray optical unit and mirror module characterization | 27 |
| 2.10 | Conclusions and outlook | 28 |
| | References | 29 |
| 3 | Plasma etching of silicon pore optics before coating deposition | 33 |
| 3.1 | Introduction | 34 |
| 3.2 | Evaluating the impact of plasma etching on surface roughness | 34 |
| 3.3 | Investigating coating stability on non-patterned SPO plates | 36 |
| 3.4 | Validating coating stability on patterned SPO plates | 37 |
| 3.5 | Conclusions and discussion | 40 |
| | References | 43 |
| 4 | Laue lens for radiation therapy with hard X-ray photons | 45 |
| 4.1 | Introduction | 46 |
| 4.2 | Silicon Laue components | 47 |
| 4.3 | Lens design method | 50 |
| 4.3.1 | System parameters | 50 |
| 4.3.2 | System constraints | 51 |
| 4.3.3 | Dimensions and shape of the focus | 52 |
| 4.3.4 | Energy versus convergence angle | 53 |
| 4.3.5 | Diffractiion orders | 53 |
| 4.3.6 | SiLC reflectivity and spectrum | 54 |
| 4.3.7 | SiLC Simulation Code (SSC) | 54 |

| | |
|--|-----------|
| 4.4 Optimized lens design | 55 |
| 4.4.1 Decisions on the system parameters | 55 |
| 4.4.2 Optimization process | 56 |
| 4.4.3 Performance | 57 |
| 4.5 Conclusions and future work | 60 |
| References | 62 |
| 5 Conclusions and outlook | 67 |
| References | 71 |
| Summary | 73 |
| Samenvatting | 75 |
| List of Publications | 77 |
| Curriculum Vitæ | 79 |
| Acknowledgements | 81 |