



Universiteit
Leiden
The Netherlands

On periodically driven quantum systems

Tarasinski, B.M.

Citation

Tarasinski, B. M. (2016, September 20). *On periodically driven quantum systems*. Casimir PhD Series. Retrieved from <https://hdl.handle.net/1887/43150>

Version: Not Applicable (or Unknown)

License:

Downloaded from: <https://hdl.handle.net/1887/43150>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/43150> holds various files of this Leiden University dissertation.

Author: Tarasinski, B.M.

Title: On periodically driven quantum systems

Issue Date: 2016-09-20

On periodically driven quantum systems

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 20 SEPTEMBER 2016
KLOKKE 15.00 UUR

DOOR

Brian Michael Tarasinski

GEBOREN TE BERLIJN (DUITSLAND) IN 1988

Promotor: Prof. dr C. W. J. Beenakker
Co-promotor: Dr J. K. Asbóth (Hungarian Academy of Sciences)

Promotiecommissie: Prof. dr P. W. Brouwer (FU Berlin, Duitsland)
Dr M. T. Wimmer (TU Delft)
Prof. dr E. R. Eliel
Prof. dr V. Vitelli

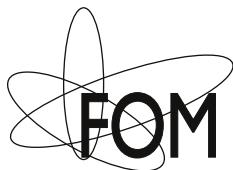
Casimir PhD Series Delft-Leiden 2016-24

ISBN 978-90-8593-268-0

An electronic version of this thesis can be found
at <https://openaccess.leidenuniv.nl>

Dit werk maakt deel uit van het onderzoekprogramma van de Stichting voor Fundamenteel Onderzoek der Materie (FOM), die deel uit maakt van de Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).

This work is part of the research programme of the Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organisation for Scientific Research (NWO).



Cover: Geometric interpretation of the two winding numbers of a non-trivial time evolution operator of a driven Su-Schrieffer-Heeger model (cf. Chapter 3).

Contents

1	Introduction	1
1.1	Preface	1
1.2	Floquet formalism	2
1.3	Random walks and quantum walks	4
1.4	Generalizations and related concepts	10
1.5	Band topology	11
1.6	Bulk-boundary correspondence	16
1.7	Quantum algorithms	20
1.8	This thesis	24
2	Scattering theory of topological phases in discrete-time quantum walks	29
2.1	Introduction	29
2.2	Discrete-time quantum walks	30
2.3	Scattering in quantum walks	33
2.4	Symmetries of quantum walks	35
2.5	Topological invariants of gapped quantum walks	38
2.5.1	Topological invariants	38
2.5.2	Boundary states	40
2.6	Topological invariant of unbalanced quantum walks	41
2.7	Examples	41
2.7.1	Split-step walk	42
2.7.2	Four-step walk	43
2.7.3	Symmetry class DIII	44
2.7.4	Disorder	46
2.8	Experiment	46
2.9	Conclusion	49
2.A	Numerical implementation	50
2.B	Symmetries of the reflection matrix	52
2.B.1	Derivation of the symmetry relations	52
2.B.2	Basis transformations	53
2.C	Protected boundary states	54

3 Chiral symmetry and bulk-boundary correspondence in periodically driven one-dimensional systems	57
3.1 Introduction	57
3.2 Floquet formalism	58
3.2.1 Chiral symmetry of periodically driven systems.	59
3.2.2 Topological invariants due to chiral symmetry	60
3.2.3 Topological invariants of the driven system	61
3.2.4 Geometrical picture	63
3.2.5 Tuning the invariants	63
3.3 Example: the periodically driven SSH model	64
3.4 Outlook	66
3.A Derivation of Eqs. (3.10)	67
3.B Geometrical picture	68
3.C The $\mathbb{Z}_2 \times \mathbb{Z}_2$ invariant	69
3.D Mapping to the discrete time quantum walk	70
4 Attractor-repeller pair of topological zero-modes in a non-linear quantum walk	73
4.1 Introduction	73
4.2 Formulation of the linear quantum walk	74
4.3 Introduction of a nonlinearity	75
4.4 Collapse onto a zero-mode	75
4.5 Initial states without particle-hole symmetry	78
4.6 Discussion	79
5 Quench dynamics of fermion-parity switches in a Josephson junction	83
5.1 Introduction	83
5.2 Microscopic model	85
5.3 Scattering formulation	86
5.4 Linear sweep through the fermion-parity switch	89
5.5 Transferred charge	92
5.6 Conclusion	94
5.A Model Hamiltonian	95
5.B Details of the calculation of the Green's function	95
5.B.1 Evaluation of the determinant	95
5.B.2 Normalization of the excited state	97
5.C Scattering formula for the charge transfer in the adiabatic regime	98

Contents

5.D Multi-channel probe	101
5.D.1 Coupling matrix	101
5.D.2 Scattering matrix	102
5.D.3 Transferred charge	103
5.D.4 Relation of the reduction factor to the Andreev conductance	104
6 Spin-orbit interaction in InSb nanowires	105
6.1 Introduction	105
6.2 Magnetoconductance measurements in 3D nanowires . . .	106
6.3 Evaluation of weak (anti-)localization in the quasiclassical theory	109
6.3.1 The quasiclassical theory	109
6.3.2 Monte Carlo evaluation	111
6.4 Experiments	115
6.4.1 Device fabrication	120
6.4.2 Estimation of mobility, mean free path and $\frac{l_e}{W}$. . .	121
6.4.3 Nanowire width	123
6.4.4 Estimation of the number of occupied subbands . .	123
6.4.5 Topological gap as a function of mobility and spin-orbit strength	123
6.5 Supplementary experimental data	126
Bibliography	131
Samenvatting	149
Summary	153
Zusammenfassung	155
Curriculum Vitæ	159
List of publications	161

