



Universiteit
Leiden
The Netherlands

Dislocations in stripes and lattice Dirac fermions

Mesaroš, A.

Citation

Mesaroš, A. (2010, October 6). *Dislocations in stripes and lattice Dirac fermions*. Casimir PhD Series. Retrieved from <https://hdl.handle.net/1887/16013>

Version: Corrected Publisher's Version

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

License: <https://hdl.handle.net/1887/16013>

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

Dislocations in Stripes and Lattice Dirac Fermions

Andrej Mesaroš

Dislocations in Stripes and Lattice Dirac Fermions

P R O E F S C H R I F T

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR AAN DE UNIVERSITEIT LEIDEN, OP GEZAG VAN
RECTOR MAGNIFICUS PROF. MR. P. F. VAN DER HEIJDEN,
VOLGENS BESLUIT VAN HET COLLEGE VOOR PROMOTIES
TE VERDEDIGEN OP WOENSDAG 6 OKTOBER 2010
TE KLOKKE 13.45 UUR

DOOR

Andrej Mesarоš

GEBOREN TE SENTA, SERVIË,
IN 1982

Promotiecommissie:

Promotor: Prof. dr. J. Zaanen

Overige leden: Prof. dr. J. M. van Ruitenbeek (Universiteit Leiden)

Prof. dr. C. Morais Smith (Universiteit Utrecht)

dr. C. F. J. Flipse (Technische Universiteit Eindhoven)

Prof. dr. C. W. J. Beenakker (Universiteit Leiden)

Prof. dr. A. Achúcarro (Universiteit Leiden)

dr. V. Vitelli (Universiteit Leiden)

Casimir PhD Series, Delft-Leiden, 2010-20

ISBN 978-90-8593-086-0

The research described in this thesis was supported by the Netherlands Organisation for Scientific Research (NWO) through a Spinoza Prize grant.

Mojoj porodici

CONTENTS

1	Introduction	1
1.1	Effective theories	2
1.1.1	Gravity in elasticity	4
1.2	Topological defects	8
1.2.1	Vortex	11
1.2.2	Crystal dislocations	12
1.3	Physical systems studied in this thesis	15
1.3.1	Graphene	16
1.3.2	Topological insulators	17
1.3.3	The high- T_c cuprates	19
1.4	This thesis	22
2	Parallel Transport of Electrons in Graphene Parallels Gravity	27
2.1	Introduction	27
2.2	Electron Berry phase and the Burgers vector of dislocations	28
2.3	Torsion in elasticity and its coupling to fermions	31
2.4	Curvature and disclinations	34
2.5	General torsion couplings	35
2.6	Conclusions	36
3	Valley Conserving Decoherence in Graphene and Dislocations	39
3.1	Introduction	39
3.2	General properties of a dislocated AB ring	42
3.3	Dislocated Aharonov–Bohm ring at zero temperature	43
3.4	Modeling the decoherence at finite temperature	46
3.4.1	The Feynman path approach	49
3.4.2	The valley dependent Büttiker dephasing probe	52
3.5	Conclusions	56
3.6	Appendix	57

4 Electronic States of Graphene Grain Boundaries	61
4.1 Introduction	61
4.2 Dislocations in graphene as base of grain boundary models	62
4.2.1 Graphene dislocation structure in tight-binding	62
4.2.2 Continuum model of dislocations	65
4.2.3 Continuum model of dislocation arrays	67
4.3 Tight-binding model of relaxed amorphous grain boundaries	70
4.3.1 The method	70
4.3.2 Summary of results	71
4.4 Discussion and conclusions	72
5 Dislocations and the Identity of Majorana Fermions	77
5.1 Introduction	77
5.2 Dislocations and Majorana states: conductance symmetries	78
5.3 The proposed interferometer setup	79
5.3.1 Scattering formalism	80
5.3.2 Detecting Majoranas with dislocations	83
5.4 Conclusions	86
6 Stripes and Phonon Anomalies in Cuprates	87
6.1 Introduction	87
6.2 Elastic model of the CuO layer in the stripe phase	89
6.3 “Fingerprints” of 1D stripe polarization in the phonon anomaly	91
6.3.1 Doping dependence of the phonon anomaly	92
6.3.2 Temperature and wave-vector dependence of the phonon anomaly	95
6.4 Conclusions	96
7 Coupled Nematic and Smectic Order in Underdoped Cuprates	97
7.1 General order parameters of the Z-map	98
7.1.1 Symmetry properties	99
7.1.2 The nematic and smectic (stripe) orders	99
7.1.3 Stripe dislocations	101
7.2 GL theory for the interplay of nematic and smectic	103
7.3 Phenomenological GL parameters from cross-correlations	105
7.4 Nematic fluctuations caused by stripe dislocations	106
7.5 Discussion and concluding remarks	110
8 Conclusions	113
Bibliography	117
Samenvatting	131
Summary	133

Publications	139
Curriculum Vitae	141
Acknowledgements	143