



Universiteit
Leiden
The Netherlands

Fermions and bosons : excitons in strongly correlated materials

Rademaker, L.

Citation

Rademaker, L. (2013, December 11). *Fermions and bosons : excitons in strongly correlated materials*. *Casimir PhD Series*. Retrieved from <https://hdl.handle.net/1887/22839>

Version: Not Applicable (or Unknown)

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

Downloaded from: <https://hdl.handle.net/1887/22839>

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

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/22839> holds various files of this Leiden University dissertation.

Author: Rademaker, Louk

Title: Fermions and bosons : excitons in strongly correlated materials

Issue Date: 2013-12-11

Fermions and Bosons

Excitons in strongly correlated materials

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. C. J. J. M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op 11 december 2013
te klokke 15:00 uur

door

Louk Rademaker
geboren te Vleuten-De Meern (Utrecht), Nederland in 1986

Promotiecommissie

- Promotoren: prof. dr. J. Zaanen (Universiteit Leiden)
prof. dr. ir. H. Hilgenkamp (Universiteit Twente and Universiteit Leiden)
- Overige leden: prof. dr. J. van den Brink (IFW Dresden)
prof. dr. A. J. Millis (Columbia University)
prof. dr. H. T. C. Stoof (Universiteit Utrecht)
prof. dr. E. R. Eliel (Universiteit Leiden)
prof. dr. C. W. J. Beenakker (Universiteit Leiden)

The cover shows the painting *Contra-compositie van dissonanten XVI* by Theo van Doesburg, Collectie Gemeentemuseum Den Haag. Reprinted with permission. Van Doesburg founded the famous 'De Stijl' art movement in Leiden. This painting is created in 1925, the year of birth for fermions: Pauli presented his exclusion principle and Uhlenbeck and Goudsmit discovered the electron spin.

The research presented in this thesis was supported by the Netherlands Organization for Scientific Research (NWO) through a Vici grant.

Contents

1	<i>Introduction: Quantum Matters</i>	7
2	<i>Phenomenology of exciton bilayers</i>	13
	2.1 <i>Bilayer excitons and condensation</i>	13
	2.2 <i>Ginzburg-Landau theory and flux quantisation</i>	16
3	<i>Fermionic models of correlated bilayers</i>	23
	3.1 <i>The Hubbard model and its problems</i>	23
	3.2 <i>The BCS theory of electron-hole pairing</i>	26
	3.3 <i>Numerical approach: Determinant Quantum Monte Carlo</i>	29
4	<i>Exciton-spin dynamics in the Mott insulating state</i>	47
	4.1 <i>Strong coupling limit and the $t - J$ model</i>	47
	4.2 <i>Frustration of a single exciton in an antiferromagnet</i>	57
5	<i>Exciton condensation in the $t - J$ model</i>	75
	5.1 <i>Enhanced spin itineracy in the exciton condensate</i>	76
	5.2 <i>Finite exciton densities: the full phase diagram</i>	82
6	<i>Influence of long-range interactions</i>	117
	6.1 <i>Complex ordering phenomena</i>	117
	6.2 <i>Generalized Wigner crystals, domain walls and stripes</i>	121
7	<i>Conclusions and outlook</i>	135
	7.1 <i>Propositions on quantum matter</i>	138
	<i>Bibliography</i>	145
	<i>Samenvatting</i>	163
	<i>Curriculum Vitae</i>	171

Publications 173

Acknowledgements 175