

Mesoscopic Bose-Einstein condensates in optical lattices

Peter Schlagheck



Humboldt Kolleg

*Controlling quantum matter:
From ultracold atoms to solids*

Ultracold interacting bosonic atoms in optical lattices

M. Lewenstein *et al.*, *Adv. Phys.* 56, 243 (2007)

I. Bloch, J. Dalibard, and W. Zwerger, *Rev. Mod. Phys.* 80, 885 (2008)

→ nonlinear dynamics and many-body physics ...

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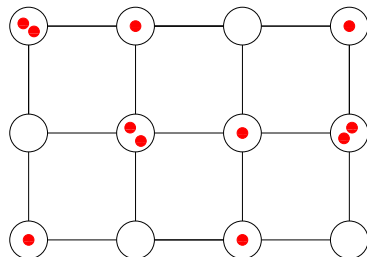
I. Bloch, J. Dalibard, and W. Zwerger, *Rev. Mod. Phys.* 80, 885 (2008)

microscopic occupancies (3D lattices) \longrightarrow many-body regime

\longrightarrow few atoms per lattice site

\longrightarrow quantum simulation . . .

Munich, Harvard, Zurich. . .



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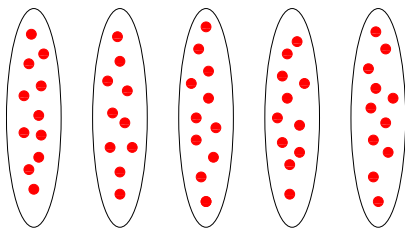
I. Bloch, J. Dalibard, and W. Zwerger, *Rev. Mod. Phys.* 80, 885 (2008)

macroscopic occupancies (1D lattices)

Heidelberg, Pisa, Florence, Toulouse ...

Nonlinear BEC dynamics:

- gap solitons,
- Josephson tunneling,
- localisation, ...

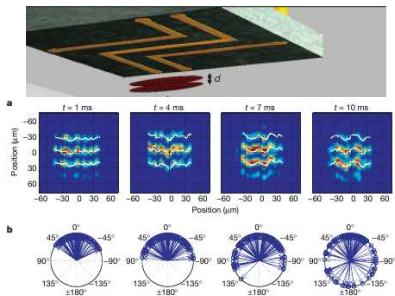


→ rich physics beyond mean-field ...

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Dephasing in splitted 1D
(quasi) condensates:

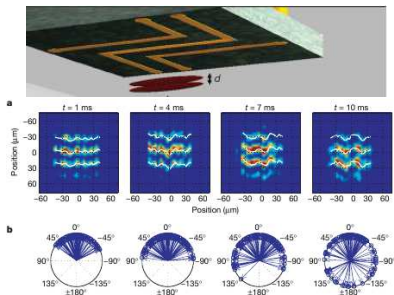
S. Hofferberth *et al.*, Nature 449, 324
(2007)



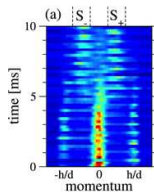
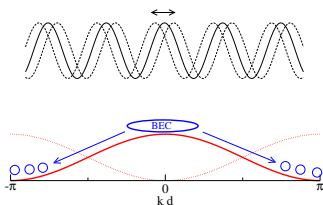
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S. Hofferberth *et al.*, Nature 449, 324
(2007)



Depletion in shaken lattices:

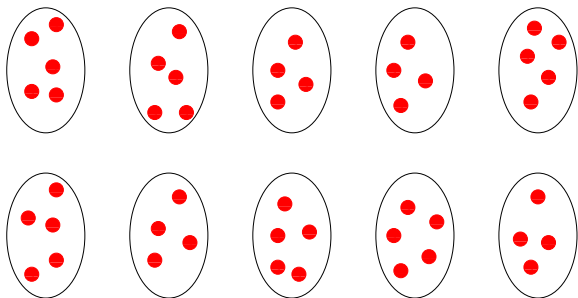


E. Michon *et al.*,
New. J. Phys. 20,
053035 (2018)

(see also L. Feng *et al.*, Nat. Phys.
14, 269 (2018))

Ultracold interacting bosonic atoms in optical lattices

→ explore physics of Bose gases in optical lattices with *mesoscopically* populated lattice sites (featuring some 10 ... 50 atoms per site)



Ultracold interacting bosonic atoms in optical lattices

- explore physics of Bose gases in optical lattices with *mesoscopically* populated lattice sites (featuring some 10 ... 50 atoms per site)
- interplay of nonlinear BEC (?) dynamics and quantum depletion on each site with lattice dynamics (hopping, disorder, localisation, ...)
- cross-over from mean-field to many-body regime

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Numerical tools:

- Truncated Wigner method for average behaviour of Bose gas
[J. Dujardin *et al.*, Annalen der Physik 527, 629 \(2015\)](#)
- Maslov WKB method to capture quantum interference effects
[S. Tomsovic *et al.*, Phys. Rev. A 97, 061606\(R\) \(2018\)](#)

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- interplay of nonlinear BEC (?) dynamics and quantum depletion on each site with lattice dynamics (hopping, disorder, localisation, ...)
- cross-over from mean-field to many-body regime
- mesoscopic BEC in more exotic lattices ? (synthetic dimensions, momentum space lattices, superradiance lattices, time crystals, ...)