Coherent networks of photon Bose-Einstein condensates

Charlie Matsch, Mario Vretenar, Jan Klaers

Adaptive Quantum Optics (AQO), MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Introduction

Here, we investigate networks of photon Bose-Einstein condensates (pBECs). We create a network of individually pumped trap sites that are connected via waveguides to allow nearest neighbour interactions. This system (similar to the XY-model for (ferro)magnetic systems) should exhibit vortices and a BKT phase transition.

We report on our preliminary results of creating coherent networks of pBECs. All neighbouring sites are coupled symmetric (ferromagnetic).

Controlling potential landscape

The optical pump creates a high chemical potential. The photons thermalise via the dye and condense [1]. The transmitted cavity light is imaged on a camera.

One mirror is nanostructured (with Si layer) that creates a potential landscape for the photons.

Photon energy inside cavity

\[ E \approx \frac{c^2}{n^2} + \frac{(nk_r)^2}{2m_{ph}} - \frac{c^2 \Delta d}{2D_0} \]  
(Paraxial approx. \( k_r \ll k_z \))

Height map of a nanostructured mirror showing a 3x3 network.

The trap sites are connected via waveguides allowing nearest neighbour interactions. Each trap site is pumped with a laser.

Experimental setup

We use a spatial light modulator (SLM) to pump each individual trap site. We can pump each spot with an arbitrary intensity.

The transmitted cavity light is analysed with a spectrometer and send trough an interferometer to check for coherence. We interfere the two outermost trap sites with each other.

Preliminary results

Network of 7x7 trap sites with symmetric nearest neighbour coupling.

Interference of the upper and lower trap sites shows that the network is coherent.

Example of a network with anti-symmetric coupling between neighbouring trap sites.

\[ D_0 n^2 E \approx m_{ph} c^2 + \frac{\hbar k_{\text{rest}}^2}{2m_{ph}} + \frac{\hbar k_{\text{kin}}^2}{2m_{ph}} - \frac{\hbar k_{\text{pot}}^2}{2m_{ph}} \]  
(Paraxial approx. \( k_r \ll k_z \))

\[ 0.0 \quad 0.2 \quad 0.4 \quad 0.6 \quad 0.8 \quad 1.0 \]

Normalised intensity

\[ \int_0^1 |\psi(x)|^2 dx = 1 \]