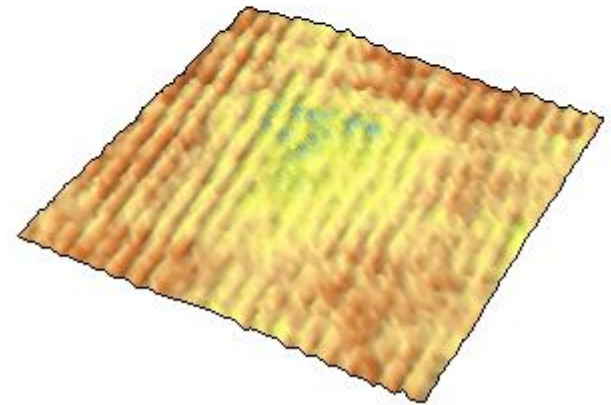


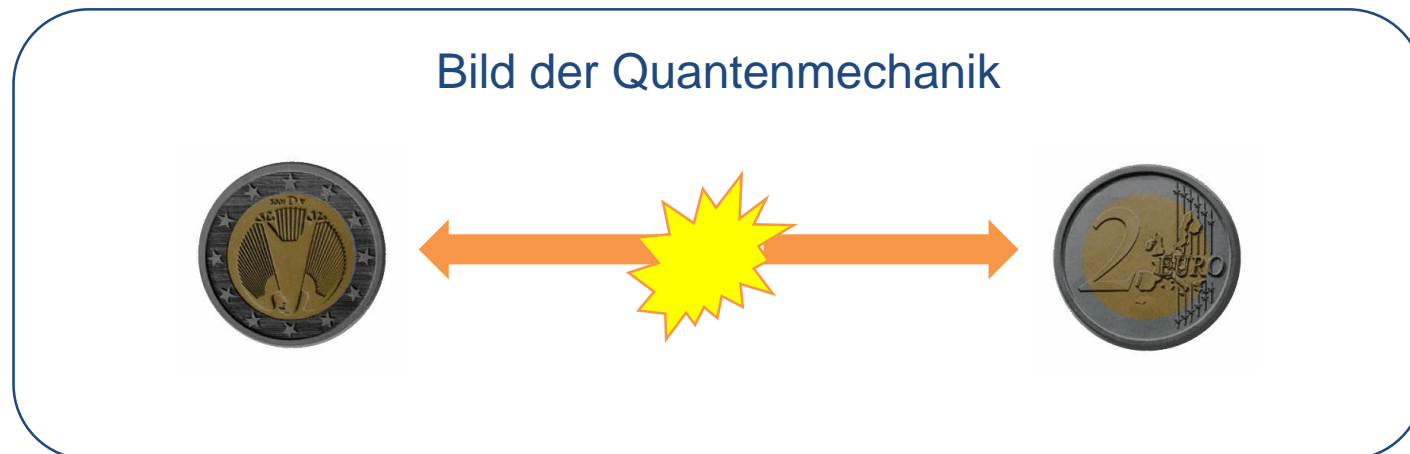
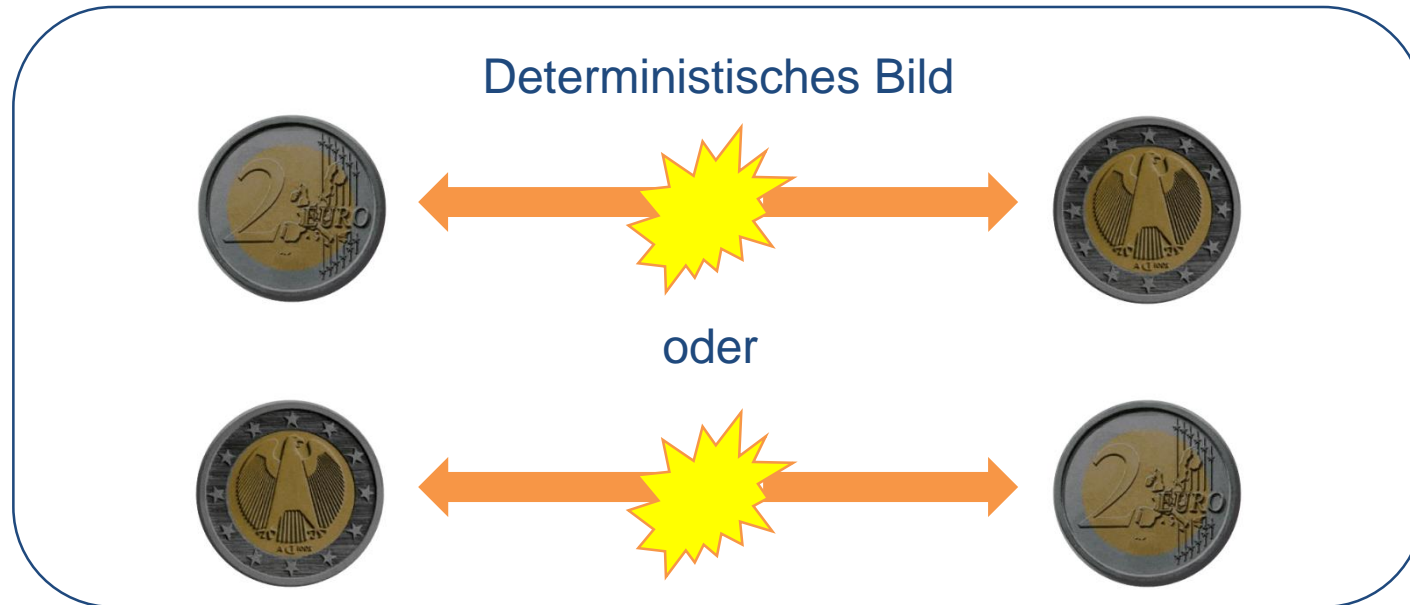
# Optik mit ultrakalten Atomen

Carsten Klempt  
Wolfgang Ertmer

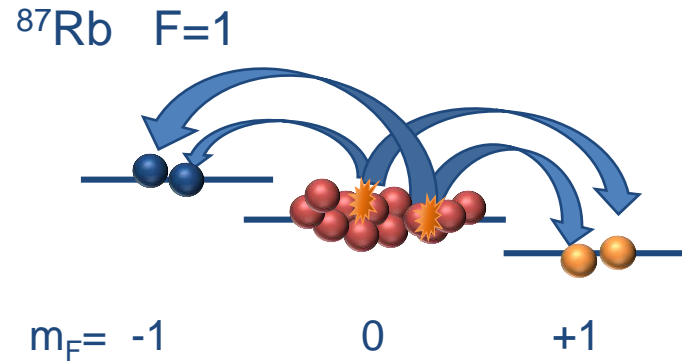
*Institut für Quantenoptik*



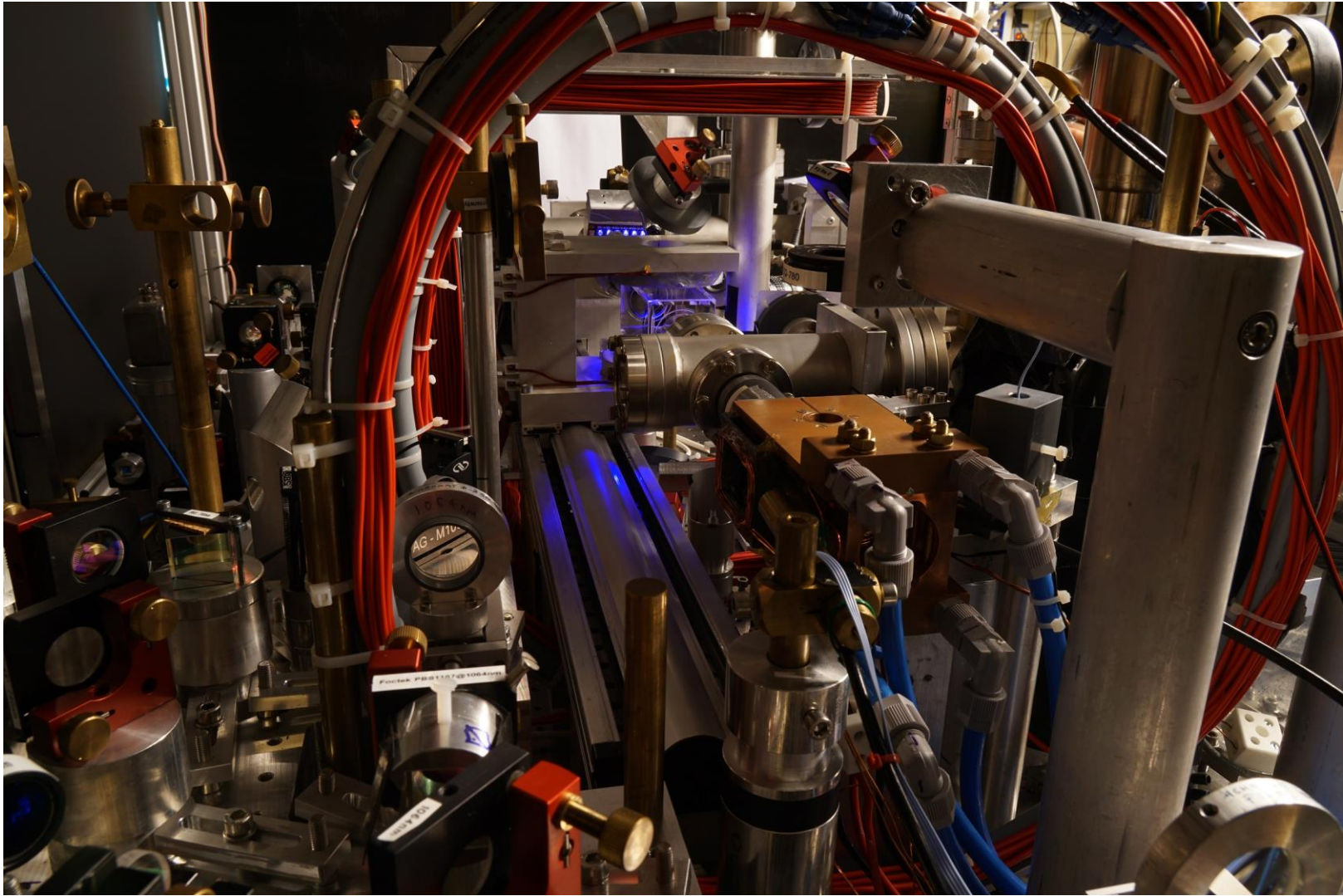
# Verschränkte Atome



# Erzeugung verschränkter Atome



Spinor Bose-Einstein Kondensat



**Improvement of an Atomic Clock using Squeezed Vacuum**I. Kruse,<sup>1</sup> K. Lange,<sup>1</sup> J. Peise,<sup>1</sup> B. Lücke,<sup>1</sup> L. Pezzè,<sup>2</sup> J. Arlt,<sup>3</sup> W. Ertmer,<sup>1</sup> C. Lisdat,<sup>4</sup> L. Santos,<sup>5</sup> A. Smerzi,<sup>2</sup> and C. Klempt<sup>1</sup><sup>1</sup>*Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany*<sup>2</sup>*QSTAR, INO-CNR and LENS, Largo Enrico Fermi 2, I-50125 Firenze, Italy*<sup>3</sup>*Institut for Fysik og Astronomi, Aarhus Universitet, Ny Munkegade 120, DK-8000 Århus C, Denmark*<sup>4</sup>*Physikalisch-Te* **QUANTUM ENTANGLEMENT**Lange *et al.*, *Science* **360**, 416–418 (2018)<sup>5</sup>*Institut für Theoretische***Entanglement between two spatially separated atomic modes**Karsten Lange,<sup>1</sup> Jan Peise,<sup>1</sup> Bernd Lücke,<sup>1</sup> Ilka Kruse,<sup>1</sup> Giuseppe Vitagliano,<sup>2,3</sup> Iagoba Apellaniz,<sup>3</sup> Matthias Kleinmann,<sup>3,4</sup> Géza Tóth,<sup>3,5,6</sup> Carsten Klempt<sup>1\*</sup>

Modern quantum technologies in the fields of quantum computing, quantum simulation, and quantum metrology require the creation and control of large ensembles of entangled particles. In ultracold ensembles of neutral atoms, nonclassical states have been generated with mutual entanglement among thousands of particles. The entanglement generation relies on the fundamental particle-exchange symmetry in ensembles of identical particles, which lacks the standard notion of entanglement between clearly definable subsystems. Here, we present the generation of entanglement between two spatially separated clouds by splitting an ensemble of ultracold identical particles prepared in a twin Fock state. Because the clouds can be addressed individually, our experiments open a path to exploit the available entangled states of indistinguishable particles for quantum information applications.

## ARTICLE

Received 9 Jun 2015 | Accepted 23 Oct 2015 | Published 27 Nov 2015

**Satisfying the Einstein-Podolsky-Rosen (EPR) criterion with massive particles**J. Peise<sup>1</sup>, I. Kruse<sup>1</sup>, K. Lange<sup>1</sup>, B. Lücke<sup>1</sup>, L. Pezzè<sup>2,3,4</sup>, J. Arlt<sup>3</sup> & C. Klempt<sup>1</sup>

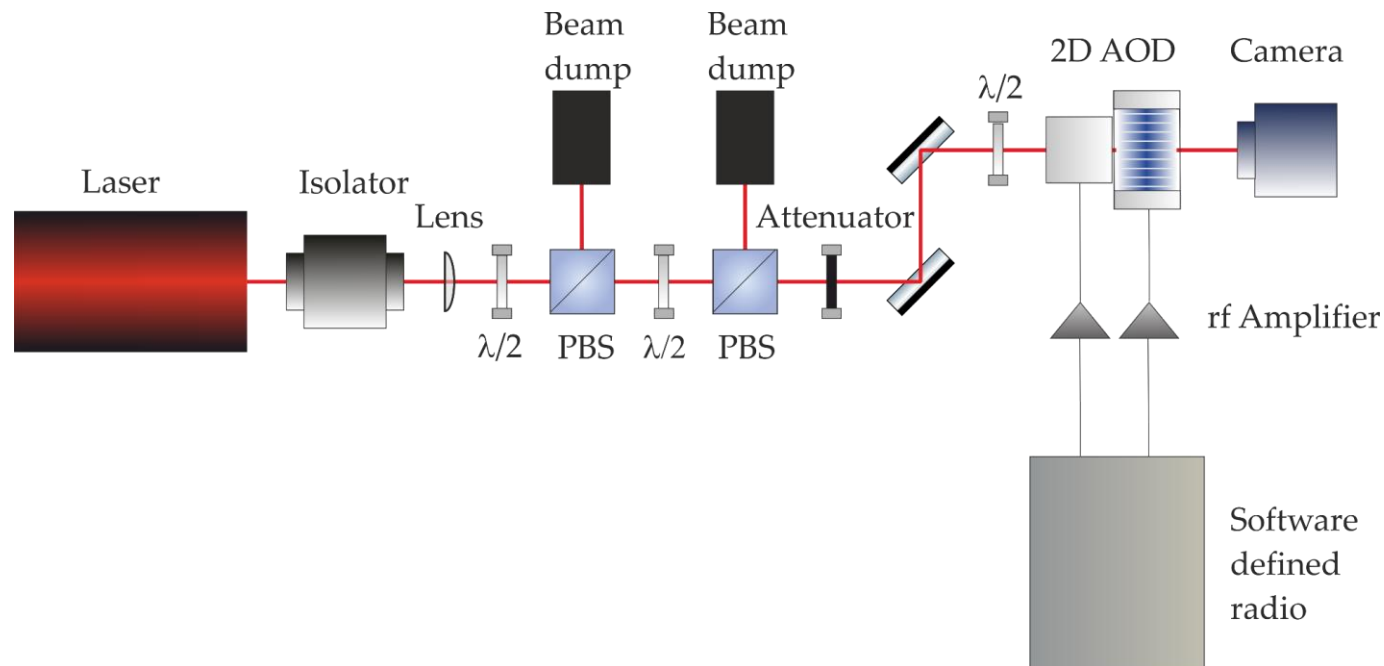
In 1935, Einstein, Podolsky and Rosen (EPR) questioned the completeness of quantum mechanics by devising a quantum state of two massive particles with maximally correlated space and momentum coordinates. The EPR criterion qualifies such continuous-variable



# Masterarbeit Mareike Hetzel



## Painted Optical Potentials



# C++ Programmierung

```
for (int count = 0; count < spb; count++) {
    double n = static_cast<double>(count);

    buffer[0][n] = 0.6 * exp(5 * prefactor * n) * exp(phase_correction);
    buffer[1][n] = 0.3 * exp(-3 * prefactor * n) + 0.3 * exp(5 * prefactor * n);
}
```

```
while (true) {
    if (stop_signal_called) break;

    tx_stream->send(
        buff_ptrs, spb, md
    );
}
```



```
C:\Windows\system32\cmd.exe
Win32: Microsoft Visual C++ version 14.0; Boost_105900; UHD_003.010.001.001-velo
asc

Creating the usrp device with: addr0=192.168.40.2...
-- X300 initialization sequence...
-- Determining maximum frame size... 8000 bytes.
-- Setup basic communication...
-- Loading values from EEPROM...
-- Setup RF Frontend clocking...
-- Radio tx clock=200
-- Creating USA UDP transport for 192.168.40.2:49153
-- Creating USA UDP transport for 192.168.40.2:49153
-- DMA FIFO Running BIST for FIFO 0... pass (Throughput: 1304.1MB/s)
-- DMA FIFO Running BIST for FIFO 1... pass (Throughput: 1304.7MB/s)
-- Creating USA UDP transport for 192.168.40.2:49153
-- LRFNoC Radiol Performing register loopback test... pass
-- LRFNoC Radiol Performing register loopback test... pass
-- Creating USA UDP transport for 192.168.40.2:49153
-- LRFNoC Radiol Performing register loopback test... pass
-- LRFNoC Radiol Performing register loopback test... pass
-- Creating USA UDP transport for 192.168.40.2:49153
-- Creating USA UDP transport for 192.168.40.2:49153
-- Creating USA UDP transport for 192.168.40.2:49153
-- Creating USA UDP transport for 192.168.40.2:49153
-- Performing timer loopback test... pass
-- Performing timer loopback test... pass
Using Device: Single USRP:
Device: X-Series Device
Mboard 0: X310
RX Channel: 0
RX DSP: 0
RX Dboard: A
RX Subdev: UBX RX
RX Channel: 1
RX DSP: 0
RX Dboard: B
RX Subdev: UBX RX
TX Channel: 0
TX DSP: 0
TX Dboard: A
TX Subdev: UBX TX
TX Channel: 1
TX DSP: 0
TX Dboard: B
TX Subdev: UBX TX

Setting TX Rate: 33.333333 Msps...
Actual TX Rate: 33.333333 Msps...

Setting TX Freq: 75.000000 Mhz...
Actual TX Freq: 75.000000 Mhz...

Setting TX Gain: 4.500000 dB...
Actual TX Gain: 4.500000 dB...

Setting TX Freq: 75.000000 Mhz...
Actual TX Freq: 75.000000 Mhz...

Setting TX Gain: 4.500000 dB...
Actual TX Gain: 4.500000 dB...

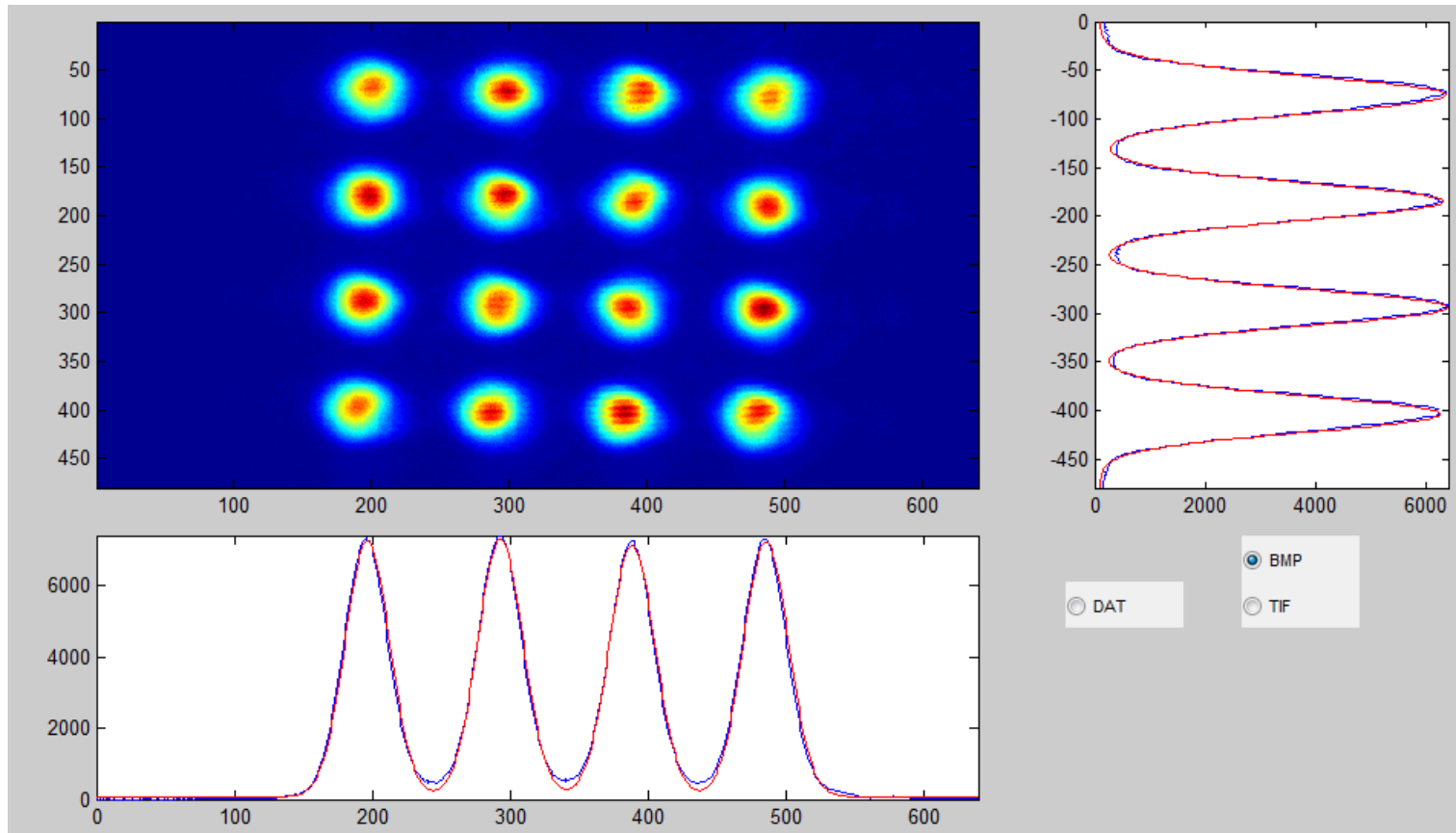
-- Creating USA UDP transport for 192.168.40.2:49153
-- Creating USA UDP transport for 192.168.40.2:49153
Setting device timestamps to 0...
-- 1) catch time transition at pps edge
-- 2) set times next pps (synchronously)
Checking TX: TXIQs locked...
Press Ctrl + C to stop streaming...
```

Ettus Research  
USRP X310

<https://www.ettus.com/product/details/X310-KIT>

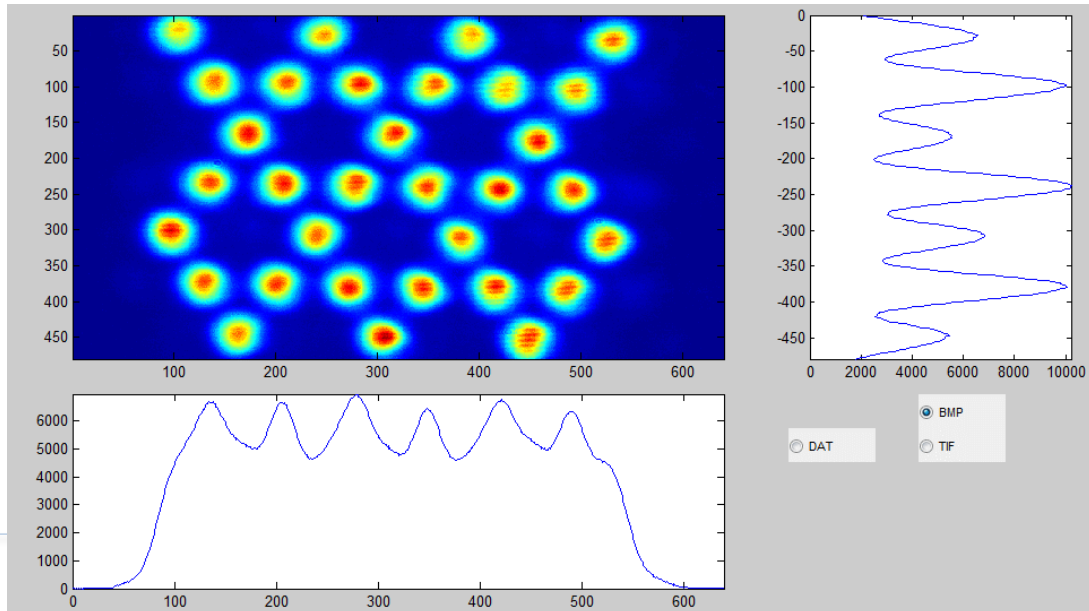
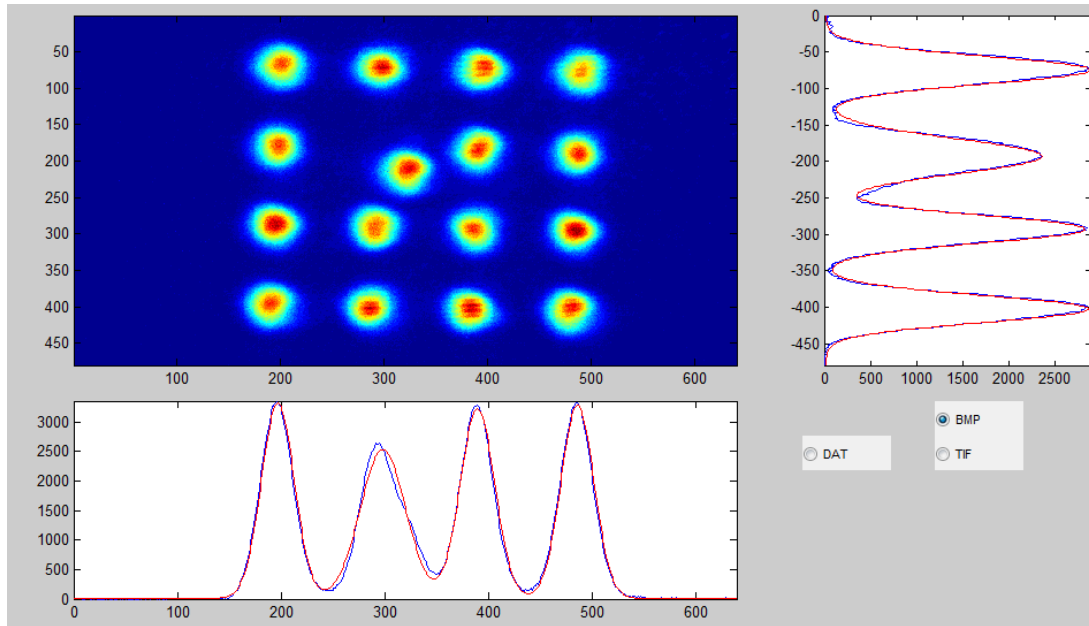
# Regular lattice

Deflected beams in the test setup imaged on the CCD camera

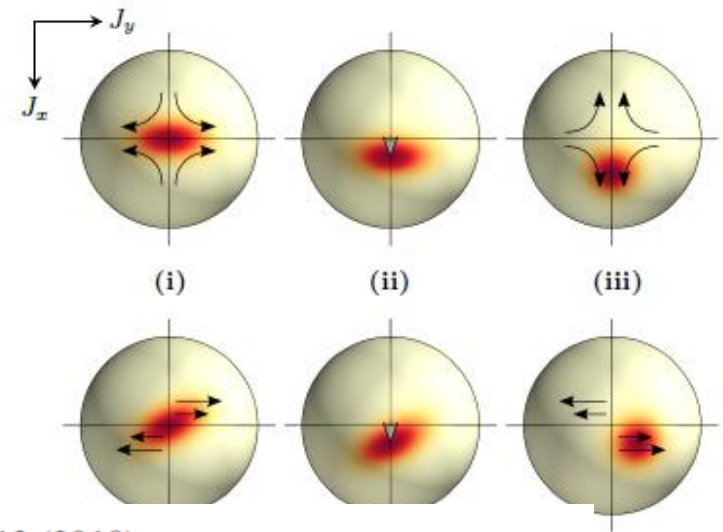




# Similar lattices



# Masterarbeit Fabian Anders




PHYSICAL REVIEW A 97, 043813 (2018)

## Phase magnification by two-axis countertwisting for detection-noise robust interferometry

Fabian Anders,<sup>1</sup> Luca Pezzè,<sup>2</sup> Augusto Smerzi,<sup>2</sup> and Carsten Klempt<sup>1</sup>

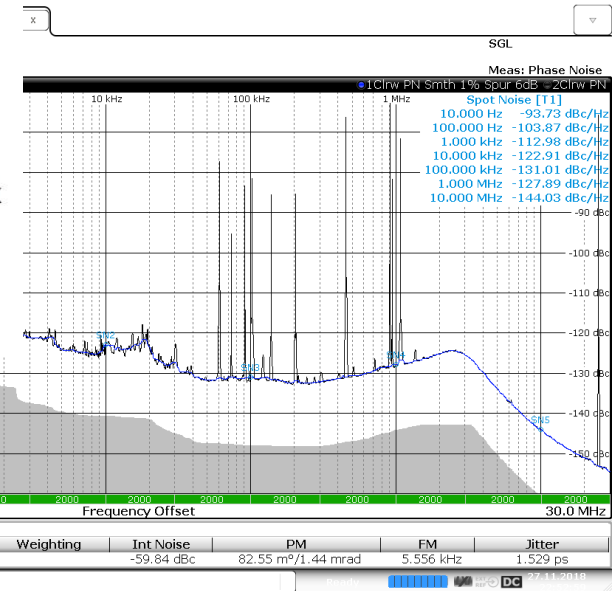
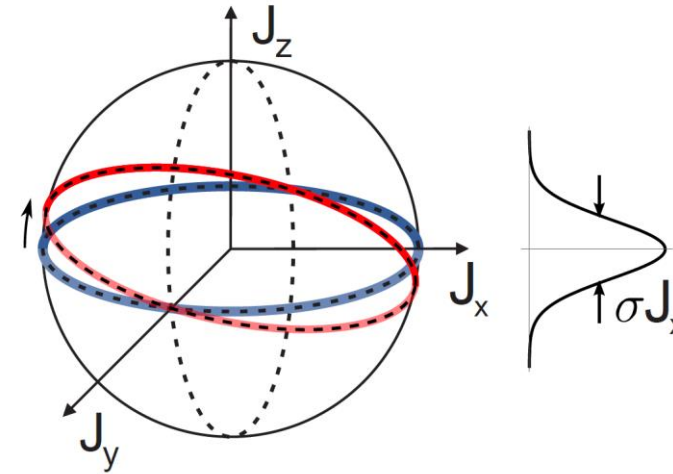
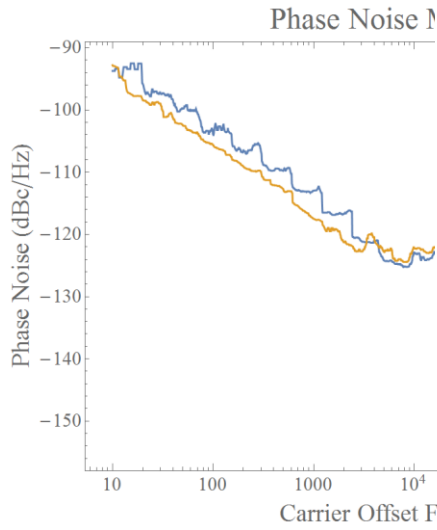
<sup>1</sup>*Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany*

<sup>2</sup>*QSTAR, INO-CNR and LENS, Largo Enrico Fermi 2, I-50125, Firenze, Italy*

 (Received 8 November 2017; published 9 April 2018)

Entanglement-enhanced atom interferometry has the potential of surpassing the standard quantum limit and eventually reaching the ultimate Heisenberg bound. The experimental progress is, however, hindered by various technical noise sources, including the noise in the detection of the output quantum state. The influence of detection noise can be largely overcome by exploiting echo schemes, where the entanglement-generating interaction is

# Masterarbeit Bernd Meyer



Date: 27.NOV.2018 22:52:59

# Bachelor-, Masterarbeiten

Quantenphysik und Verschränkung

Ultrakalte Atome

Laser

Elektronik

Vakuumtechnik

Hochfrequenzelektronik

Simulation

&

ein nettes Team