Università degli Studi di Bari Aldo Moro
INFN Istituto Nazionale di Fisica Nucleare Sezione di Bari

Dipartimento Interateneo di Fisica "M. Merlin"

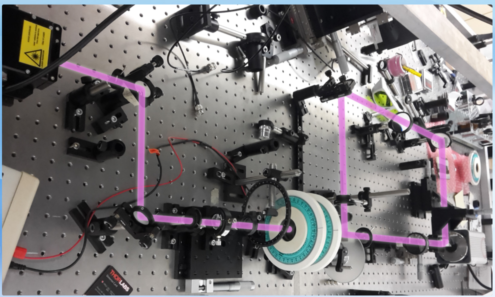
Quantum Correlations and Quantum Applications

Giovanni Scala

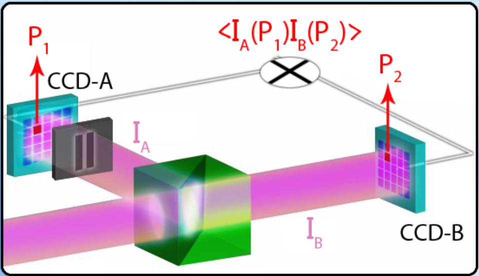
Corso di Dottorato XXXIII Ciclo

Correlation Imaging

Correlation imaging offers new applications for industry and revolutionary methods for investigating fundamental Physics.



Correlation means answering this question.
When CCD detector A observes light at a pixel P_1 how often does CCD detector B observe light at a pixel P_2?



Fluctuation function variance which rules the signal-to-noise ratio.

$$\mathcal{F}_{AB}(\boldsymbol{p}_1) = \left\langle \sigma_{AB}(\boldsymbol{p}_1)^2 \right\rangle - \langle \sigma_{AB}(\boldsymbol{p}_1) \rangle^2$$

$$\sigma_{AB}(\boldsymbol{p}_1) = \sum_{\boldsymbol{p}_2} \Delta I_A(\boldsymbol{p}_1) \Delta I_B(\boldsymbol{p}_2), \quad \Delta I_A(p_1) = I_A(p_1) - \langle I_A(p_1) \rangle_t$$

Properties of the light

Different properties of the source and several experimental parameters will be investigated, as well as the kind of light, and consequently, how to highlight the relevant physical phenomena.

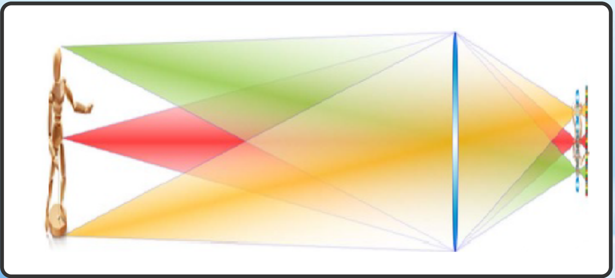
GOAL

- **Control the Signal-to-Noise ratio.**
- **Enhacements in optics devices**

" Compartison of the signal-to-noise characteristics of quantum versus thermal ghost imaging "

M.N.O'Sullivan, K.W.C. Chan and R.W. Boyd, *Phys.Rev.A*, 2010

Correlation Plenoptic Imaging



Imaging with a light-field camera. A microlens array for the retracking of the light rays.

"Correlations plenoptic imaging"
M. D'Angelo, F.V. Pepe, A. Garuccio, G. Scarcelli
Physical Review Letters, (2016)+**Patents**

Engineered Quantum Systems

Requirements

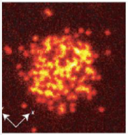
- Initialization in pure quantum states
- Controlled couplings
- Reduced decoherence
- Quantum measurements

for what?

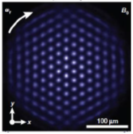
- Controlling geometry and dimension
- Controlling interactions
- Investigate models of interest
- Novel quantum phases

Experimental Platforms

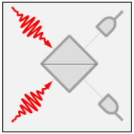
Ultracold atoms



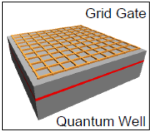
Trapped ions



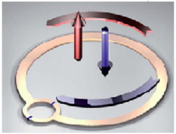
Photons



Quantum dots

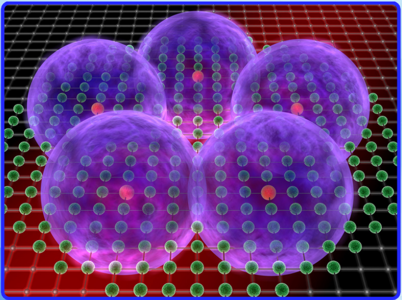


Superconducting quantum bits

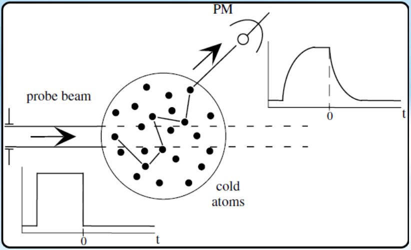


Cold Atoms

Analyze light scattering on cold atomic clouds and determine collective properties from correlation functions.

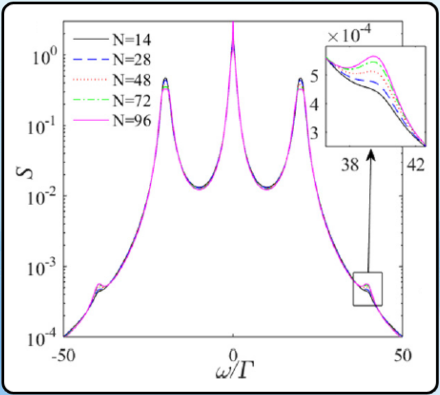


Radiation trapping setup



Focus on signatures of ***quantum cooperativity***

Fluorescence spectrum for a cold cloud atoms



R. Kaiser et al.,*Phys. Rev. A*, 95, 053625 (2017)

FIRST ORDER

- Typical Mollow triplet (sigle atom)

SECOND ORDER

- Cooperative quantum effect (many-body systems)

Spectral function

$$S(\omega) = \lim_{T\to\infty} \lim_{t\to\infty} \int_{-T}^{T} d\tau \left\langle E(\hat{\boldsymbol{n}}, t) E^{\dagger}(\hat{\boldsymbol{n}}, t+\tau) \right\rangle e^{i\omega t}$$


GRAZIE
PER
L'ATTENZIONE