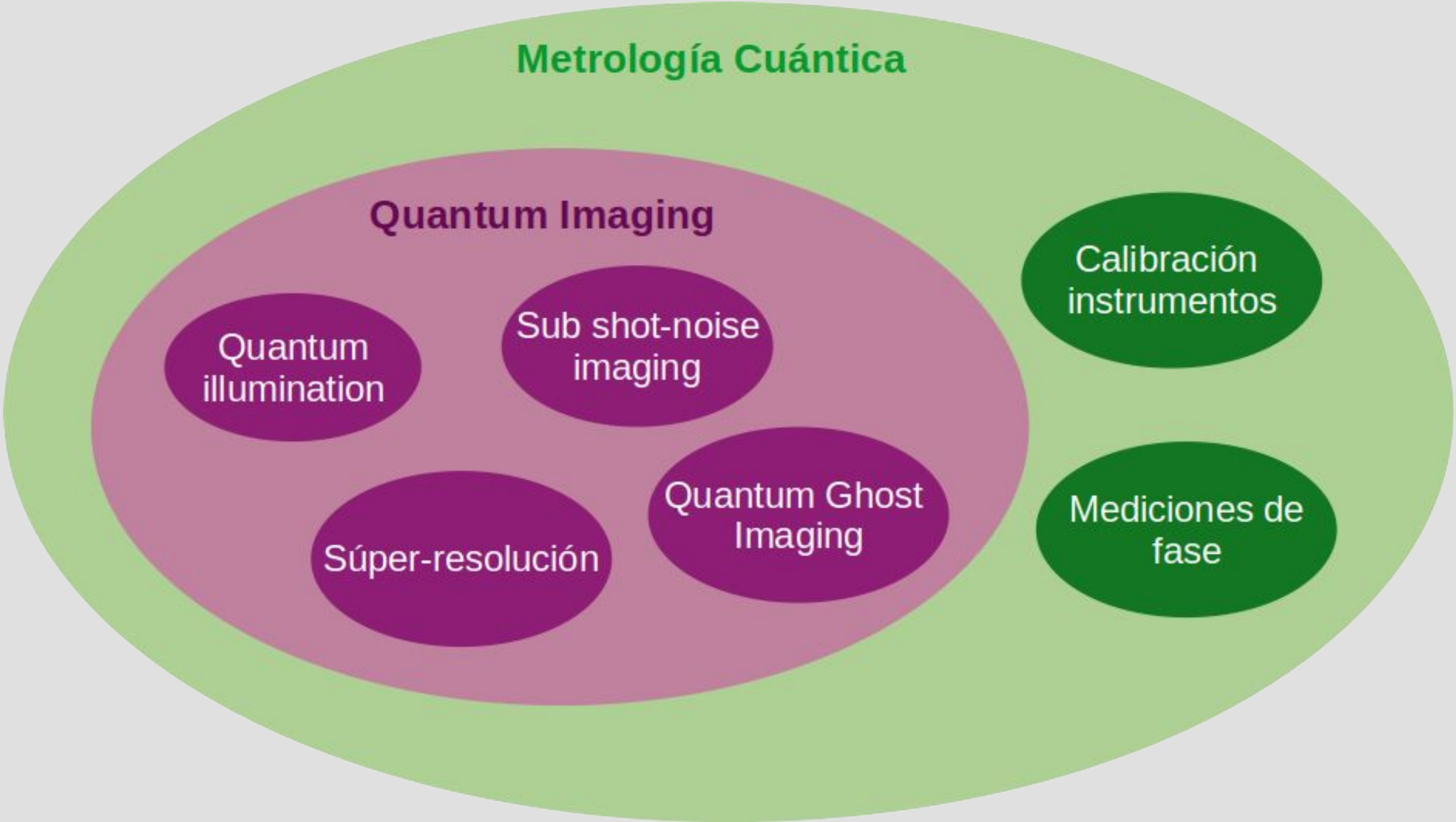
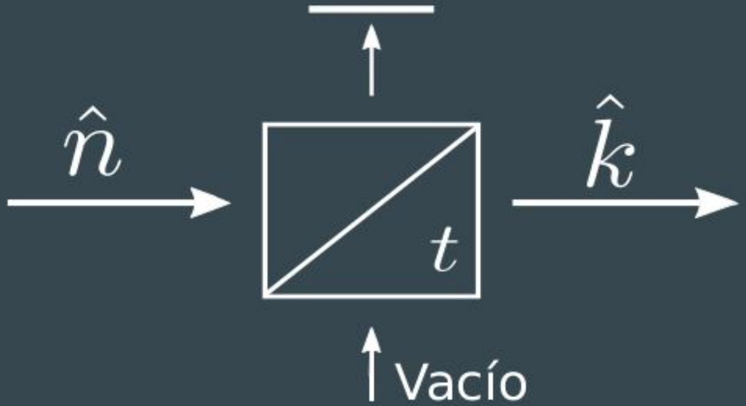
Metrología cuántica: medición de absorbancias


Metrología Cuántica
Quantum Imaging
Quantum illumination
Sub shot-noise imaging
Quantum Ghost Imaging
Súper-resolución
Calibración instrumentos
Mediciones de fase

Objeto con transmisión t



Se busca reducir este término

Media $\langle \hat{k} \rangle = t\langle \hat{n} \rangle$

Varianza $\langle \Delta^2 \hat{k} \rangle = t(1-t)\langle \hat{n} \rangle + t^2\langle \Delta^2 \hat{n} \rangle$

Distribuciones de la variable aleatoria *número de fotones* (n)

Límite clásico: fuente con estadística de Poisson

Ejemplo: láser atenuado sin fluctuaciones en el número medio de fotones

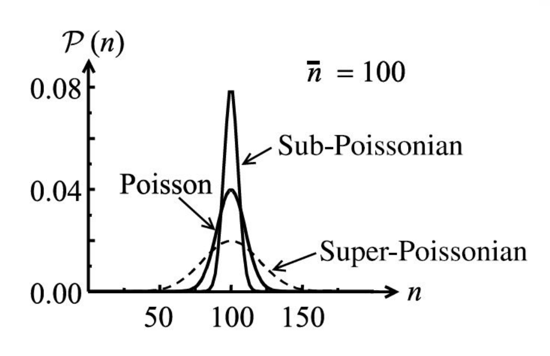
$$E(n) = \mu \qquad Var(n) = \mu$$

Fuentes de luz no-clásicas: estadística sub-Poisson

Ejemplo: fuentes basadas en generación de pares SPDC

$$E(n) = \mu$$

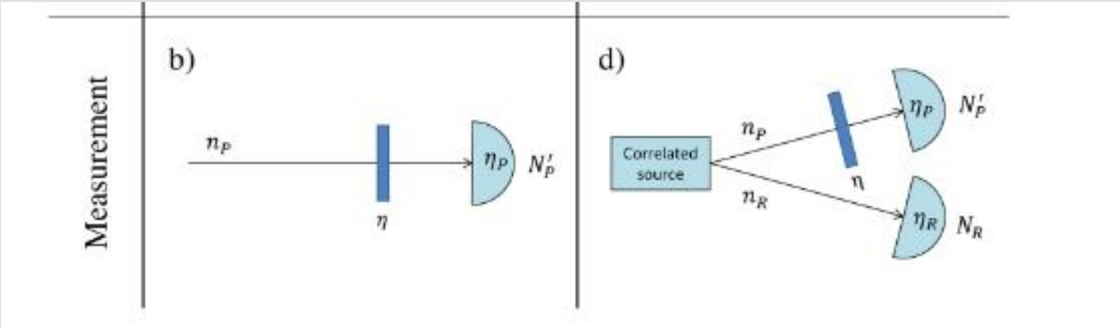
$$Var(n) < \mu$$

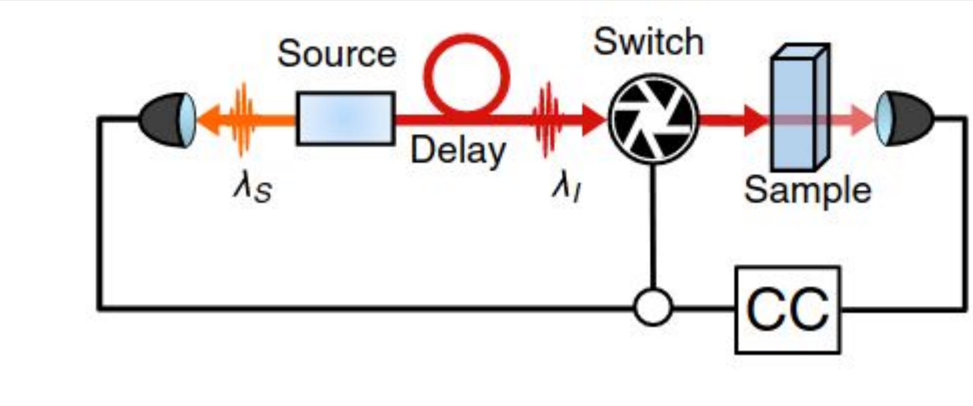


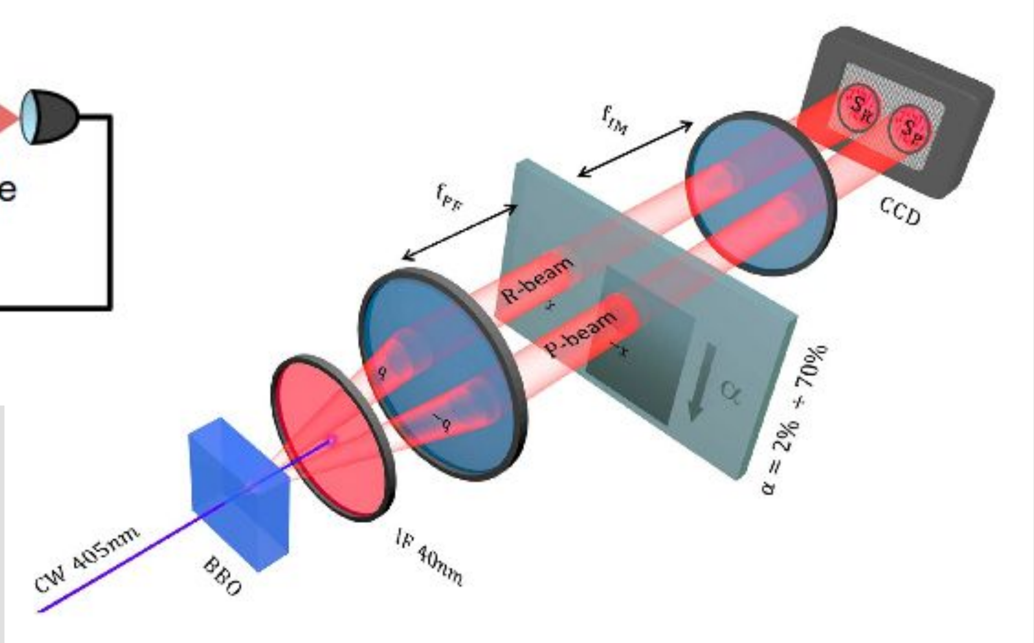
Bosque particular:

¿Qué tipo de medición? ¿Cuál es el mejor estimador? ¿En qué régimen se puede trabajar?

Tipo de medición





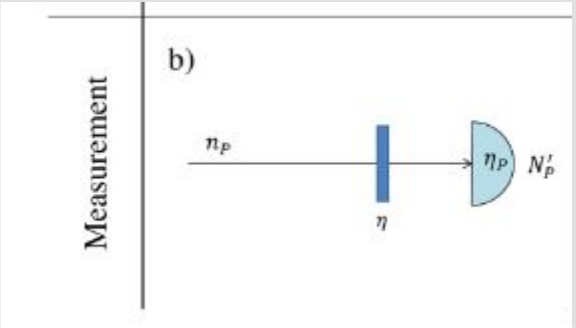


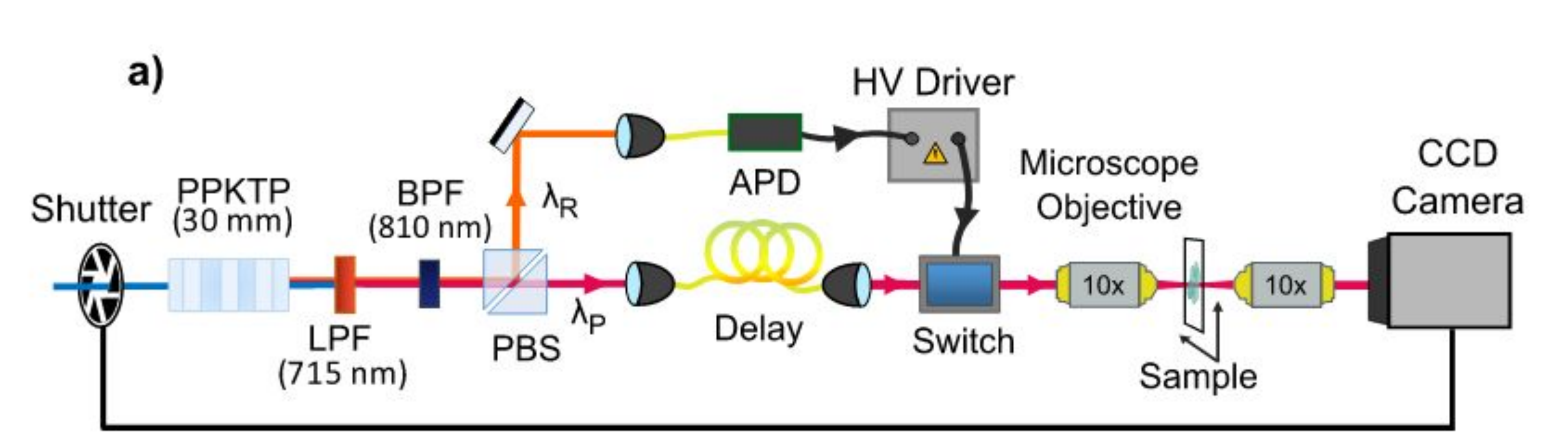
Research Article Vol. 27, No. 21 / 14 October 2019 / *Optics Express* 30810

Optics EXPRESS

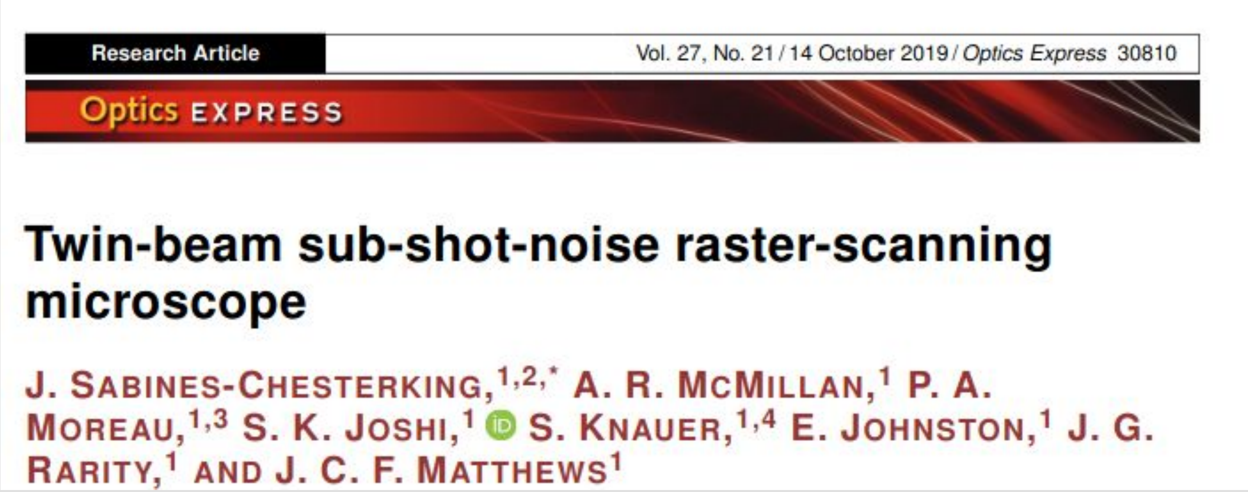
Twin-beam sub-shot-noise raster-scanning microscope

J. SABINES-CHESTERKING,[1,2,*] A. R. MCMILLAN,[1] P. A. MOREAU,[1,3] S. K. JOSHI,[1] S. KNAUER,[1,4] E. JOHNSTON,[1] J. G. RARITY,[1] AND J. C. F. MATTHEWS[1]





Mediciones directas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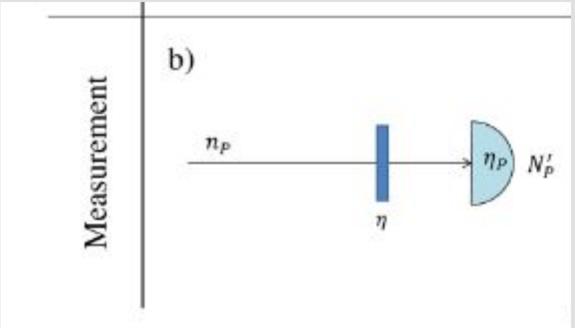


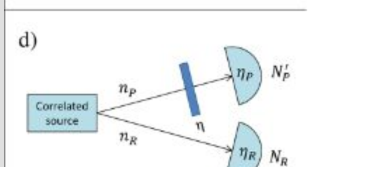
Factor de mejora:

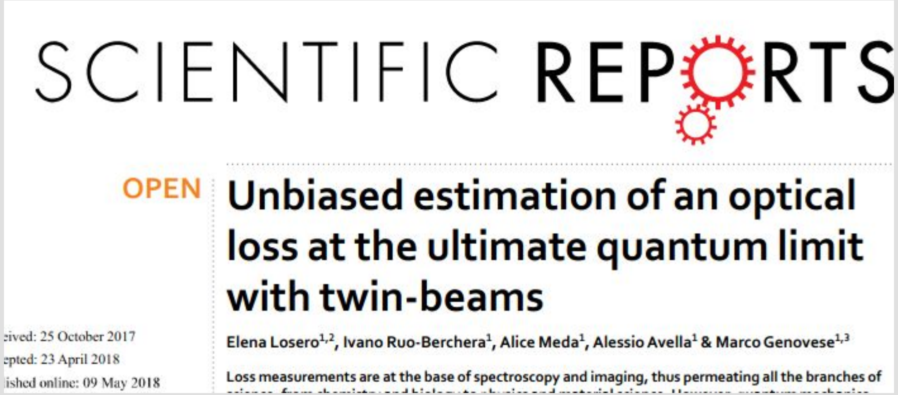
$1,76 \pm 0,09$

Estimador:

$$\hat{\eta}_S = \hat{\eta}_P / \hat{\eta}_{P'} = \frac{\langle N_C \rangle}{\langle N_R \rangle} \Big/ \frac{\langle N'_C \rangle}{\langle N'_R \rangle}.$$

Mediciones diferenciales





SCIENTIFIC REPORTS

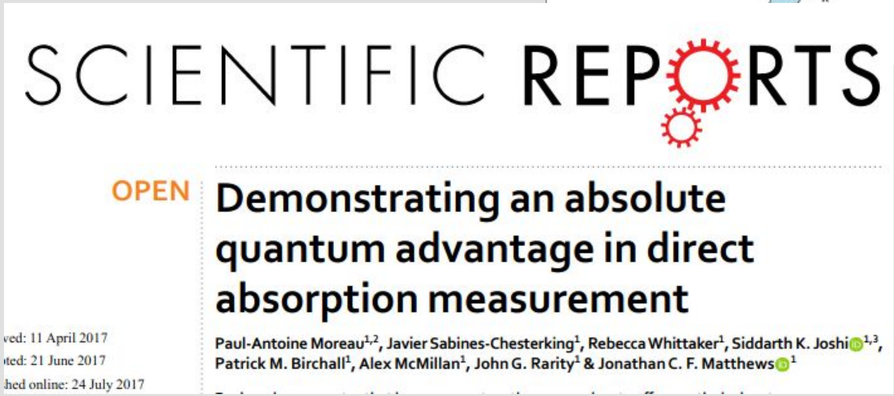
OPEN

Unbiased estimation of an optical loss at the ultimate quantum limit with twin-beams

…eived: 25 October 2017
…epted: 23 April 2018
…ished online: 09 May 2018

Elena Losero[1,2], Ivano Ruo-Berchera[1], Alice Meda[1], Alessio Avella[1] & Marco Genovese[1,3]

Loss measurements are at the base of spectroscopy and imaging, thus permeating all the branches of



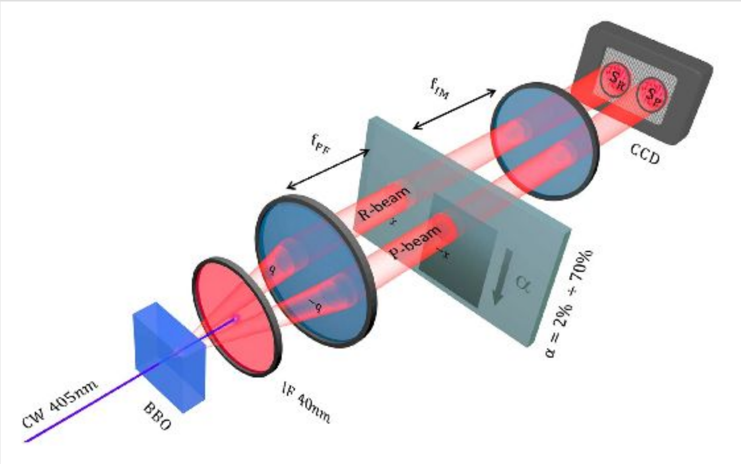
SCIENTIFIC REPORTS

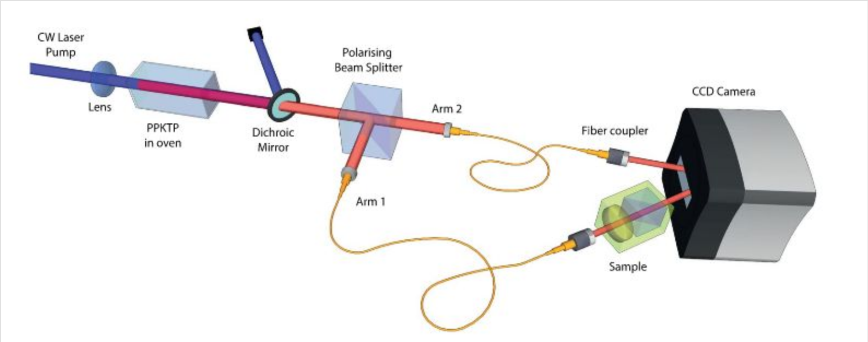
OPEN

Demonstrating an absolute quantum advantage in direct absorption measurement

…ved: 11 April 2017
…ted: 21 June 2017
…hed online: 24 July 2017

Paul-Antoine Moreau[1,2], Javier Sabines-Chesterking[1], Rebecca Whittaker[1], Siddarth K. Joshi[1,3], Patrick M. Birchall[1], Alex McMillan[1], John G. Rarity[1] & Jonathan C. F. Matthews[1]





Mediciones diferenciales

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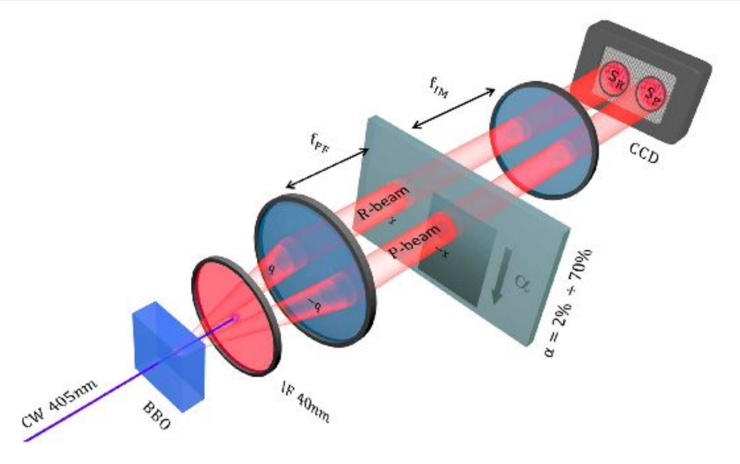


Estimadores:

$$S_\alpha = 1 - \gamma \frac{N_P'}{N_R}.$$

$$S_\alpha' = 1 - \frac{N_P' - k\Delta N_R + \delta E}{\langle N_P \rangle},$$

Factor de mejora:

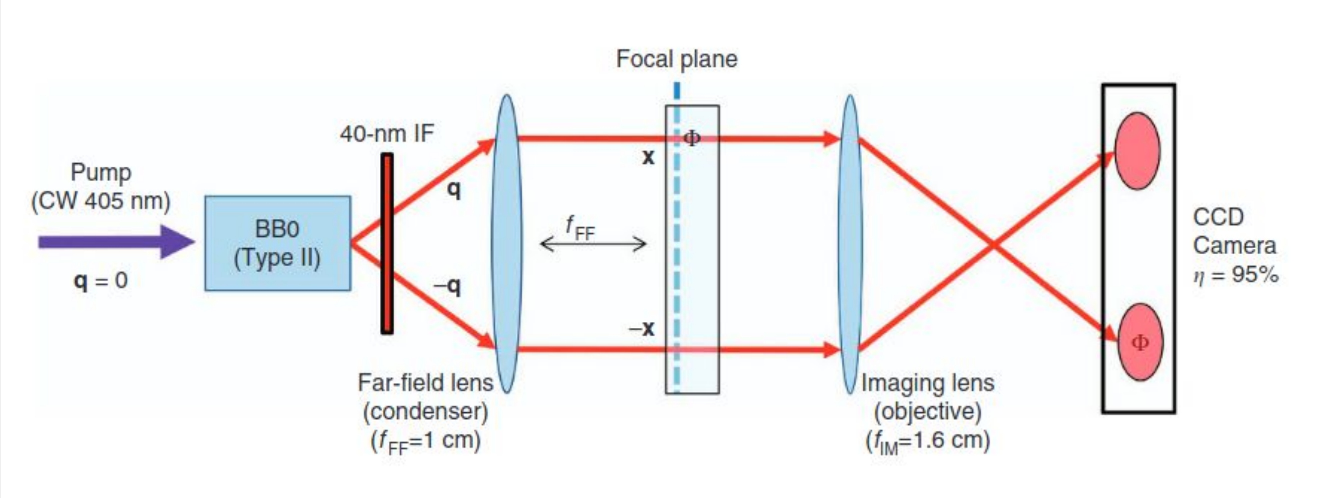
$$1,51 \pm 0,13$$

Sin resolución espacial

Mediciones diferenciales con resolución espacial

Realization of the first sub-shot-noise wide field microscope

Nigam Samantaray[1,2], Ivano Ruo-Berchera[1], Alice Meda[1] and Marco Genovese[1,3]



Mediciones diferenciales con resolución espacial

Realization of the first sub-shot-noise wide field microscope

Nigam Samantaray[1,2], Ivano Ruo-Berchera[1], Alice Meda[1] and Marco Genovese[1,3]

Estimador:

$$\langle N_1 - N_{2,\alpha} \rangle = \alpha \langle N \rangle$$

Factor de mejora:

≈ 1.25

Medición directa, usando fuentes de fotones individuales

Fuente de fotones BinMux-SP

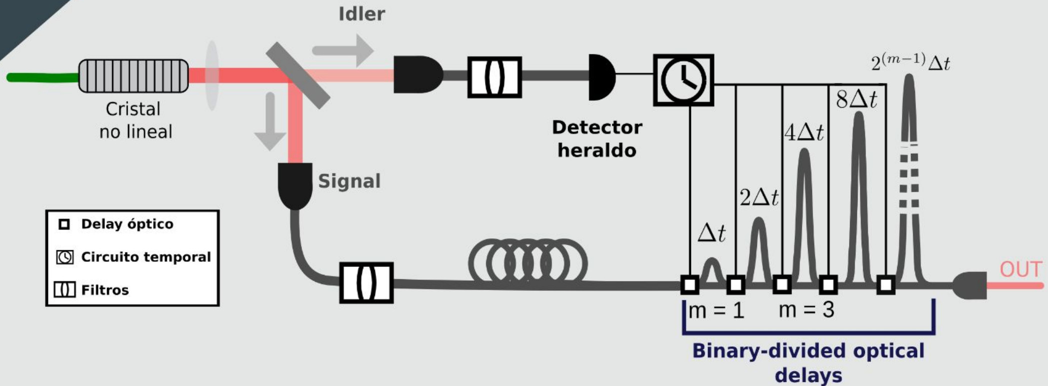
- Basada en SPDC con bombeo CW

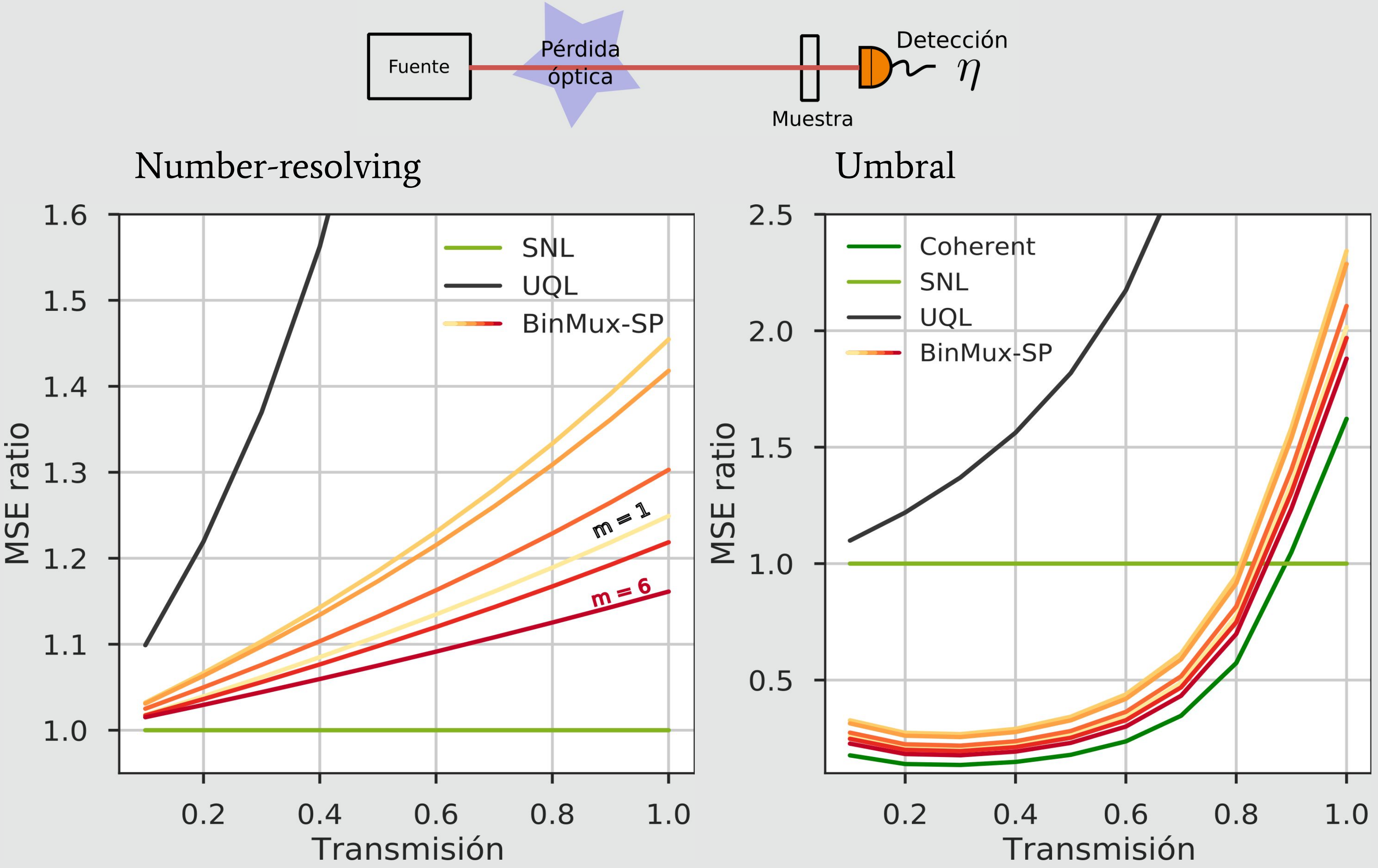
  Generación de pares de fotones gemelos

- Multiplexado temporal

- Sincronización con clock

A. G. Magnoni, et. al., Performance of a temporally multiplexed single-photon source with imperfect devices, Quantum Information Processing 18, 311 (2019).




Fuente
Pérdida óptica
Muestra
Detección
η
Number-resolving
Umbral
MSE ratio
Transmisión
SNL
UQL
BinMux-SP
Coherent
m = 1
m = 6

Medición diferencial, con resolución espacial usando Skipper-CCD

LAMBDA

Proyectos en curso / Projects

1. Óptica Cuántica con Skipper-CCD / Quantum Optics with Skipper-CCD
2. Desarrollo de técnicas de detección de neutrones basadas en centelladores / Development of neutron detectors based on scintillators
3. Búsqueda de materia oscura / Dark Matter searches
4. Física experimental de neutrinos de reactor con Skipper-CCD / Reactor-neutrino physics experiments using Skipper-CCDs

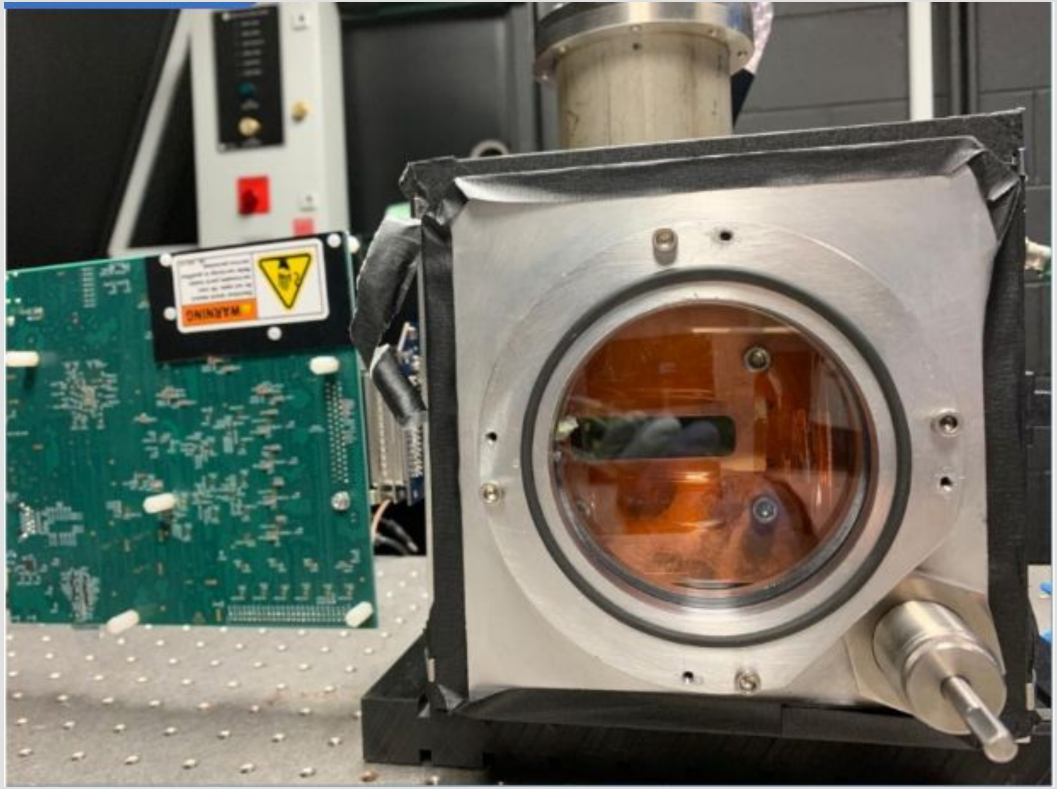
Investigadores / Researchers

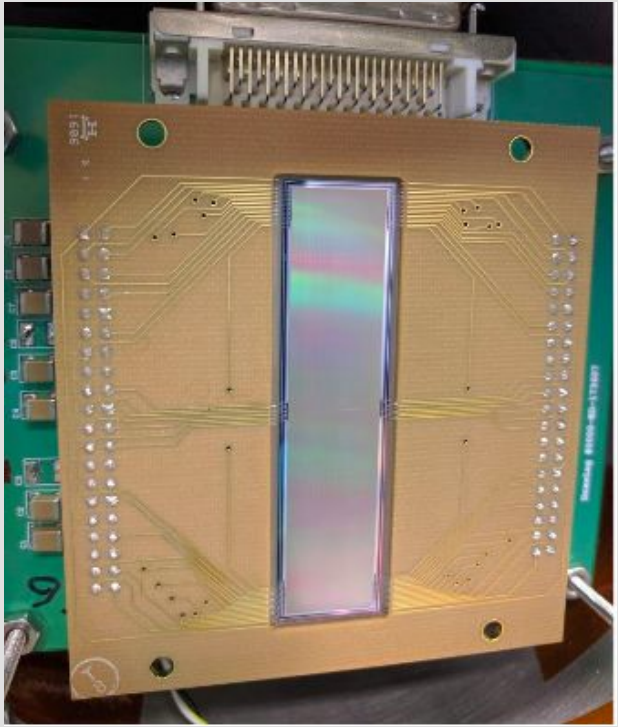
- Darío Rodrigues (rodriguesfm [at] df.uba.ar)
- Javier Tiffenberg (javiert [at] fnal.gov)
- Ricardo Piegaia (aia [at] df.uba.ar)

SENSEI EXPERIMENT

VIOLETA COLLABORATION

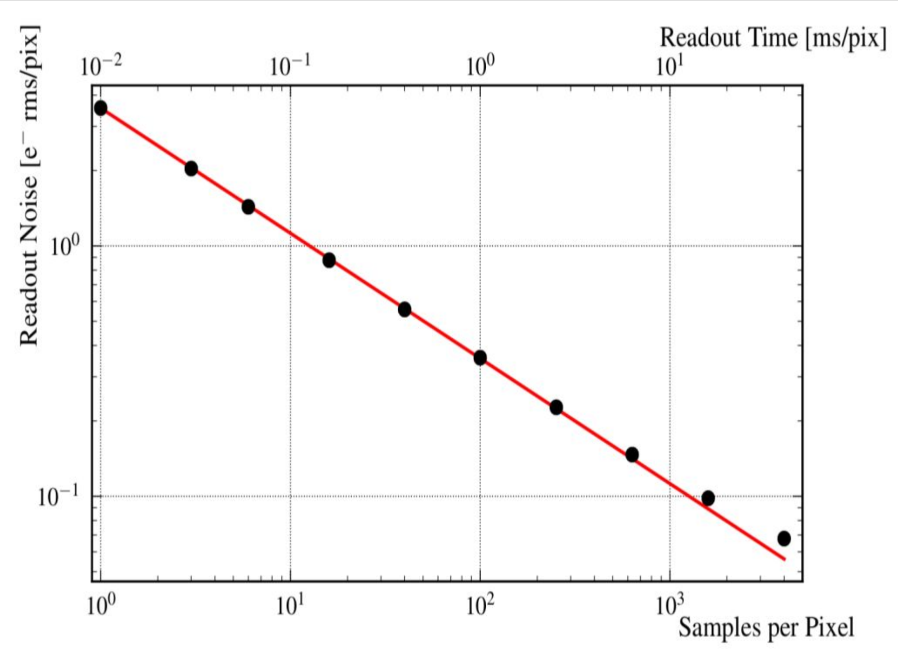
Skipper CCD

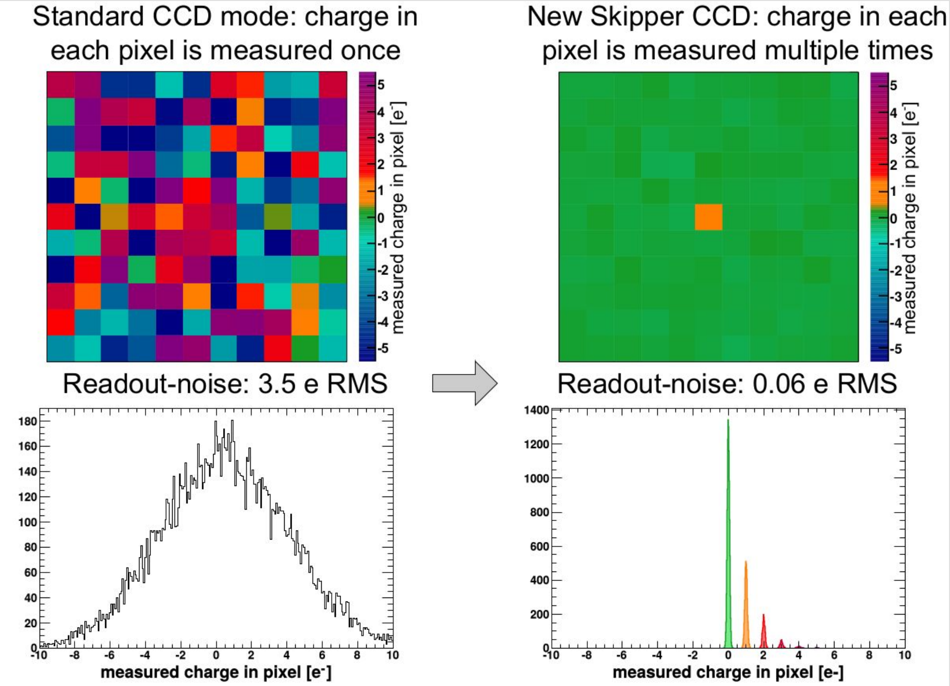




Fermilab + Berkeley lab

Skipper CCD - readout noise





Skipper CCD en óptica cuántica

Characteristics	Value	Unit
Format	4126 x 886	pixels
Pixel Scale	15	um
Thickness	200	um
Silicon Resistivity	10	kΩ
Dark current	<<1	e^-/pix/day
Operating Temperature	120 - 160	K
Readout noise (1 sample)	2	e^- rms/pix
Readout noise (150 samples)	0.16	e^- rms/pix
Readout time (/pix/sample)	10 - 40	μs

$$Detection\ efficiency\ @810nm \geq 0.9$$

1 fotón arranca 1 electrón y puedo contar electrones

↓

Tengo un detector que resuelve número de fotones con resolución espacial

↓

THE DREAM

NRF (noise reduction factor)

$$\sigma = \frac{<\Delta^2(N_1 - N_2)>}{<N_1> + <N_2>}$$

$$\sigma_{eff} = \sigma f^{(TWB)} + f^{(noise)}$$

$$f^{(noise)} = \frac{\Delta^{(el)^2}}{N^{(tot)}} + \frac{N^{(st)}}{N^{(tot)}}$$

Normal CCD

$$\Delta^{(el)} \sim 5e^- /pix$$

PIXIS: 400B Teledyne, Princeton Instrument

Skipper-CCD

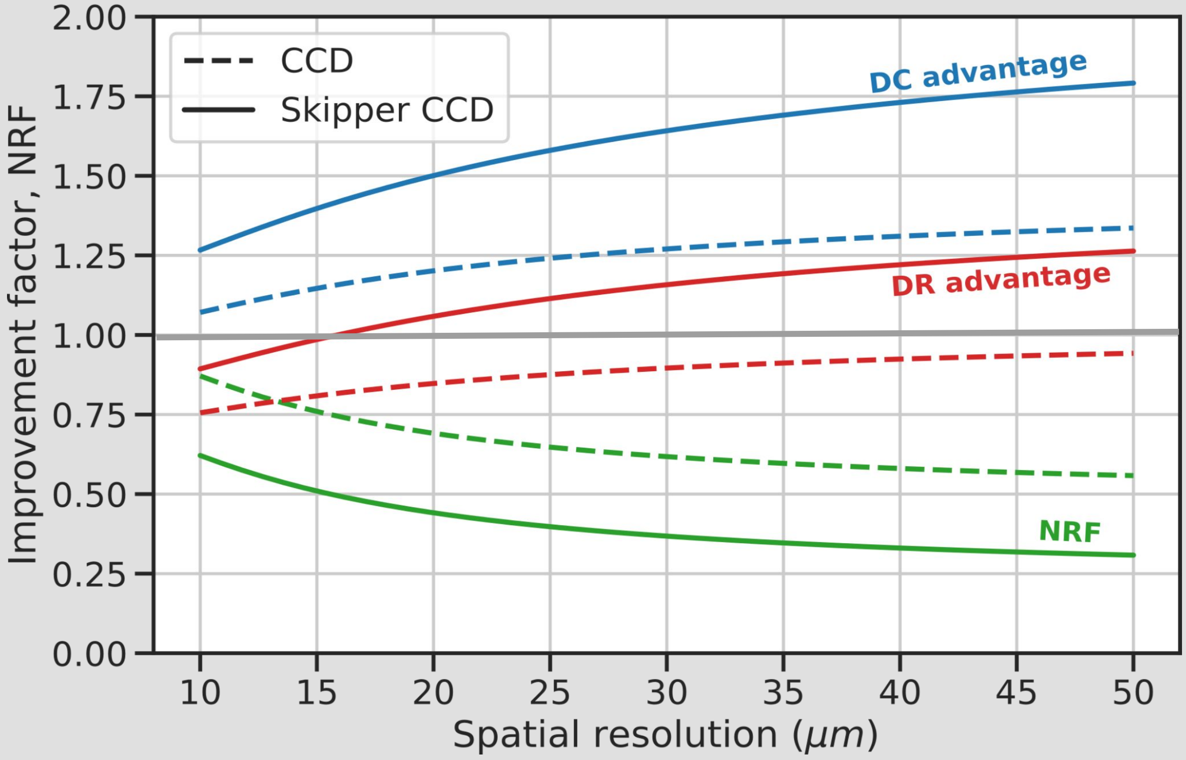
$$\Delta^{(el)} \sim 0.1e^- /pix$$

Realization of the first sub-shot-noise wide field microscope

Nigam Samantaray[1,2], Ivano Ruo-Berchera[1], Alice Meda[1] and Marco Genovese[1,3]

Photons per pixel: 100;

absorbance: 1%



- Implementación experimental (en LAMBDA (por ahora el LIAF :))
- Estudio riguroso del impacto de cada parámetro mediante simulaciones Monte Carlo (tesis Muri Bonetto).
- Evaluación de diferentes estimadores (también la tesis de Muri): ¿cociente, máxima verosimilitud, estimación Bayesiana?

Resumen de la semana

https://arxiv.org/pdf/2108.11343.pdf

Experimental investigation of convex mixtures of Markovian and Non-Markovian single qubit channels on NISQ devices

I. J. David,[1] I. Sinayskiy,[1,2] and F. Petruccione[1,2]

[1]*School of Chemistry and Physics, University of KwaZulu-Natal, Durban 4001, South Africa*
[2]*National Institute for Theoretical and Computational Sciences (NITheCS), South Africa*

(Dated: August 26, 2021)

Noisy Intermediate Scale Quantum (NISQ) devices have been proposed as a versatile tool for simulating open quantum systems. Recently, the use of NISQ devices as simulators for non-Markovian open quantum systems has helped verify the current descriptions of non-Markovianity in quantum physics. In this work, convex mixtures of channels are simulated using NISQ devices and classified as either Markovian or non-Markovian using the CP-divisibility criteria. Two cases are considered: two Markovian channels being convexly mixed to form a non-Markovian channel and vice versa. This work replicates the experiments performed in a linear optical setup, using NISQ devices, with the addition of a convex mixture of non-Markovian channels that was designed to address some of the problems faced in the experiments performed in the linear optical setup. The NISQ devices used were provided by the IBM Quantum Experience (IBM QE). The results obtained show that, using NISQ devices and within some error, convex mixtures of Markovian channels lead to a non-Markovian channel and vice versa.

Review de NISQ: https://arxiv.org/pdf/2101.08448.pdf (21/01/2021)

Noisy intermediate-scale quantum (NISQ) algorithms

Kishor Bharti,[1,*] Alba Cervera-Lierta,[2,3,*] Thi Ha Kyaw,[2,3,*] Tobias Haug,[4] Sumner Alperin-Lea,[3] Abhinav Anand,[3] Matthias Degroote,[2,3,5] Hermanni Heimonen,[1] Jakob S. Kottmann,[2,3] Tim Menke,[6,7,8] Wai-Keong Mok,[1] Sukin Sim,[9] Leong-Chuan Kwek,[1,10,11,†] and Alán Aspuru-Guzik[2,3,12,13,‡]

https://arxiv.org/pdf/2108.11362.pdf
26 agosto

Near Term Algorithms for Linear Systems of Equations

Aidan Pellow-Jarman,[1,*] Ilya Sinayskiy,[2,3,†] Anban Pillay,[1,4,‡] and Francesco Petruccione[2,3,§]

[1]*School of Mathematics, Statistics and Computer Science, University of KwaZulu-Natal, Durban, KwaZulu-Natal, 4001, South Africa*
[2]*Quantum Research Group, School of Chemistry and Physics, University of KwaZulu-Natal, Durban, KwaZulu-Natal, 4001, South Africa*
[3]*National Institute for Theoretical and Computational Sciences (NITheCS), South Africa*
[4]*Centre for Artificial Intelligence Research (CAIR), cair.org.za*

Finding solutions to systems of linear equations is a common problem in many areas of science and engineering, with much potential for a speed up on quantum devices. While the Harrow-Hassidim-Lloyd (HHL) quantum algorithm yields up to an exponential speed up over classical algorithms in some cases, it requires a fault tolerant quantum computer, which is unlikely to be available in the near-term. Thus, attention has turned to the investigation of quantum algorithms for noisy intermediate-scale quantum (NISQ) devices where several near-term approaches to solving systems of linear equations have been proposed. This paper focuses on the Variational Quantum Linear Solvers (VQLS), and other closely related methods. This paper makes several contributions that include: the first application of the Evolutionary Ansatz to the VQLS (EAVQLS), the first implementation of the Logical Ansatz VQLS (LAVQLS), based on the Classical Combination of Quantum States (CQS) method , the first proof of principle demonstration of the CQS method on real quantum hardware and a method for the implementation of the Adiabatic Ansatz (AAVQLS). These approaches are implemented and contrasted.

In this paper a few approaches to solving systems of linear equations on near-term quantum hardware have been presented. Each approach that differs from the standard VQLS approach tries to offer some advantage over the standard approach, however whether the proposed advantages of these algorithms actually apply in implementation is yet to be conclusively seen. Some potential problems with these approaches have been highlighted and it is left to a future work to investigate the realistic advantages of these approaches. It may be the case that some of these approaches offer significant advantages over the standard VQLS approach, however this is still unclear.

Review de NISQ: https://arxiv.org/pdf/2101.08448.pdf (21/01/2021)

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Numerical Security Proof for Decoy-State BB84 and Measurement-Device-Independent QKD Resistant against Large Basis Misalignment

Wenyuan Wang[1] and Norbert Lütkenhaus[1]

[1] *Institute for Quantum Computing and Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1*

(Dated: August 26, 2021)

In this work, we incorporate decoy-state analysis into a well-established numerical framework for key rate calculation, and apply the numerical framework to decoy-state BB84 and measurement-device-independent (MDI) QKD protocols as examples. Additionally, we combine with these decoy-state protocols what is called "fine-grained statistics", which is a variation of existing QKD protocols that makes use of originally discarded data to get a better key rate. We show that such variations can grant protocols resilience against any unknown and slowly changing rotation along one axis, similar to reference-frame-independent QKD, but without the need for encoding physically in an additional rotation-invariant basis. Such an analysis can easily be applied to existing systems, or even data already recorded in previous experiments, to gain significantly higher key rate when considerable misalignment is present, extending the maximum distance for BB84 and MDI-QKD and reducing the need for manual alignment in an experiment.

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One limitation in the previous works is that the numerical approach has not yet been combined with the established technique of decoy states. Most of the applications above consider only single photon sources, except

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misalignment is present, extending the maximum distance for BB84 and MDI-
the need for manual alignment in an experiment.

Quantum Key Distribution (QKD) [1] can provide information-theoretic security between two communicating parties, Alice and Bob. Until recently, a new proof had to be derived for each new type of protocol or new side channel considered.

In Refs. [2, 3], a novel numerical framework has been proposed that can take in a universal set of descriptions for a protocol and the simulated/experimental data from a quantum channel, and numerically bound the key rate with a streamlined algorithm. Such a numerical framework has the great advantage of being able to use a common algorithm to calculate the key rate for various protocols, thus avoiding specialized approaches that work only for each particular setting. The streamlined approach also makes it easier to apply finite-size analysis to protocols. The numerical framework has been successfully applied to various protocols such as BB84, measurement-device-independent (MDI) QKD, three-state protocol, discrete-modulated continuous variable (CV) QKD, and side channels such as unbalanced phase-encoding and detector efficiency mismatch in BB84 [2–5]. The finite-size analysis for the framework is demonstrated in Ref. [6].

Numerical Security Proof for Decoy-State BB84 and Measurement-Device-Independent QKD Resistant against Large Basis Misalignment

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(Dated: August 26, 2021)

In this work, we incorporate decoy-state analysis into a well-established numerical framework for key rate calculation, and apply the numerical framework to decoy-state BB84 and measurement-device-independent (MDI) QKD protocols as examples. Additionally, we combine with these decoy-state protocols what is called "fine-grained statistics", which is a variation of existing QKD protocols that makes use of originally discarded data to get a better key rate. We show that such variations can grant protocols resilience against any unknown and slowly changing rotation along one axis, similar to reference-frame-independent QKD, but without the need for encod rotation-invariant basis. Such an analysis can easily be applied to already recorded in previous experiments, to gain significantly high misalignment is present, extending the maximum distance for BB the need for manual alignment in an experiment.

The second aspect of our work is the use of what is called "fine-grained statistics" in the numerical framework. This is a technique where Alice and Bob use the full set of detector click data, including the cross-basis events where they chose different bases (which are often discarded) in the security analysis, to better characterize the channel and get higher key rate. This is rather natural for a numerical approach, because it treats all observed data as constraints in an optimization problem, and adding more constraints to the same problem simply helps us get a tighter bound on the key rate, without requiring any modifications to the security proof framework. The technique has previously been applied

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University of Waterloo, Waterloo, Ont

(Dated: August 26, 2

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Note that for this approach, there are two important limitations so far: (1) Similar to RFI-QKD, here we have to assume that the misalignment angle is only slowly drifting and not quickly changing with time (such that a constant rotation angle can be assumed); (2) the analysis in this work works only for the asymptotic (infinite data) regime, and combing decoy states with the finite-size analysis [6] in the numerical framework will be the subject of future works.

Quantum frequency conversion of vacuum squeezed light to bright tunable blue squeezed light and higher-order spatial modes

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Quantum frequency conversion, the process of shifting the frequency of an optical quantum state while preserving quantum coherence, can be used to produce non-classical light at otherwise unapproachable wavelengths. We present experimental results based on highly efficient sum-frequency generation (SFG) between a vacuum squeezed state at 1064 nm and a tunable pump source at 850 nm $\pm$ 50 nm for the generation of bright squeezed light at 472 nm $\pm$ 4 nm, currently limited by the phase-matching of the used nonlinear crystal. We demonstrate that the SFG process conserves part of the quantum coherence as a 4.2($\pm$0.2) dB 1064 nm vacuum squeezed state is converted to a 1.6($\pm$0.2) dB tunable bright blue squeezed state. We furthermore demonstrate simultaneous frequency- and spatial-mode conversion of the 1064-nm vacuum squeezed state, and measure 1.1($\pm$0.2) dB and 0.4($\pm$0.2) dB of squeezing in the TEM_{01} and TEM_{02} modes, respectively. With further development, we foresee that the source may find use within fields such as sensing, metrology, spectroscopy, and imaging.

New bounds on adaptive quantum metrology under Markovian noise

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We analyse the problem of estimating a scalar parameter g that controls the Hamiltonian of a quantum system subject to Markovian noise. Specifically, we place bounds on the growth rate of the quantum Fisher information with respect to g, in terms of the Lindblad operators and the g-derivative of the Hamiltonian H. Our new bounds are not only more generally applicable than those in the literature—for example, they apply to systems with time-dependent Hamiltonians and/or Lindblad operators, and to infinite-dimensional systems such as oscillators—but are also tighter in the settings where previous bounds do apply. We derive our bounds directly from the stochastic master equation describing the system, without needing to discretise its time evolution. We also use our results to investigate how sensitive a single detection system can be to signals with different time dependences. We demonstrate that the sensitivity bandwidth is related to the quantum fluctuations of $\partial H/\partial g$, illustrating how 'non-classical' states can enhance the range of signals that a system is sensitive to, even when they cannot increase its peak sensitivi

We arrive at our bounds using different methods from those in prior work. Unlike previous analyses, our derivation does not rely on discretising the time evolution of the system. Instead, we use symmetric logarithmic derivatives to directly bound the time derivative of the QFI starting from the SME, enabling a fully time-dependent treatment. We compare our results in detail to existing bounds, showing that ours are tighter even in the restricted settings where the latter apply.