Quantum Technologies within INFN: status and perspectives

Monday, 20 January 2020 - Tuesday, 21 January 2020

Padova - Università degli Studi, Palazzo del Bo'

Book of Abstracts

Contents

Session I / 11

Theoretical foundations of Quantum Information

Corresponding Author: dariano@unipv.it

Session I / 12

Quantum computation and simulation and their application to High Energy Physics.

Session I / 21

Quantum metrology, sensing & imaging

Session I / 13

Status and perspectives of Quantum Sensing in Particle Physics

Session I / 14

Ion beam techniques for the development of solid-state quantum devices

Session I / 15

Satellite Quantum Communication

Corresponding Author: paolo.villoresi@pd.infn.it

Session I / 46

Theoretical Foundations of Quantum Information

Authors: Giacomo Mauro D'Ariano[1]; QUit group[None]

[1] *University of Pavia*

Corresponding Author: giacomo.dariano@unipv.it

The talk is divided in three short sections:
1) A practical application: quantum tomography in x-ray medical apparata (project founded by CERN based on
2) A theoretical tool: the "quantum comb" (general method for optimisation of quantum circuits, algorithms, protocols, …)
3) New foundations: "Information"as a paradigm for Quantum Theory and Quantum Field Theory.

Session I / 50

Ion beam techniques for the development of solid-state quantum devices

Author: Jan Meijer[1]

[1] *University Leipzig*

Corresponding Author: jan.meijer@uni-leipzig.de

The second quantum mechanical revolution is based on the manipulation and control of single or coupled quantum systems called qubits.The negatively charged NV centers based on the nitrogen atom and a vacancy in diamond is one of these solid state qubits at room temperature. Ion implantation is the only way to generate and address NV centers in diamond with high lateral resolution. Recently, we have found that additional sulfur implantation in diamond solves this problem and increase the creation yield of shallow implanted NVs from 7% to 80%, all NV centers are negatively charged and furthermore the method increases the coherence time of the NVs by a factor of 20.
The talk will discuss the state of the art of single-ion nano-implantation techniques and new developments in materials science to overcome the limitations encountered in the construction of NV centers so far.

Session I / 31

Optical quantum metrology sensing & imaging

Author: marco genovese[1]

[1] *INRIM*

Corresponding Author: m.genovese@inrim.it

In the last years the specific properties of quantum states (as entanglement), for long time considered as peculiarities discussed by the restricted community of physicists interested in the foundations of quantum mechanics, became a fundamental resource for the development of new technologies (as quantum communication, computation and imaging), collectively dubbed "quantum technologies" .

In this talk, after a generic introduction, I will introduce in details the new possibilities in imaging and sensing offered by quantum measurements in optical domain. In particular I will discuss the opportunities provided by photon number correlated states: quantum imaging & sensing based on photon correlated states (as ghost and sub shot noise imaging, quantum illumination,⋯), quantum enhanced correlation interferometry (with particular concern to quantum improvements of the holometer, addressed to search for quantum gravity effects), …

Session II / 16

The SIQUST project

Corresponding Author: forneris@to.infn.it

Session II / 17

The SECRET project

Corresponding Author: giuseppe.vallone@pd.infn.it

Session II / 18

The PACE-IN project

Corresponding Author: paolo.facchi@ba.infn.it

Session II / 19

The QuICHE project

Corresponding Author: chiara@unipv.it

Session II / 20

The Qu3D project

Corresponding Author: milena.dangelo@ba.infn.it

Session II / 37

The QuantHEP project

Corresponding Author: elisa.ercolessi@bo.infn.it

Session II / 53

The SECRET project

Authors: Giuseppe Vallone[1]; Paolo Villoresi[2]

[1] *PD*

[2] *Università and INFN Padova*

Corresponding Author: giuseppe.vallone@pd.infn.it

One popular way to realize quantum communication protocols is through energy-time entanglement (and its synchronized version, called time-bin), since it is robust to environmental disturbances during optical fiber propagation. However, most experiments based on this type of entanglement have an inherent flaw, called the post-selection loophole, which compromises security unless extra assumptions are taken. The members of the SECRET consortium have considerable experience in proposing and realising schemes of entanglement demonstration without the post-selection loophole. The aim of SECRET is to move post-selection loophole-free energy-time/time-bin entanglement towards practical applications such as quantum cryptography, as well as aim towards the building blocks of the Quantum Internet, such as quantum relays.

Session II / **22**

Qu3D - Quantum 3D imaging at high speed and high resolution

Author: Milena D'Angelo[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: milena.dangelo@ba.infn.it

Qu3D aims at designing and implementing quantum plenoptic cameras: radically novel 3D imaging devices exploiting both momentum-position entanglement and photon-number correlations to enable the typical refocusing and ultra-fast, scanning-free, 3D imaging capabilities of plenoptic devices, but with dramatically enhanced performances.
Qu3D merges scientific research and engineering for optimizing the performances of the developed devices in terms of resolution, DOF, noise, and, most challenging, acquisition and elaboration speed. Key elements are world-class single-photon sensor arrays, as well as methods and algorithms for data acquisition, elaboration and analysis inspired by machine learning, compressive sensing, and quantum tomography, combined with high-performance low-level programming of fast computing platforms.

Session II / **30**

The QuantHEP project

Author: Elisa Ercolessi[1]

Co-authors: Simone Montangero [2]; Paolo Facchi [3]

[1] *BO*

[2] *Univ. di Padova*

[3] *BA*

Corresponding Author: elisa.ercolessi@bo.infn.it

The goal of the project QuantHEP (Quantum Computing Solutions for High-Energy Physics) is to investigate the potential of quantum computation for particle-physics challenges, as a solution to the formidable problem of analysing and simulating events from experiments of high-energy particles. To deal with such challenges a multidisciplinary approach is essential, spanning from quantum analog and digital computing and quantum simulation to both theoretical and experimental high-energy physics.
QuantHEP aims at developing quantum algorithms for event selection and reconstruction, using them to perform proof-of-principle analysis of real data from CERN. We will also develop software

libraries to simulate particle physics'objects, as building blocks for the quantum simulation of scattering processes. Finally, the project has a foundational character, putting forward an original comprehensive approach to investigate the potential of quantum computation for particle physics challenges.

Session II / 52

The PACE-IN project

Author: Paolo Facchi[1]

[1] *BA*

Corresponding Author: paolo.facchi@ba.infn.it

Photon-Atom Cooperative Effects at Interfaces

Functional devices for quantum information processing and communication must make use of appropriate matter-light interfaces. Their key role in bringing quantum devices towards practical applications is essential. Hence, building the conceptual and technological base for such interfaces will pave the way for the scalable quantum computation and quantum Internet.
The overall objective of this project is to meet the critical challenge of studying, implementing and optimizing ground-breaking, dynamically-controlled interfaces between matter and light, for the successful implementation of scalable quantum technologies in combination with long distance quantum communication.

CONSORTIUM
Coordinator: *Robin Kaiser* (CNRS, FR)
Paolo Facchi (INFN, IT)
Gershon Kurizki (Weizmann Institute Science, IL)
David Petrosyan (FORTH, GR)
Helmut Ritsch (Universitaet Innsbruck, AT)
Lukáš Slodička (Palacký University Olomouc, CZ)

Session II / 54

Quantum information and communication with high-dimensional encoding: the QuICHE project

Author: Chiara Macchiavello[1]

[1] *University of Pavia*

Corresponding Author: chiara.macchiavello@unipv.it

High-dimensional photonic quantum information promises considerable advantages compared to the two-dimensional qubit paradigm, from increased quantum communication rates to increased robustness for entanglement distribution. The QuICHE project aims to unlock the potential of high-dimensional quantum technology by encoding information in the spectral-temporal degrees of freedom of light. In this project matched experimental tools and theoretical architectures for manipulating and characterizing such states will be developed, and their use in applications will be demonstrated, providing a unified platform for high-dimensional optical quantum information processing, communication, and sensing.

Session III / 58

Quantum Information Transfer in Positronium Annihilation

Corresponding Author: sebastiano.mariazzi@unitn.it

Session III / 59

DEMETRA: DEcoherence Mitigation through EnvironmenTal Radioactivity Abatement

Corresponding Author: laura.cardani@roma1.infn.it

Session III / 60

Quasi-Instantaneous online trigger based on optical neural network

Session III / 61

Quantum Computation of Thermal Averages in the Presence of a Sign Problem

Corresponding Author: marco.cardinali@pi.infn.it

Session III / 62

Certification of multiphoton experiments/Engineering and characterization of structured light

Corresponding Author: alessia.suprano@uniroma1.it

Session III / 63

Quantum noise reduction in the interferometric gravitational wave detector Virgo/EPR experiment for gravitational wave detectors

Corresponding Authors: zendri@pd.infn.it, valeria.sequino@roma2.infn.it

Session III / 64

Nanowires quantum detectors

Corresponding Author: vittorio.bellani@unipv.it

Session III / 65

Magnetic sensing with laser-synthesized nanodiamonds

Corresponding Author: antonio.miotello@unitn.it

Session III / 66

A macroscopically extended coherent state in Er:YSO

Corresponding Author: caterina.braggio@pd.infn.it

Session III / 67

Implantation of silicon-vacancy single-photon emitters at the Tandetron accelerator of INFN Florence for application in quantum technologies

Corresponding Author: stefano.lagomarsino@roma1.infn.it

Session III / 68

”PHOS4BRAIN: Design and operation of Silicon Photonics optical links, as enabling technology for quantum communications

Corresponding Author: gabriele.ciarpi@ing.unipi.it

Session III / 69

Use of silicon photonic integrated circuits in quantum computing applications

Corresponding Author: andrea.salamon@roma2.infn.it

Session III / 70

The SIMP project

Corresponding Author: claudio.gatti@lnf.infn.it

Session III / 71

Optimal Control for the Quantum Simulation of Nuclear Dynamics

Corresponding Author: pederiva@science.unitn.it

Session III / 72

Optical links for atomic gravity sensors

Corresponding Author: fiodor.sorrentino@ge.infn.it

Session III / 73

Bell inequalities violation by entangled single photon states generated from a laser, a led, or a halogen lamp

Corresponding Author: valter.moretti@unitn.it

Session III / 4

DEMETRA: DEcoherence Mitigation through EnvironmenTal Radioactivity Abatement

Author: Laura Cardani[1]

[1] *ROMA1*

Corresponding Author: laura.cardani@roma1.infn.it

Superconducting circuits are emerging as leading candidates for qubits as they offer fast gate times and high fidelity, and because of their simple design and fabrication. The current limit of superconducting circuits is their poor coherence time. This value, today on the order of hundreds of μs, should be improved to a few milliseconds for an efficient quantum processor.
The DEMETRA project, funded by an INFN starting grant, tackles a too-long neglected source of decoherence: radioactivity. Cosmic rays, but also the decay products of the radioactive contaminations in the laboratory environment, can release energy in the qubit destroying its coherence. Radioactivity can also limit the potential of quantum error correction, which relies on the assumption that the qubits deposited on the same substrate are not affected by correlated errors. In this contribution we present the first measurements preformed operating superconducting circuits in the underground Laboratories of Gran Sasso.

Session III / 5

Nanowires quantum detectors

Authors: Vittorio Bellani[1]; Andrea Marini[2]; Francesco Rossella[3]

[1] *Department of Physics, University of Pavia & INFN*

[2] *Department of Physical and Chemical Sciences, University of L'Aquila & INFN*

[3] *NEST, Scuola Normale Superiore, CNR Nano & INFN*

Corresponding Author: vittorio.bellani@unipv.it

In recent years semiconductor nanowires (NWs) for quantum technologies have been raising great interest, due to the development of quantum devices and detectors. Among them InAs and InAs-GaSb core shell NWs are of special interest as they are shown to be suitable as sensors, with applications in domains as detectors of radiation [1,2] and of chemical species [3], and can readily be fabricated within current nano- processing technologies. In last years our teams have been fabricating and studying, with experiments and theoretical analysis, the functioning and response of these detectors and sensors. I will present some results of our research [1-3].

1. V. Demontis et al, Sensors 19, 2994 (2019).
2. M. Rocci et al., Nano letters 16 (12), 7950 (2016).
3. F. Floris et al., Materials 12, 3572 (2019).

Session III / 7

Magnetic sensing with laser-synthesized nanodiamonds

Authors: Luca Basso[1]; Nicola Bazzanella[1]; Massimo Cazzanelli[1]; Enrico Moser[1]; Antonio Miotello[1]

[1] *Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy*

Corresponding Author: antonio.miotello@unitn.it

Nitrogen-vacancy (NV)-doped nanodiamonds (NDs) have applications in quantum-sensing of temperature and magnetic fields. We succeded in ns laser-synthesis,from graphite, of fluorescent NV-NDs w/o any post-process activation as opposed to current production techniques. Proof of NDs formation is given by SAED, SEM and Raman spectroscopy. NV centers are probed by spectrally-resolved Optically Detected Magnetic Resonance. A thermodynamic model was developed to explain NDs formation under ns laser ablation. Advanced room-T opto-magnetic sensing properties of our NDs are reported.
1. M. Cazzanelli, L. Basso, E. Moser, N. Bazzanella, and A. Miotello. Subm. Nanoletters (2019)
2. L. Basso, N. Bazzanella, M. Cazzanelli, and A. Miotello.Carbon 153, 148 (2019).
3. L. Basso, F. Gorrini, M. Cazzanelli, N. Bazzanella, A. Bifone, and A. Miotello, Nanoscale 10, 5738 (2018).
4. L. Basso, F. Gorrini, N. Bazzanella, M. Cazzanelli, C. Dorigoni, A. Bifone, and A. Miotello,Appl. Phys. A 124, 72 (2018).

Session III / 9

Quantum Information Transfer in Positronium Annihilation

Authors: Sebastiano Mariazzi[1]; Ruggero Caravita[2]; Luca Povolo[3]; Luca Penasa[4]; Giancarlo Nebbia[5]; Roberto Sennen Brusa[6]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *CERN*

[3] *University of Trento-TIFPA*

[4] *University of Trento_TIFPA*

[5] *PD*

[6] *TN*

Corresponding Author: sebastiano.mariazzi@unitn.it

We are forming a network of labs under the QUITPA (Quantum Information Transfer in Positronium Annihilation) acronym, to study quantum information transfer in positronium (Ps: bound state e+ e-) decay.
The pioneering study of correlation between the quantum numbers of Ps and theory-predicted entanglement of the polarization of its annihilation γs will be performed.
Present groups:
-Antimatter, Uni-Trento-TIFPA: e+/Ps physics
-J-PET, Jagiellonian Uni-Cracow: γ detectors
-INFN-PD: γ detectors
-Quantum, Uni-Vienna, quantum theory
The experiment requires:
-a cold Ps beam on 23S long lived level with laser-selected magnetic quantum number
-determine the polarization of Ps annihilation γs via detection of primary and scattered Compton γs
-compare the measurements with theory predictions.
Details about the project are given enlightening issues as the detector design and the selection of the Ps magnetic quantum number. Impact on different fields (QI, Astrophysics, Med., CPT) are discussed.

Session III / 10

Quasi-Instantaneous online trigger based on optical neural network

Author: Daniele Sanvitto[1]

[1] *CNRNANOTEC, Institute of Nanotechnology*

Corresponding Author: dsanvitto@gmail.com

The trend in particle physics experiment is to move the off-line analysis to real-time analysis and even to first-level trigger. The most powerful approach would be an hardware implement of machine learning techniques. Nowadays, this goal is limited by the computing power, power consumption and processing speed of traditional computing elements.
A novel approach is to use a neural network based on highly-nonlinear optical nodes to implement in real-time the necessary first-level trigger algorithms. Here we propose to develop an hardware implementation of machine learning techniques for nuclear physics experiments based on a lattices of exciton-polariton condensates which already proved to be able to out perform any previous hardware implementation.

Session III / 28

A macroscopically extended coherent state in Er:YSO

Author: Caterina Braggio[1]

Co-authors: Federico Chiossi [2]; Giovanni Carugno [1]; Antonello Ortolan [3]; Giuseppe Ruoso [3]

[1] *PD*

[2] *P*

[3] *LNL*

Corresponding Author: caterina.braggio@pd.infn.it

Various ways to modify the absorption and emission rates of atoms or molecules have been sought in the field of quantum optics for applications such as metrology, light energy harvesting and quantum information processing.
A promising approach is based on the correlated decay of emitters (Dicke's superradiance), which can also take place in large atomic samples, including through the spontaneous formation of a macroscopic dipole, the so-called superfluorescence (SF).
We will report about realisation of SF in a solid state system, whose remarkable parameters make it an ideal test bed for quantum optics effects. In particular, this physical system might be used to test super-absorption, the conceptual counterpart of the enhanced emission process observed in our laboratory, paving the way to weak signal (photon and particle) sensing.

Session III / 29

PHOS4BRAIN: Design and operation of Silicon Photonics optical links, as enabling technology for quantum communications

Authors: Fabrizio Palla[1]; Guido Magazzu'[1]; Simone Cammarata[2]; Sergio Saponara[3]; Gabriele Ciarpi[3]; Fabrizio Di Pasquale[4]; Stefano Faralli[5]; Velha Philippe[5]; Marco Grazzini[6]; Francois Vasey[None]; Carmelo Scarcella[7]; Jan Troska[7]; Andrea Kraxner[7]

[1] *PI*

[2] *University of Pisa*

[3] *DII*

[4] *Scuola Superiore S. Anna*

[5] *Scuola S. Anna Pisa*

[6] *Università di Pisa*

[7] *CERN*

Corresponding Authors: fabrizio.palla@pi.infn.it, guido.magazzu@pi.infn.it, cammarata.simone@yahoo.it, s.saponara@gmail.com, gabriele.ciarpi@ing.unipi.it

Silicon-photonic design capability is useful in implementing quantum communication apparata, where light-based data transfer is envisioned, or for quantum key distribution in quantum cryptography.
To this aim, PHOS4BRAIN is a project funded by INFN CSN5 to design and operate high-speed radiation hard links using Photonic Integrated circuits (PIC): custom-designed Mach-Zehnder Modulators (MZM) have been shown able to withstand NIEL up to 1E16 n/cm2 and doses of ~1 Grad. Key to the exploitation of this technology is the ability to drive the MZM with suitable electronic circuits. A driver chip has been fabricated in 2019, in TSMC 65 nm and successfully operated, with single ended amplitude of 1.2 V and bandwidth of 3.5 GHz. After 800 Mrad the output voltage dropped by 25%. Used to drive a MZM and Ring Resonators (RR) shows a 3 dB bandwidth of about 2 GHz.
We are now co-designing a PIC with MZM and RR in ISIPP50g technology and a new driver in TSMC 28 nm targeting 12 GHz, due in 2020.

Session III / 32

The SIMP project

Author: Claudio Gatti[1]

[1] *LNF*

Corresponding Author: claudio.gatti@lnf.infn.it

New technologies and skills are needed to face future challenges of fundamental physics, ranging from understanding the nature of Dark Matter to fundamental problems of Quantum Field Theory. The low-mass frontier of Dark Matter, the measurement of the neutrino mass, the search for new light bosons in laboratory experiments, all require detectors sensitive to excitations of meV or smaller. The project objective is the development of SIngle Microwave Photon (SIMP) sensors to strenghten INFN skills and technologies for facing these challenges.

The SIMP Project, a collaboration among researchers of INFN, CNR, FBK and INRIM, proposes two solutions for photodetectors:
1. Current Biased Josephson Junction (10-50 GHz)
2. Transition Edge Sensor (30-100 GHz)
We will discuss the solutions identified to develop the sensors, outline the program for the next years, and report the progress made during the first year of activity.

Session III / 36

Quantum Computation of Thermal Averages in the Presence of a Sign Problem

Authors: Giuseppe Clemente[1]; Marco Cardinali[2]; Claudio Bonati[1]; Enrico Calore[3]; Leonardo Cosmai[4]; Massimo D'Elia[1]; Alessandro Gabbana[5]; Davide Rossini[1]; Sebastiano Schifano[3]; Raffaele Tripiccione[3]; davide vadacchino[6]

[1] *PI*

[2] *Istituto Nazionale di Fisica Nucleare*

[3] *FE*

[4] *BA*

[5] *University of Ferrara*

[6] *INFN Sezione di Pisa*

Corresponding Author: marco.cardinali@pi.infn.it

We illustrate the application of Quantum Computing techniques to the investigation of the thermodynamical properties of a simple system, made up of three
quantum spins with frustrated pair interactions and affected by a hard sign problem
when treated within classical computational schemes.
We show how quantum algorithms completely solve the problem, and discuss how
this can apply to more complex systems of physical interest.

Session III / 41

Use of silicon photonic integrated circuits in quantum computing applications

Authors: Roberto Ammendola[1]; Carmine Attanasio[2]; Davide Badoni[1]; Vincenzo Bonaiuto[3]; Mauro Casalboni[3]; Fabio De Matteis[4]; Giovanni Di Giuseppe[5]; Roberto Francini[3]; Luca Frontini[6]; Roberto Gunnella[5]; Valentino Liberali[6]; Paolo Prosposito[7]; Andrea Salamon[1]; Gaetano Salina[1]; Matteo Salvato[3]; Mattia Scagliotti[3]; Fausto Sargeni[8]; Seyedruhollah Shojaii[9]; Alberto Stabile[6]; Gabriella Trucco[10]

[1] *ROMA2*

[2] *Università degli Studi di Salerno*

[3] *Università degli Studi di Roma Tor Vergata*

[4] *Universita' degli Studi di Roma Tor Vergata*

[5] *Università degli Studi di Camerino*

[6] *MI*

[7] *Industrial Engineering Department University of Rome Tor Vergata*

[8] *mattia.scagliotti@roma2.infn.it*

[9] *University of Melbourne*

[10] *Università degli Studi di Milano*

Corresponding Author: andrea.salamon@roma2.infn.it

The idea of using a quantum system to simulate another quantum system was proposed by R.P Feynman at the beginning of 80's. Since then many theoretical and experimental discoveries (e.g. Shor's algorithm, KLM scheme) followed, giving the birth to quantum information processing science.
Photons are one of the preferred vehicles to implement quantum logic gates and many examples of discrete components linear optics quantum computing devices have been realized.
Silicon photonics offers the possibility to implement linear optics quantum gates in a single integrated circuit. Given its high refractive index and low dispersion, silicon represents a high quality material for light guiding devices.
Two INFN experiments on silicon photonics in collaboration with IHP foundry have been funded by CSN5 (SPE in 2017-2019 and QUICHE in 2020).
We discuss the proposal of a quantum information processing silicon photonic integrated circuit working within ITU C-band (1550 nm).

Session III / 44

Optimal Control for the Quantum Simulation of Nuclear Dynamics

Author: Francesco Pederiva[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: francesco.pederiva@unitn.it

The standard model of quantum computation aims to approximate an arbitrary unitary transformation using a universal set of quantum gates. While this approach has the advantage to detach the development of algorithms from a specific hardware implementation, it might still be quite impractical in the NISQ technology era. The Quantum Coherent Device group at LLNL is developing a quantum computing facility based on coupling resonating cavities to a superconductive transmon in which multi-state qudits are driven by an external fine-tuned pulse in order to implement an arbitrary unitary transformation as a single gate. A first application of this concept to the study of time propagation of spin states of two neutrons interacting via a realistic Hamiltonian including one-pion-exchange effects will be introduced. Results obtained with a device simulator including noise as characterized from measurements on the actual qudits will be presented.

Session III / 51

Optical links for atomic gravity sensors

Author: Fiodor Sorrentino[1]

[1] *GE*

Corresponding Author: fiodor.sorrentino@ge.infn.it

Atomic gravimeters are the most precise absolute gravity sensors. A main feature of atom interferometers is the ability to perform differential measurements, in gradiometric configuration, with almost perfect suppression of vibration noise. So far this has been achieved on baselines of the order of the meter. By combining optical metrology and atom optics methods, the OLAGS program will develop coherent optical links between atomic sensors over long distances, to increase the sensitivity to gravitational gradient and its temporal variations. Long baseline differential gravity measurements can find application in the search for Dark Matter from ultralight fields and in the detection of Gravitational Waves. The detection of gravitational anomalies, combined with precise soil displacement measurements, becomes crucial for the characterization of geophysical phenomena e.g. hydrology of the aquifers, elastic deformation of rocky bodies, migration of magmatic-hydrothermal fluids.

Session III / 40

Certification of multiphoton experiments

Authors: Taira Giordani[1]; Chiara Esposito[1]; Niko Viggianiello[1]; Fulvio Flamini[1]; Marco Romano[1]; Matteo Pompili[1]; Andrea Crespi[2]; Roberto Osellame[2]; Nathan Wiebe[3]; Mattia Walschaers[4]; Andreas Buchleitner[5]; Daniel J. Brod[6]; Ernesto F. Galvão[7]; Gonzalo Carvacho [8]; Nicolò Spagnolo[1]; Fabio Sciarrino[1]

[1] *Dipartimento di Fisica, Sapienza Università di Roma*

[2] *Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche (IFN-CNR), Milano, Italy.*

[3] *Station Q Quantum Architectures and Computation Group, Microsoft Research, Redmond, WA, USA*

[4] *5 Laboratoire Kastler Brossel, Sorbonne Universités, CNRS, ENS-PSL Research University, Collège de France*

[5] *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany*

[6] *Instituto de Fisica, Universidade Federal Fluminense*

[7] *Instituto de Fisica, Universidade Federal Fluminense*

[8] *Dipartimento di Fisica, Sapienza Univrsità di Roma*

Corresponding Author: taira.giordani@uniroma1.it

Recently, single-photon states have been extensively employed as information carriers in several quantum information protocols. In this framework multiphoton interference plays a crucial role for the hardness of simulating bosons statistics, thus preventing a direct verification of multiphoton experiments. The latest results on Boson Sampling make available multiphoton states up to 20 photons. Finding efficient techniques for assessing the presence of multiphoton interference is thus highly desirable. Here we present two strategies for the certification of multiphoton experiments. In the first method a suitable design of simultaneous Hon-Ou-Mandel tests, very well-known methods in quantum optics, enables to quantify photon indistinguishability in states produced by a single-photon source. The second technique finds signatures of multiphoton interference from the statistical properties of two-mode correlation functions retrieved by photons distributions in the output of a boson sampler.

Session III / 42

Quantum noise reduction in the interferometric gravitational wave detector Virgo

Author: Jean-Pierre Zendri[1]

[1] *INFN*

Corresponding Author: zendri@pd.infn.it

The methods currently used and the results achieved in Virgo for the reduction of the quantum shot noise through the use of frequency-independent squeezed light sources will be reviewed. In the second part of the presentation it will be described the ongoing R&D activity aimed for the realization of a frequency dependent squeezed light source for Advanced Virgo Plus. The use of this source should allow, starting from the next scientific run, to obtain a reduction of the detector quantum noise on the whole detection band.

Session III / **57**

BELL INEQUALITY VIOLATION BY ENTANGLED SINGLE PHOTON STATES GENERATED FROM A LASER, A LED , OR A HALOGEN LAMP

Authors: N Leone[1]; M Pasini[1]; Stefano Azzini[1]; L Pavesi[1]; S Mazzucchi[2]; V Moretti[2]; D Pastorello[2]

[1] *University of Trento - Department of Physics*

[2] *University of Trento - Department of Mathematics*

We present an experiment regarding the CHSH inequality violation by single photons, thus concerning the failure of contextuality instead of locality in quantum physics. Single photons are generated by different sources (Laser, led and a halogen lamp). This experiment proves that it is possible to continuously pass from a quantum description of CHSH inequality violation, where violation implies no classical non-contextual description, to a completely classical description where CHSH are violated in terms of classical intensities.The crucial difference regards the possibility to count single photons. The results of the experiment can have applications in the implementation and certification of quantum random number generators (QRNG) and to increase the security of QKD protocols. Our results confine the need of expensive sources of single photons, e.g. heralded photons, to those Quantum Information protocols that require a deterministic time of arrivals of the single photons.

Session III / **26**

Implantation of silicon-vacancy single-photon emitters at the Tandetron accelerator of INFN Florence for application in quantum technologies

Authors: Stefano Lagomarsino[1]; Silvio Sciortino[1]; Assegid M. Flatae[2]; Nicla Gelli[1]; Lorenzo Giuntini[3]; Massimo Chiari[3]; Francesco Taccetti[3]; Mirko Massi[3]; Lukas Hunold[2]; Florian Sledz[4]; Haritha Kambalathmana[5]; Marco Bellini[6]; Chiara Corsi[7]; Mario Santoro[6]; Mario Agio[4]

[1] *INFN, Florence*

[2] *Laboratory of Nano-Optics, University of Siegen*

[3] *INFN Florence*

[4] *Laboratory of nano-optics, University of Siegen.*

[5] *Laboratory of nano-optics, University of Siegen*

[6] *INO Florence*

[7] *LENS Florence*

Corresponding Author: lagomarsino@fi.infn.it

The 3 MV Tandetron accelerator beamline at LABEC (Florence) has been upgraded to ion implantation experiments for fabrication of single-photon emitters. Silicon ions have been implanted in single- and poly-crystalline diamond matrices, in the 0-2.4 μm range of depths (0.2-11 MeV energy), down to the diffraction limit of lateral resolution, over a fluence range of $10^7 - 10^{15}$ cm^{-2}. A furnace operating in high-vacuum (10^{-7} mBar) has been employed to activate negative Silicon-Vacancy

(SiV-) centers with a yield in the order of 3%, while room temperature fs-laser activation experiments are underway. The photoluminescence properties of the SiV centers have been studied from 20 to 800 ℃, including their single-photon emission characteristics. Single-photon emitters have been obtained, exhibiting a short excited-state lifetime (~1 ns), a strong zero-phonon transition with a narrow linewidth (~1.6 nm) and a very small inhomogeneous broadening (0.015 nm).

56

Recapitulation

1

Saluti istituzionali dell'Università degli Studi di Padova e dell'Istituto Nazionale di Fisica Nucleare

2

Discussion and round table