

Quantum Technologies within INFN: status and perspectives



Report of Contributions

Contribution ID: 1

Type: **not specified**

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

Contribution ID: 2

Type: **not specified**

Discussion and round table

Contribution ID: 4

Type: **Contribution from scientific community**

DEMETRA: DEcoherence Mitigation through EnvironmenTal Radioactivity Abatement

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 performed operating superconducting circuits in the underground Laboratories of Gran Sasso.

Primary author: CARDANI, Laura (ROMA1)

Presenter: CARDANI, Laura (ROMA1)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 5

Type: **Contribution from scientific community**

Nanowires quantum detectors

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).

Primary authors: Prof. BELLANI, Vittorio (Department of Physics, University of Pavia & INFN); Dr MARINI, Andrea (Department of Physical and Chemical Sciences, University of L'Aquila & INFN); Dr ROSSELLA, Francesco (NEST, Scuola Normale Superiore, CNR Nano & INFN)

Presenter: Prof. BELLANI, Vittorio (Department of Physics, University of Pavia & INFN)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 7

Type: **Contribution from scientific community**

Magnetic sensing with laser-synthesized nanodiamonds

Nitrogen-vacancy (NV)-doped nanodiamonds (NDs) have applications in quantum-sensing of temperature and magnetic fields. We succeeded 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).

Primary authors: Dr BASSO, Luca (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy); Dr BAZZANELLA, Nicola (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy); Dr CAZZANELLI, Massimo (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy); Dr MOSER, Enrico (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy); Prof. MIOTELLO, Antonio (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy)

Presenter: Prof. MIOTELLO, Antonio (Dipartimento di Fisica, Università degli Studi di Trento, via Sommarive 14, 38123-Povo (TN) Italy)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 9

Type: **Invited talk "successful initiative within INFN"**

Quantum Information Transfer in Positronium Annihilation

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 γ s 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 γ s via detection of primary and scattered Compton γ s
- 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.

Primary authors: MARIAZZI, Sebastiano (Istituto Nazionale di Fisica Nucleare); CARAVITA, Ruggero (CERN); Mr POVOLO, Luca (University of Trento-TIFPA); Mr PENASA, Luca (University of Trento_TIFPA); NEBBIA, Giancarlo (PD); BRUSA, Roberto Sennen (TN)

Presenter: MARIAZZI, Sebastiano (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 10

Type: Invited talk "successful initiative within INFN"

Quasi-Instantaneous online trigger based on optical neural network

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.

Primary author: Dr SANVITTO, Daniele (CNRNANOTEC, Institute of Nanotechnology)

Presenter: Dr SANVITTO, Daniele (CNRNANOTEC, Institute of Nanotechnology)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 11

Type: **Invited keynote talk**

Theoretical foundations of Quantum Information

Monday, 20 January 2020 14:15 (30 minutes)

Presenter: D'ARIANO, Giacomo (PV)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 12

Type: **Invited keynote talk**

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

Monday, 20 January 2020 14:45 (30 minutes)

Presenter: MONTANGERO, Simone (Univ. di Padova)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 13

Type: **Invited keynote talk**

Status and perspectives of Quantum Sensing in Particle Physics

Monday, 20 January 2020 16:15 (30 minutes)

Presenter: GRASSELLINO, Anna (FNAL)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 14

Type: **Invited keynote talk**

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

Monday, 20 January 2020 16:45 (30 minutes)

Presenter: MEJIER, Jan (Leipzig)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 15

Type: **Invited keynote talk**

Satellite Quantum Communication

Monday, 20 January 2020 17:15 (30 minutes)

Presenter: Prof. VILLORESI, Paolo (Università and INFN Padova)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 16

Type: **Invited talk "successful initiative within INFN"**

The SIQUST project

Tuesday, 21 January 2020 09:00 (20 minutes)

Presenter: FORNERIS, Jacopo (INFN Torino, Università di Torino)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 17

Type: **Invited talk "successful initiative within INFN"**

The SECRET project

Tuesday, 21 January 2020 09:20 (20 minutes)

Presenter: VALLONE, Giuseppe (PD)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 18

Type: **Invited talk "successful initiative within INFN"**

The PACE-IN project

Tuesday, 21 January 2020 09:40 (20 minutes)

Presenter: FACCHI, Paolo (BA)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 19

Type: **Invited talk "successful initiative within INFN"**

The QuICHE project

Tuesday, 21 January 2020 10:00 (20 minutes)

Presenter: MACCHIAVELLO, Chiara (P)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 20

Type: **Invited talk "successful initiative within INFN"**

The Qu3D project

Tuesday, 21 January 2020 10:50 (20 minutes)

Presenter: D'ANGELO, Milena (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 21

Type: **Invited keynote talk**

Quantum metrology, sensing & imaging

Monday, 20 January 2020 15:15 (30 minutes)

Presenter: GENOVESE, Marco (INRIM)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 22

Type: **Invited talk "successful initiative within INFN"**

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

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.

Primary author: D'ANGELO, Milena (Istituto Nazionale di Fisica Nucleare)

Presenter: D'ANGELO, Milena (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 26

Type: **Contribution from scientific community**

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

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 $10^7 - 10^{15} \text{ cm}^{-2}$. 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 °C, 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).

Primary authors: Dr LAGOMARSINO, Stefano (INFN, Florence); Prof. SCIORTINO, Silvio (INFN, Florence); Dr FLATAE, Assegid M. (Laboratory of Nano-Optics, University of Siegen); Dr GELLI, Nicla (INFN, Florence); Prof. GIUNTINI, Lorenzo (INFN Florence); Dr CHIARI, Massimo (INFN Florence); Dr TACCETTI, Francesco (INFN Florence); Dr MASSI, Mirko (INFN Florence); Dr HUNOLD, Lukas (Laboratory of Nano-Optics, University of Siegen); Dr SLEDZ, Florian (Laboratory of nano-optics, University of Siegen.); Dr KAMBALATHMANA, Haritha (Laboratory of nano-optics, University of Siegen); Prof. BELLINI, Marco (INO Florence); Dr CORSI, Chiara (LENS Florence); Dr SANTORO, Mario (INO Florence); Prof. AGIO, Mario (Laboratory of nano-optics, University of Siegen.)

Presenter: Dr LAGOMARSINO, Stefano (INFN, Florence)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 28

Type: **Contribution from scientific community**

A macroscopically extended coherent state in Er:YSO

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.

Primary author: BRAGGIO, Caterina (PD)

Co-authors: CHIOSSI, Federico (P); CARUGNO, Giovanni (PD); ORTOLAN, Antonello (LNL); RUOSO, Giuseppe (LNL)

Presenter: BRAGGIO, Caterina (PD)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 29

Type: **Contribution from scientific community**

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

Silicon-photonic design capability is useful in implementing quantum communication apparatus, 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.

Primary authors: PALLA, Fabrizio (PI); MAGAZZU', Guido (PI); CAMMARATA, Simone (University of Pisa); SAPONARA, Sergio (DII); CIARPI, Gabriele (DII); DI PASQUALE, Fabrizio (Scuola Superiore S. Anna); FARALLI, Stefano (Scuola S. Anna Pisa); PHILIPPE, Velha (Scuola S. Anna Pisa); GRAZZINI, Marco (Università di Pisa); VASEY, Francois; SCARCELLA, Carmelo (CERN); TROSKA, Jan (CERN); KRAXNER, Andrea (CERN)

Presenters: PALLA, Fabrizio (PI); MAGAZZU', Guido (PI); CAMMARATA, Simone (University of Pisa); SAPONARA, Sergio (DII); CIARPI, Gabriele (DII)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 30

Type: **Invited talk "successful initiative within INFN"**

The QuantHEP project

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.

Primary author: ERCOLESSI, Elisa (BO)

Co-authors: MONTANGERO, Simone (Univ. di Padova); FACCHI, Paolo (BA)

Presenter: ERCOLESSI, Elisa (BO)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 31

Type: **Invited keynote talk**

Optical quantum metrology sensing & imaging

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), ...

Primary author: GENOVESE, marco (INRIM)

Presenter: GENOVESE, marco (INRIM)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 32

Type: **Contribution from scientific community**

The SIMP project

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 strengthen 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.

Primary author: GATTI, Claudio (LNF)

Presenter: GATTI, Claudio (LNF)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 36

Type: **Contribution from scientific community**

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

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.

Primary authors: CLEMENTE, Giuseppe (PI); CARDINALI, Marco (Istituto Nazionale di Fisica Nucleare); BONATI, Claudio (PI); CALORE, Enrico (FE); COSMAI, Leonardo (BA); D'ELIA, Massimo (PI); GABBANA, Alessandro (University of Ferrara); ROSSINI, Davide (PI); SCHIFANO, Sebastiano (FE); TRIPICCIONE, Raffaele (FE); VADACCHINO, davide (INFN Sezione di Pisa)

Presenter: CARDINALI, Marco (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 37

Type: **Invited talk "successful initiative within INFN"**

The QuantHEP project

Tuesday, 21 January 2020 11:10 (20 minutes)

Presenter: ERCOLESSI, Elisa (BO)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 40

Type: **Contribution from scientific community**

Certification of multiphoton experiments

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 Hong-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.

Primary authors: Ms GIORDANI, Taira (Dipartimento di Fisica, Sapienza Università di Roma); Ms ESPOSITO, Chiara (Dipartimento di Fisica, Sapienza Università di Roma); Dr VIGGIANIELLO, Niko (Dipartimento di Fisica, Sapienza Università di Roma); Dr FLAMINI, Fulvio (Dipartimento di Fisica, Sapienza Università di Roma); Mr ROMANO, Marco (Dipartimento di Fisica, Sapienza Università di Roma); Mr POMPILLI, Matteo (Dipartimento di Fisica, Sapienza Università di Roma); Dr CRESPI, Andrea (Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche (IFN-CNR), Milano, Italy.); Dr OSELLAME, Roberto (Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche (IFN-CNR), Milano, Italy.); Prof. WIEBE, Nathan (Station Q Quantum Architectures and Computation Group, Microsoft Research, Redmond, WA, USA); Dr WALSCHAERS, Mattia (5 Laboratoire Kastler Brossel, Sorbonne Universités, CNRS, ENS-PSL Research University, Collège de France); Prof. BUCHLEITNER, Andreas (Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany); Dr BROD, Daniel J. (Istituto de Fisica, Universidade Federal Fluminense); Prof. GALVÃO, Ernesto F. (Instituto de Fisica, Universidade Federal Fluminense); Dr CARVACHO , Gonzalo (Dipartimento di Fisica, Sapienza Università di Roma); Dr SPAGNOLO, Nicolò (Dipartimento di Fisica, Sapienza Università di Roma); Prof. SCIARRINO, Fabio (Dipartimento di Fisica, Sapienza Università di Roma)

Presenter: Ms GIORDANI, Taira (Dipartimento di Fisica, Sapienza Università di Roma)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 41

Type: **Contribution from scientific community**

Use of silicon photonic integrated circuits in quantum computing applications

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).

Primary authors: AMMENDOLA, Roberto (ROMA2); Prof. ATTANASIO, Carmine (Università degli Studi di Salerno); BADONI, Davide (ROMA2); Prof. BONAIUTO, Vincenzo (Università degli Studi di Roma Tor Vergata); Prof. CASALBONI, Mauro (Università degli Studi di Roma Tor Vergata); DE MATTEIS, Fabio (Università degli Studi di Roma Tor Vergata); Prof. DI GIUSEPPE, Giovanni (Università degli Studi di Camerino); Prof. FRANCINI, Roberto (Università degli Studi di Roma Tor Vergata); FRONTINI, Luca (MI); Prof. GUNNELLA, Roberto (Università degli Studi di Camerino); LIBERALI, Valentino (MI); PROSPPOSITO, Paolo (Industrial Engineering Department University of Rome Tor Vergata); SALAMON, Andrea (ROMA2); SALINA, Gaetano (ROMA2); Dr SALVATO, Matteo (Università degli Studi di Roma Tor Vergata); SCAGLIOTTI, Mattia (Università degli Studi di Roma Tor Vergata); Prof. SARGENI, Fausto (mattia.scagliotti@roma2.infn.it); SHOJAIL, Seyedruhollah (University of Melbourne); STABILE, Alberto (MI); TRUCCO, Gabriella (Università degli Studi di Milano)

Presenter: SALAMON, Andrea (ROMA2)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 42

Type: **Contribution from scientific community**

Quantum noise reduction in the interferometric gravitational wave detector Virgo

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.

Primary author: Dr ZENDRI, Jean-Pierre (INFN)

Presenter: Dr ZENDRI, Jean-Pierre (INFN)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 44

Type: **Contribution from scientific community**

Optimal Control for the Quantum Simulation of Nuclear Dynamics

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.

Primary author: PEDERIVA, Francesco (Istituto Nazionale di Fisica Nucleare)

Presenter: PEDERIVA, Francesco (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 46

Type: **Invited keynote talk**

Theoretical Foundations of Quantum Information

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.

Primary authors: Prof. D’ARIANO, Giacomo Mauro (University of Pavia); QUIT GROUP

Presenter: Prof. D’ARIANO, Giacomo Mauro (University of Pavia)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 50

Type: **Invited keynote talk**

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

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.

Primary author: MEIJER, Jan (University Leipzig)

Presenter: MEIJER, Jan (University Leipzig)

Session Classification: Session I

Track Classification: Keynote talks

Contribution ID: 51

Type: **Contribution from scientific community**

Optical links for atomic gravity sensors

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.

Primary author: SORRENTINO, Fiodor (GE)

Presenter: SORRENTINO, Fiodor (GE)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 52

Type: **Invited talk "successful initiative within INFN"**

The PACE-IN project

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)

Primary author: FACCHI, Paolo (BA)

Presenter: FACCHI, Paolo (BA)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 53

Type: **Invited talk "successful initiative within INFN"**

The SECRET project

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.

Primary authors: VALLONE, Giuseppe (PD); Prof. VILLORESI, Paolo (Università and INFN Padova)

Presenter: VALLONE, Giuseppe (PD)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 54

Type: **Invited talk "successful initiative within INFN"**

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

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.

Primary author: Prof. MACCHIAVELLO, Chiara (University of Pavia)

Presenter: Prof. MACCHIAVELLO, Chiara (University of Pavia)

Session Classification: Session II

Track Classification: Successful initiatives within INFN

Contribution ID: 56

Type: **not specified**

Recapitulation

Contribution ID: 57

Type: **Contribution from scientific community**

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

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.

Primary authors: Dr LEONE, N (University of Trento - Department of Physics); Dr PASINI, M (University of Trento - Department of Physics); Dr AZZINI, Stefano (University of Trento - Department of Physics); Prof. PAVESI, L (University of Trento - Department of Physics); Prof. MAZZUCCHI, S (University of Trento - Department of Mathematics); Prof. MORETTI, V (University of Trento - Department of Mathematics); Prof. PASTORELLO, D (University of Trento - Department of Mathematics)

Presenter: Dr AZZINI, Stefano (University of Trento - Department of Physics)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 58

Type: **Contribution from scientific community**

Quantum Information Transfer in Positronium Annihilation

Tuesday, 21 January 2020 12:30 (15 minutes)

Presenter: MARIAZZI, Sebastiano (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 59

Type: **not specified**

DEMETRA: DEcoherence Mitigation through EnvironmenTal Radioactivity Abatement

Tuesday, 21 January 2020 12:45 (15 minutes)

Presenter: CARDANI, Laura (ROMA1)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: **60**

Type: **not specified**

Quasi-Instantaneous online trigger based on optical neural network

Tuesday, 21 January 2020 14:00 (15 minutes)

Presenter: Dr SANVITTO, Daniele (CNR Nanotec)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 61

Type: **Contribution from scientific community**

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

Tuesday, 21 January 2020 14:15 (15 minutes)

Presenter: CARDINALI, Marco (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 62

Type: **not specified**

Certification of multiphoton experiments/Engineering and characterization of structured light

Tuesday, 21 January 2020 14:30 (20 minutes)

Presenters: SUPRANO, Alessia (Università di Roma "Sapienza"); Mrs GIORDANI, Taira (University of Rome)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 63

Type: **not specified**

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

Tuesday, 21 January 2020 14:50 (20 minutes)

Presenters: ZENDRI, Jean-Pierre (INFN); SEQUINO, Valeria (ROMA2)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 64

Type: **Contribution from scientific community**

Nanowires quantum detectors

Tuesday, 21 January 2020 15:10 (15 minutes)

Presenter: BELLANI, Vittorio (P)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 65

Type: **Contribution from scientific community**

Magnetic sensing with laser-synthesized nanodiamonds

Tuesday, 21 January 2020 15:25 (15 minutes)

Presenter: MIOTELLO, Antonio (Istituto Nazionale di Fisica Nucleare)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 66

Type: **Contribution from scientific community**

A macroscopically extended coherent state in Er:YSO

Tuesday, 21 January 2020 15:40 (15 minutes)

Presenter: BRAGGIO, Caterina (PD)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 67

Type: **Contribution from scientific community**

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

Tuesday, 21 January 2020 16:20 (15 minutes)

Presenter: LAGOMARSINO, Stefano (INFN)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 68

Type: **Contribution from scientific community**

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

Tuesday, 21 January 2020 16:35 (15 minutes)

Presenter: CIARPI, Gabriele (DII)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 69

Type: **Contribution from scientific community**

Use of silicon photonic integrated circuits in quantum computing applications

Tuesday, 21 January 2020 16:50 (15 minutes)

Presenter: SALAMON, Andrea (ROMA2)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 70

Type: **Contribution from scientific community**

The SIMP project

Tuesday, 21 January 2020 17:05 (15 minutes)

Presenter: GATTI, Claudio (LNF)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 71

Type: **Contribution from scientific community**

Optimal Control for the Quantum Simulation of Nuclear Dynamics

Tuesday, 21 January 2020 17:20 (15 minutes)

Presenter: PEDERIVA, Francesco (TIFP)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 72

Type: **Contribution from scientific community**

Optical links for atomic gravity sensors

Tuesday, 21 January 2020 17:35 (15 minutes)

Presenter: SORRENTINO, Fiodor (GE)

Session Classification: Session III

Track Classification: Contributions from the scientific community

Contribution ID: 73

Type: **Contribution from scientific community**

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

Tuesday, 21 January 2020 17:50 (15 minutes)

Presenters: Dr AZZINI, Stefano (University of Trento - Department of Physics); MORETTI, Valter (Università di Trento - Matematica & INFN-TIFPA)

Session Classification: Session III

Track Classification: Contributions from the scientific community