

SPW
2019

SINGLE PHOTON WORKSHOP

Politecnico di Milano
Milan, 21-25 October 2019

Event organized by



POLITECNICO
MILANO 1863

In cooperation with



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Single Photon Workshop 2019

Single Photon Workshop 2019 is the ninth installment in a series of workshops on SINGLE-PHOTON TECHNOLOGIES AND APPLICATIONS. SPW 2019 is intended to bring together a broad range of people with interests in single-photon sources, single-photon detectors, photon entanglement, and their use in scientific and industrial applications. It is an exciting opportunity for those interested in these technologies to learn about the state of the art and to foster continuing partnerships with others seeking to advance the capabilities of such technologies.

The four main areas of the single-photon scientific research and industrial applications are covered by the workshop:

- **Single-Photon Detectors**
Devices, circuits and systems to achieve single-photon sensitivity
- **Single-Photon Sources**
Materials, schemes and architectures to generate and control light emission at single photon level
- **Applications**
Single-photon technologies for scientific and industrial applications, from ground to space, from life science to quantum information processing
- **Metrology**
Validation techniques and instrumentation to prove single-photon generation and acquisition.

About Politecnico di Milano

Politecnico di Milano is a scientific-technological university which trains engineers, architects and industrial designers.

The University has always focused on the quality and innovation of its teaching and research, developing a fruitful relationship with business and productive world by means of experimental research and technological transfer.

Research has always been linked to didactics and it is a priority commitment which has allowed Politecnico Milano to achieve high quality results at an international level as to join the university to the business world. Research constitutes a parallel path to that formed by cooperation and alliances with the industrial system.

Knowing the world in which you are going to work is a vital requirement for training students. By referring back to the needs of the industrial world and public administration, research is facilitated in following new paths and dealing with the need for constant and rapid innovation. The alliance with the industrial world, in many cases favored by Fondazione Politecnico and by consortiums to which Politecnico belong, allows the university to follow the vocation of the territories in which it operates and to be a stimulus for their development.

The challenge which is being met today projects this tradition which is strongly rooted in the territory beyond the borders of the country, in a relationship which is developing first of all at the European level with the objective of contributing to the creation of a single professional training market. Politecnico takes part in several research, sites and training projects collaborating with the most qualified European universities. Politecnico's contribution is increasingly being extended to other countries: from North America to Southeast Asia to Eastern Europe. Today the drive to internationalization sees Politecnico Milano taking part into the European and world network of leading technical universities and it offers several courses beside many which are entirely taught in English.

Scientific Committee

Félix Bussi eres (University of Geneva, Switzerland)
Jessica Cheung (NPL, UK)
Christopher Chunnillall (NPL, UK)
Ivo Pietro Degiovanni (INRIM, Italy)
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Stefan Kueck (PTB, Germany)
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Alan L. Migdall (NIST, USA)
Alberto Tosi (Politecnico di Milano, Italy)
Hugo Zbinden (University of Geneva, Switzerland)

Program Committee

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Franco Zappa (Politecnico di Milano, Italy)
Hugo Zbinden (University of Geneva, Switzerland)

Local Committee

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Angelo Gulinatti (Politecnico di Milano, Italy)
Ivan Rech (Politecnico di Milano, Italy)
Federica Villa (Politecnico di Milano, Italy)
Franco Zappa (Politecnico di Milano, Italy)
Massimo Ghioni (Politecnico di Milano, Italy)

Platinum Sponsors



Gold Sponsors



Silver Sponsors



Venue

Workshop venue

Aula Magna Carassa e Dadda
Politecnico di Milano, Campus Bovisa,
Building BL28,
Via Lambruschini 4, 20156 Milano (MI), Italy

Welcome cocktail

Monday 21st October 2019

Rectorate building at "Leonardo Campus" of Politecnico di Milano.
Piazza Leonardo da Vinci 32, 20133 Milano. Building 1.

How to reach Leonardo Campus

Take Line 2 of the underground railway: MM2 green line.

Get off the train at the PIOLA station.

Take the left-hand exit from Piola station; walk along Via D'Ovidio, keeping to the left and cross Via Bonardi: you will arrive in Piazza Leonardo da Vinci. Politecnico di Milano is facing you.

Conference dinner

Wednesday 23rd October 2019

Castello Sforzesco, Milano.

Castello Sforzesco, Piazza Castello, Milano.

How to reach Castello Sforzesco

From SPW 2019 workshop venue

Walk to "Milano Nord Bovisa" train station and take a train to "Cadorna" station (travel time is 6 minutes).

You need the Biglietto ordinario" of ATM (2 euro).

When exiting the Cadorna station, turn left and walk along Via Marco Minghetti to get to the castle.

Guided tours

Before the conference dinner, guided tours of Castello Sforzesco will be organized (free of charge), including Leonardo's Special.

The year 2019 marks the 500th anniversary of Leonardo da Vinci's death. Milano is the city where Leonardo da Vinci stayed the longest. Here Leonardo arrived in 1482, at the service of Duke Ludovico Sforza, and his presence has left an indelible mark in the history and artistic production of the City and in the entire region of Lombardy.

For this reason, Milano and Lombardy will dedicate a whole year to the Maestro.

More info on SPW website (<https://spw2019.polimi.it>).

Wireless access

- Guest users members of an Eduroam federated entity can access the "eduroam" Wi-Fi network using the credentials provided by their institution of affiliation. The connection will be permanent and encrypted.
- Other guest users will be provided with other Wi-Fi credentials on site.

Important contacts

Emergency telephone number:

112

POLIMI emergency call center:
internal phones)

+39 02 2399 9399 (only 9399 from

e-mails:

spw2019@polimi.it (generic needs)

spw2019-reg@fondazione.polimi.it (registration)

About Milano

With a population of about 1.3 million, Milan, the capital of Lombardy, is located in the Po Valley, not far from the Alps with the great lakes (Lake Como, Lake Maggiore, Lake Lugano) to the North. Milan is considered the Italian economic and finance center, with the headquarters of the Stock Exchange and of many of the most important industrial and financial businesses of the Country. The city hosted the Universal Exposition in 2015 under the theme "Feeding the planet, energy for life".

It is also the Italian symbol of fashion and design: it hosts many of the main Italian fashion maisons and international design fairs, such as "Settimana della Moda" (Milan Fashion Week) and the "Salone Internazionale del Mobile" (Milan Furniture Fair); also, a Design School operates at Politecnico di Milano.

Milan hosts the "Teatro alla Scala", considered the temple of lyrics all over the world, and several prose theatres such as the "Piccolo Teatro" founded by Giorgio Strehler.

In Milan are located the headquarters of the main daily newspapers (Il Corriere della Sera, Il Sole 24 Ore) and many of the main Italian publishers (Mondadori, Feltrinelli, Garzanti, Rizzoli).

The city offers to visitors the possibility to admire a wide range of monuments, museums and buildings reflecting the vestiges of history and culture left by many people who lived here. The ancient Roman remains are preserved at the Colonne di San Lorenzo, whereas the Romanesque can be admired at Sant'Ambrogio, Sant'Eustorgio or San Simpliciano Basilicas. The Duomo is one of the largest cathedrals in the world and the most important example of Gothic architecture in Italy. The Castello Sforzesco, built on the wishes of the Duke Francesco Sforza, nowadays hosts the Michelangelo's "Pietà Rondanini" and several museums. The church of Santa Maria delle Grazie hosts the famous masterpiece "The Last Supper" by Leonardo da Vinci - declared part of the World Heritage by UNESCO.

The city has always participated actively to the National History since its origins, contributing to the purposes and the aims that led to reunification of Italy in the 18th century. Some distinguished people, who gave a significant contribution to Italian culture, lived in Milan, such as Leonardo da Vinci (who lived in Milan from 1482 to 1500), the poet and novelist Alessandro Manzoni, the musician Arturo Toscanini, the writer Carlo Emilio Gadda, the film director Luchino Visconti. Two Nobel prizes operated in Milan: Giulio Natta (1963, in chemistry) and Dario Fo (1997, in literature).

The year 2019 marks the 500th anniversary of Leonardo da Vinci's death: Milano is the city where Leonardo da Vinci stayed the longest. Here Leonardo arrived in 1482, at the service of Duke Ludovico Sforza, and his presence has left an indelible mark in the history and artistic production of the City and in the entire region of Lombardy. For this reason, Milano and Lombardy will dedicate a whole year to the Maestro: visit the Social Program page for additional information on dedicated events.

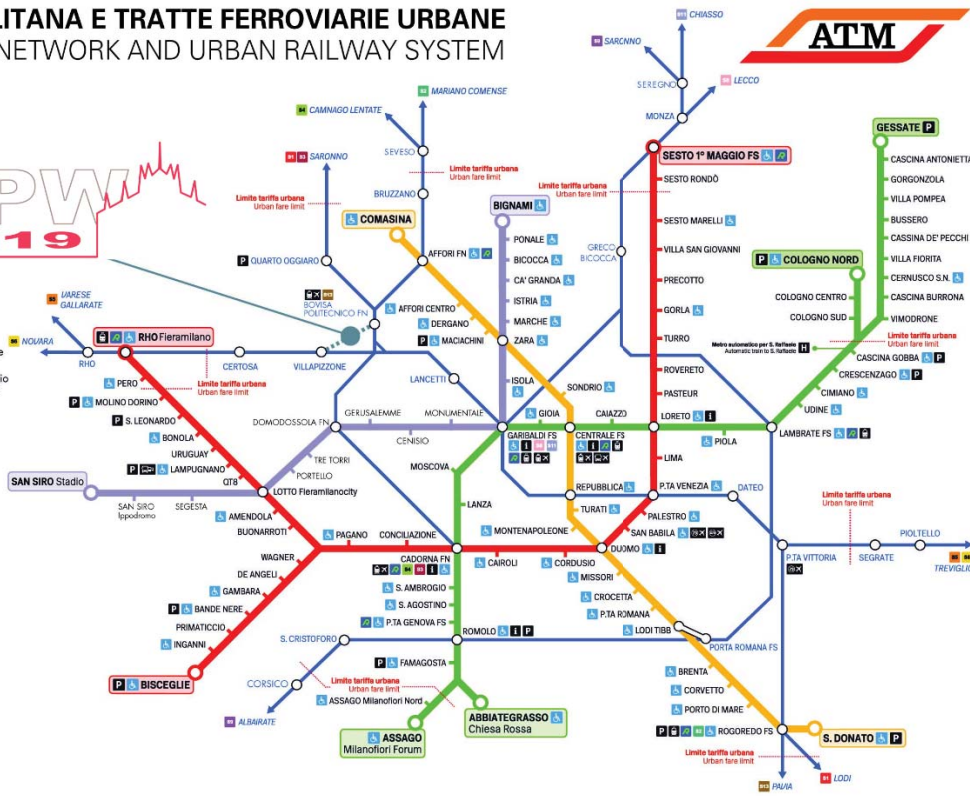
More info on SPW website (<https://spw2019.polimi.it>).

Local transportation

RETE METROPOLITANA E TRATTE FERROVIARIE URBANE UNDERGROUND NETWORK AND URBAN RAILWAY SYSTEM

- M1** Metropolitana linea 1
Underground line 1
- M2** Metropolitana linea 2
Underground line 2
- M3** Metropolitana linea 3
Underground line 3
- M5** Metropolitana linea 5
Underground line 5
- Stazione accessibile**
Accessible station
- ATM Point**: informazioni e punto vendita
ATM Point: information and retail
- Linee ferroviarie regionali**
Regional railways
- Interscambio con rete ferroviaria**
Connection with railway system
- Autobus X73 Express e 73 per Aeroporto di Linate**
Bus X73 Express and 73 to Linate Airport
- Autobus per Aeroporto di Linate, Malpensa e Orio al Serio**
Bus service to Linate, Malpensa and Orio al Serio Airports
- Treno per Aeroporto di Malpensa**
Train to Malpensa Airport
- Bus terminal**
Bus terminal
- P** Parcheggio di corrispondenza ATM
ATM interchange parking areas
- S** **Linee ferroviarie suburbane**
Suburban railways
- S1** Saronno - Milano Passante - Lodi
- S2** Mariano Comense - Milano Passante - Milano Rogoredo
- S3** Saronno - Milano Cadorna
- S4** Camnago Lentate - Seveso - Milano Cadorna
- S5** Varese - Milano Passante - Treviglio
- S6** Novara - Milano Passante - Treviglio
- S8** Lecco - Carnate - Milano P.ta Garibaldi
- S9** Saronno - Milano S. Cristoforo - Albairate
- S11** Chiasso - Como S. Giovanni - Milano P.ta Garibaldi
- S13** Milano Bovisio - Milano Passante - Pavia

SPW
2019



Ordinary Ticket (or Biglietto Ordinario) – Price: € 2.00

Valid for 90 minutes after stamping, gives you unrestricted travels for all the Milan Municipality area, including the area where SPW 2019 is located.

The ticket is valid for a single journey on the underground or rail network, including the urban rail lines of Trenord and the 'Passante Ferroviario' (Urban Railway Network).

One Day Ticket – Price: € 7.00

Valid for 24 hours after stamping, gives you unrestricted travels for all the Milan Municipality area.

3 Days Ticket – Price: € 12.00

Valid for 3 consecutive days from the day of the first validation until the end of the service on the third day, without limit to the number of journeys within the Milan Municipality area.

Carnet 10 tickets – Price: € 18.00

A block of 10 ordinary tickets. The trips cannot be used on road services managed by operators other than ATM and Trenord; it cannot be used by more than one person at the same time.

Weekly pass – Price: € 17.00

Valid from Monday to Sunday of the same week until the end of the service of Sunday, without limit to the number of journeys within the territory defined by the zones purchased.

You can also travel on the metro by paying at the ticket gate with your **contactless card** (Mastercard, Visa, Maestro and VPay).

Or you can download the **ATM Milano official** app and purchase tickets there.

Program Overview

Monday, October 21, 2019	
08:00	Registration opening
09:00	Welcome
09:10	Session 1 - Sources I
10:40	Coffee break
11:10	Session 2 - Applications I
13:00	Platinum sponsor presentation
13:05	Lunch
14:20	Session 3 - Detectors I
15:50	Coffee break
16:20	Session 4 - Metrology I
18:30	Welcome reception@Leonardo

Wednesday, October 23, 2019	
09:00	Session 9 - Applications IV
10:50	Coffee break
11:20	Session 10 - Metrology III
12:50	Platinum sponsor presentation
12:55	Lunch
14:10	Session 11 - Detectors III
16:00	Coffee break
16:30	Session 12 - Sources II
18:30	Guided tours of Castello Sforzesco
20:00	Dinner at Castello Sforzesco

Lunches, coffee breaks, welcome reception, dinner and guided tour at Castello Sforzesco are included in the registration fee.

Tuesday, October 22, 2019	
09:00	Historical perspective by S. Cova
09:15	Session 5 - Detectors II
10:45	Coffee break
11:15	Session 6 - Metrology II
12:35	Platinum sponsor presentation
12:40	Lunch
13:55	Session 7 - Applications II
15:45	Platinum sponsor presentation
15:50	Coffee break
16:20	Session 8 - Applications III
18:10	Poster session I

Thursday, October 24, 2019	
09:00	Session 13 - Sources III
10:50	Coffee break
11:20	Session 14 - Applications V
12:50	Platinum sponsor presentation
12:55	Lunch
14:10	Session 15 - Detectors IV
16:00	Coffee break
16:30	Session 16 - Applications VI
18:20	Poster session II

Friday, October 25, 2019	
09:00	Session 17 - Detectors V
10:50	Coffee break
11:20	Session 18 - Sources IV
13:10	Lunch
14:15	Session 19 - Applications VII
16:05	Concluding remarks
16:15	Farewell coffee

Monday, October 21, 2019

08:00	Registration opening	
09:00	Welcome	
09:10	Session 1 Sources I Chair: A. Migdall	S. Reitzenstein - Deterministically fabricated quantum dot - waveguide systems for on-chip quantum optics
09:40		F. Graffitti - Direct generation of tailored ultrafast entanglement
10:00		S. Haffouz - InAsP quantum dot nanowires for telecom single photon emission
10:20		T. Mueller - Quantum teleportation using highly coherent emission from telecom C-band quantum dots
10:40	Coffee break	
11:10	Session 2 Applications I Chair: M. Lucamarini	E. Diamanti - Demonstrating quantum advantage with practical photonic systems
11:40		F. Xu - Experimental Quantum Switching for Exponentially Superior Quantum Communication Complexity
12:00		D. Cozzolino - Hybrid entanglement distribution through an air-core fiber
12:20		C. Vigliar - High-Dimensional Chip-to-Chip Entanglement Distribution through Multicore Fibres
12:40		J. Chiles - Nanowire Detection of Photons from the Dark Side
13:00	Platinum sponsor presentation: ID Quantique	
13:05	Lunch	
14:20	Session 3 Detectors I Chair: A. Gulinatti	E. Charbon - Massively parallel, three-dimensional photon counting: a versatile tool for quantum experimentalists and consumers
14:50		E. Conca - Wide-area fast-gated single-photon detector with integrated TDC for near-infrared spectroscopy applications
15:10		F. Acerbi - Silicon photomultipliers optimized for cryogenic temperatures
15:30		S. Grosse - Single-Photon Detectors based on CSPAD technology
15:50	Coffee break (sponsored by Excelitas)	
16:20	Session 4 Metrology I Chair: E. Diamanti	F. Piacentini - New Frontiers in Quantum Measurement: Protective Measurement, Genetic Quantum Measurement and Robust Weak Measurement
16:40		L. Shalm - Certified Randomness Expansion using a Loophole-Free Bell Test
17:00		C. Chunnillall - Investigations towards transmitting time and QKD signals over the same optical fibre
17:20		M. Lasota - Reliable estimation of the statistics of photons emitted from an unknown source of light
17:40	Transfer to Leonardo campus	
18:30	Welcome reception @ Leonardo campus	
20:30	End	

Tuesday, October 22, 2019

09:00	Historical perspective by Sergio Cova	
09:15	Session 5 Detectors II Chair: H. Zbinden	B. Korzh - Advances in superconducting nanowire single photon detectors and related applications
09:45		V. Verma - Kilopixel arrays of superconducting nanowire single-photon detectors
10:05		D.H. Smith - Multiplexed Superconducting Nanowire Single-Photon Detectors on UV-Written Silica Waveguides
10:25		F. Martini - SNSPD readout using the amplitude multiplexing approach
10:45	Coffee break (offered by PicoQuant)	
11:15	Session 6 Metrology II Chair: C. Chunnillall	S. Polyakov - First quantum-measurement-inspired, scalable communication protocol and its experimental demonstration
11:35		S. Schwarz - Reconstructing ultrafast energy-time entangled two-photon pulses
11:55		D. Fuster - Development of a plug&play single photon source using electro-optical pumping schemes
12:15		H. Ollivier - Quantum dot based single photon sources: performance reproducibility
12:35	Platinum sponsor presentation: attocube / Quandela	
12:40	Lunch	
13:55	Session 7 Applications II Chair: J. Matthews	M. Lucamarini - Measurement Device Independent Quantum Cryptography
14:25		M. Minder - Experimental quantum key distribution beyond the repeaterless secret key capacity
14:45		M. Avesani - Practical Source-Device-Independent Quantum random number generators
15:05		S. Wengerowsky - In-field entanglement distribution over a 96 km and a 192 km submarine optical fibre
15:25		S. Wengerowsky - An entanglement-based wavelength-multiplexed Quantum Communication Network
15:45	Platinum sponsor presentation: MPD /OEC	
15:50	Coffee break	
16:20	Session 8 Applications III Chair: M. Ghioni	K. Suhling - Time-correlated single photon counting wide-field Fluorescence Lifetime Imaging Microscopy
16:50		D. Tabakaev - Entangled two-photon absorption and the quantum advantage in sensing
17:10		A. Ingle - Towards General-Purpose Passive Imaging with Single-Photon Sensors
17:30		D. Lindell - Efficient Confocal Non-Line-of-Sight Imaging
17:50		A. White - Realtime photon-number resolution & Imaging via photon counting
18:10	Poster session I	
19:30	End	

Wednesday, October 23, 2019

09:00	Session 9 Applications IV Chair: F. Bussieres	J. Matthews - Integrated Homodyne Detection for Large Scale Silicon Quantum Photonics
09:30		F. Ceccarelli - Low-power reconfigurable photonic integrated circuits fabricated by femtosecond laser micromachining
09:50		P. Connolly - Multispectral single-photon imaging using high efficiency plasmonic metasurface filters
10:10		S. Olivier - Towards an integrated quantum photonics platform on silicon for secured communications
10:30		J. Renema - Imperfect Gaussian Boson Sampling is Classically Simulable
10:50	Coffee break (offered by ID Quantique)	
11:20	Session 10 Metrology III Chair: S. Kueck	I. Degiovanni - Light sources characterisation and optical modes reconstruction
11:50		Y.-L. Mao - Error-Disturbance Trade-off in Sequential Quantum Measurements
12:10		A. Paterova - Infrared metrology with visible light
12:30		K. Laiho - Characterizing heralded single photons from a Bragg-reflection waveguide loss-tolerantly via moment generating function
12:50	Platinum sponsor presentation: PicoQuant	
12:55	Lunch	
14:10	Session 11 Detectors III Chair: A. Tosi	B. Aull - Large-Format Image Sensors Based on Integration of Custom Geiger-Mode Avalanche Photodiode Arrays with All-Digital CMOS Circuits
14:40		C.-Y. Park - Room temperature operation of InP/InGaAs single photon avalanche diode
15:00		G. Buller - Planar Geometry Ge-on-Si Single-Photon Avalanche Diode Detectors for the Short-Wave Infrared
15:20		G. Acconcia - Fully integrated electronics for high-performance and high-speed acquisition with Single Photon Avalanche Diodes
15:40		M. Salomoni - Future perspective of SiPM technology
16:00	Coffee break	
16:30	Session 12 Sources II Chair: C. Toninelli	C.A. Solanas - Scalable interfacing of quantum photonic platforms: solid-state single-photon sources and reconfigurable photonic circuits
16:50		T. Heindel - Single-Photon QKD using Engineered Solid-State Quantum-Light Sources
17:10		S.D. Tchernij - Electrical control of Nitrogen - Vacancy centers in diamond
17:30		S. Ecker - Overcoming noise in entanglement distribution through high-dimensional encoding
17:50	Transfer to Castello Sforzesco	
18:30	Guided tours of Castello Sforzesco	
20:00	Dinner at Castello Sforzesco	
23:00	End	

Thursday, October 24, 2019

09:00	Session 13 Sources III Chair: T. Gerrits	C. Toninelli - Single-molecule based single photon sources
09:30		R. Schofield - Nanophotonic waveguide coupling to organic molecules in micro-capillaries
09:50		H. Abudayyeh - Quantum light manipulation: A path towards efficient pure room-temperature single photon sources
10:10		H. Wang - Single photons for quantum technologies
10:30		G. Solomon - Filter-free single-photon emission in an integrated cavity-waveguide device
10:50	Coffee break (offered by attocube / Quandela)	
11:20	Session 14 Applications V Chair: S. W. Nam	K. Srinivasan - Quantum source and frequency conversion technologies based on integrated nanophotonics
11:50		J. Adcock - Programmable multiphoton graph states on a silicon chip
12:10		G. Kavuri - Towards a loophole-free Bell experiment on a tabletop
12:30		Z.-H. Xiang - Network Integration of Quantum Dot Device and Entanglement in Cambridge Fiber Network
12:50	Platinum sponsor presentation: Excelitas	
12:55	Lunch	
14:10	Session 15 Detectors IV Chair: I. Rech	S. W. Nam - From dark matter detection to artificial intelligence: applications of superconducting nanowire single photon detectors
14:40		M. Perrenoud - High detection rate and high efficiency with parallel SNSPDs
15:00		S. Buckley - Progress in superconducting optoelectronic networks for neuromorphic computing
15:20		T. Takumi - Time-resolved measurement of a single-photon wave packet with an optical Kerr effect
15:40		E. Fossum - Quanta Image Sensor Progress Review
16:00	Coffee break	
16:30	Session 16 Applications VI Chair: F. Zappa	S. Verghese - Self-driving cars and lidar
17:00		G. Musarra - Single-photon, single-pixel intelligent Lidar
17:20		A. Maccarone - Three dimensional imaging of dynamic underwater scenes using single photon detection
17:40		R. Tobin - Depth imaging through obscurants using single photon detection in the short-wave infrared
18:00		M. Laurenzis - Computational imaging with SPADs at SWIR wavelengths
18:20	Poster session II	
19:40	End	

Friday, October 25, 2019

09:00	Session 17 Detectors V Chair: F. Villa	J. Rothman - Reaching for GHz single photon detection rates with HgCdTe APD detectors
09:30		L. Gasparini - CMOS-SPAD arrays for Quantum Imaging Applications
09:50		M. Zarghami - A Novel Approach to High Dynamic Range Imaging with CMOS-SPADs
10:10		G. Jegannathan - Current-assisted single photon avalanche diode(CASPAD) in 350 nm CMOS
10:30		G. Tortarolo - Towards Single-Photon Microscopy: Exploiting Extra Spatio-Temporal Information Provided by SPAD Array Detectors in Laser Scanning Microscopy
10:50	Coffee break (offered by MPD /OEC)	
11:20	Session 18 Sources IV Chair: F. Piacentini	P. Michler - Quantum dots at telecom wavelengths for single- and entangled photon sources
11:50		S. Francesconi - Engineering two-photon wavefunction and exchange statistics in a semiconductor chip
12:10		C. P. Lualdi - High-Efficiency Time-Multiplexed Single-Photon Source
12:30		C. Marvinney - Toward control of the quantum state of hBN single-photon emitters
12:50		J. Grim - Three-Quantum-Dot Superradiance in a Photonic Crystal Waveguide Enabled by Scalable Strain Tuning
13:10	Lunch	
14:15	Session 19 Applications VII Chair: I. Degiovanni	Q. Zhang - Single photon technology in Long Distance Quantum Communication
14:45		F. Xu - Experimental quantum repeater without quantum memory
15:05		A. Scriminich - Hong-Ou-Mandel interference of polarization qubits stored in independent room-temperature quantum memories
15:25		S. Grandi - Towards long distance entanglement between a photon and a solid-state quantum memory
15:45		M. F. Askarani - Entanglement and non-locality between disparate solid-state quantum memories mediated by photons
16:05	Concluding remarks	
16:15	Farewell coffee	
16:45	End	

Abstracts of oral presentations

Fully integrated electronics for high-performance and high-speed acquisition with Single Photon Avalanche Diodes

Giulia Acconcia¹, Angelo Gulinatti¹, Massimo Ghioni¹, Ivan Rech¹

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Nowadays, single photon sensitivity can be achieved with different kind of detectors, as Photomultiplier Tubes (PMTs), Single Photon Avalanche Diodes (SPADs) and Superconducting Nanowire Single-Photon Detectors (SNSPDs). Compared to the others, SPADs offer clear advantages being solid-state devices that can be operated at room temperature or with moderate cooling. Many applications currently benefit from the exploitation of SPADs both in counting and in timing measurements. Nevertheless, operating SPADs at high count rates is still an open challenge. A remarkable research effort has been made in the past few years to increase the speed of SPAD-based acquisition system. High speed, indeed, would open the way to the exploitation of SPADs in even a larger number of applications and advanced measurements as the study of the ocean environment to investigate the effects of climate changes by spaceborne LiDAR [1] or *in vivo* measurements in biosciences. To address speed issues that currently limit SPAD-based systems, we have developed fast and fully-integrated electronics. Our approach is based on the exploitation of custom-technology SPADs, also developed by us at Politecnico di Milano, because they have been proven suitable to achieve excellent results in terms of high photon detection efficiency (also in the red region of the spectrum), along with low noise (both in terms of dark counts and afterpulsing) and timing performance. Custom SPADs require external electronics to be operated at the best of their possibilities. To this aim, we designed a fully integrated Active Quenching Circuit (AQC) able to drive different kinds of external detectors up to a rate as high as 160Mcps as shown in Fig. 1 (Left). To the best of our knowledge, this is the highest count rate achieved so far with an external custom SPAD. The prompt quench of the avalanche current and the high quality of the SPAD fabrication process allow us to limit the afterpulsing probability below few percent even with a dead time as short as 6.2ns. In timing, we demonstrated that, with fast and high-performance electronics designed on purpose, it is possible to push the operating speed of a single channel well beyond the actual limitations (typically 1% or 5% of the excitation rate) while avoiding that pile-up distortion affects the measurement [2]. To demonstrate the practical feasibility of this solution we designed an AQC with a finely tunable dead time to match the excitation period of a 80MHz laser and a fully differential pick-up circuit providing picoseconds timing jitter even at high count rates. The timing signal has then to be fed to a time measurement circuit. Exploiting a Si-Ge 0.35 μ m technology we developed a Time-to-Amplitude Converter (TAC) able to provide a state-of-art timing precision of less than 4.3ps rms (corresponding to 10ps FWHM). Fig. 1 (Right) shows the rms timing jitter as a function of the measured start-stop interval. The new TAC provides excellent performance both in terms of precision and linearity with a Differential Non Linearity lower than 0.25% of the LSB rms (1.5% peak to peak). Featuring an area occupation of 1mm² (considering also the integrated DAC to use the dithering technique) and an overall power dissipation as low as 70mV, the designed circuit will be the building block of future multichannel systems.

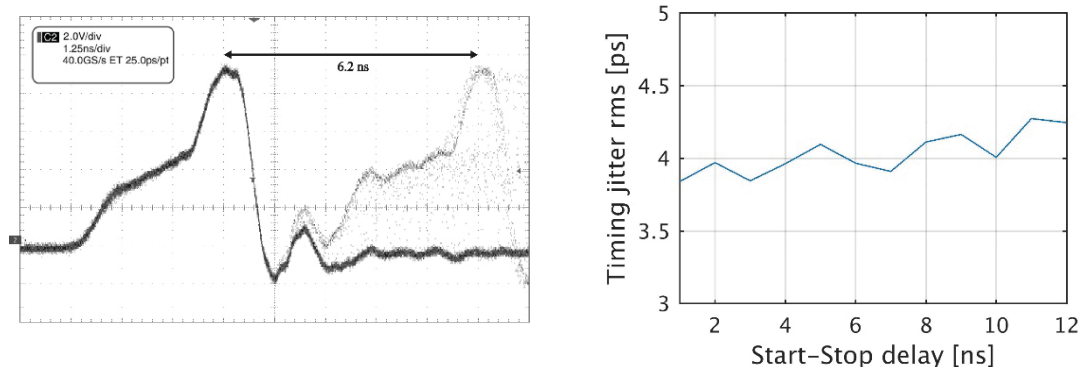
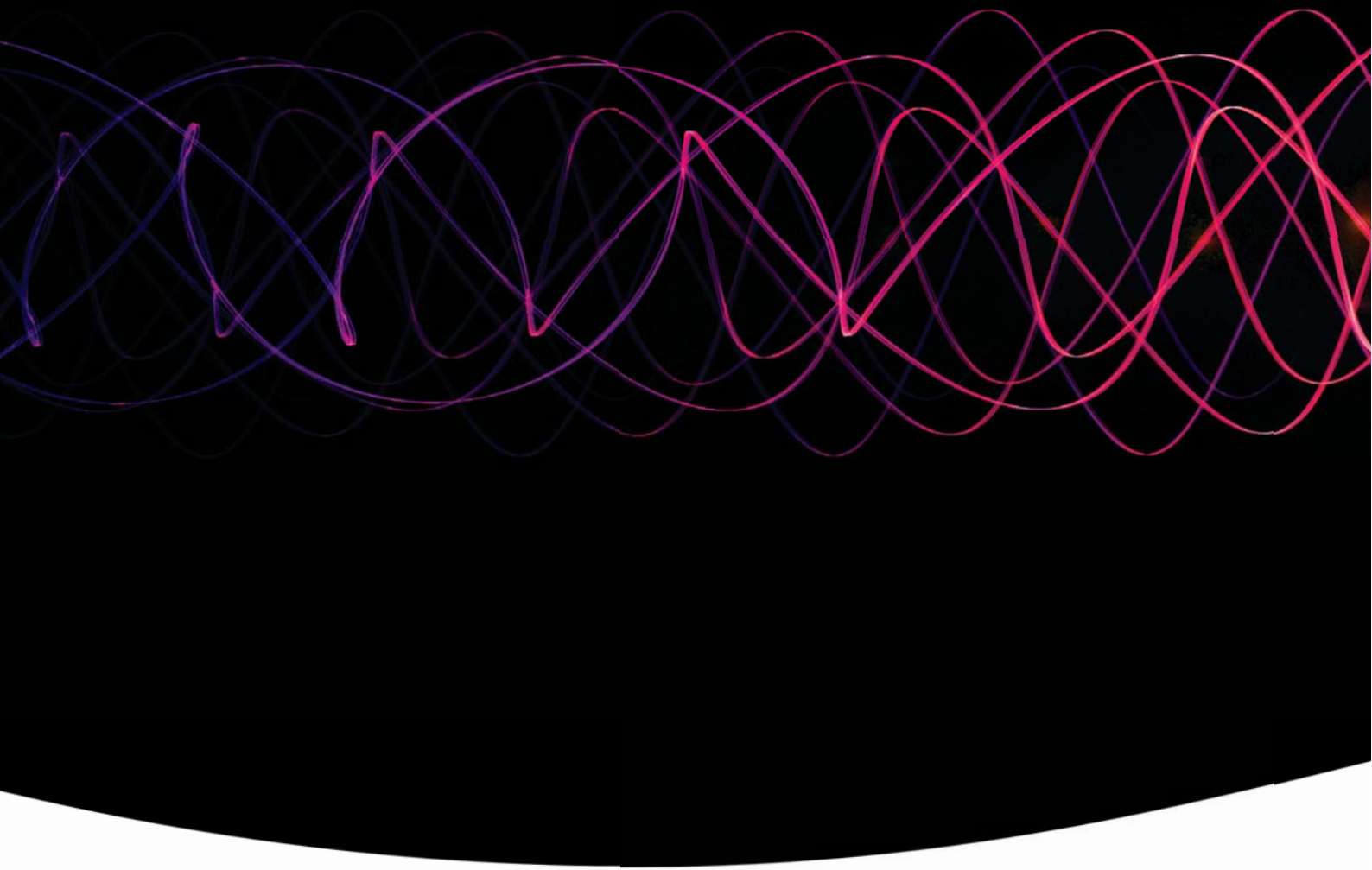


Fig. 1 (Left) Anode waveform of a custom-technology SPAD driven at 160Mcps by an external fully integrated AQC (Right) Timing precision of the TAC: rms jitter is lower than 4.3ps on the whole Full Scale Range

References

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