POLITECNICO DI MILANO

PhD in INGEGNERIA DELL'INFORMAZIONE / INFORMATION TECHNOLOGY - 39th cycle

Research Area n. 2 - Electronics

THEMATIC Research Field: ELECTRONIC DEVICE AND INSTRUMENTATION FOR QUANTUM IMAGING

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Quantum Ghost Imaging (QGI) typically relays on arrays of photo detectors with high sensitivity and gated mode operation, for the imaging beam detection. In remote QGI long optical delay lines must be added on the imaging path, in order to match the delays of the idler beam that travels to the remote target. Pitsch et al. (2021) preliminary demonstrated that this application benefits from the exploitation of SPAD arrays working in photon timing regime. Indeed, the arrival times of both the photons on the idler and imaging beam can be compared in post processing, to distinguish entangled photon pairs from background and noise, without the need for optical delay lines. The objective of the present research is the development of a new SPAD array specifically designed for QGI. The main parameters that will be taken into account will be the SPAD array geometry and pixel number, the overall detection probability and the timing jitter. Then, having a 2D array (instead of the linear array presented in Pitsch et al. (2021)) with a sufficient number of pixels (in the order of 32 × 32 or 64 × 64) allows to obtain an image without scanning the scene, with obvious advantages in terms of measurement time. Additionally, the SPAD array that will be developed will include Time-to-Digital Converters (TDCs) to time-stamps the incoming photons in the individual pixels.

Methods and techniques that will be developed and used to carry out the research	The PhD candidate will develop electronic boards and will design schematics and layout of microelectronic chips. The PhD student will investigate SPAD detectors and imagers and will employ state-of-the-art CMOS technologies (e.g., 40nm and/or 28nm) and also in 3D-IC assembly, in order to reach advanced performance and system compactness. He will optimize the overall detection probability of the quantum imagers, in order to achieve the desired signal to noise ratio in detecting entangled photon pairs, with high fill-factor and detection duty cycle, defined as the ratio between the TDC full-scale range (i.e., time interval during which the detected photons can by time stamped) and the frame time (typically limited by the array readout time). The array readout should be performed as fast as possible (high bandwidth and low voltage output signals) and the TDC FSR must be extended to entirely cover the frame time (typically in the order of 5-10 µs for 32 × 32 or 64 × 64 pixels arrays). Alternatively, evet-driven readout schemes can be used, to overcome the limitations of frame-based approaches. Finally, the timing jitter directly impact the selectivity in detecting entangled photon pairs and distinguishing them from the so-called “false coincidences” due to two independent spurious events happening on the bucket detector and on the imaging array within a limited time interval. Time jitter is influenced by the SPAD and front-end electronics timing response and by the TDC jitter and resolution. SPADs and front-end jitter in the order of 30 ps can be achieved, whereas TDC resolution in the order of 300 ps are obtained with relatively old technology nodes (like the 0.35 µm one used in Pitsch et al. (2021)), but it can be easily improved with more scaled technologies.The SPAD array will be designed with EDA tools, like the Cadence suite for integrated circuits. The integrated circuit will be fabricated in a high-end silicon foundry, then it will be fully characterized by the PhD student for assessing electrical and optical performance. The SPAD array will be mounted in a camera, i.e., an electronic system composed of a few printed circuit boards (PCB) designed and programmed by the PhD student. The PCBs will be designed with

	advanced EDA tools, like Altium suite, and will include programmable devices, like FPGA (Field-Programmable Gate Array) and microcontrollers.
Educational objectives	The PhD student will learn how to design, simulate, prototype and characterize devices, microelectronic chips and electronic boards employing SPAD imagers, microcontrollers and FPGAs. The PhD student will develop also applications and graphical user interfaces to enable users to manage and control the electronic instrumentation will be developed during the PhD research. The doctorate activity will include attendance of academic courses, conferences, summer schools and workshops.
Job opportunities	The PhD studies will allow to acquire all required skills and know-how to enable a swift transition to high-level research and development companies and institutes. The POLIMI's research group has already many contacts with R&D centers and end-users, which employed previous PhD students and post-docs, trained in the research group.
Composition of the research group	1 Full Professors 2 Associated Professors 0 Assistant Professors 6 PhD Students
Name of the research directors	Alberto Tosi, Franco Zappa, Federica Villa

Contacts
E-mail: alberto.tosi@polimi.it Phone: +39-02-2399.6174 E-mail: franco.zappa@polimi.it Phone:+39-02-2399.6149 E-mail: federica.villa@polimi.it Phone:+39-02-2399.4003

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--

Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Premiality:
Premialities will be recognized to the PhD candidate:
i) up to 2,500.00 euro (gross amount) after completion of the I year, provided that she/he demonstrates a significant contribution to the growth of scientific excellence, the industrial valorization of the research, the networking and communication activities of the research group and of the Department;
ii) up to 2,500.00 euro (gross amount), after completion of the II year, provided that she/he has published at least one paper on a scientific journal and demonstrates a continuous and significant contribution to the growth of scientific excellence, the industrial valorization of the research, the networking and communication activities of the research group and of the Department;
iii) up to 2,500.00 euro (gross amount), after completion of the III year, provided that she/he has published at least two papers on a scientific journal and demonstrates a continuous and significant contribution to the growth of scientific excellence, the industrial valorization of the research, the networking and communication activities of the research group and of the Department.

EDUCATIONAL ACTIVITIES (purchase of study books and material, including computers, funding for participation in courses, summer schools, workshops and conferences): financial aid per PhD student

COMPUTER AVAILABILITY: individual use

DESK AVAILABILITY: individual use