



Il laboratorio congiunto Q@TN, che mette insieme le competenze dell'Università di Trento, FBK, CNR e INFN per ricerca e innovazione nell'ambito delle scienze e tecnologie quantistiche (QT), organizza un workshop a Trento gestito in modalità duale, presenza ed online, con l'obiettivo di presentare le facilities tecnologiche trentine, le attività in ambito QT in corso presso l'INFN e raccogliere e discutere spunti di progetti di sviluppo di dispositivi, tecnologie ed esperimenti. Questo workshop sarà seguito da una visita alle facilities sperimentali di FBK e UNITN durante la quale si potranno ulteriormente approfondire aspetti tecnici.

Il workshop è inteso come fase preliminare di un percorso che prevede la possibilità di utilizzare le facilities trentine per sviluppo di dispositivi o per introdurre nuove idee di processo per dispositivi dedicati alle QT. Per partire con una collaborazione sostanziale, si intende promuovere in autunno un bando per idee progettuali coperto con risorse di Q@TN per l'utilizzo delle suddette facilities. Il workshop si svolgerà con la presentazione di sei piattaforme tecnologiche di rilievo per le QT da parte di ricercatori direttamente coinvolti nelle facilities, seguite ciascuna da una presentazione da parte di ricercatori INFN sulle attività di ricerca relative alla tecnologia stessa.

Technologies and Platforms for QT within the Q@TN joint lab and their applications

FBK building

8-9 September 2021

8 September

9:30 – 9:40 – welcome and introduction to Q@TN

9:40 – 10:30

Photonic Integrated Circuits (PICs)

In recent years, Q@TN developed integrated optical circuits in different material platforms (silicon-oxy-nitride, silicon-nitride and silicon on insulator) via the **S and D** facilities. These waveguides are transparent from 0.5 μm to 6 μm . Propagation losses range from 0.5 to 5 dB/cm depending on material and wavelength. Optical components realized are coupler, splitter, resonator, interferometers, in and output tapers etc. Nonlinear waveguides allow for the generation of entangled photons using an external pump laser. Tuning and switching with thermal heater technology. Applications: realisation of a few optical qubits, quantum optical experiments, quantum simulation, etc.

Speakers:

9:40 – 10:00 M. Ghulinyan (FBK) PICs technologies at Trento

10:00 – 10:20 A. Salamon (RM2) Photonic Integrated Circuits (PICs)

10:20 – 10:30 Questions, comments

10:30 – 11:00 Coffee break

11:00 – 11:50

Ion deterministic implantation for colour centre formation

Equipment in the cleanrooms of FBK allows for the implantation of N and Si to realize local implant in SiC, diamond or other wide bandgap semiconductors. A vacuum furnace for colour centre formation is also present. Local implantation can be obtained either by masking or for silicon by local implantation with a focused ion beam.

Envisioned applications in QT:

- using electronic spin for a variety of measurements of magnetic and electric fields, temperature, pressure, pH, paramagnetic molecular species.

- Single spin sensors (Quantum dots, semiconductor virtual atoms): using single spins in solid state electrical and optical schemes.

11:00 – 11:20 J. Forneris (TO) Deterministic implantation technologies and colour centres

11:20 – 11:40 D. Giubertoni Experimental activities at Trento

11:40 – 11:50 Questions, comments

11:50 – 12:20

Single photon detectors

The Iris Unit of FBK has outstanding experience in integrated radiation and imaging sensors. Single photon sensors like SPAD based on CMOS technology or silicon photomultipliers based on the in-house silicon technology are already used





for QT experiments like imaging of correlated photons (super resolution microscopy) or ghost imaging. These sensors be used close to RT. There is also a very low noise cryogenic detector technology available. Timing resolution 200 ps for entangled photons.

11:50 – 12:10 M. Perenzoni (FBK) Single photon detectors

12:10 – 12:20 Questions, comments

12:20 – 13:45 Lunch break

13:45 – 15:00

RF technology

Control and use of radio waves plays an important role in a series of potential applications in QT especially in controlling the occupation of energy levels in colour centres. FBK has long experience in RF technologies and components:

Design, development, prototyping and experimental characterization of a wide variety of MEMS-based Radio Frequency passive components (RF-MEMS). The complexity of such devices ranges from simple electrostatically driven micro-relay, ohmic and capacitive (switched capacitors), to multi-state reconfigurable/tunable networks, like phase shifters, power attenuators, switching matrices, resonators, filters, and so on. All the mentioned devices exhibit remarkable characteristics in terms of low-loss (below -1 dB up to 50-60 GHz for basic switches), high-isolation (better than -30 dB up to 30-40 GHz), linearity, power consumption, configurability and wide-frequency operability, from nearly-DC, up to 100 GHz, and depending on the design, up to sub-THz frequencies (200-300 GHz).

14:00 – 14:20 C. Braggio (PD)

14:20 – 14:40 Gatti (LNF)

14:40 – 15:00 I. Iannacci (FBK)

15:00 – 15:10 Questions, comments

15:10 – 16:00

Fabrication technology for Josephson junctions, SQUIDs and parametric amplifiers

Josephson junctions are used as the key nonlinear element for realisation of qubits based on superconducting circuits. Our technology for realisation of Josephson junction's is based on double angle evaporation using aluminium as superconductor and aluminium oxide as dielectric layer, Resonators are available in coplanar waveguides based on aluminium. SQUID circuits based on two Josephson junctions can for example be realized.

Application in precision metrology, quantum computing, digital computing, SQUID based parametric amplifiers.

15:10 – 15:30 B. Margesin (FBK) Superconductor technologies at Trento

15:30 – 15:50 A. Giachero (MI-B) Travelling wave parametric amplifiers.

15:50 – 16:00 Questions, comments

16:00 – 16:20 Coffee break

16:20 – 16:50

Ultracold atoms

Laser cooling is one of the key technologies leading to the application of atomic spectroscopy to QT. We have expertise in the laser cooling and the production of quantum degenerate gases of most of the atomic species of interest to QT, including most of the alkali (Li, Na, K, Rb, Cs) and strontium. We developed an innovative experimental setup that allows for the study of Bose-Einstein condensates in magnetic fields stable at the micro Gauss level, hence paving a way to unexplored settings for quantum simulation of both magnetic materials and fundamental interactions. Our innovative sources of cold atoms find applications in optical metrology, atomic clocks and Rydberg atom quantum logic.

16:20 – 16:40 G. Ferrari (TN) Cold atoms at Trento

16:40 – 16:50 Questions, comments

16:50 – 18:00 Open discussion, planning.

9 September

Visit to the facilities for interested and available people.

- FBK clean room, labs
- UNITN labs (photonics, cold atoms, material depositions)

