Consortium

Universities and Research Institutes:

Coordinator: Consiglio Nazionale delle Ricerche (CNR – Italy)

Eidgenössische Technische Hochschule Zürich (ETH – Switzerland)

Technische Universität München (TUM – Germany)

Centre National de la Recherche Scientifique (CNRS – France)

Agenzia Spaziale Italiana (ASI – Italy)

Companies:

Alpes Lasers (Switzerland)

IRsweep (Switzerland)

ppqSense (Italy)

Menlo Systems (Germany)

Thales Research & Technology (France)

QUANTUM FLAGSHIP

Qombs

Main results

August 2020

Performed work and main results

WP1 – Design:

- **New QCL active regions** for improved frequency comb operation have been designed and optimized. They have the **potentiality** of exhibiting enhanced **nonclassical features** in the emission.

WP2 – Fermionic analog simulator:

- A **large spacing 1D optical lattice** to mimic the multi-well configuration of QCL heterostructures has been realized.
- The **behavior/dynamics of the Fermi gas in a single 2D layer** is **under characterization**.

WP2 – Bosonic analog simulator:

- An interferometric protocol producing, separating and recombining multiple copies of a single Bose-Einstein condensate has been developed. A **multimode Kapitza-Dirac beam-splitter** has been realized.
- To reduce the amplitude of oscillations in the trap we decided to shift to a **"Bragg interferometer",** where only two momentum components are present. We found that interatomic interactions affect the fringe wave vectors k, both for the free-space and the in-trap Bragg interferometers. Understanding the role of such interactions has a key role for the project.

WP3 – QCL devices Fabrication:

- **Several QCL devices** have been **fabricated** employing current technology and distributed among the project partners for characterization.
- **Optimized procedures for fabrication** have been tested and used for fabricating new devices based on the design developed within the project.
- A **new waveguide type**, including a plasmonic layer in the top cladding, has been developed and realized. The **first characterization results look promising**.

Performed work and main results

WP4 – Characterization of new QCL devices:

- The **classical characterization of several QCL devices** has been performed (frequency/intensity noise), showing good results in terms of spectral coverage, frequency and amplitude noise. The parameter will be used as benchmarks for **future characterizations** of optimized devices.
- The **quest for nonclassical features (squeezing)** in the new QCLs emission started. The search for nonclassical features in QCL-combs emission is **ongoing**, results are expected in the second project period.
- The **new devices** have been **tested for applications** such as dual-comb spectrometers.

WP6 – Dissemination:

- In total, **11 peer-reviewed papers** regarding the results obtained within the project have been **published** (or are in press) in high-impact international journals.
- Several people involved in the project participated to numerous **international conferences** disseminating the obtained results.
- The **organization of an international conference** on QCLs is ongoing (IQCLSW 2020).

Main results - Summary

Objective	Achievement	Still to realize
Design and fabrication of new QCL devices	Numerically-optimized devices realized	Quantum-simulation-optimized devices realized
Realization of a quantum simulator of QCLs transport	Large spacing 1D optical lattice to mimic QCL potential	Loading the atoms, simulating transport
Demonstration of nonclassical features in QCL emission	Implementation of a mid-infrared balanced detector, characterization of detectors, discovery of optimal laser operating condition for investigation	Demonstration of squeezed/ entangled emission, test of several devices
Applications (sensing, communication, range find, anemometry)	New devices to be used for applications fabricated, dual-comb spectrometer tested	Development of the applications