chist-era

CHIST–ERA Proposal Template

Project Acronym

CQC

Project Full Title

Composing Quantum Channels

Addressed Call Topic : QIFT

Coordinator contact point for the proposal

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Partners' people involved in the realisation of the project

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	Germany	TUM/Department of Mathematics	Michael M. Wolf	postdoc
2	Switzerland	ETH Zurich/ Department of Physics	Matthias Christandl	postdoc
3	Spain	UCM/Department of Mathematical Analysis	David Perez-Garcia	postdoc

Duration: 36 36 months

Summary of the project*:*

The power of information theory – classical as well as quantum – originates in the abstraction of information from its physical carrier. On this level of discussion, every process, every time evolution and every operation is described by *a quantum channel* – an input-output relation abstracting from the microscopic origin of the physical dynamics. Quantum channels are therefore central objects and basic building blocks in quantum information theory. The composition of quantum channels is a very natural operation arising in most physical situations. Sequential composition arises, for instance, when two quantum processes are carried out one after the other. It is therefore surprising that a systematic study is still missing that analyses the effect of composition on basic properties of quantum channels, such as the ability to reliably transmit quantum information.

With this project we propose to fill this gap and provide a first in-depth analysis of fundamental properties of quantum channels, with a particular emphasis on the behaviour under sequential and parallel composition. We will, furthermore, initiate the study of complexity-theoretic properties of quantum channels, thereby providing a novel computer science perspective on quantum channels.

We expect the results from this project to have a profound impact to the study of quantum spin chains, quantum complexity theory and quantum cryptography. The project as well as the consortium is of interdisciplinary nature and will use modern tools from operator space theory, signal processing, convex geometry and complexity theory.

Relevance to the topic addressed in the call*:*

The proposed project is multi-disciplinary, bringing together expertise from mathematics, physics and computer science, and aims at developing a deeper fundamental understanding of the nature of information in quantum mechanics by providing the first in-depth study of quantum channels under composition. The project therefore directly addresses the first objective of the QIFT call by developing a new fundamental understanding of a basic building block of quantum information theory.

As we detail in the proposal, our work will have direct impact on the study of new algorithms, computation paradigms and communication protocols. The project consortium uses advanced and to a large extent non-standard tools in order to follow new high-impact research directions and provide a better understanding of the basic building blocks of quantum information theory.

CHIST–ERA Proposal Template

Project Acronym

DIQIP

Project Full Title

Device-Independent Quantum Information Processing

Addressed Call Topic (QIFT[1] or BASCC[2]): QIFT

Coordinator contact point for the proposal

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[1] *Quantum Information Foundations and Technologies*
[2] *Beyond Autonomic Systems – the Challenge of Consciousness*

Partners' people involved in the realisation of the project[3]

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	Spain	ICFO-The Institute of Photonic Sciences (ICFO)	Antonio Acín	Maciej Lewenstein Lluis Masanes
2	Switzerland	GAP-Optique, ETH (GAP-ETH)	Nicolas Gisin	Renato Renner Stefan Wolf Yeong-Cherng Liang
3	France	Laboratoire de Recherche en Informatique (LRI)	Sophie Laplante	Julia Kempe Iordanis Kerenidis Frédéric Magniez Miklos Santha
4	Belgium	Université Libre de Bruxelles / Laboratoire d'Information Quantique (ULB)	Serge Massar	Stefano Pironio Jonathan Silman Ross Duncan Unknown (PhD or post-doc)
5	UK	University of Bristol (UoB)	Sandu Popescu	Noah Linden Andreas Winter Nicolas Brunner
6	UK	Royal Holloway, University of London (RH)	Jonathan Barrett	

(Use as much lines as needed)

[3] *If the people are for the moment unknown, specify the level of expertise sought (PhD, post-doc, engineer, professor…)*

Duration: 36 months

Summary of the project[4] *(publishable abstract, max. ½ page):*

Device-Independent Quantum Information Processing represents a new paradigm for quantum information processing: the goal is to design protocols to solve relevant information tasks without relying on any assumption on the devices used in the protocol. For instance, protocols for device-independent key distribution aim at establishing a secret key between two honest users whose security is independent of the devices used in the distribution. Contrary to standard quantum information protocols, which are based on entanglement, the main resource for device-independent quantum information processing is quantum non-locality. Apart from the conceptual interest, device-independent protocols offer important advantages from an implementation point of view: being device-independent, the realizations of these protocols, though technologically challenging, are more robust against device imperfections. Current and near-future technology offer promising perspectives for the implementation of device-independent protocols.
This project explores all these fascinating possibilities. Its main objectives are (i) obtaining a better characterization of non-local quantum correlations from an information perspective, (ii) improve existing and derive new application of this resource for device-independent quantum information processing and (iii) design feasible implementations of device-independent protocols. We plan to tackle these questions with an inter-disciplinary approach combining concepts and tools from Theoretical and Experimental Physics, Computer Science and Information Theory.

Relevance to the topic addressed in the call[5] *(max. ¼ page):*

The present proposal is clearly relevant to two of the four topics listed in the QIFT CHIST-ERA call (section 2.1). It is a proposal exploring a new paradigm for quantum information theory, which will provide new fundamental understandings, methods and protocols (topic 1). Moreover, feasible proposals for the implementation of device-independent protocols will open the way to few qubits proof-of-principle experimental realizations of new intrinsically quantum protocols with no classical analog (topic 4). Moving to the expected impact, our proposal will significantly improve the understanding of the quantum nature of information (objective 1) and its inter-disciplinary character will contribute to strengthen the interaction among the different communities involved in the field (objective 5).

4 Be precise and concise. This summary will be used to select suited reviewers for the proposal.
5 Be precise and concise. Relevance to the topic addressed in the call is an essential eligibility criterion.

CHIST–ERA Proposal

Project Acronym

HIPERCOM

Project Full Title

High Performance Coherent Quantum Communications

Addressed Call Topic (QIFT[1] or BASCC[2]): **QIFT**

Coordinator contact point for the proposal

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Partners' people involved in the realisation of the project[3]

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Other personnel participating in the project***
1 Coord.	Belgium	Université Libre de Bruxelles (**ULB**) / Centre for Quantum Information and Communication	Nicolas J. Cerf	Evgueni Karpov, Raul Garcia-Patron
2	France	Institut d'Optique Graduate School (**IO**) / Laboratoire Charles Fabry	Philippe Grangier	Rosa Tualle-Brouri, Rémi Blandino
3	Germany	Max Planck Society / Max Planck Institute for the Science of Light (**MPL**)	Gerd Leuchs	Peter van Loock, Christoph Marquardt
4	UK	University of York (**UY**) / Computer Science Department	Samuel L. Braunstein	Stefano Pirandola
5	France	Telecom Paris Tech (**TPT**) / Laboratoire Traitement et Communication de l'Information	Eleni Diamanti	Damian Markham
6	France	SeQureNet (**SQN**)	Sebastien Kunz-Jacques	Paul Jouguet

[1] Quantum Information Foundations and Technologies
[2] Beyond Autonomic Systems – the Challenge of Consciousness
[3] If the people are for the moment unknown, specify the level of expertise sought (PhD, post-doc, engineer, professor…)

chist-era

Duration: 36 months

Summary of the project *(publishable abstract, max. ½ page):*

Coherent optics has been known since the 1960's to be, in principle, the best tool to achieve very high bandwidths and bit rates in optical communication. While the development of fiber optical amplifiers in the 1980's has reduced the need for developing such a technology, the advent of quantum information sciences has triggered a renewed interest in using coherent optics to realize high-rate quantum communication systems. The present project is focused on *coherent quantum communication* as a way to combine the intrinsically very high rates achievable by homodyne or heterodyne detection with the fundamental benefits of using quantum mechanics such as unconditional security.

Unlike with classical communication systems, an optical amplifier cannot be used as a repeater in a quantum communication setup because it is inherently limited by quantum noise. The thrust of this project is to explore different techniques aiming at circumventing this problem and improving the range of coherent (also called continuous-variable) quantum communication systems, with a special emphasis on today's most developed platform towards practical applications, namely continuous-variable quantum key distribution.

Different strategies will be followed in order to attain this goal, ranging from the use of classical coding and other post-processing algorithms, which is the most directly applicable solution in the short term, to more elaborate longer-term techniques relying on specific quantum optical schemes and ultimately on the use of quantum coding. In particular, the potential solutions offered by the heralded noiseless linear amplifier, or other non-Gaussian heralded operations, will be investigated in detail.

The specificity of our consortium is to combine the strength of 5 academic groups having an outstanding track record in the area of coherent (continuous-variable) quantum information science, including 2 theory (ULB, UY) and 3 experimental (IO, MPL, TPT) groups, together with 1 industrial partner (SQN) who will naturally orient the research towards the needs of the information society. We envision that this synergy between applied and fundamental – both theoretical and experimental – teams will be highly stimulating and productive, and will reinforce European competitiveness in information technologies.

Relevance to the topic addressed in the call *(max. ¼ page):*

The project directly addresses two out of the four topics of the call:

1. Quantum information theory, algorithms and paradigms: new fundamental understandings, methods and quantum algorithms, computation paradigms and communication protocols;

3. Long distance quantum communication: technologies able to overcome the current distance limitation of quantum communication;

The present project is clearly oriented towards quantum communication, and aims at developing both classical and quantum error-correcting codes as well as alternative methods or protocols to overcome the current limitations of quantum communication systems, both in terms of rate (for quantum key distribution) and distance (in general). This will be achieved by carrying out research on a wide spectrum of issues, ranging from very practical ones (such as the implementation of very fast classical error-correcting codes for continuous-variable quantum key distribution) up to very fundamental ones (such as addressing the ultimate capacity of bosonic quantum channels). The expected impact of the project should cover all five objectives of the call, especially objective 4 (technology transfer) since a special attention will be given to (hardware and software) technologies that can be directly exploited by our industrial partner SQN.

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CHIST–ERA Proposal Template

Project Acronym

QINVC

Project Full Title

Quantum Information with NV Centres

Addressed Call Topic (QIFT[1] or BASCC[2]): QIFT

Coordinator contact point for the proposal

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[1] *Quantum Information Foundations and Technologies*
[2] *Beyond Autonomic Systems – the Challenge of Consciousness*

Partners' people involved in the realisation of the project[3]

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	France	CEA Saclay/SPEC	Daniel ESTEVE	Patrice BERTET Denis VION Postdoc PhD
2	France	ENS Cachan/ Laboratoire de Photonique Quantique et Moléculaire (UMR CNRS 8537)	Jean-François ROCH	Vincent JACQUES Frédéric GROSSHANS Piernicola SPINICELLI Anaïs DREAU PhD
3	Germany	Stuttgart University	Jörg WRACHTRUP	Fedor Jelezko Friedemann Reinhard postdoc
4	Germany	Univ. of Bochum/RUBION	Jan MEIJER	S. Pezzagna PhD
5	UK	Univ. of Warwick, Dept. of Physics	Mark NEWTON	PhD

(Use as much lines as needed)

[3] *If the people are for the moment unknown, specify the level of expertise sought (PhD, post-doc, engineer, professor…)*

chist-era

Duration: 36 months

Summary of the project[4] *(publishable abstract, max. ½ page):*

The aim of **QINVC** is to exploit the superior quantum coherence of **the spins of the negatively charged Nitrogen-Vacancy (NV)** colour centres in diamond, at both room and low temperature, for quantum information processing (QIP). This system is indeed among the best solid-state quantum systems in terms of coherence, ease of manipulation by ESR, and addressability down to the single spin using optical microscopy. Our project first focuses on two **hybrid strategies for QIP (WP1).** The first one consists in fabricating **regular arrays of single NV centres,** with gate operation performed using a movable NV spin placed at the apex of a cantilever, coming close enough to get entangled with a NV spin on the lattice using magnetic dipolar interaction. The fabrication method is based on pulsed ion beam implantation through a tiny hole threading the tip of an AFM cantilever, or through the voids of a mask deposited at the surface of the diamond sample. The second strategy implements a **hybrid architecture for QIP based on circuit QED and ensembles of NV spins**: transmon qubits are coupled to ensembles of NV spins through the resonator in which they are embedded. The NV spins will be used as a long-coherence time quantum memory for the transmon qubits which will be used to process quantum information.

QINVC will investigate in WP2 **the optical properties of NV centres at low temperature**. The first goal of WP2 is to transfer the optical techniques used at room-temperature to control electron and nuclear spins to low-temperatures, in the purpose of applying them to hybrid quantum circuits (WP1). A second goal is to investigate the potential of NV centres ensembles to build a quantum memory for optical photons.

These ambitious goals will request the **optimisation of NV centre production and their spin properties in synthetic diamond** (WP3) using state-of-the-art methods and beyond. This will be done in collaboration with the world industrial leader on the production of synthetic diamond Element6 Ltd. Engineered implantation of single N impurities with nanometer resolution will be performed for WP1, and suitable concentrations will be prepared for both WP1 and WP2. Sample processing will be developed for these two WPs in order to minimize the unwanted defects that cause decoherence. Innovative fabrication techniques will be also developed, such as the preferential alignment of NV centres under uniaxial stress, an appealing possibility.

Relevance to the topic addressed in the call[5] *(max. ¼ page):*

QINVC involves the best microscopic solid-state system and the best superconducting qubit circuits considered up to now for QIP, and aims at developing challenging QI architectures based on them. The project addresses the main issue of combining quantum coherence, addressability, and scalability. The construction and operation of a microscopic array of spins, and the development of a hybrid architecture based on spin ensembles, are relevant for the QIFT target outcome (2,4) and impact. Apart from QIP, the central issue of entanglement will be addressed, and the engineering of NV centres with enhanced properties will have multidisciplinary spin-offs, e.g. for magnetic imaging and sensing.

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[4] *Be precise and concise. This summary will be used to select suited reviewers for the proposal.*
5 Be precise and concise. Relevance to the topic addressed in the call is an essential eligibility criterion.

CHIST–ERA Proposal Template

Project Acronym

QScale

Project Full Title

Quantum technologies for extending the range of quantum communications

Addressed Call Topic (QIFT or BASCC): **QIFT**

Coordinator contact point for the proposal

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Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	FRANCE	Laboratoire Kastler Brossel, Université P. et M. Curie, Ecole Normale Superieure, CNRS *(LKB)*	J. Laurat	C. Fabre (Pr.), L. Veissier (PhD), L. Giner (PhD), O.Morin (PhD), X (Post-doc)
2	SWITZERLAND	Group of Applied Physics, University of Geneva *(GAP)*	N. Gisin	N. Sangouard (Assoc. Pr.), X (PhD)
3	ITALY	Istituto Nazionale di Ottica, *(INO-CNR)*	M. Bellini	F. Marin (Pr.), I. Herrera (Post-doc), P. Lombardi (PhD), F. Minardi (Res.), A. Zavatta (Res.), X (Post-doc)
4	GERMANY	Universität des Saarlandes *(UdS)*	J. Eschner	J. Gosh (Post-doc), C. Kurz (pre-doc), J. Brito (pre-doc), X(Post-doc)

5	SPAIN	Institute of Photonic Sciences, Barcelona *(ICFO)*	H. de Riedmatten	M.Gundogan (PhD), X (Post-doc), X (PhD)
6	ITALY	Quanta System *(QuantaS)*	F. Ferrario	A. Agliati, F. Paleari, F. Paglia, C. Malvicini, F. Brioschi

chist-era

Duration: 36 months

Summary of the project *(publishable abstract, max. ½ page):*

The QScale project focuses on the development of advanced quantum communication technologies, specifically of quantum repeater architectures**,** which represent a major and timely challenge for the field of quantum information science and technology.

Quantum repeaters are needed in order to overcome losses and errors in the transmission of quantum data. It allows the distribution of entanglement at arbitrary large distances, which is a universal resource for quantum information applications, including quantum cryptography and quantum teleportation.

The first part of the project is devoted to photonic components, i.e. the development of entangled photonic sources compatible with quantum memories, and of continuous-variable quantum light pulses, including non-Gaussian fields for hybrid quantum repeater architectures.
In the second part, efficient coupling between light and material systems will be implemented. It will allow the reversible mapping of quantum photonic information into and out of the memory device or the synchronized emission of single-photons from remote systems. Several materials, including cold and ultra-cold atomic ensembles, trapped-ion strings and rare-earth ion doped crystals will be studied.
The third part will integrate these outcomes. It will address effective storage of entanglement in the devices developed previously, assessing their ability to operate as nodes of quantum repeaters. It will also pave the way towards deterministic entanglement swapping. The various photonic carriers and material memory systems investigated above will be compared.
Finally, procedures and architectures for quantum repeater systems based on the previous elements will be examined and investigated, including novel hybrid schemes and new deterministic operations. Their implementation with the devices developed in the project will be assessed.

At present quantum repeaters constitute a well-identified milestone on the quantum technology road maps, so the proposed project is a high-risk but also high-pay-off one.

Relevance to the topic addressed in the call *(max. ¼ page):*

This subject corresponds to topic 3 of the CHIST-ERA Call, “Long-distance quantum communications”. It aims at developing relevant components of quantum repeater architectures and integrating them for the implementation of long-distance communication schemes. It holds the promise for bringing major advances for quantum communications and technologies able to overcome the current distance limitation of quantum communication, by developing operational quantum repeaters.

CHIST–ERA Proposal Template

Project Acronym

QUASAR

Project Full Title

Quantum States: Analysis and Realizations

Addressed Call Topic (QIFT[1] or BASCC[2]): QIFT

Coordinator contact point for the proposal

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Partners' people involved in the realisation of the project

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	Germany	University of Munich / Faculty of Physics LMU	Harald Weinfurter	Christian Schwemmer, Daniel Richart-Lampert (+ 1 post-doc)
2	Austria	Academy of Sciences OEAW	Anton Zeilinger	Philip Walther (+ 1 post-doc)
3	Italy	Sapienza Universita di Roma / Department of Physics UNIROMA1	Paolo Mataloni	Fabio Sciarrino Giuseppe Vallone Roberta Ramponi Roberto Osellame (+ 1 post-doc)

[1] *Quantum Information Foundations and Technologies*
[2] *Beyond Autonomic Systems – the Challenge of Consciousness*

4	Italy	OPTOTEC SpA	Stefano Pitassi	L. Duca M. Villani T. Pensato
5	Poland	Warsaw University / Faculty of Physics UWAW	Rafal Demkowicz-Dobrzanski	Konrad Banaszek Jan Kolodynski (+1 post-doc, +1 PhD student)
6	Poland	University of Gdansk / Institute for Theoretical Physics and Astrophysics GD	Marek Zukowski	R. Horodecki M. Horodecki P. Horodecki K. Horodecki M. Kus, M. Wiesniak W. Laskowski
7	Spain	University of the Basque Country / Department of Theoretical Physics BILB	Geza Toth	I. Urizar-Lanz G. Vitagliano
8	Germany	University of Siegen / Department of Physics USI	Otfried Gühne	M. Kleinmann T. Moroder (+1 post-doc)

Duration: 24 months

Summary of the project:

Quantum Information Processing and Quantum Communication brought a radical, paradigmatic change in our understanding of the nature of information and of its use. Progress in efficient quantum computation and communication will be possible provided we gain a significantly improved comprehension of the underlying principles of quantum physics, have scalable analysis tools available to study the dynamics, decoherence, as well as the applicability of large quantum states, and, last but not least, have reliable and robust quantum technology components available.

The main objectives of QUASAR are thus to

- apply foundational principles of quantum physics to identify novel protocols for quantum communication and to optimize the efficient usage of quantum channels, both in theory and experiment
- develop scalable methods for quantum state analysis and introduce application oriented witnesses with high statistical significance and robustness against experimental imperfections
- implement these methods to analyse the dynamics and their applicability for quantum metrology for different decoherence models and identify possible feedback protocols to adaptively optimize metrological tasks.
- develop a new approach for the production of highly integrated and reliable waveguide quantum circuits and implement photonic quantum logic operation for robust manipulation of high-dimensional multiqubit states and for quantum simulation tasks.

QUASAR unites a broad variety of partners, ranging from theoretical and mathematical physics all the way to experimental quantum and nonlinear optics and includes an industrial partner focusing on possible deployment of integrated quantum logic circuits.

Relevance to the topic addressed in the call:

The project QUASAR addresses the challenges in the field of Quantum Information Foundations and Technology by focusing on the underlying principles of the nature of information and quantum speed-up and on possibilities of communication protocols. We will design scalable and robust tools for efficient analysis of multiqubit quantum states, and will develop reliable technologies, i.e., micro-optics and integrated waveguide components for robust operation of photonic quantum logic gates. Feedback optimization for quantum metrology in the presence of noise and decoherence as well as for enhanced long-range quantum communication will enable unprecedented characteristics. Finally, we will show the power and efficiency of the new tools in quantum simulation and communication demonstrations and work towards transfer of the developed quantum technologies to industry.

CHIST–ERA Proposal Template

Project Acronym

R-ION

Project Full Title

Rydberg excited Calcium Ions for Quantum Interactions

Addressed Call Topic: QIFT

Coordinator contact point for the proposal

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Partners' people involved in the realisation of the project

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
1 Coordinator	United Kingdom	University Nottingham (UN)	Igor Lesanovsky	Weibin Li, Post-Doc (NN)
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3	Germany	University Mainz (JGU_W)	Jochen Walz	Daniel Kolbe, Ruth Steinborn, Post-Doc (NN)
4	Germany	University Mainz (JGU_S)	Ferdinand Schmidt-Kaler	Kilian Singer, Post-Doc (NN)

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Duration: 36 months

Summary of the project

Trapped cold ions are among the most advanced systems to implement quantum information processing. In current experiments entanglement of the qubits, represented by long lived internal atomic states, is achieved via quantum control of the (collective) motion of the ion crystal. Instead, we propose an unprecedented experimental program supported by theory, where the huge dipole moments associated with Rydberg excited ions are the basis of extremely strong spin-dependent long range interactions, and thus exceptionally fast entangling operations as basic building blocks for quantum computing and quantum simulation. While in the short term the fundamental questions to be explored are the understanding of Rydberg excitation and dynamics of single and multiple ions stored in linear Paul traps, and the various ways of manipulating this dynamics with external electromagnetic fields, the long term promise of this project is a potentially scalable very fast ion trap quantum processor, and in particular also a novel efficient quantum simulator of spin models, for Heisenberg type interactions to exotic matter with topological phases. A main experimental challenge is the requirement of a coherent light source near 122nm for the ion Rydberg excitation. Our consortium is in the remarkable and unique situation where in a single laboratory both these coherent light sources as well as advanced ion quantum computing setups are available, thus allowing us to explore this extremely promising new frontier of Rydberg ion quantum information processing on a comparatively short time scale. The planned experiments will be based on the well established techniques of ion trapping, quantum state detection and manipulation with laser fields. An adapted quantum shelving method is proposed to detect transitions to Rydberg states with unity detection efficiency on individual ions even in large crystals. Initially we will accurately determine energy levels and atomic properties of ion Rydberg states, and then we aim for mutual Rydberg state interactions of adjacent ions. Such gate interactions, Rydberg induced quantum phase transitions and a full tomography of the resulting quantum state benefit from the highly developed schemes in quantum information processing. In the future, beyond the experimental horizon of the three-year project, fast Rydberg ion quantum logic operations could possibly be combined with the conventional gate schemes and modern ion trap technology.

Relevance to the topic addressed in the call

We address the long range strong Rydberg interactions with trapped ions, providing a novel basic physical system for quantum logic interactions. The strongly interacting Rydberg dipoles give rise to fast interactions and gate operations are expected to be at least one order of magnitude faster than it is possible today. Using large trapped ion crystals we aim at scaling up the so far very successful ion quantum processing. Rydberg gate operations have the potential to overcome complications from the vibrational mode structure of even large, eventually two and three dimensional ion crystals. The novel gate scheme will allow one to address ion crystals containing one order of magnitude more ions for studying spin models exhibiting quantum phase transitions. In such a way the trapped ion quantum computing will allow quantum simulations of many-body problems with a significant step towards order of 100 ions.

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CHIST–ERA Proposal Template

Project Acronym

SSQN

Project Full Title

The Solid-State Quantum Network

Addressed Call Topic (QIFT or BASCC): QIFT

Coordinator contact point for the proposal

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Partners' people involved in the realisation of the project

Partner Number	***Country***	***Institution/ Department***	***Name of the group leader***	***Name of other personnel participating in the project***
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2	Germany	Universitaet Wuerzburg, Technische Physik (UWUERZ)	Martin Kamp	Alfred Forchel Stephan Reitzenstein Sven Höfling
3	France	CNRS/LPN, Laboratoire de Photonique et de Nanostructures	Pascale Senellart	Loic Lanco Olivier Krebs Aristide Lemaitre Isabelle Sagnes Paul Voisin
4	UK	Imperial College London, Blackett Labs	Terry Rudolph	Sean Barrett

(Use as much lines as needed)

chist-era

Duration: 36 months

Summary of the project *(publishable abstract, max. ½ page):*

Quantum communication, the transfer of quantum superposition states over long distances, is presently limited to about 200km (both in optical fibre and free space) due to unavoidable photon absorption losses. For this reason, theoretical schemes to extend this distance using “entanglement swapping” and “teleportation” have been established. By concatenating short entanglement swapping sub-sections it is in principle possible to generate entangled (correlated) bits over very long distances with bit rate only limited by the losses in one short section. If realised this would extend quantum communication applications such as quantum cryptography and quantum teleportation out to distances of thousands of kilometres.

In this consortium we propose to work towards such a deterministic quantum network based on semiconductor quantum dot-micropillar cavity systems. We will generate entangled photon sources from the biexciton-exciton cascade of a quantum dot (QD), with a potential fidelity of >90%. Moreover, we will develop a QD-spin micropillar cavity system, which acts as an all-in-one spin-photon-interface and a Bell-state analyser. This component eliminates the need for synchronous arrival of the two photons, and allows a wait-until-success protocol over the timescale of the spin coherence time (microseconds to milliseconds). Further subcomponents will include electro-optically tuneable single photon sources and recently proposed sequentially entangled sources.

With this suite of subcomponents we will be able to realise all the functions required for a scalable quantum network including the final entanglement purification steps. This is in contrast to previous experimental demonstrations of entanglement swapping (and teleportation) which were probabilistic and thus unscalable.

The project involves collaboration between four partners. We will bring together two world-class groups, LPN and Würzburg (UWUERZ), working on micropillar cavities producing highly efficient entangled pair sources (LPN), and strongly-coupled QD-spin-cavity systems (UWUERZ), with the aim of addressing the challenging issues of entangled-pair sources and spin-cavity systems. Theoretical support for novel and practical entanglement schemes will be provided by Imperial College (IMP), and the experimental implementation will be performed by Bristol (BRIS) and LPN, who have world-class expertise in quantum optical communication , QD spins and semiconductor microcavity quantum electro-dynamics.

Relevance to the topic addressed in the call *(max. ¼ page):*

This project directly addresses CHISTERA GOALS 3: Technologies able to overcome the current distance limitation of quantum communication. In the final outcome our solid state quantum network could provide quantum bit rates that fall only polynomially with distance as predicted in the initial theoretical predictions of quantum repeaters.

We will overcome distance limitations by using (i) solid-state deterministic entangled photon sources and (ii) long-coherence time, efficiently-coupled QD-spin interfaces. The inherently scalable modules may be linked to produce, in principle, unlimited quantum communication distances.