**ALLEGATO 10**

**BANDO PUBBLICO PER LA SELEZIONE DI PROPOSTE PROGETTUALI, FINALIZZATE ALLA CONCESSIONE DI FINANZIAMENTI PER ATTIVITA' COERENTI CON QUELLE DELLO SPOKE 1 "PERVASIVE AND PHOTONIC NETWORK TECHNOLOGIES AND INFRASTRUCTURES" DELL'INIZIATIVA "RESEARCH AND INNOVATION ON FUTURE TELECOMMUNICATIONS SYSTEMS AND NETWORKS, TO MAKE ITALY MORE SMART (RESTART)" A VALERE SULLE RISORSE DEL PIANO NAZIONALE DI RIPRESA E RESILIENZA (DI SEGUITO PNRR), IN ATTUAZIONE DELL'INVESTIMENTO 1.3 – CREAZIONE DI "PARTENARIATI ESTESI ALLE UNIVERSITÀ, AI CENTRI DI RICERCA, ALLE AZIENDE PER IL FINANZIAMENTO DI PROGETTI DI RICERCA DI BASE" NELL' AMBITO DELLA MISSIONE 4 "ISTRUZIONE E RICERCA" – COMPONENTE 2 "DALLA RICERCA ALL' IMPRESA", (PE 0000001), DI CUI ALL'ART. 5, DELL'AVVISO PUBBLICO NR. 341.2022**

**CODICE BANDO: IEIIT-RESTART-SP1-03**

**CUP B53C22003970001**

**Requisiti scientifici**

**Green optical technologies: materials and meta-materials, integrated circuits and low-energy transceivers, propagation models, capacity scaling & QKD-secured transmissions**

The activities are synergic with and complement the existing activities planned in the Structural project S4 Engineering Photonic Devices And Systems Towards A Green Optical Network Infrastructure for 6G (RIGOLETTO), and in particular they will be included in the planned activities for Tasks 2.1, 2.2, 3.1, 3.3, 4.1 and 6.1 of RIGOLETTO. The complete description of RIGOLETTO is provided as Allegato 9 of this call.

Specifically, activities must comply with the following requirements.

**Activity 2.1 (complementing T2.1 of RIGOLETTO)**

**Description of the activities**

The need to exploit new materials stands alongside with the increasing need of tunable and reconfigurable on-chip systems, with high efficiency in terms of scalability, power consumption, and working bandwidth, especially in view of the 5G/6G ICT and IoT applications. The scope of this call is the development of novel Materials-based Devices and Systems for Ultra-Fast electronics.

The most promising novel materials involve ferroelectrics (FE), such as Hafnium Zirconium Oxides, carbon materials, such as graphene, and phase change materials (PCM), such as VO2, characterized by fast tunability properties that can be useful for a wide variety of electronic circuits and systems. The main activities will focus on fundamental study of the above materials in terms of physical/atomistic properties, like density of electronic states, atomic structure, complex permittivity and permeability in the frequency ranges up to mm wavelengths.

Regarding the ferroelectrics (FE)-based ultra-high frequency devices, it is expected the realization of low TRL prototypes of miniaturized phase shifters, filters, antennas and antenna array. Another outcome could be the fabrication of rectennas and RF harvesters based on MIM (metal-insulator-metal) tunnelling diodes, where the insulator is given by Hafnium Zirconium Oxides (HZO)

The research developed in the present call will enable the design of reconfigurable components like oxide-based RF-switches, which can change their characteristics on ns and ps time scales. It is expected that such switches, preferably designed in a coplanar structure, will show ultra-low insertion losses (< 0.2 dB), high

isolation (>25dB), and switching times in the range of 100 ps up to 100 ns. Moreover, PCM-based components are expected to be characterized by a wide bandwidth from 1 GHz up to 100 GHz. The proposed activities require the inclusion of an industrial exploiter (IC manufacturer) with the aim to fabricate and demonstrate the impact of the proposed innovation in terms of new materials.

**Relation with the RIGOLETTO project workpackages**

**WP2: T2.1 – Materials, metamaterials and integration technologies (TL: POLIBA)**

The objective is to cover a large scope of T2.1 by demonstrating, as a proof of concept, that graphene, FE and PCM devices can open the way to improve the design in the following application areas: 1) low insertion loss phase shifters; 2) fast and self-tuning matching networks; 3) reconfigurable antennas on portable devices; 4) wide band/wide scan phased arrays. A further major goal will be prototyping graphene-based ballistic components operating at room temperature. For instance, geometrical and ballistic diodes aimed at detection and mixing up to the THz range should be designed and realized. In terms of theory and numerical tools, it is expected to develop a theoretical-computational platform bridging from discrete, atomistic level to the continuum level.

**Deliverables**

- A2.1_D1: End-User requirements and specification – Month 3
- A2.1_D2: Report on atomistic modeling of 2D and FE materials – Month 6
- A2.1_D3: Multiscale modelling tool-kit for reconfigurable devices – Month 9
- A2.1_D5: Report on smart material development and characterization – Month 11
- A2.1_D6: Samples supply for subsystem/demonstrator fabrication – Month 15
- A2.1_D7: Demonstration and test of reconfigurable arrays and related sub-modules – Month 22

**Activity 2.2 (complementing T2.2 and T4.1 of RIGOLETTO)**

**Description of the activities**

The scope of this call is the development of fully integrated transmitters for radio over fiber-optical communication systems based on integrated photonic technologies. The performance in terms of bandwidth, linearity and power consumption has to be optimized through the co-design and co-packaging of the photonic and electronic integrated circuits and should be based on specifications given by an industrial end-user. The main goal is to design a hardware device composed of an electronic and a photonic unit, integrated on a single chip. Fabrication of devices should be carried out utilizing standardized processes that are routinely used in photonic and electronic foundries, also by making use of expertise of companies involved in the consortium. The transmission scheme needs to rely on multilevel and OFDM-based modulation formats with a single channel bandwidth in the range of 30- 40 GHz. Transmission test have to be carried out using state of the art telecommunication test-beds, potentially including measuring sessions with industrial and potential user companies, active in the telecom industry. The enhancement of the performance of the transmission system (in terms of BER of the received signal and signal to noise ratio levels at the receiver side) can be achieved through the design and development of a heterogeneously integrated erbium doped waveguide amplifier (gain > 20 dB in the C-band) and through the optimization of the electronic radio frequency driver circuits. The aim of the project is to design and develop a fully packaged transmitter scheme (photonic unit co-packaged with the electronic unit) and a discrete gain unit packaged with input and output optical fiber. Proposals should include in the consortium potential exploiters of the final system and industrial companies with significant involvement in optical fiber telecommunication system field.

**Relation with the RIGOLETTO project workpackages**

**WP2: T2.2 – Photonic integrated circuits and components (TL: SSSA)**

The expected project should support T2.2 by targeting the following relevant results:

- the development of novel strategies for the co-design and co-packaging of integrated active photonic circuits including the integration of driving electronic circuits
- The development of novel integrated circuits for signal amplification

**WP4: T4.1 – Low-energy and high-rate transceiver (TL: POLIMI)**

The expected project should support T4.1 by targeting the following relevant results:

- the development of a transmitter based on the co-design and co-integration of photonic and electronic components for radio over fiber transmission;
- the study of the feasibility of integrated receiver optimized for radio over fiber applications;
- the development of heterogeneous photonic circuits for the realization of amplified and fully integrated transceivers.

**Deliverables**

- A2.2_D1: Specifications and Design of the erbium implantation process and co-design (microelectronics and photonics) of the optical transmitter – Month 6
- A2.2_D2: Design and development of low- loss optical waveguides – Month 10
- A2.2_D3: Development of the integrated photonic/microelectronic circuits for the transmitter – Month 12
- A2.2_D4: Experimental test of the optical transmitter – Development and test of highly doped – Erbium doped waveguides – Month 16
- A2.2_D5: Study of the integrated receiver and post-receiver RF amplifier – Month 20
- A2.2_D6: Final test of the integrated transmitter based on co-design and co-integration of electronic and photonic circuits and of the integrated erbium doped waveguide amplifier –Month 24

**Activity A2.3 (complementing T3.1, T3.3 and covering T6.1 of RIGOLETTO)**

**Description of the activities**

This task faces the issues of theoretical and practical integration of QKD channels into optical fiber WDM/SDM transmission by developing a suitable propagation and system model that takes into account the transmission of both classical and quantum channels in order to evaluate the impact of each relevant physical parameter on the final performance of each channel and the feasibility of the design.

The following preliminary activities in support of the demonstration need to be completed: (i) theoretical modeling and/or numerical analysis of design and propagation in special fibers such as hollow-core fibers and fibers for SDM (multi-mode and multi-core), as well as amplification in special and doped fibers; (ii) SDM and multi-band transmission models, SDM-approach to capacity scaling also in the access network (SDM PON), modeling of multiband transmission.

The demonstration phase requires to design and implement on-field demonstration of a space-division multiplexed (SDM) transmission in SDM fibers deployed in a testbed, where classical WDM signals carrying multi-level QAM modulation are encrypted with either discrete- or continuous-variable quantum keys distributed in the same fiber channel. A distributed city-wide testbed with deployed SDM fibers should be available to the respondent(s) to the call. The consortium should engage in the demonstration phase and industrial partner acting as exploiter and co-developer of the hardware.

**Relation with the RIGOLETTO project workpackages**

**WP3: T3.1 – Propagation modeling in novel fibers and devices (TL: UNIPD)**

The call covers the scope of T3.1 as regards propagation models for SDM fibers with focus on the interplay between nonlinear effects, modal dispersion and mode-dependent loss. It addresses specifically coupled-core MCFs and FMFs with lumped amplification. In addition, the call covers the area of numerical modeling of non-ideal behavior, propagation, and amplification in hollow-core and multi-core fibers with extensions to multi-band systems.

**WP3: T3.3 – Capacity scaling via SDM/MB (TL: TBD after cascade calls)**

The call covers the scope of T3.3 as regards nonlinear interference in the case of multi-band systems, including stimulated Raman scattering and resource allocation strategies and efficient spatial switching management in SDM-PON.

**WP6: T6.1 – QKD-secured DM transmission (TL: TBD after cascade calls)**

The call entirely covers T6.1 objectives by demonstrating on-field transmission of encrypted classical (QAM-modulated) signals in a coherent SDM-WDM system. Encryption must rely on a quantum key distributed in the same SDM fiber, so as to demonstrate the coexistence of quantum and classical signals in the same fiber-optic channel, by exploiting wavelength multiplexing in combination with spatial multiplexing. A full chain including key generation and distribution, signal generation, encryption, transmission, and decryption must be implemented.

**Deliverables**

- A2.3_D1 – Report about analytical models for NLIN in SDM systems and multi-multi-band SDM systems Month 5
- A2.3_D2 – Report on Algorithms for optimal SDM-PON resource management - Month 9
- A2.3_D3 - Software tool for SDM transmission in the considered SDM systems and documentation - Month 12
- A2.3_D4 – Report on the design of the demo experiment, including quantum/classical interference analysis - Month 16
- A2.3_D5 - Demo experiment and report on results - Month 24

**Additional Constraints**

Proposals should clearly indicate how they will achieve the following constraints in terms of budget allocation. Compliance with the following requirements will be mandatory for proposals to be considered eligible. In addition to the general constraints already specified in the call, the following constraints must be met:

- Between 15% and 20% of the allocated budget should be devoted to a mix of the following:
  - activities devoted to the development of new hardware components;
  - involvement of industrial partners whose key focus is on business verticals relevant for the topic of the call, e.g., healthcare, energy, automotive, transportation, smart cities, Industry 4.0.
- The breakdown of funding requested to the activities of Topic 1 must fall within the following ranges:
  - Activity 2.1: max funding € 500.000,00
  - Activity 2.2: max funding € 500.000,00
  - Activity 2.3: max funding € 763.000,00