Dipartimento di Ingegneria
dell'Informazione, Elettronica
e Telecomunicazioni

Announcement of 36 months Position for Early-Stage-Researcher H2020-MSCA-ITN "MOCCA - Multiscale optical frequency combs: advanced technologies and applications"

MOCCA is a **European Industrial Doctorate (EID)** consortium of high profile Partners in the United Kingdom, France, Italy and Germany, including academic partners Aston University (Birmingham, UK), La Sapienza University of Rome (Rome, Italy), CNRS-C2N/ University of Paris-Saclay, (Paris, France), RWTH Aachen University (Acheen, Germany) as well as industrial partners THALES (France), Nokia-Alcatel III-V Labs (France) and AMO GmbH (Germany).

Title: **Optical frequency comb dynamics for novel microcomb sources**

Background: High-precision optical frequency combs (OFCs), often referred to as optical rulers, had a strong impact on metrology and spectroscopy in the last decade. Recent advances in the technology of optical micro-cavities contribute to the development of chip-scale OFC sources [1]. The mechanism for comb formation in microcombs is the cubic or Kerr nonlinearity of the waveguide material, which leads to dissipative modulation instability [2], followed by cascaded four-wave mixing (FWM). In spite of the many exciting achievements in the field of micro-combs, namely optical frequency combs based on high-Q micro-resonators, several open questions and challenges remain. For example, the relatively high continuous wave (CW) pump power, the poor conversion efficiency from the CW pump to the comb, the complex stabilization required for coherent soliton combs, and the scarcity of available pumps in some spectral regions such as the visible and the mid-infrared.
It has recently been demonstrated that frequency combs also can be generated in quadratic nonlinear media, see figure and refs. [3–6]. Quadratic combs may operate with substantially decreased pump power compared to Kerr combs, and may permit the direct generation of combs in spectral regions where the generation of conventional Kerr combs is difficult to achieve, e.g., because no suitable pump sources are available or because the dispersion properties of the material are not conductive to comb generation.

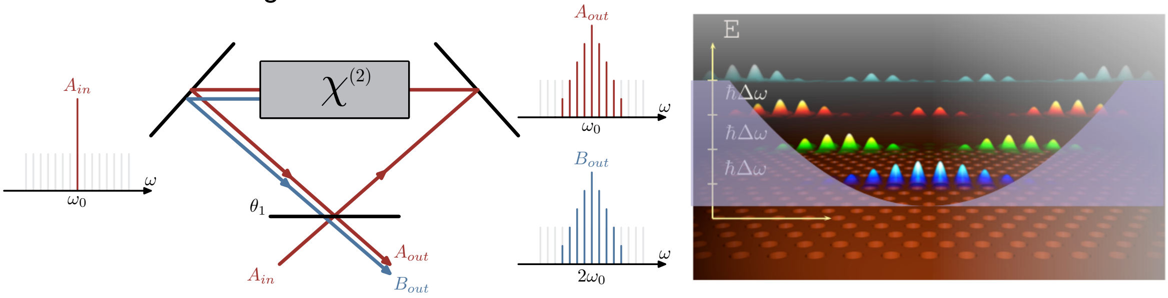

Figure: schematic of quadratic combs from intracavity second-harmonic generation (right); harmonic photonic potential in novel microresonators (right).

These founding results have opened a new research field with potentially huge impact in metrology, but also in communications and optical signal processing. A crucial aspect is the perspective of integration in a photonic platform and therefore easy deployment of OFC-technology. This timely meets the emergence of novel

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photonic platforms based on III-V semiconductors, which, in contrast to Silicon, support quadratic nonlinearities [7].
Another fundamental aspect relates to the possibility of combs in resonators not involving interactions among longitudinal/azimuthal modes (rings, disks, toroids), rather among either transverse mode, as is the case of axial photonics (SNAP) [8], or purely stationary modes in photonic crystals (PC) [9], which have been shown recently to allow equi-spaced eigenfreqiencies. The important implication is that physics similar to OFC is expected there [10]. The theory has not yet been fully developed, let alone experiments.

Overview: **Objectives**: (1) to develop a general theory of quadratic and cubic OFCs; (2) to determine the build-up and stability of broadband, phase-locked OFCs; Develop a theory for unconventional resonators sustaining OFC (4) experimental demonstration of new sources for energy efficient and broadband OFCs.

Expected Results:
a) Theory:
Models for build-up and evolution of the fields in microresonators and active cavities for maximum spectral broadening; study how gain, path length fluctuations and environmental factors influence the stability of the intra-cavity nonlinear spectral broadening; conditions for minimizing quantum phase-noise and obtaining mode-locking and comb coherence; study comb generation by multimodal models, involving the minimization of Lyapunov functionals;comb generation in novel micro-resonator (photonic crystal [9], SNAP [8]), unified model for harmonic photonic potential.
b) Experiments
Design waveguide components for multimode phase matching. Quadratic combs based on the InGaP on oxide [7] nonlinear technology. Experimental study of phase noise and comparison with theory.

Planned secondments: THALES (France): 9 months: training on theoretical characterization of dual OFC based on SNAP, photonic crystal cavity and semiconductor platforms; III-V LABs (France): 9 months: training on semiconductor-based OFC technologies.
Host institution and PhD enrolmentenrollment: La Sapienza University of Rome (Italy)
Supervisor(s): S. Wabnitz (stefan.wabnitz@uniroma1.it), Sapienza University of Rome (Italy); co-supervisors during the secondment: A. De Rossi, (alfredo.derossi@thalesgroup.com), THALES; F. Raineri (fabrice.raineri@c2n.upsaclay.fr), CNRS/C2N/University of Paris-Saclay

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