POLITECNICO
MILANO 1863

# Supervisor Expression of Interest
# MSCA - Marie Sklodowska Curie Action - (PF) Postdoctoral Fellowship 2022

| | |
|---|---|
| **Supervisor name:** | Marco Marangoni |
| Email address: | marco.marangoni@polimi.it |
| Link *"Pagina docente":* | https://www.fisi.polimi.it/it/personale/marangoni |
| Department Name: | Physics |
| Research topic: | Optical metrology |
| MSCA-PF Research Area Panels: | ☐ CHE_Chemistry<br>☐ ECO_Economic Sciences<br>☐ ENG_Information Science and Engineering<br>☐ ENV_Environmental and Geosciences<br>☐ LIF_Life Sciences<br>☐ MAT_Mathematics<br>☐ **PHY_Physics**<br>☐ SOC_Social Sciences and Humanities |
| Politecnico di Milano Areas: | ☐ Cultural Heritage<br>☐ Smart Cities<br>☐ **Horizon Europe Missions**<br>☐ Health<br>☐ Industry 4.0 |
| Brief description of the Department and Research Group (including URL if applicable): | The Physics Department comprises 70 faculty members, 18 technical and administrative staff people, 100+ PhD students and 40+ PostDocs. The research activities of the Department are mainly experimental and focused on the two broad areas of Photonics and Nanotechnologies. The activity of the group of Marco Marangoni, in particular, focuses on the development of high-precision and high-sensitivity laser spectrometers for fundamental science, such as primary thermometry and comparative analysis of transition energies with quantum-mechanical models, and for medical and environmental applications, such as breath analysis and trace gas detection. Marco Marangoni is the group leader of two laboratories, namely CHROME (https://www.fisi.polimi.it/en/research/research_structures/laboratories/chrome) and COSMOS (https://www.fisi.polimi.it/en/research/research_structures/laboratories/cosmos). |

POLITECNICO
MILANO 1863

| Title | Stimulated-Raman-Scattering metrology of infrared-inactive transitions |
|---|---|

**Brief project description:**
**(max 1 page)**
The invention of optical frequency combs has been a change of paradigm for optical metrology, enabling thousands of transitions to be characterized in the frequency domain with unprecedented accuracy. The absence of native frequency comb sources in the mid-infrared has privileged the investigation of overtone bands in the near-infrared. Less studies have focused on fundamental rovibrational transitions, even less on purely rotational transitions and only few exceptions have addressed so far quadrupole transitions, which are the only available spectral signatures for homonuclear molecules and in general for Infrared-inactive transitions.
In this project we intend to further develop and bring to application a recently introduced comb-calibrated spectroscopic tool that fills the above gap, by enabling frequency metrology of Raman-active transition and thus of quadrupole transitions in a two-octave spanning range, from 50 to 5000 $cm^{-1}$. This is equivalent to cover all fundamental rovibrational bands as well as purely rotational bands. The spectrometer exploits a Stimulated-Raman-Scattering interaction of the gas target with two comb-calibrated near-infrared cw lasers in a multi-pass cell. It has been applied so far only to the transition frequency of the Q(1) 1-0 line of molecular hydrogen at 4155 $cm^{-1}$, reaching an accuracy of few parts-per-billion ($1.3 \cdot 10^{-5}$ $cm^{-1}$). This is an order of magnitude better than the experimental state of the art obtained by Resonantly-Enhanced Multiphoton-Ionization and a factor of 2 better than the current theoretical benchmark obtained by initio-calculations.
Starting from this background, the project addresses two major research (1) and innovation (2) axes. (1): The spectrometer is going to be applied to the accurate determination of several transition energies of molecular hydrogen and its isotopologues of both fundamental rovibrational and purely rotational bands; experimental findings will be compared to ab-initio predictions, possibly setting stringent tests of quantum-electro-dynamics on molecular species. (2) The spectrometer will be technically upgraded by replacement of the multipass cell with a hollow-core fiber (HCF) to upscale its sensitivity: thanks to the tight optical confinement and the low losses, HCFs are predicted to enhance the nonlinear Raman signals by two orders of magnitude, making it possible to probe lines at very small pressures with high signal-to-noise-ratio. This will significantly reduce the impact of systematic errors in the extrapolation to zero pressure of line center frequencies, eventually bringing the final accuracy to the sub-ppb level.
Overall, the project activity is deeply rooted in the field of lasers, nonlinear optics and precision molecular spectroscopy, but the implications of the project are likely to impact straightforwardly on many other fields such as astrophysics, optical metrology or medicine. The research training program will be primarily based on training-through-research under the supervision of Prof. Marangoni by means of an individual personalized action. The training activities will include learning hard skills of complementary nature to the background of the applicant, as well as soft skills to enrich and strengthen his team-leading and team-working attitude, his communication skills and also his capability of making decisions.