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M2 research Internship

Visible-Light Generation in Whispering-Gallery-Mode Microspheres via Optical Nonlinearity

Duration: February to July 2026
Supervisor: Stéphane Trebaol, Hélène Ollivier, Yannick Dumeige
Research team: Photonic Systems at Foton Institute - Lannion - France
Keywords: High-Q microresonator, nonlinear optics, laser, visible light, single photon counting

Context

Compact and highly coherent visible light sources are essential building blocks for metrological applications such as integrated atomic clocks, as well as for quantum technologies including sensing, communication, and computing. The optimization of photonic components relies on the development of integrated narrow-linewidth lasers, optical frequency combs, and efficient cryogen-free single-photon sources. Whispering-gallery-mode (WGM) microresonators have been extensively studied for decades due to their exceptional properties, such as high Q-factors, long photon lifetimes, and small mode volumes. These unique features have enabled the demonstration of various linear, nonlinear, and quantum photonic devices based on WGM resonators.

In recent years, the growing demand for compact coherent sources operating at shorter wavelengths has motivated the research community to explore the potential of WGM resonators in this spectral range. Several recent demonstrations include self-injection-locked lasers[1], laser frequency stabilization[2], rare-earth-doped microlasers[3], and nonlinear optical sources such as Kerr frequency combs[4]. Atom-based quantum technologies, in particular, require light sources operating at wavelengths resonant with specific atomic transitions. Light generation based on nonlinear optical processes provides a versatile approach to achieve such emission wavelengths for laser[5] or photon-pair generation[6].

We propose to develop compact WGM microsphere light sources operating in the visible range, based on optical nonlinear processes such as stimulated Brillouin (SBS) and Raman (SRS) scattering, and Kerr effect through four-wave mixing (FWM). Various materials—including polymers, oxide glasses, and fluoride glasses—will be investigated to identify the optimal host matrix that offers a suitable balance between strong optical nonlinearities and a broad transparency window in the visible spectrum. The primary milestone of this project is the demonstration of a narrow-linewidth visible microsphere laser based on stimulated Brillouin scattering. In the next stage, Kerr frequency comb generation in the normal group velocity dispersion (GVD) regime will be explored at visible wavelengths. Upon successful demonstration of Kerr FWM, we will investigate the spontaneous FWM regime to achieve photon-pair generation and characterize its correlation properties aiming towards quantum applications.

The intern will benefit from a dynamic and collaborative research environment. The project is part of ongoing national and international collaborations, in connection with several funded research programs. The intern will work within an active research team including faculty members, postdoctoral researcher, PhD students, and research engineers, and will have access to the laboratory's experimental facilities. Further information about the team's research activities can be found on our website (https://www.institut-foton.eu/laser-visible-uv/).

Objectives

In this research internship project, the intern will:

- Learn to fabricate high-Q microspheres resonator using various techniques.
- Learn to fabricate fiber tapers used for light coupling inside high-Q microspheres
- Characterize linear and nonlinear properties of high-Q microresonators using existing optical setups
- Observe and analyze the spectral signatures of nonlinear processes such as SBS, SRS and FWM in a high-Q microsphere at visible wavelengths
- Investigate modal dispersion engineering strategies in microresonators to compensate for material GVD and optimize phase-matching conditions for FWM.

References

1. Savchenkov, A. A. *et al.* "Application of a self-injection locked cyan laser for Barium ion cooling and spectroscopy." *Sci Rep* **10**, 16494 (2020).
2. Perin, G., *et al.* "High-Q Whispering-Gallery-Modes Microresonators for Laser Frequency Locking in the Near-Ultraviolet Spectral Range." *Journal of Lightwave Technology* **42**, 5214–5222 (2024).
3. Sureshkumar, A. *et al.* "Yellow stimulated emission from Dy^{3+}-doped silica glass microspheres." *Opt. Express, OE* **33**, 15802–15813 (2025).
4. Tian, K. *et al.* "Blue band nonlinear optics and photodarkening in silica microdevices." *Photon. Res., PRJ* **10**, 2073–2080 (2022).
5. Clementi, M. *et al.* "Ultrabroadband milliwatt-level resonant frequency doubling on a chip." *Nat Commun* **16**, 6164 (2025).
6. Hashimoto, Y. *et al.* "On-chip photon-pair generation in a silica microtoroidal cavity." *Opt. Express* **29**, 3533 (2021).

Qualifications

Candidates should hold a Master's degree in Photonics (or an equivalent field), preferably with demonstrated knowledge and experience in laser physics, nonlinear optics, laser and nonlinear characterization, optical instrumentation, and laser frequency stabilization or locking techniques.

The ideal candidate will have a strong interest in experimental work, complemented by an openness to modelling and simulation activities. Good communication skills in English, both written and spoken, are required.

About the Institut FOTON (CNRS, UMR6082)

The Institut FOTON is a research unit of the French National Centre for Scientific Research (CNRS) associated to University of Rennes 1 and the National Institute for Applied Sciences (INSA) of Rennes. FOTON is composed of three research teams: the "Optoelectronics, Heteroepitaxy and Materials" team, the "laser Dynamics, microwave photonics, Polarimetry, terahertz, imaging" team located in Rennes, and the "Photonic Systems" team located in Lannion. The successful candidate will carry out research in Lannion. More information about FOTON can be found at: http://foton.cnrs.fr.

Application procedure

Please submit your application at your earliest convenience by e-mail to:
Stéphane Trebaol (stephane.trebaol@enssat.fr)
Your application should include:

- Cover letter
- Detailed CV
- Copy of M.Sc. degree or equivalent
- Grade transcripts
- List of publications, if applicable
- Contact details of two references

All qualified candidates are invited to apply.