SPPIN SAINTS-PERES Paris Institute for the Neurosciences

Institut Langevin ONDES ET IMAGES

Internship offer

Université de Paris

cnrs

Eigen-modes transmission through forward scattering media

Scientific context and challenge: Imaging and data transmission through scattering samples is of key importance in many fields ranging from biological imaging in tissues to free space telecommunications. However, when light passes through complex media, it undergoes aberrations and multiple scattering, distorting spatial information into highly complex patterns. Several strategies have been investigated to address this problem and to control light intensity through complex media using spatial light modulators. However, this approach requires optimizing the input wavefield to the specific diffuser at play.

Proposed original approach: In this project, we propose to rely on a different strategy that consists in relying on the statistical parameters of the complex medium. For instance, multiple scattering media exhibit eigenmodes solution of the diffusion equation [1]. The *Singular Imaging Group* has developed specific expertise in wavefront sensing [2,3], complex light imaging [4], phase conjugation through a scattering tissue [5] and spectral properties of forward scattering media [6]. In this latter work, analytical calculations involves a second order differential equation recalling the quantum harmonic oscillator. Relying on this result, the proposed internship project aims at developing an experimental strategy to excite the eigen-modes of forward scattering media to transmit data.

Work description: As an intern, you will have to:

- Design a new experimental proof of principle optical system
- Perform the corresponding advanced data processing
- Perform numerical simulations to simulate the experimental system
- Characterize and quantify both numerically and experimentally the performances of the methods

The candidate should be motivated to work in experimental optics and programming. A solid theoretical background in wave and statistical physics is necessary, and basic programming skills in Python/Matlab are required.

The internship is designed to evolve into a PhD project.

Contact: Marc Guillon (marc.guillon@u-paris.fr)

References:

[1] O. S. Ojambati, H. Yılmaz, A. Lagendijk, A.P. Mosk and W. L. Vos, *Coupling of energy into the fundamental diffusion mode of a complex nanophotonic medium*, **New J. Phys. 18,** 043032 (2016)

[2] B. Blochet, N. Lebas, P. Berto, D. Papadopoulos, M. Guillon, *Single-shot hyperspectral wavefront sensing*, **Nat Commun,** in press, *arXiv:2410.19097* (2025)

[3] B. Blochet, G. Lelu, M. Alonso, M. Guillon, *Quantitative polarimetric wavefront imaging*, under review at **Optica 12(7),** 907-913 (2025)

[4] T. Wu, P. Berto, M. Guillon, *Reference-less complex wavefields characterization with a high-resolution wavefront sensor*, **Appl. Phys. Lett.** 118(25) 251102 (2021)

[5] T. Wu, Y. Zhang, B. Blochet, P. Arjmand, P. Berto, M. Guillon, *Single-shot digital optical fluorescence phase conjugation through forward multiple-scattering samples*, **Science Adv.** 10(3), eadi1120 (2024)

[6] L. Zhu, J. Boutet de Monvel, P. Berto, S. Brasselet, S. Gigan, M. Guillon, *Chromato-axial memory effect through a forward-scattering slab*, **Optica** 7(4), 338 (2020)