Master in Photonics – "PHOTONICS BCN"
Master ERASMUS Mundus "EuroPhotonics"

MASTER THESIS PROPOSAL

Dates: April 2023 – July or September 2023

Laboratory: Wavefront Engineering Group, www.ub.edu/waveng.
Institution: Universitat de Barcelona; Facultat de Física, Departament de Física Aplicada.
City, Country: Barcelona - Spain

Title of the master thesis:
Estimation of the longitudinal component of tightly focused beams using deep learning models.

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Keywords: Highly focused beam, phase retrieval, convolutional neural networks.

Summary of the subject (maximum 1 page):

Highly focused beams play a key role in a variety of problems such as microscopy, nonlinear optics or plasmonics, among others. In such conditions, the electric field of the beam is no longer transverse to the direction of propagation. For high numerical aperture focusing systems, the energy of the transverse and longitudinal components can be of the same order of magnitude [1]. Nevertheless, the measure of the latter is still a difficult problem that requires the use of indirect methods [2]. Recently, we proposed a technique for estimating the longitudinal component based on the phase retrieval algorithm [3] and the application of the Gauss theorem [4].

In this master thesis, we propose to estimate the longitudinal component of a focused beam by training a conditional generative adversarial *pix2pix* network [5, 6]. The training set is generated by synthetically producing many realistic beams using the Richards-Wolf equation [7]; then, the Stokes parameters of the transverse component of the focused beam will be used as input images. It is expected that the pix2pix network will provide the intensity of the longitudinal component.

Results will be compared with those obtained using the phase retrieval method.

References:

[1] Dorn, R., Quabis, S. & Leuchs, G. Sharper focus for a radially polarized light beam. *Phys. Rev. Lett.* **91**, 233901 (2003).
[2] Novotny, L., Beversluis, M., Youngworth, K. & Brown, T. Longitudinal field modes probed by single molecules. Phys. Rev. Lett. **86**, 5251 (2001).
[3] Fienup, J. R. Phase retrieval algorithms: A comparison. Appl. Opt. 21, 2758–2769 (1982).
[4] Maluenda, D., Aviñoá, M., Ahmadi, K. et al. Experimental estimation of the longitudinal component of a highly focused electromagnetic field. Sci Rep **11**, 17992 (2021).
[5] Isola, P., Zhu, J. -Y., Zhou, T. and Efros, A. A., Image-to-Image Translation with Conditional Adversarial Networks, *2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 5967-5976 (2017).
[6] pix2pix: Image-to-image translation with a conditional GAN https://www.tensorflow.org/tutorials/generative/pix2pix
[7] Richards, B. & Wolf, E. Electromagnetic diffraction in optical systems. ii. structure of the image field in an aplanatic system. *Proc. Math. Phys. Eng. Sci.* **253**, 358–379 (1959).

Objectives:

- Explore different deep learning models (DLM).
- Generate a synthetic dataset to feed a DLM.
- Adapt a DLM to estimate the longitudinal component of the beam from its transversal irradiance.
- Use the generated software on experimental data.

Additional information (if needed):

Required:

- Excellent programming skills (preferable Python)
- Good knowledge of machine learning techniques. It is highly advisable to be fulfilled the objectives of *Machine learning on classical and quantum data.*