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Instituto Superior Técnico - Campus Alameda

Book of Abstracts

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Quantitative and qualitative methods in elemental analysis via X-Ray fluorescence for materials' characterization

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This project focused on the initial work and methodology for a thesis project on the qualitative and quantitative elemental analysis of alumina (Al2O3) crystals doped with various elements, using Energy Dispersive X-ray Fluorescence (EDXRF). The broader thesis aims to adapt and optimize the existing X-ray fluorescence setup at FCUL to identify and quantify dopants within alumina crystals as accurately as possible. Initial measurements showed accurate characterization of metallic samples with higher atomic numbers, while challenges remain in reliably detecting lower atomic number elements such as aluminum (Z=13) and sulfur (Z=16). A characterization of the incident radiation field was performed to better understand its interaction with the samples and improve measurement accuracy. Future work will focus on implementing advanced analytical software tools and Monte Carlo simulations to enhance data analysis and validate experimental results, as well as exploration of alternative processes to X-ray fluorescence in order to reduce disperse radiation.

2

Grayscale lithography of diffractive micro-optics

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This work explores the design, fabrication (via binary lithography), and preliminary testing of transmissive binary diffractive axicons. The study investigates the axicon's phase modulation functionality and diffraction behavior under broadband femtosecond Yb (ytterbium) pulsed laser illumination, addressing challenges such as limited phase accuracy by using binary lithography instead of more precise but complex grayscale techniques.
Axicons, a type of Diffractive Optical Element (DOE), are critical for structured light generation and spatiotemporal beam shaping, with applications in nonlinear optics and ultrafast photonics. When illuminated, axicons produce concentric diffraction rings, with the first-order ring being a key feature corresponding to the desired Bessel-like profile.
A 5 mm diameter binary axicon was designed using scalar diffraction theory and fabricated on a fused silica substrate using two microfabrication methods: metal lift-off and ion beam etching (IBE). While the lift-off process was hindered by incomplete resist removal and metal delamination, the IBE method successfully produced functional axicons. Preliminary optical testing confirmed the generation of the expected first-order diffraction ring under broadband Yb illumination (centered at 1030 nm), validating the device's basic phase modulation capability.
This study lays the groundwork for scaling to grayscale lithography, to improve diffraction efficiency and spectral resolution, and ultimately enabling the generation of spatiotemporally structured beams (commonly referred to as 'light springs') for high-resolution beam manipulation.

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Development of an LED-based External Quantum Efficiency measurement setup and validation tests on practical photovoltaic devices

Author: Tobias Kompatscher[None]

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Failure and loss analysis in photovoltaic (PV) cells requires detailed knowledge of various electrical parameters, including the external quantum efficiency (EQE). EQE quantifies how effectively a solar cell converts incident photons into charge carriers and is defined as the ratio of collected charge carriers to the number of incident photons.

The standard EQE measurement procedure involves a monochromator-based system. Although this technique provides very precise results, it has some significant drawbacks: it is time-consuming, it reduces the intensity of the light reaching the cell, and it involves a complex setup with many moving parts.

Therefore, scientists are exploring alternative approaches to develop faster techniques that ideally require less complex and less costly setups. One promising method involves the use of LED illumination sources, which not only allow for spectral tuning to closely match the solar spectrum but also enable the integration of power measurements with rapid, spectrally resolved analysis.

Because of its potential to overcome key limitations of conventional methods, the development of a measurement device that makes use of this approach represents a valuable area of research—making it a fitting and meaningful focus for my thesis work.

4

Computational modelling of decision-making in individuals with OCD versus healthy controls

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This project focuses on behaviour modelling. It aims to unravel differences in decision-making data between individuals with Obsessive-Compulsive Disorder and healthy controls. The topic can be considered as part of Computational Psychiatry, an area of proven usefulness in the discovery of properties of mental disorders. Well-established methods, such as Reinforcement Learning and Bayesian Inference, will be applied to the construction of computational models. These will then be fitted to data from a Reversal Learning Task performed by both individuals with and without the disorder, experimentally collected under the umbrella of a larger project of the Neuropsychiatry Group of the Champalimaud Foundation. This kind of task explores how the participants adapt to sudden swaps of reward/punishment contingencies. The ultimate goal is to explain and uncover differences in the mechanisms involved in the two populations, for instance, by checking if some coarse model parameters differ consistently for the obsessive-compulsive subpopulation or if they make less use of certain kinds of cognition (such as Bayesian Inference for considering hidden states). These can eventually lead to future quantitative markers with clinical applications.

5

Machine Learning Techniques for Particle Flux Reconstruction applied to the ESA JUICE mission radiation monitor

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The Jovian system comprises a multitude of objects, such as the planet Jupiter and a large number of satellites, with the largest four being the Galilean moons Io, Europa, Callisto, and Ganymede. In April 2023, the European Space Agency (ESA) launched the Jupiter Icy Moons Explorer (JUICE) mission, projected to arrive at Jupiter in July 2031, and it will perform many studies of Jupiter and its icy moons. To monitor the radiation intensity of the spacecraft's surrounding environment and to provide alerts so it can protect itself, JUICE is equipped with the RADiation-hard Electron Monitor

(RADEM). RADEM will characterize the Jovian radiation environment and support anomaly identification. The detector will also be operating during the whole trip to Jupiter, which includes three Earth flybys, and a Venus flyby, allowing it to study the Van Allen belts during the Earth flybys, the cosmic ray gradient of the solar system and to characterize Solar Particle Events (SPEs). In this project, I will develop a neural network model that uses the measured count rates and each energy bin's response function to estimate the incident particle flux spectrum.

6

Transmission Spectroscopy using exoplanet's high resolution spectra

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In this project, the presence of the sodium doublet (NaI D1 and D2) was detected in the Wasp-76b atmosphere's transmission spectrum, an ultra-hot Jupiter. First, it is done an introduction about this planet's characteristics and the methods that were used to obtain all the spectra. It was analyzed 70 high-resolution spectra from ESPRESSO (Echelle Spectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations) instrument at the Very Large Telescope (VLT) of an 2018's night. Then, it was done the first corrections of the spectra which include the correction of the time and the Doppler shift to the star's rest frame. After that, it was obtained the weighted average of all the spectra with non transit exposures (master-out), without the contribution of Earth's atmosphere, the noise and the strong telluric features. Furthermore, it was divided all the spectra by the master-out and the Wiggles correction were done and the final shift to the Planet's rest frame. Finally, with another weighted average, it was obtained the final spectrum with transit exposures (master-in). In the end, it was calculated the quality of the detection (significance), with values of 9.27σ and 8.52σ which are quite good, because it is considered a detection from 5σ of significance.

7

Plasma current ramp up stability analysis in JET and JT-60SA

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This project focused on the preparatory work for a master's thesis on magnetohydrodynamic (MHD) stability analysis of the plasma current ramp-up phase in Tokamak devices, with particular attention to the JET and JT-60SA reactors. As nuclear fusion emerges as a promising clean energy source, understanding and controlling instabilities during plasma initiation is essential to improving reactor performance. The report introduces the theoretical framework of ideal MHD, including equilibrium configurations, surface quantities, and the Grad–Shafranov equation. Emphasis is placed on the energy principle, which underpins linear MHD stability analysis, allowing the identification of potential instabilities, either pressure-driven or current-driven, through analysis of the system's potential energy variation.