1. EXCELLENCE (4 pages max)

1.1. Pre-proposal's context, positioning and objective(s)

OGRES - optimization of Gap-plasmon Resonators for Environmental Systems

Directors: Pauline Bennet (IM2NP) and Aude L. Lereu (Institut Fresnel)

Context and state-of-the art

Advanced nanomaterials, especially metallic nanoparticles, exhibit unique and customizable optical properties, which have revolutionized the fields of sensing [1-4], imaging [5-7] and nanophotonics [8-12]. The nanoparticle-on-mirror (NPoM) [13-16] configuration is a specific geometry that combines a metallic nanoparticle and a flat metallic surface separated by a dielectric nanometer-scale gap (see step 1 on Figure 1). Nanocubes are typically preferred in NPoM due to their sharp corners and flat surfaces [17]. If the dielectric gap is sufficiently thin, a unique propagating mode exists in the structure: the gap-plasmon, which produces a stronger enhancement of the electromagnetic field than Surface Plasmon Resonance systems. NPoM can thus be a great platform for detecting a wide range of analytes, from biological molecules to environmental pollutants [10,11]. Indeed, such a system is highly responsive to changes in the refractive index of the surrounding medium [18,19], the spacer thickness [20] and composition [21], and the nanoparticle size and shape [22], making it well-suited for sensing applications. Considering the need for highly sensitive, selective, and rapid environmental monitoring strategies able to detect a wide range of pollutants, this project aims to explore new NPoM architectures for sensing applications by relying on modern and efficient optimization algorithms [23].

Objectives and hypothesis

Tuning individual NPoM resonance through size, shape and material has been demonstrated to be an effective method to design sensors [24]. Often, a better cavity is obtained for thinner spacer thickness between the nanocube and the substrate (<10 nm), but a thinner spacer leads to a more difficult coupling between the incident light and the gap-plasmon mode. Moreover, coupled modes involving multiple nanoparticles may have the potential to offer even stronger field enhancements and confinement. Therefore, the optimization, fabrication and characterization of these complex architectures remains challenging. To this end, precise design and nanoscale characterization strategies are required in order to produce reliable sensors suitable for real-world applications.

With this project, we aim to gain a better understanding of the coupling mechanisms, in the cavity and/or between neighboring nanocubes in complex NPoM structures. The investigation of plasmonic modes and couplings, by mapping the electromagnetic field around and under the cubes using nanometrology (near-field optical microscopy and cathodoluminescence) and numerical tools will allow us to investigate the radiative losses of the modes, whether to the external continuum or to other plasmonic modes. The better understanding of these mode coupling mechanisms is a required step to move toward complex architecture designed by modern inverse design methods. Indeed, recent studies have demonstrated the effectiveness of optimization algorithms in guiding nanophotonic design, revealing their strong potential to discover novel material configurations with photonic performances surpassing the state of the art [25-27]. These optimization approaches belong to the broader field of artificial intelligence (AI) and enable the exploration of vast and highly complex design spaces. As different optimization procedures may lead to different results [28], this project aims to benchmark a few promising optimization methods, first on a single nanocube resonator, then on a more complex NPoM structure, with a focus on the sensitivity for volatile organic components (VOCs) sensing application such as ozone detection [16].

Methodology

Step 1: Single nanocube based optimization

We propose to fully validate our models and methods first on the single nanocube resonator. By using the numerical models already available at IM2NP and UNamur, the first step will be to benchmark several optimization methods on a well-understood structure: the single nanocube resonator.

The number of parameters of the single nanocube resonator is limited by the simple geometry of the system: taking into account the nanocube size, metal type (gold or silver), the dielectric gap thickness and material (polymers), and the metallic thickness on the substrate, only a few (<10) parameters are to be optimized. However, one can imagine a large variety of objectives (or cost functions) depending on the targeted optical response: the quality factor of the cavity, the electromagnetic field intensity, the sensitivity of the sensor, etc. While all of these different objectives are related, they may lead to different optimization results due to the different level of complexity (direct or indirect relations) between the parameters and the expected optical response (see Figure 1).

Furthermore, a large variety of optimization algorithms – or inverse design methods – are available and the selection of a specific one is not straightforward. If Differential Evolution (DE) is particularly known to be effective to optimize photonic structures [25], Broyden-Fletcher-Goldfarb-Shanno (BFGS) [29] or similar local optimization techniques may be more effective on the single nanocube resonator system due to the limited number of parameters. In addition, the Surrogate-Based-optimization (SBO) method developed by the Cenaero partners has proven to be promising to optimize complex optical structures but remains to be tested on plasmonic structures. It is therefore essential to benchmark these different methods by following the methodology presented in [25] to ensure the reliability and consistency of the methods, in order to obtain novel and efficient structures – with a first focus on a single nanocube resonator, before testing with more complex NPoM structures.

As numerical optimization is computationally demanding, these simulations will be made on the AMU and UNamur meso-center computing centers, in addition to the Cenaero resources, through the Minamo software.

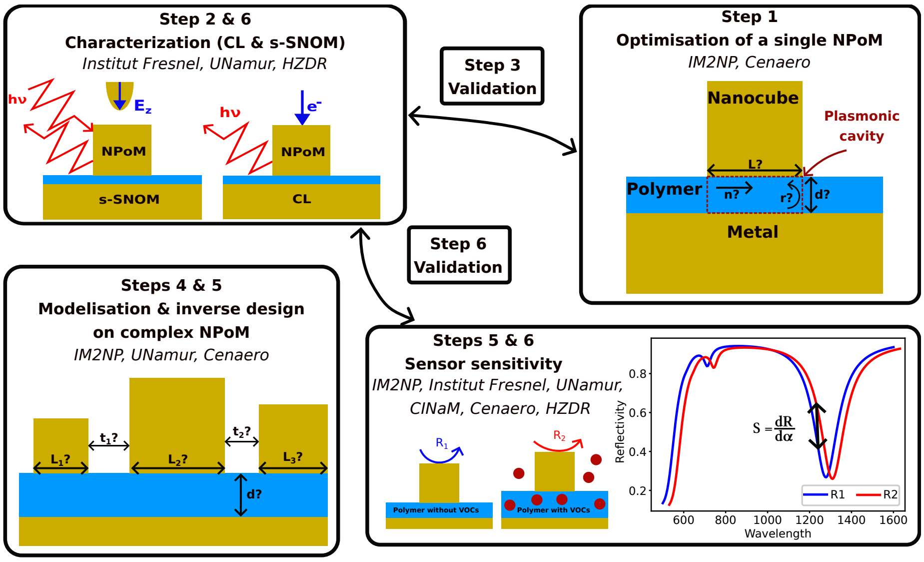


Figure 1: General overview of the PhD project steps, with relevant partners

Step 2: Single nanocube characterization

We want to finely characterize the single nanocube as a function of cube size and materials, to provide correlative information on its optical and structural responses at the nanoscale. To this end, we will use scattering - Scanning Nearfield Optical Microscopy (s-SNOM)[30] available in Institut Fresnel, and cathodoluminescence (CL) [31] available in Helmholtz-Zentrum Dresden-Rossendorf (HZDR) lab. These two techniques are powerful for characterizing plasmonic structures, providing high spatial resolution and spectral information.

s-SNOM is a technique that combines atomic force microscopy with interferometric illumination and collection of the optical near field. The main advantages of using s-SNOM are its capacities to 1) map the resulting electric field from a single subunit with size as low as 30 nm in order to highlight the plasmonic resonances, propagation and coupling, 2) achieve a 10 nm spatial resolution regardless of the excitation wavelength from VIS to IR range, and 3) probe in-depth a sample over 50 to 80 nm in the visible range [32-40]. Cathodoluminescence brings other insights on the structure and optical properties by analyzing the light emitted when an electron beam interacts with a plasmonic material. This method can reveal key properties such as resonance wavelengths, mode distributions, and coupling effects between nanoparticles. The ability to probe both spectral and spatial plasmonic features makes these nanometrology techniques essential for optimizing plasmonic structures.

Step 3: Single nanocube model validation

An open-source Rigorous Coupled Wave Analysis (RCWA) method and a Finite-Difference-Time-Domain (FDTD) software are available at IM2NP [41, 42]. Moreover, the UNamur partner has a s-SNOM simulation toolbox precisely dedicated to reproducing s-SNOM experimental results. A systematic comparison between experimental and simulated data will allow to 1) ensure the full understanding of the plasmonic behavior, 2) check that all physical phenomena are correctly taken into account in the simulations.

Once the modelisation, characterization and optimization methods cited in the previous steps are thoroughly tested and validated on the single nanocube resonator, we will be ready to apply them to more complex structures.

Step 4: Modelisation of the complex NPoM

To go further, we will upgrade the single nanocube-based configuration into a more complex NPoM system made of several nanocubes. Because of potential coupling effects between nanocubes, the distance between them can strongly modify the optical response of the system. Effects of periodicity and disorder in the nanocube arrangement can also influence the photonic properties, as diffraction and scattering effects may occur [43,44]. A step of physical and numerical analysis of the coupling between nanocubes will be realized between IM2NP and UNamur, supported by s-SNOM characterizations from Institut Fresnel to better understand how the number and arrangement of NPoM influences the sensing properties. These modelisations will allow us to guide the future optimization constraints (range of resonator sizes and distances, pre-selected materials, resonator number, etc.).

Step 5: Inverse Design of the complex NPoM

Based both on the results from step 1 – regarding the optimization methods – and step 4 – regarding the optical response of complex NPoM systems – this step will take the inverse design process further, in order to optimize a VOCs sensor platform, primarily focusing on its sensitivity.

Indeed, optical sensing is a powerful tool for environmental detection, including monitoring pollutants and gases, as it allows non-invasive, remote, and highly precise measurements [23]. In this framework, we propose to target common VOCs, such as benzene and ozone, to test the optimization process of a complex NPoM architecture on a concrete sensing application and to evaluate the sensitivity of the proposed platform. More precisely, the sensor optimization will focus on the maximization of the sensitivity S defined as $S = dR/d\alpha$ with R the reflectance of the system and α the quantity of detected VOCs (typically in ppm). Starting from the preliminary results of CINaM [45], we will consider a dielectric gap composed of polymer (e.g. PPMA) sensitive to a specific VOC (e.g. Toluene). Indeed, in the presence of VOC, the polymer will expand or shrink (depending on the polymer/VOC interaction), leading to a change of the refractive index and / or the thickness of the dielectric material inside the cavity, and thus to a change in the reflectance of the sensor (see steps 5 and 6 on Figure 1).

The inverse design of complex NPoM architectures will be carried out using the optimization methods already benchmarked on step 1: DE, BFGS and the advanced SBO actively developed by the Cenaero partner. This strategy will allow us to consider both the optimized properties of individual nanocavities and the coupling effects between adjacent nanocubes. In addition, Cenaero's SBO platform enables the use of significantly more complex and computationally intensive simulations, while naturally accommodating design constraints and robustly handling simulation failures.

Step 6: Experimental and sensing capability validation

To fabricate the optimized complex structure, the expertise of the three laboratories from Marseille will be leveraged. First, evaporation techniques from Institut Fresnel will allow to deposit metallic layers on silicon substrates. Then, the "template stripping" method developed at IM2NP will be used to obtain a metallic surface with a very low surface roughness (<1 nm). These low roughness substrates will be functionalized at IM2NP or CINaM, before the deposition of the metallic nanocubes by an auto-assembly method in CINaM.

Once the optimized architecture is fabricated, another round of s-SNOM (Institut Fresnel) and cathodoluminescence (HZDR) measurements will be made. If needed, the model constraints will be fine-tuned until we obtain a complete agreement between the experimental and simulated data.

Finally, to validate the complex NPoM optimization process, a validation of the sensing capabilities will be performed. As the optimization process will focus on the sensor sensitivity as described in the step 5, the sensitivity at a specific wavelength when exposing the architecture to VOC molecules (IM2NP and CINaM) will be measured and compared to the simulated results. Here, a feedback step into the optimization tools will be done to iterate between design and fabrication, in order to obtain the best possible structure.

1.2. Interdisciplinary dimension of the project

Consortium and planning

This project is part of a consortium made of three AMU's labs: the CINaM, the IM2NP and the Institut Fresnel; and of 3 international partners: Helmholtz-Zentrum Dresden-Rossendorf (HZDR) in Dresden, Germany, Cenaero and UNamur in Belgium. The CINaM is developing a bottom-up self-assembly approach to fabricate NPoM by synthesizing metallic nanocubes on a metallic substrate. The IM2NP has the expertise in plasmonics and modelisation for optimizing photonic systems. Those laboratories are already collaborating in national projects funded by the ANR on nanocubes modeling and physical analysis, the ANR PlasMORE-Light (nanocubes for solar cells systems, IM2NP and CINaM) and the ANR SWAG-P (nanocubes for biosensing, IM2NP, and CINaM). The Institut Fresnel has the expertise in plasmonics and optical resonances for sensing and imaging applications and in near field optical microscopy. Institut Fresnel and IM2NP are already collaborating through an AMUtech program on complementary topics. The international partner at HZDR, through its department at Ion Beam Center, is expert in cathodoluminescence investigations. Cenaero has strong expertise in design optimization, supported by the development of its design space exploration and machine-learning based optimization and data analysis platform. UNamur partner brings long-standing expertise in theoretical photonics, including both analytical and numerical developpments. UNamur and Cenaero partners already collaborated in the supervision of a joint phD thesis.

As the focus of this PhD program is on the nanometrology and the coupled resonators modelisations, the PhD will be essentially hosted between the Institut Fresnel (Supervisor Aude LEREU, expert in nanometrology, plasmonics and optical resonances), and the IM2NP (co-supervisor Pauline BENNET, expert in modelisation and optimization of plasmonic systems). The candidate will receive a strong support from the partners. In particular, two short stays in HZDR laboratory (Dresden) will be dedicated to CL experiments, first on the single nanocube resonator and then on the more complex NPoM structure, when optimization and fabrication processes are done. Moreover, collaboration with Belgium partners will launch the optimization step with SBO through the Minamo software in Cenaero and the use of the s-SNOM toolbox developed in UNamur. As the methods are numerical, a remote access to the simulation and optimization tools is planned, in addition to regular meetings in Belgium (for the candidate) and/or in Marseille (for the partner mentors). The fabrication steps will be done in CINaM as soon as optimised structures are designed. More generally, a bi-annual meeting will be held with all the consortium to discuss the advancement of the project, with a minimum of one annual meeting in person in Marseille or in Namur

Interdisciplinary dimension

This project requires expertise in Physics, Chemistry, Computer science and Programming - more precisely in Optics, Optical near field, Nanosciences and Nanotechnologies, Numerical programming, optimization, Chemical synthesis, and Sensing. It also combines both theoretical and applied research. All mentioned expertise is present within the consortium and demonstrate that the interdisciplinarity is necessary to this project.

Intersectoral dimension

In addition to being part of an international consortium, the proposed project will benefit from the expertise of industrial partners who already work with consortium members (ATTOCUBE group, A. Lereu's collaboration for s-SNOM). The candidate will also participate in the Jeunes Chercheurs Associés (JCA) cooperative activities. JCA is an organization specialized in the promotion of academic skills into the socio-economic world via collaborations between academic researchers, university promotion departments, and industrial or cultural companies. The PhD candidate will benefit from the JCA network, resources and mentoring from its President Victor Valentini.

2. IMPACT (2 pages max)

2.1. Expected impact of the project on the candidate's career

The proposed PhD training and research project is expected to have a strong impact on the fellow's career by providing them a unique set of interdisciplinary skills in physics and numerical methods, cutting-edge technical skills in nanotechnology, and a wide professional network. The project also combines fundamental and applied research in the field of environmental sensing through state-of-the-art experimental techniques for nanostructure characterization, data analysis, advanced modelisation for plasmonic system, and modern optimization platform, applied to a reliable environmental sensor. The candidate will also interact with chemists in CINaM for the fabrication of the samples. The acquired skills are highly sought after in both academic and non-academic sectors, making the candidate versatile and competitive for future opportunities of their choice. In addition to the participation in a multidisciplinary and international consortium, the collaborations with non-academic partners will offer valuable exposure to industry standards, especially through the collaboration with the JCA cooperative. These experiences will significantly enhance the candidate's ability to transition seamlessly between academic research and industry innovation.

Finally, the development of transferable skills – such as communication, leadership, and networking – through conference presentations, scientific publication writing and long-term project management will prepare the candidate for diverse career paths. By the end of the PhD, the fellow will have proven themselves as a highly skilled researcher with the ability to drive impactful, cross-sectoral innovations in fundamental and applied research.

2.2. Expected impact for the thematic axis

This project closely aligns with the research priorities of the SCHADOC program, particularly in the areas of the Artificial Intelligence (AI) applications and Environmental Challenges field. Indeed, by applying inverse design methods – a part of AI field – to optimize NPoM architectures for pollutants or gas detection, this project will allow a better understanding of how we can rely on AI methods to conceive better photonic devices. In that sense we aim to propose a reliable AI workflow to automatically design complex NPoM sensors. **As a consequence, this project contributes to the Artificial intelligence and its applications axis.**

The project is expected to make significant advancements both in fundamental and applied research within the fields of:

1. Inverse design for photonics: While numerical optimization processes are obviously essential to discover novel and more efficient photonic structures, it is important to also highlight that AI research is always searching for practical applications to test and improve their methods. The field of photonics has the advantage of encompassing a large variety of systems, ranging from simple to complex structures, and therefore provides relevant test cases for modern AI techniques.

2. Nanometrology and computational science: Through the comparison of nanoscale metrology techniques with state-of-the-art simulation tools, to fully describe the optical and structural response of NPoM structures, this project will motivate a detailed study of the agreement between experimental and numerical techniques.

3. Advancing Environmental Sensing Technologies: Despite being a mostly fundamental project, it will pave the way to future work on environmental sensing, by providing a new framework to inverse design sensors for detecting pollutants or gases with unprecedented accuracy and efficiency. More broadly, the project will contribute to environmental and sustainable development goals by addressing challenges related to clean air monitoring that could be extended to water quality for example.

Furthermore, this project has motivated the consortium members to work towards a more long-term collaboration which would carry on beyond the PhD work – through a European project for example.

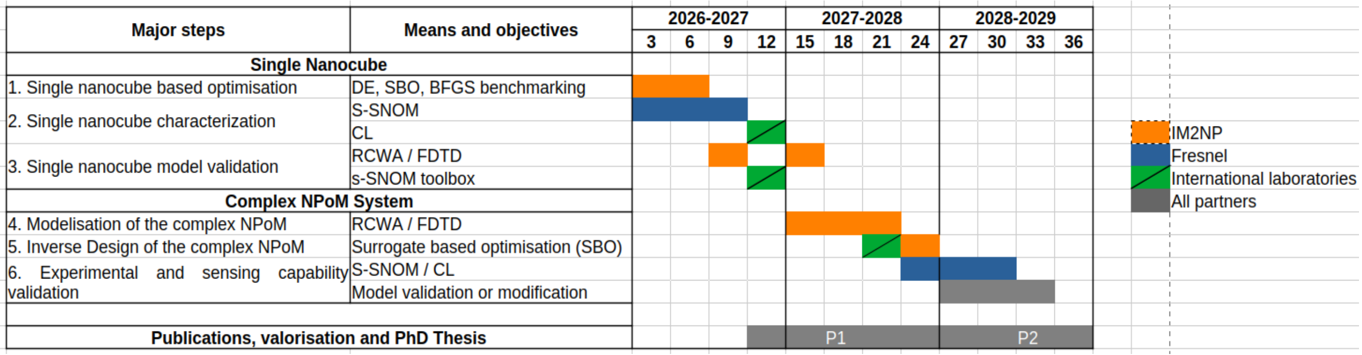
2.3. Dissemination, exploitation and communication activities planned

Several aspects of this research will generate fundamental and/or applied knowledge that will be reported in scientific communications (see Figure 2 for planned publications). This will be achieved through high-impact journal publications, presentations at international and/or national conferences, and participation in specialized workshops on nanophotonics, plasmonic technologies, AI applications and sensors. Open-access publications will be prioritized to ensure widespread availability of the results. Prior to publication, all papers will be archived in the HAL platform and ArXiv preprints servers for the sake of equity and sharing. In addition, a regular collaboration with the JCA cooperative will allow a strong industrial promotion of the scientific research and skills developed during the PhD program. Finally, considering the innovative methodologies and/or devices that will be developed during the project, discussions within the consortium will be held regarding potential patent applications.

In terms of science popularization, the Institut Fresnel and IM2NP laboratories regularly take part in local science festivals and diverse public events where the participation of PhD students is highly emphasized by the communication staff. Finally, the members of the consortium are also regularly involved in events aiming to promote science among young people and/or women.

3. IMPLEMENTATION (2 pages max)

3.1. Work plan



Major steps	Means and objectives	2026-2027				2027-2028				2028-2029			
		3	6	9	12	15	18	21	24	27	30	33	36
Single Nanocube													
1. Single nanocube based optimisation	DE, SBO, BFGS benchmarking	🟧	🟧										
2. Single nanocube characterization	S-SNOM	🟦	🟦	🟦									
	CL				🟩								
3. Single nanocube model validation	RCWA / FDTD			🟧		🟧							
	s-SNOM toolbox				🟩								
Complex NPoM System													
4. Modelisation of the complex NPoM	RCWA / FDTD					🟧	🟧	🟧					
5. Inverse Design of the complex NPoM	Surrogate based optimisation (SBO)							🟩	🟧				
6. Experimental and sensing capability validation	S-SNOM / CL								🟦	🟦	🟦		
	Model validation or modification									▨	▨	▨	
Publications, valorisation and PhD Thesis					▨	▨	▨ P1	▨	▨	▨	▨	▨ P2	▨

🟧 IM2NP
🟦 Fresnel
🟩 International laboratories
▨ All partners

Figure 2: Gantt chart for the optimization of a Gap-plasmon Resonator for Environmental Systems (OGRES)

The work plan will cover the steps mentioned earlier in the implementation strategy as illustrated in the Gantt chart, Fig. 2 with the envisioned timeline.

First year of PhD : Dedicated to single nanocube investigation

The first months of the thesis will be devoted to acquiring skills in s-SNOM technique at the Institut Fresnel applied to single NPoM samples already synthesized by the CINaM.

The first envisioned steps are: 1) with a reference sample, getting used to the atomic force microscopy part (~1st month) 2) testing the whole s-SNOM technique (~3-6th month), 3) getting used to the s-SNOM data analysis in collaboration with UNamur and 4) testing different NPoM structures for statistical investigation (end ~9th month). Note that the second part of the first year, the candidate will use advanced simulation codes, available with the UNamur international partner, to model the s-SNOM experimental results.

In parallel, the candidate will start, at the IM2NP, benchmarking optimization methods like Differential Evolution (DE), BFGS and the Surrogate-Based optimization (SBO) with Cenaero partner to design the best single cavity system. This will allow to highlight the advantages and limitations of each method and test various optimization parameters and cost functions.

Although feedbacks with the two Belgian partners will start from the beginning of the PhD with the s-SNOM toolbox and with the SBO method, a first stay will be planned for the PhD candidate within these teams (~10-11th month). Then, a month (~11-12th month) with the HZDR partner will be planned to complete the s-SNOM data set with cathodoluminescence measurements.

Second year of PhD : Dedicated to complex NPoM system

The major part of the second year will be dedicated to the modeling and optimization of the complex NPoM system at the IM2NP. The candidate will investigate different configurations in terms of nanoparticles geometry, size, assembly of several NPs by taking into account the feasibility in order to guide the fabrication of a complex structure. Another stay in Belgium will be planned close to Month 21 to ease the use of the SBO method.

A realization of optimized structures will be done by the end of the second year by the CINaM colleagues (Olivier Margeat and Beniamino Sciacca) and the fabricated optimized NPoM structures will be characterized experimentally by s-SNOM and CL (end ~2nd year, beginning of third year).

Third year of PhD : Dedicated to the validation of the complex NPoM system

A refining of the models with new data will be done and iterated as needed. After a physical characterization by s-SNOM and CL, the best of the optimized components will be then evaluated in terms of sensing performances. To do this, the candidate will test the optimized platform in realistic conditions for VOC detection in collaboration with the CINaM similarly to a previous work [16,45](~30th month).

The relevance of a patent application will be evaluated at this stage. The last months will be dedicated to the manuscript writing and defense.

Opportunities for the candidate to participate to international and national conferences will be proposed throughout the PhD. Furthermore, publications in plasmonics and sensing journals (e.g. ACS Photonics, Nano Letters, Optics Express, APL Photonics) will be done when the project progress allows it.

Budget

Note that the accompanying expenses will be mainly used to cover the candidate missions and publication fees. For the missions we include the stay in the international laboratories, as well as participation to national and international conferences. The rest of the expenses will be covered by the consortium. The candidate will benefit from the various available techniques present within the three labs of AMU and within the international partners.

Risk management

The goal of the first year will be mainly for the candidate to acquire the technical and scientific skills and principles both in nanometrology and numerical methods. With the diverse expertise as well as the various state-of-the-art equipment's available to the applicant, this first year is low risk but high gain as it should bring new insights in NPoM understanding.

The sample realizations will benefit from the expertise from the different AMU labs involved in the project and from the large facilities on nanofabrication such as Planete (CINaM) and Espace Photonique (Institut Fresnel). This will allow the investigation of the NPoM response as a function of geometry and materials.

Regarding the modeling and inverse design processes, the first risk is that the complexity of multi-cube NPoM structures is too computationally expensive to model. In this case, access to the AMU computation mesocenter can be used to overcome this challenge. Another risk is that the home-made simulation codes available at IM2NP are not powerful enough to model the fine details of the complex NPoM response. This is also why the UNamur partner can bring its expertise in numerical modeling. If this fails too, the candidate will be able to turn to commercial (Lumerical, Reticolo) or open source (DIOGENES, SimPhotonics) simulation software already available in the teams.

Concerning surrogate-based optimization, the main risk is that the surrogate model may fail to accurately capture the underlying simulations. However, this issue appears unlikely, as Cenaero already has experience dealing with optimization relying on highly complex simulations. In such a case, more advanced machine-learning-based surrogate models can be employed to enhance the modeling capabilities [51-53]. The risk is manageable as Cenaero already has an experience with these more specific models.

Finally, the implementation of a VOC detection platform is a long-term goal of the partners, but this PhD work will focus on a classical VOC molecule as in the preliminary results [45], in order to validate the first performances of the sensing platform. The validation task is risky as it is highly dependent on the pollutant or analyte to detect, and it may be difficult to pinpoint the best single detection channel. Further investigation of VOC-specific parameters (e.g. the chemistry of the gap polymer) to achieve the best sensitivity and selectivity are beyond the scope of this thesis.

4. ETHICS SELF-ASSEMENT

8 ARTIFICIAL INTELLIGENCE	**YES/NO**	**Information to be provided**	**Documents to be provided/kept on file**
Does this activity involve the development, deployment and/or use of Artificial Intelligence-based systems?	**Yes**	This research activity involves the use of AI methods to design advanced nanocube-based sensing systems. Surrogate Based optimization uses mathematical modeling techniques to predict the plasmonic behavior of complex systems in order to accelerate the mapping of various possible configurations to identify the most relevant ones. Artificial Neural Networks (ANN) are among the possible mathematical models which can be used in this context. This proposed ANN technique has the ability to quickly predict the optical response of complex photonic system, without the need to precisely solve Maxwell's equations, which typically require extensive computation times. Moreover, the inverse design process aims to determine structural parameters (such as dimensions) from optical characteristics. Due to the complexity of the studied systems, single spectra often lead to degenerate results. The ANN methods will only suggest new configurations for human evaluation, and at each step of the process, researchers will assess the reliability of the generated data. A known limitation of this ANN method is its potential to suggest irrelevant structures. To mitigate this, fabrication constraints will be added to the implemented methods to limit such effects.	The most significant scientific risk lies in the training of neural networks methods, which may require (i) a too large database for the training process, and (ii) a too complex model architecture for a non-specialized PhD student to develop [27]. These drawbacks, on top of the large processing power that would be necessary in any case, can lead to a lack of convergence, i.e. unsatisfactory modeling of the physical system. The alternative would be to rely only on direct simulations of the nanophotonic structures.
All other ethics issues	No		

5. REFERENCES (Consortium references in blue)

1. Pokrajac et al. ACS Nano 15 2021. DOI: 10.1021/acsnano.1c10919
2. Diehl et al. Chemical Society Reviews, 2022. 51 DOI: 10.1039/D1CS01083B
3. Yi, and Xianyu. Advanced Functional Materials, 2022. 32 DOI: 10.1002/adfm.202113012
4. Di Fabrizio et al. J. Opt. 18 2016. DOI: 10.1088/2040-8978/18/6/063003
5. Axelrod. 2053-2563. IOP Publishing, 2022. ISBN: 978-0-7503-3349-8
6. Balaa et al. Proc. SPIE 7367 2009. ISBN: 9780819476432
7. LeMoal, et al. Biophys. J. 92 2007. DOI : 10.1529/biophysj.106.096750
8. Mayer and Hafner. Chemical reviews, 111 2011. DOI: 10.1021/cr100313v
9. Chen and Ming. Photonic Sens 2 2012. DOI: 10.1007/s13320-011-0051-2
10. Hamza, et al. Biology 11 2022. DOI: 10.3390/biology11050621
11. Jin et al. Mater Today Bio 14 2022. DOI: 10.1016/j.mtbio.2022.100263
12. Minopoli et al. Adv. Mat. Interfaces 9 2021, DOI: 10.1002/admi.202101133
13. Sugimoto and Fujii, ACS Photonics 5 2018. DOI: 10.1021/acsphotonics.7b01461
14. Baumberg et al. Nat. Materials 18 2019. DOI: 10.1038/s41563-019-0290-y
15. Shan et al. Sci Rep 14 2024. DOI: 10.1038/s41598-024-81091-w
16. **Poungsripong et al. Adv. Mater. Technol. 2024. DOI: 10.1002/admt.202400083**
17. Saito et al. The J.l of Phys. Chem. Lett. 7 2016. DOI: 10.1021/acs.jpclett.6b02393
18. Shan et al. Plasmonics 17 2022. DOI: 10.1007/s11468-022-01709-5
19. Bonyár et al. Photonics and Nanostructures 31 2018. DOI: 10.1016/j.photonics.2018.05.004
20. Zhang et al. Nanoscale Advances 4 2022. DOI: 10.1039/D1NA00777G
21. Zhang et al.. Science Advances 8 2022. DOI: 10.1126/sciadv.abj9752
22. Devaraj et al. Materials Advances 1 2020. DOI: 10.1039/D0MA00111B
23. Chau, Materials Today Physics 60, 2025. DOI:10.1016/j.mtphys.2025.101984
24. Peng et al. Chem. Sci. 15 2024. DOI: 10.1039/D3SC05722D
25. **Bennet et al. JOSA B 41 2024. DOI: 10.1364/JOSAB.506389**
26. Kim et al. Nanophotonics 2025. DOI: 10.1515/nanoph-2024-0536
27. **Khaireh-Walieh et al Nanophotonics 12 2023. DOI: 10.1515/nanoph-2023-0527.**
28. **Bennet et al. Phys. Rev. B 103 2021. DOI: 10.1103/PhysRevB.103.125135**
29. Liu et al., Mathematical programming 45 1989. DOI:10.1007/BF01589116
30. Keilmann and Hillenbrand. Phil. Trans. R. Soc. A. 362 2004. DOI: 10.1098/rsta.2003.1347
31. Kuttge et al. Appl. Phys. Lett. 93 2008. DOI: 10.1063/1.2987458
32. Govyadinov et al. J. Phys. Chem. Lett. 4 2013. DOI: 10.1021/jz400453r
33. Alonso-Gonzalez et al. Nanolett. 11 2011. DOI: 10.1021/nl2021366
34. Alonso-Gonzalez et al. Science 344 2014. DOI: 1 10.1126/science.1253202
35. Diaz-Numez et al. Sci. Report 9 2019. DOI: 10.1038/s41598-019-50392-w
36. Zhang et al. Opt. Exp. 28 2020. DOI: 10.1364/OE.386713
37. **Charrier et al. Comm. Mat. 2 2021. DOI: 10.1038/s43246-021-00166-7**
38. Stanciu et al. ACS Omega 7 2022. DOI: 10.1021/acsomega.2c00410
39. **Shurvinton et al. JEOS 20 2024. DOI: 10.1051/jeos/2024005**
40. **Bhattacharya et al. Nat. Comm. 16 2025. DOI: 10.1038/s41467-024-55353-0**
41. Granet et al., JOSA A 13 1996. DOI: 10.1364/JOSAA.13.001019
42. Lalanne et al., JOSA A 13 1996. DOI: 10.1364/JOSAA.13.000779
43. **Langevin, PhD thesis manuscript, 2022. url: hal.science/tel-04102598**
44. El Shamy et al., Appl. Phys. Lett. 115 2019. DOI : 10.1063/1.5097461
45. **Poungsripong, thesis manuscript, 2024. url: https://theses.fr/s377662**
46. **Lereu et al. Appl. Phys. Lett. 111 2017. DOI: 10.1063/1.4991358**
47. **Ndiaye et al. Appl. Phys. Lett. 103 2013. DOI: 10.1063/1.4822093**
48. **Lereu et al. Opt. Exp. 27 2019. DOI: 10.1364/OE.27.030654**
49. Storn et al. J. of global optimization 11 (1997). DOI : 10.1023/A:1008202821328
50. Hernandez et al. JOSA B 41 2024. DOI: 10.1364/JOSAB.506085
51. Wiecha et al., Photon. Res. 9, 2021. DOI:10.1364/PRJ.415960
52. Chen et al., arXiv 2022. url: arXiv:2203.01248v1.
53. **Roy et al., Physical Review A, 109, 2024. DOI: 10.1103/PhysRevA.109.013514**

JEUNES
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Lyon, France, January 26, 2026

JCA is a scientific cooperative whose mission is to facilitate the mobilisation and valorisation of researchers' skills within the socio-economic sphere. JCA relies on an interdisciplinary scientific network and works in close collaboration with university technology transfer and valorisation offices, research teams, and companies in order to translate academic research skills into operational expertise applicable to industrial and socio-economic contexts.

JCA's activities include the organisation of remunerated missions for researchers with socio-economic actors, the coordination of a national and interdisciplinary scientific network, and the support of researchers — particularly PhD candidates — in identifying, articulating, and valorising their transferable skills beyond the academic environment.

The intersectoral dimension of the OGRES project is fully aligned with JCA's missions and objectives. In this context, the recruited PhD candidate will be welcomed within the JCA cooperative and will benefit from its scientific and intersectoral networks in order to strengthen the transfer and visibility of their academic skills towards industrial partners.

More specifically, Victor Valentini, President of the JCA cooperative, commits to mentoring the recruited PhD candidate to support the translation of their academic experience into skills relevant to industrial contexts. This mentoring will take the form of regular interactions with the PhD candidate and the university technology transfer or valorisation office, with the aim of fostering meaningful collaborations between the university and socio-economic actors, notably industrial companies involved in bioprocess monitoring, such as InSpek.

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