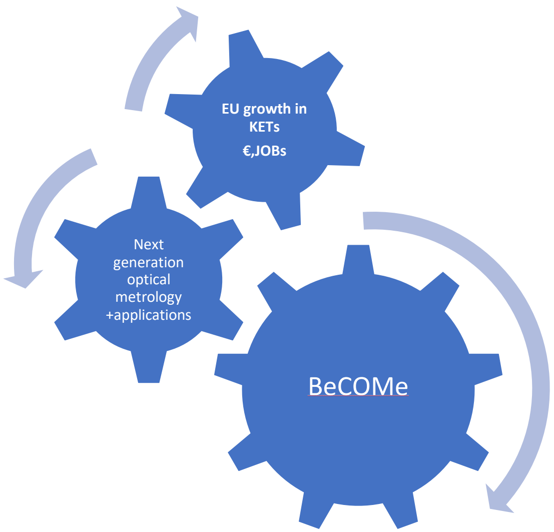
Overview

Optics-based measurement methods play an important role in four out of the six KETs, namely, Nanotechnology, MicroNano electronics, Photonics and Advanced materials. Despite the many advantages of optical systems (speed, non- invasiveness, high-precision, moderate investments, integrability) the operational spatial resolution attainable in classical optical metrology is still essentially limited by the wavelength of the light. Therefore, novel and robust metrology solutions are needed that maintain all the recognised benefits of optical methods while substantially overcoming the current limitations.

The overall goal of this project is to set the basis for realisation of the next generation of optical metrology systems, with unprecedented performances in terms of spatial resolution, traceability, reliability, robustness.



WP1: Exploiting light-matter interaction under strong spatial-coupling regime

To achieve **deep sub-wavelength (target λ/10)** spatial resolution, with **sub-nanometric uncertainty**, far-field illumination and far-field detection schemes.

- Inverse methods & multiple scattering effects in far-field systems
- Full pupil fields optimization
- Metamaterials-enhanced probe-target interaction
- Design, realization and validation of reference artefacts

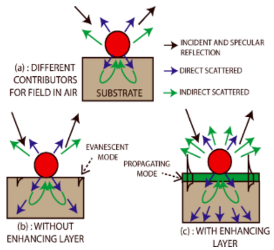
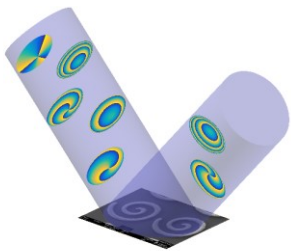


Figure from article: "Exploiting evanescent-wave amplification for subwavelength low contrast particle detection", S. Roy et al., Phys. Rev. A96, 013814 (2017)

WP2: Topological information and spatial spectroscopy methods

To exploit **topological structures** in electromagnetic fields and map how such topological information transforms after interacting with matter.

- Vectorial Helmholtz Natural Modes, Hypermodal imaging
- Applications to modal scatterometry and lens-less imaging
- Direct spectroscopy of spatial channels



WP3: Coherent-link between optical scale and nanoscale

To realize and demonstrate near-field techniques to measure **deep sub-wavelength** gratings down to the regime << λ/10. **To metrologically link** near-fields methods to far-field methods.

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- Advanced metrological near-field methods such as spectroscopic SNOM and photonic nanojets
- Linkage near-field-far field methods
- Nanoscale form and symmetry measurements

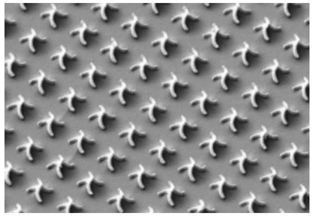

Figure from article: "Elevating optical activity: Efficient on-edge lithography of three-dimensional starfish metamaterial", K. Dietrich et al., Appl. Phys. Lett.. 104, 193107 (2014)

WP4: Spatial entanglement and novel quantum metrology

To apply **sub-shot noise quantum technologies and novel quantum-measurement paradigms** to low and high NA optical systems. To realise input fields with **spatially-entangled optical channels** and to map their coupling with nano-targets.

- Wide field quantum imaging in deep sub shot noise regime (beyond 7dB)
- Super-resolution exploiting anti-bunching and structured light at single photon level
- Topology-driven spatial entanglement

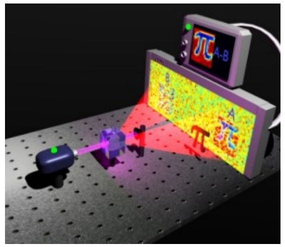

Figure from article: "Exploiting PDC spatial correlations for innovative quantum imaging protocols", M. Genovese et al., Proc. SPIE 8163, 816302 (2011)

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First results

WP1: Higher-order probe-target interactions:

A solution to the wild divergence of Born series for strong scattering regime has been found for the 1D case. Extension to higher dimensionalities will be addressed. The same problem has been approached from a different viewpoint, namely by using Bayesian inversion methods. Tests of the algorithms for solving the inverse problem in scattering have been performed successfully.

WP2: Topological structures:

A fully vectorial expansion of the field in vectorial Helmholtz Natural Modes has been achieved. This will serve as basis to map spatial topological information and start spatial spectroscopy for high-NA systems. Also, the limit that can be achieved by a generic optical measurement scheme, by using Fisher information has been addressed.

WP3: Near-field techniques:

Plasmonic lens design has been optimised. Numerical simulations of Mueller matrices of differently shaped micro- and nanostructures have been performed for achieving enhanced nano-form metrology.

WP4: Quantum technologies for low and high NA systems:

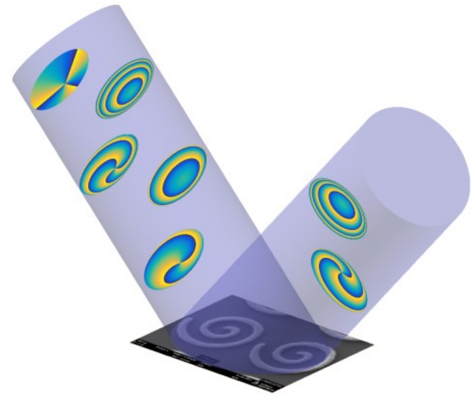
Absorption measurements in the sub-shot noise regime towards the ultimate quantum limit by twin beam has been realised with the best sensitivity per photon ever achieved.

BeCOMe

Beyond Classical Optical Metrology

EMPIR/EURAMET Project 17FUN01

Light-matter interplay for optical metrology beyond the classical spatial resolution limit



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