Laboratoire : Laboratoire de Physique des Lasers (LPL), UMR 7538.
PhD Thesis**: Highly excited Rydberg atoms interacting with planar and nanostructured surfaces**
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Scientific Background: The interaction of atoms with the macroscopic environment (Casimir-Polder interaction) is a fundamental problem of quantum electrodynamics (QED) with implications in nanophotonics and precision measurements. In the nanoscale, atom-surface interactions are due to fluctuations of the atomic dipole, with an energy of $-C_3/z^3$ (z is the atom-surface distance and C_3 is the van der Waals coefficient).

Group: The SAI group has pioneered atom-surface interaction experiments using selective reflection measurements (probing atoms typically ~100nm from the surface), as well transmission spectroscopy in cells of nanometric thickness (30-1000nm). The SAI group has also studied the coupling of atoms with evanescent surface waves (polaritons) and demonstrated the possibility of tuning atom-surface forces.

Research project:
Highly excited atoms (Rydberg atoms) have electronic wavefunctions that can extend up to hundreds of nanometers. The study of Rydberg-surface interactions is of fundamental importance, in particular when the atomic size is comparable to the atom-surface distance. In this case, QED theory predicts that higher-order interactions (due quadrupole and not just dipole fluctuations) need to be considered but these predictions remain so far without experimental verification.

Additionally, probing Rydberg atoms in compact solid-state platforms is recently gaining considerable attention for quantum technology related applications. Nevertheless, placing Rydberg atoms close to dielectric surfaces is an important challenge due to enormous atom-surface attractions. An efficient way to counter this problem is to couple Rydberg atoms to surface polaritons, which allows tuning of the Rydberg-surface interaction from a giant attraction down to repulsion. This requires the use of nanostructured metasurfaces with tailored resonances at THz frequencies (resonant with Rydberg dipole couplings).

The PhD thesis will evolve according to the following steps:

1) Measurements of the Rydberg-surface interaction by selective reflection or thin cell spectroscopy with *planar* dielectric surfaces (without deposited metasurfaces). These measurements will allow us to measure the van der Waals coefficient of Rydbergs and possibly demonstrate higher-order effects.
2) Develop detailed theoretical calculations of the Rydberg-surface interaction that can be compared with experimental results. Additionally, develop calculations of Rydberg-metasurface interaction based on numerical approaches.
3) Design, fabrication and characterization of metasurfaces that are resonant with Rydberg atoms.
4) Fabrication of vapor cell with metasurfaces and dedicated spectroscopic measurements of the Casimir-Polder, Rydberg-metasurface interactions. The aim of this part of the project will be to demonstrate the possibility of tuning Rydberg-surface interactions.

This is a collaborative project between the SAI group of USPN and the theory group of Stefan Scheel in the University of Rostock. The metamaterials will be fabricated in collaboration with D. Wilkowski of the Nanyang Technical University. The collaboration is financed by the ANR project SQUAT.

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