SUMMARY OF RESEARCH PROJECT
RENNES METROPOLE MOBILITY GRANT FOR INCOMING FOREIGN PHD STUDENTS

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Topic: "*Plasmon and periodicity assisted wideband absorbers for solar cells and biosensors*"

Periodically structured scatterers, or finite-periodic gratings, arrays or chains of particles and holes in metallic screens (in 3-D) or wires and slots (in 2-D), are attracting large attention of researchers in today's nanophotonics. This is caused by the effects of extraordinarily large reflection, transmission, emission, and near-field enhancement that have been found in the scattering of light by periodic scatterers. Recently it has been discovered that these phenomena are explained by the existence of so-called grating resonances or poles of the field function (a.k.a. geometrical, lattice and Bragg resonances). Their wavelengths are just above the Rayleigh wavelengths, i.e. period being a multiple of the wavelength if all elementary scatterers of a grating are excited in the same phase and their size is a fraction of the period. In the wave scattering by infinite gratings, they lead to almost total reflection of the incident field by a thin-dielectric-wire grating in a narrow wavelength band. Another type of resonances is observed for sub-wavelength noble-metal particles and wires in the mid-infrared and optical bands. It is known that small material objects can exhibit resonance behavior at certain frequencies for which the object permittivity is negative and the free-space wavelength is large in comparison to object dimensions. The latter condition clearly suggests that these resonances are electrostatic in nature. Excitation of plasmons results in powerful enhancement of scattered and absorbed light that is used in the design of optical antennas and biochemical sensors for advanced applications. In the leading terms, the plasmon resonance wavelength depends on the noble-metal object shape but not on its dimensions. Periodicity-caused resonances can enhance or inhibit plasmon resonances in noble-metal wire and particle aggregates. This opens a way for designing novel efficient frequency-selective functional elements such as plasmonic beam splitters, deflectors, prisms, lenses, elliptic, parabolic and corner reflectors, and others that can be well transparent in the range of wavelengths out of the working band.

We propose to study resonant behavior of the scattering characteristics for the gratings of different configurations made from nano-size noble-metal and dielectric wires which can be used as substrates for solar cells and biosensors. The method of analysis will be based on the rigorous expansion of the fields in terms of the corresponding cylindrical functions in local coordinates of each wire, using the addition theorems for these functions, and satisfying the boundary conditions. Each problem will be reduced to the Fredholm second-kind matrix equation with favorable features to guarantee the convergence of the algorithm and thus the reliability of the obtained numerical results.

To understand the nature of resonances, we will also study the associated eigenvalue problems for the grids of passive scatterers and investigate the interaction of resonances of different types. In the modified formulation, the eigenvalue analysis will be applied for the lasing modes of the grids equipped with active regions in the form of so-called quantum wires.

As a result of project, we will obtain new and accurate knowledge about the resonant behaviour of finite grids made of sub-wavelength noble-metal and dielectric wires in the optical range, where plasmon, "wire" and "grating" resonances can be observed. Bringing together these types of resonances in the periodically structured sub-mm-wave and optical components may lead to the novel features of solar cells and plasmonic biosensor substrates. Varying all grid parameters (size of wires, grid period, angle of incidence, number of scatterers, grid configuration) we will obtain a full account of its resonant behavior. Such information is necessary when designing periodically structured substrates for biosensors and solar cells. This will complement earlier numerical studies of infinite grids of perfectly electrically conducting and dielectric wires. Reliability of results will follow from the use of full-wave simulation method based on the Fourier expansions and addition theorems.

Another part of the results will be about the enhanced spontaneous emission and lasing in the considered resonant structures. These results will potentially lead to appearance of more efficient and cheaper technologies of the design of periodically structured microcavity lasers with improved and optimized characteristics. Such lasers will be attractive sources of light in the high-density photonic integrated circuits.

All listed above gives a strong hope that our research has good chances to mature and reach a sustainable funding from national and international R&D agencies. Proposed research topic and program appears to be perfectly in line with Prof. Sauleau's scope of interest.