| **Tytuł projektu** |
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| Oddziaływanie światła z symetrycznymi i asymetrycznymi układami atomowymi |
| **Project title** |
| **Interaction of light with quantum systems of different degrees of symmetry** |
| **Dyscyplina /Area of science** |
| Nauki fizyczne |
| **PROJECT DESCRIPTION** |

**Project goals**

- Comprehensive study of influence of atomic system's asymmetry on its interactions with light.
- Enhancing performance of asymmetric systems as optically tunable sources of low-frequency radiation by shaping geometrical and spectral properties of photonic environment.
- Exploration of regime where interaction of light with asymmetric systems is a nonmonotonic function of the driving field in the context of applications for highly-sensitive metrology of strong fields or tunable optical switches.

**Outline**

The project is focused on interactions of atomic systems of different degrees of symmetry with laser fields and photonic environments with a high degree of controllability, such as optically dressed media or nanoparticles. By atomic systems we mean molecules, quantum dots, defects in crystalline lattices, etc. Their geometrical structure can be expressed in terms of intrinsic permanent or transition dipole and higher-multipole electric and magnetic moments.

Previously, a presence of permanent dipole moment has been shown to unlock a new effect: an asymmetric system subject to illumination with a resonant beam at optical frequency becomes a source of coherent radiation of optically tunable frequency, typically in the GHz - THz range. Performance of this effect can be boosted in coherent ensembles of atomic systems and depends on geometrical and spectral properties of photonic environment. The latter aspect has not yet been extensively studied. An unexplored regime where the coupling becomes a nonmonotonic function of the driving field promises additional new effects with applications for highly-sensitive metrology of strong fields or tunable devices to steer coupling between several atomic systems.

In free space these effects are weak. Enhanced, they might be exploited for THz sources, computing devices or metrology. However, for a significant signal-to-noise ratio all these applications either require atomic systems of remarkably large dipole moments, or interaction enhancement e.g. using (nano)structured photonic environments. In this project we propose to explore both possibilities to identify scenarios where a specific degree of asymmetry might unlock new or enhance otherwise weak physical effects.

This PhD project will be conduct in close cooperation with the University Aldo Modo in Bari, Italy. Partners will provide training on selected methods of modelling atomic dynamics. Additionally, close contact with experimental groups realizing related research will facilitate design of experiments to verify our theoretical predictions.

**Work plan**

1. Study of coherent dynamics of light and isolated (a)symmetric atomic systems in regimes where the Rabi frequency is a nonlinear function of the driving field.

2. Study of pulse propagation in atomic-system ensembles embedded in different photonic environments.
3. Study of dipole-dipole coupling and superradiance of (a)symmetric atomic systems in dispersive photonic environments.
4. Preparation of thesis and additional problems.

**Literature**

O. V. Kibis, et al.; Phys. Rev. Lett. 102(2) (2009), 023601.
I. Yu. Chestnov, et al.; Acs Photonics 4(11) (2017), 2726-2737.
J. Hou, K. Słowik et al.; Phys. Rev. B. 89 (2014), 235413.
A.Crespi et al.; Phys. Rev. Lett. 122 (2019), 130401.

**Required initial knowledge and skills of the PhD candidate**

Analytical thinking

Excellent academic record in Physics or related

Basic programming skills

Good command in written and spoken English

Not required but welcome: Experience in quantum optics or atomic physics confirmed with co-authored scientific articles, conference presentations, internships on related subjects

**Zgłaszający projekt/ Autorka projektu //Submitting Person/Author of the project**

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**Proponowani promotorzy i mentorzy/prospective supervisors**

1) promotor główny/ main supervisior

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| 2) promotor pomocniczy / co-supervisor | |
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