Quantum plasmonics and nano-optics (experiments)

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There are two experimental projects available.

Nanoscale Bose-Einstein Condensates and lasers

Nanoplasmonics deals with surface plasmon polaritons (SPPs) which are light bound on the surface of a metal. The special feature is that such light can be confined to smaller scales than the wavelength of light (which is in micrometers): it can be called “nanolight”. “Nanolight” has special properties such as extremely high field intensity. SPPs are already applied in biosensors, and the most important future applications are envisioned to be novel light sources, solar energy harvesting, and cancer therapy. Our group has been pioneering the use of plasmonics to create novel types of coherent light sources, such as nanoscale lasers and, very recently, Bose-Einstein condensates (BEC).

The review article by P. Törmä and W.L. Barnes on these systems contains a video abstract that discusses exciting prospects of these systems, and also shows how our lab looks like, see http://iopscience.iop.org/article/10.1088/0034-4885/78/1/013901

Recently, we achieved nanoscale lasing in nanoparticle arrays, see the Aalto News and an article in Helsingin Sanomat (both contain a video, in English in the former and Finnish in the latter):
http://www.hs.fi/tiede/art-2000005034015.html

We have a world record in the linewidth of such lasers, only 0.09 nanometers.

Spatial evolution of (from left) thermalization, lasing, and Bose-Einstein condensation.

Our very recent breakthrough is the observation of a first plasmonic Bose-Einstein condensate. Bose-Einstein condensation is a phenomenon predicted by Bose and Einstein more than hundred years ago, and observed in a few different systems ever since. Our
BEC produces coherent light somewhat similar to laser light, and is one of the fastest BECs known (dynamics in the sub-picosecond range). The BEC observation results can be found in https://arxiv.org/abs/1706.01528

Such novel nanoscale lasers and BECs offer unprecedented access to fundamental understanding of how light and matter interact in the sub-wavelength and ultrafast scales. And they provide a way to realize nanoscale light sources with unique properties, such as small footprint, ultrafast operation and low energy consumption, essential for future quantum technologies.

Now, a crucial question is: can the pumping (i.e. input of energy) of these systems be realized with low-intensity light sources, such as lamps, even sunlight, or by electrical injection? So far, all condensates and lasers of this type have been pumped with massive, expensive lasers. Achieving pumping by a low-cost, compact energy source would be a major achievement both scientifically and concerning the potential applications. In these projects, first steps towards this goal will be taken.

The Project 1 (experiment)

The goal is to pump a lasing sample and a BEC sample utilizing a low-intensity light source. You will plan and construct the optical setup needed for this, fabricate the samples and analyze the measurement results. You will use the nanofabrication tools available at Micronova cleanroom and the measurements are carried out in the state-of-the-art ultrafast dynamics laboratory of the QD group. This work constitutes a Bachelor of Science thesis or a special assignment. If you wish to do a Master’s thesis, integration of the light source on the sample can be included, as well as rate-equation modelling of the BEC and lasing dynamics if you wish to combine experimental and theoretical/computational work. This project is related to the ERC (European Research Council) Proof of Concept grant obtained by P. Törmä in 2017.

The Project 2 (experiment)

The goal is to realize electrical pumping of an organic microcavity condensate. First observation of such a condensate has been published in Nature Materials by Kostas Daskalakis, a Marie Curie postdoctoral fellow in our group https://www.nature.com/articles/nmat3874

The project involves sample fabrication by thin film growth techniques, measurements in the QD group ultrafast laboratory, and analysis of measurement results. The project is related to the OPLD Marie Curie postdoctoral grant of Kostas Daskalakis funded by the European Commission. The project can be adapted to produce a M.Sc. or B.Sc. thesis, or a special assignment.
**What will you learn in the projects**

In the fabrication work you will learn a set of state-of-the-art nanofabrication methods and how to work in a cleanroom environment. You will also learn how to plan an experiment and perform it with an advanced optical measurement setup, and how to innovate a solution to a challenging problem. Your scientific communication and collaboration skills will develop since you will work as a member of an active group.

**Who supervises you and how**


The group members supervising these projects are Dr. Tommi Hakala, who is a staff scientist at Aalto and worked previously at the Harvard University, USA, Ph.D. student Aaro Väkeväinen, and Marie Curie postdoc Kostas Daskalakis who did his Ph.D. in Imperial College London.

You will meet the group leader at least once per week, and the second supervisor (Tommi, Aaro, Kostas) almost daily. We have a system of writing your special assignment/B.Sc thesis/M.Sc. piecewise during the summer, so that you will be able to complete it promptly after the summer.

More information about the group and the research: [http://physics.aalto.fi/groups/comp/qd/](http://physics.aalto.fi/groups/comp/qd/)

Our group in Helsingin Sanomat: [http://www.hs.fi/tiede/art-2000002917734.html](http://www.hs.fi/tiede/art-2000002917734.html)

You can also ask for more information from paivi.torma@aalto.fi
Interested in your future? See from
http://physics.aalto.fi/en/groups/qd/members/alumni/
where people who worked in our group have ended up, both in academia and industry.