

# Marie Curie ITN cQOM

## Summary of the Scientific Achievements

**Name of Fellow: Stefan Walter**

**Principal Investigator: Prof. Florian Marquardt**

**Academic / Industrial Institution: University of Erlangen-Nuremberg**

**Start Date of ITN Fellowship: 01.01.2015**

**End Date of ITN Fellowship: 31.12.2015**

**Date of Report: 30.05.2016**

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### Description of research work

As a PostDoc in the theory group of Prof. Marquardt my research focus was on optomechanical systems. More specifically, I was interested in novel physics that can appear when many optical cavities are coupled to each other on an array and the links between these optical cavities consists in an optomechanical system. Previously it has been shown that such a setup could be used to create an analogue of a (static) magnetic field for the neutral photons which are free to move in such an array made of optical cavities. We were then able to make use of a peculiar and inherent feature of optomechanical systems, the so-called mechanical self-oscillations, to show that it is even possible to generate a dynamical magnetic field for photons. Most importantly, we argue that such a *dynamical magnetic field* (or equivalently also dynamical gauge field) comes about very naturally in the optomechanical setting and possibly could allow for the simulation of dynamical gauge theories, in the spirit of a quantum simulator. Today we know that the fundamental interactions between particles are mediated through gauge fields. Therefore, dynamical gauge theories are very important concepts in physics.

I was also able to continue a collaboration with colleagues from the University of Basel and the University of Luxembourg, where we have shown how to make use of a Cooper pair splitter for nonlocal quantum state engineering.

### Goals achieved and/or progress towards them

Together with Prof. Marquardt we finish the project "Dynamical Gauge Fields in Optomechanics" which is a major step towards new and unexplored physics in optomechanics. We submitted the manuscript to the arXiv preprint server and it is currently under review with Physical Review Letters. This was only a first investigation of this very intriguing subject and together with Prof. Marquardt I am currently co-supervising a Masters student with whom we are continuing to work in this direction. Moreover, I was able to present this work at various occasions, including invited and contributed talks and poster presentations.

### Training received

02/2016: Annual cQOM ITN workshop, Diavolezza

Talk: "*Dynamical Gauge Fields in Optomechanics*"

02/2015: Annual cQOM ITN workshop, Diavolezza  
Talk: "*Synchronization in the Quantum Regime*"

#### **Dissemination and outreach activities - Invited Seminar talks**

04/2016: Mesoscopic Physics Seminar  
University of Würzburg, Würzburg  
Talk: "*Dynamical Gauge Fields in Optomechanics*"

12/2015: Mesoscopic Physics Seminar  
University of Luxembourg, Luxembourg  
Talk: "*Dynamical Gauge Fields in Optomechanics*"

08/2015: IMPRS Seminar  
Max Planck Institute for the Science of Light, Erlangen  
Talk: "*Synchronization in the Quantum Regime*"

#### **List of conferences attended**

05/2016: Photons Beyond Qubits, Olomouc  
Invited Talk: "*Synchronization in Quantum Systems*"

04/2016: TopoDays 2016: Topological Effects in Photonics, Trento  
Invited Talk: "*Dynamical Gauge Fields in Optomechanics*"

03/2016: APS March meeting, Baltimore  
Contributed Talk: "*Dynamical Gauge Fields in Optomechanics*"

03/2016: GRC - Mechanical Systems in the Quantum Regime, Ventura  
Poster: "*Dynamical Gauge Fields in Optomechanics*"

03/2015: APS March meeting, San Antonio  
Contributed Talk: Synchronization in the Quantum Regime

#### **Publications:**

[1]  
E. Amitai, R. P. Tiwari, S. Walter, T. L. Schmidt, and S. E. Nigg  
"*Non local quantum state engineering with the Cooper pair splitter beyond the Coulomb blockade regime*"  
Phys. Rev. B 93, 075421 (2016)  
<http://journals.aps.org/prb/abstract/10.1103/PhysRevB.93.075421>

[2]  
S. Walter and F. Marquardt  
"*Dynamical Gauge Fields in Optomechanics*"  
arXiv:1510.06754 (preprint, under review with Phys. Rev. Lett.)  
<http://arxiv.org/abs/1510.06754>