Interacting Photons group (AMOLF)

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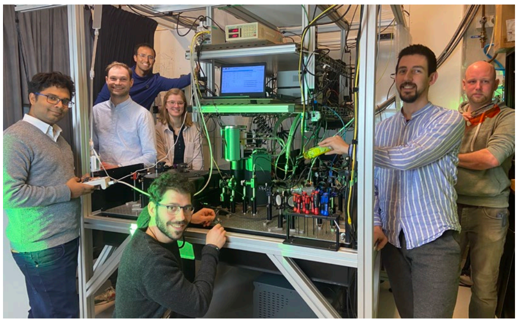


Our group searches for new physics emerging from photons interacting with each other, a noisy environment, excitons, and/or electrons. As a testbed for new ideas, we use custom-made optical systems comprising laser-driven cavities with nonlinear materials inside. We focus on answering fundamental physics questions, such as: what is the minimum energy required to make an optical switch? And how does that energy depend on the switching speed? While eminently fundamental, these questions are also relevant to energy-efficient optical information processing. The projects we offer will take you to the frontier of nanophotonics and statistical physics, in exciting experiments that promise both technical and conceptual challenges.

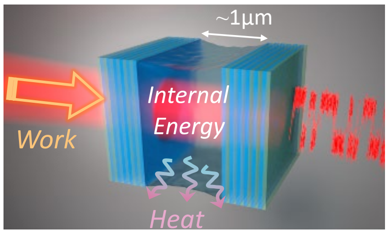
Project 1. Self-organized criticality of light

Supervisors: Vashist G. Ramesh and Roos de Boer

The human brain performs more calculations per second than the world's fastest supercomputer—all with a fraction of the power used by one incandescent light bulb. For years, researchers have hypothesized that such an extraordinary information processing capability is an emergent property of a system at the edge of a second-order phase transition, i.e., at a critical point. But how does the brain remain at a critical point (given how easy it is to drift away from it)? In other words: who is turning the knob to keep the system at the edge of a phase transition? The theory of self-organized criticality (SOC), one of the most spectacular ideas of the past 40 years of physics, emerged in response to these important questions. SOC is a mechanism by which a system can dynamically tune itself to a critical point, and from which scale-free structures (aka fractals) emerge organically in the dynamics of the system. While SOC has been theoretically explored over the past years in statistical physics and neuroscience, the potential of leveraging SOC for optical information processing has never been explored. In this project, you will perform experiments aimed at demonstrating SOC in an optical cavity. You will then explore the effects of SOC on the transmission of a small optical signal through that cavity. This project will build on recent theory and experiments from our group. In addition, we expect to recruit a theoretical physics masters student for this project; the intention is that you will work together with him/her, exploring the physics of SOC of light together.

Project 2. Measuring transient violations of the 2nd law

Supervisors: Roos de Boer and Vashist G. Ramesh



"If someone points out to you that your pet theory of the universe is in disagreement with Maxwell's equations—then so much the worse for Maxwell's equations. If it is found to be contradicted by observation—well these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."

- Sir Arthur Stanley Eddington around 1928

The 2nd law of thermodynamics has been revised many times over the past 2 decades. These revisions originated from the fact that, in small systems, thermodynamic quantities fluctuate and the 2nd law can be *apparently* violated for a short time. These "transient violations" of the 2nd law aren't really violations. They are instances in which the entropy of a system spontaneously increases, but the 2nd law still holds on average. In this project, you will construct an experimental setup to measure such "transient violations" of the 2nd law in an optical process. The setup comprises a tiny cavity as in the figure above, and a special so-called balanced homodyne detection method. You will shoot laser light into this cavity, implement a protocol in the laser intensity, and leverage recent theory from our group to formulate and test the 2nd law of thermodynamics for this process. You will then search for instances in which the 2nd law is temporarily broken, and characterize the statistics of those events.