

# Preface

Controlled manipulation of individual quantum systems is one of the most striking achievements of early twenty-first century experimental science. Today, individual atoms and photons can be guided through complex coherent evolutions with exquisite control, performing quantum information tasks previously seen only on theoreticians' notepads. One of the most critical capabilities, also one of the most challenging, is the controlled interaction of material quantum systems—atoms—with optical quantum systems—photons. This capability lies at the heart of both quantum networking, the distribution of quantum information among separated nodes, and quantum sensing, in which atoms acting as sensors are “read out” by a photonic quantum system.

Achieving control in this area requires rethinking fundamental processes such as absorption and emission of single photons. Breaking from the traditional view that these processes are immutable and unpredictable, recent experiments explore how such fundamental interactions can be shaped and controlled, an *engineering* of the atom-photon interaction. Progress has been swift, both in established methods such as cavity QED, and in wholly new methods such as heralded single-photon absorption and on-demand photon generation by parametric down-conversion. The techniques are finding application in a broad range of material systems, including trapped ions, neutral atoms, molecules, impurities in crystals, and semiconductor quantum dots.

This book aims to provide an accessible overview of the diverse but closely interconnected activities at this new frontier of quantum optics. The topics addressed include generation of indistinguishable photons, methods to make these photons compatible with the narrow transitions of atomic systems, and their interaction with solid state and atomic media. Free-space interaction between single photons and single trapped ions plays a prominent role, as does modification of emission properties and shaping of the photon wave function using cavity QED. Leaders of the field, in most cases the originators of the techniques being described,

contributed the individual chapters, each of which presents the principles, state of the art, and envisioned future of a method to engineer the atom-photon interaction.

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