Observation of light quantum jumps and time-resolved reconstruction of field states in a cavity

S. Haroche\textsuperscript{1,2}

\textsuperscript{1}Laboratoire Kastler Brossel, Ecole Normale Supérieure, Paris, France
\textsuperscript{2}Collège de France, Paris, France

After a general review of recent developments in Cavity Quantum Electrodynamics, I will focus on experiments performed at ENS on microwave fields trapped during a few tenths of a second in a very high $Q$ superconducting cavity\textsuperscript{1}.

Circular Rydberg atoms crossing the cavity one at a time are used to count trapped photons in a quantum non-demolition (QND) way, projecting in the process the field into a Fock state containing a well-defined number of light quanta\textsuperscript{2}. The subsequent evolution of these states induced by cavity damping exhibits photon number quantum jumps observed on single field trajectories\textsuperscript{3}. The usual exponential decay of the field energy is recovered by averaging over these trajectories, whose statistical analysis yields a direct measurement of all the damping rates of the field master equation\textsuperscript{4}.

By using atoms to perform QND measurements on an ensemble of cavity fields prepared in the same state, we fully reconstruct this state and its Wigner function\textsuperscript{5}. The method is applied to coherent states whose Wigner function is gaussian and to non-classical Fock and Schrödinger cat states exhibiting Wigner functions with striking non-gaussian features presenting negative values. By following the time-evolution of the reconstructed field states, we observe the progressive disappearance of these non-classical features and realize actual ‘movies’ of the decoherence phenomenon.

These studies in which photons are trapped and manipulated non-destructively by atomic beams can be viewed as the counterpart of ion trap experiments, in which atoms are localized in space and interrogated by laser beams. I will conclude by briefly discussing future projects generalizing these photon trap studies to two cavities and implementing quantum feedback methods to lengthen decoherence times in cavity QED experiments.

\textsuperscript{4}J. Bernu, C. Guerlin \textit{et al}, to be published.
\textsuperscript{5}S. Deléglise, I. Dotsenko, C. Sayrin \textit{et al}, to be published.