Dipolar light: electrically reconfigurable interacting-photon circuits using dipolar-polaritons with huge nonlinearities

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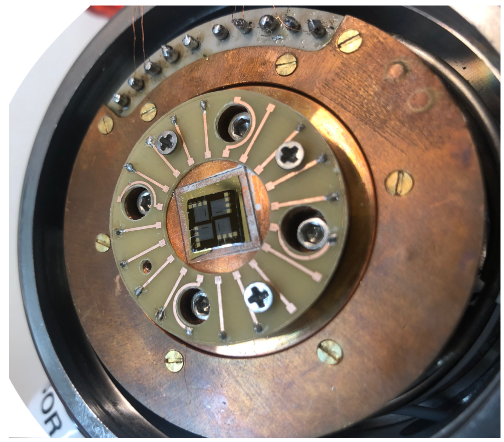
Electrically controlled photonic circuits hold promise for information technologies with greatly improved energy efficiency and quantum information processing capabilities. However, weak non-linearity and lack of electrical response of typical photonic materials have been two critical challenges. Therefore hybrid electronic-photonic systems, such as semiconductor exciton-polaritons, super-position states of confined photons and matter excitations, have been intensely investigated for their potential to allow higher nonlinearity and electrical control, but with limited success so far, as such non-polar particles do not interact sufficently with either electric fields or with other particles.



We demonstrate light circuits based on photons confined in planar waveguide geometries that are quantum mechanically hybridized with 2D-excitons that can be electrically polarized using electrical gates. The ability to hybridize dipolar excitons with confined photons allow formation of polaritons which carry effective dipole moments, leading to "interacting dipolar photons". This new concept leads to novel ways to control polaritons motion electrically, as well as tuning the position and strengths of their mutual interaction, that can reach surprisingly huge values.

Here, a new class of planar waveguide devices are shown, that elucidate the exciting physics that can be explored and the pormising quantum-photonic applications that can be developed with such on-chip dipolariton circuits: we demonstrate that remarkably, “dipolar light” can very effectively undergo coherent scattering from local electrical potentials, in a manner consistent with quantum scattering theory of ultra-light dipolar particles.

Then, we demostrate an ultrafast electrical mirror for photons with a GHz switching time, and then an electrically-controlled photon transistor based on enhanced dipolar interactions between slow polaritons. The polariton transistor displays blockade and anti-blockade by compressing a dilute dipolar-polariton pulse exhibiting very strong dipolar interactions.

Finally, we demonstrate photon correlation measurements from a transistor with resonantly injected dipolaritons, displaying both anti-bunching and bunching, reconfigured and tuned simply by changing the gate voltage, showing that such electrically controlled planar geometry of waveguided dipolaritons is a very promising platform for complex interacting light circuitry for quantum-photonics applications.

Short biography

Ronen Rapaport is a Professor of Physics at the Racah Institute of Physics at the Hebrew University of Jerusalem, Israel (HUJI). Ronen has received his PhD in Physics from the Technion, Israel in 2001, where he studied the physics of exciton polaritons. Ronen then became a principle investigator (MTS) at the Optical Physics department, Bell Laboratories, where he conducted research in various fields related to quantum nano-structures of semiconductors until 2007. Since then, Ronen is heading the Nanophotonics of Quantum Structures Lab (NPQSL) at HUJI, with research efforts ranging from many-body quantum physics of excitons and polaritons in low dimensional quantum structures, to light-matter coupling of quantum emitters and nano-optical devices for quantum information and quantum encryption.