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SINGLE PHOTON TURNSTILE DEVICE

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The idea about utilizing quantum mechanics to perform cryptography and computation has drawn a lot of interest in recent years [1]. Several schemes and systems to realize these ideas were proposed, and demonstrated. One of the most practical schemes to realize quantum cryptography is to use photons, encoding the information in the polarization of the photon [2, 3]. Quantum computation can also be performed in optical systems, and a prototype logic gate was demonstrated using single photons and a high-Q optical cavity [4]. However, in all of these schemes thus demonstrated so far, the source of photons was either highly attenuated laser or light emitting diode, or one of the photon pairs generated by parametric down-conversion process. The arrival time of the photons in these sources are determined by the Poisson statistics, and is totally random. The lack of ability to control the generation times of the photons imposes limitation on the efficiency of these schemes.

Generation of single photons with well-defined time interval is crucial in improving the efficiencies of these schemes. The generation of such photon states imply highly non-classical quantum statistics of light, as the photons need to be anti-bunched in time domain. It was proposed recently that such photon states can be generated by a mesoscopic light emitting diode with high quantum-efficiency [5]. The nonlinear Coulomb interaction of electrons and holes (Coulomb blockade) in such a device is utilized to achieve regulated pumping of the active region with a single electron and a single hole.

We have fabricated single photon turnstile device, which is a mesoscopic p-n junction that is pumped with resonant tunneling to provide single photons with well-defined generation time [5]. The $p-n$ junctions were grown by molecular beam epitaxy of GaAs/AlGaAs multilayers. Then, we fabricated sub-micron scale devices by electron beam lithography and electron cyclotron resonance reactive ion etching (ECR-RIE). In some of the devices we have observed strong evidences of turnstile operation, where single photon is emitted in a single modulation cycle. The first evidence is the frequency-dependent current with the relation $I = nef$, where e is the electron charge, f is the modulation frequency, and $n = 1, 2, 3$. This indicats that one, two and three electron-hole pairs are injected to the active region per modulation cycle, producing one, two and three photons. The second evidence is the localization of photon emission near the rising edge of the modulation pulse in time domain. This suggests that the number of electron-hole pair injected per modulation cycle is indeed finite. The experimental observation is reproduced by Monte-Carlo simulation based on a realistic model of the junction.

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