Observation of the Unconventional Photon Blockade

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- Research Interests
  - Entanglement
  - Quantum Computer
  - Quantum Matter&Optics
  - Quantum Storage

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Polarization degenerate solid-state cavity quantum electrodynamics

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High-Q nested resonator in an actively stabilized optomechanical cavity

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Letter

Fiber-Coupled Cavity-QED Source of Identical Single Photons

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CNOT and Bell-state analysis in the weak-coupling cavity QED regime

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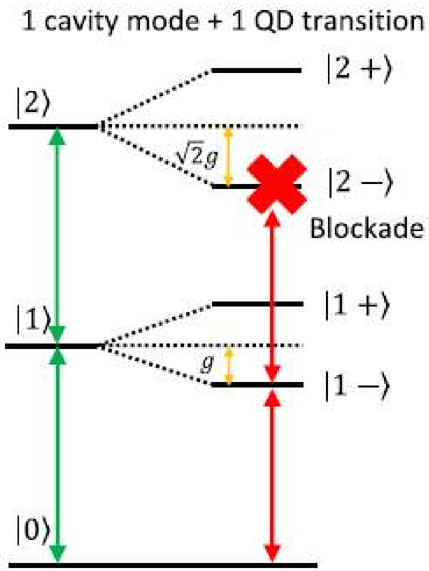
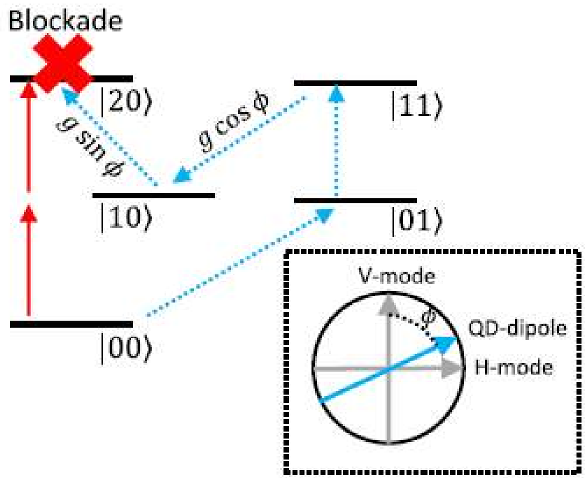
What is Photon Blockade?



- Due to the detuning between different dressed states, photon blockade occurs.
- In strong coupling region($g \gg \kappa$) and intermediate region($g \approx \kappa$)
- In weak region($g < \kappa$), the conventional photon blockade is no more

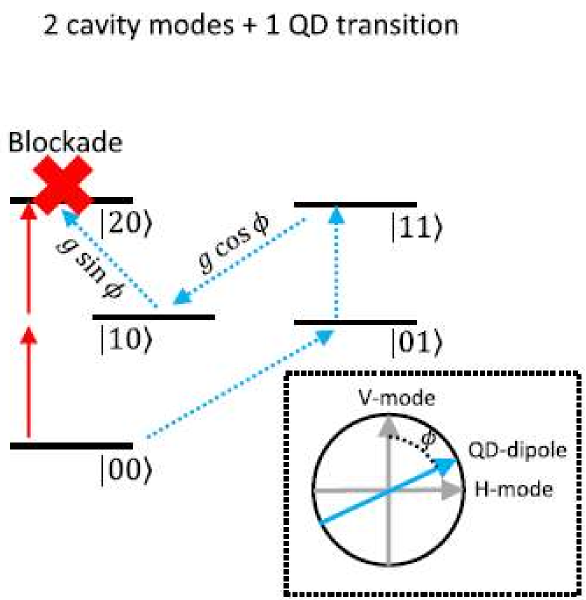
What is UPB(Unconventional Photon Blockade)?

2 cavity modes + 1 QD transition



- Occurs even in the weak coupling region($g < \kappa$)
- Two modes in the cavity: H and V polarization mode
- Quantum dot in the cavity interacts with both modes and its frequency can be tuned.
- Set ϕ = 94° for our case
- $H = (\omega_L - \omega_c^V)a_V^\dagger a_V + (\omega_L - \omega_c^H)a_H^\dagger a_H + (\omega_L - \omega_{QD})\sigma^\dagger\sigma + g(\sigma b^\dagger + \sigma^\dagger b) + \eta_H(a_H + a_H^\dagger) + \eta_V(a_V + a_V^\dagger)$
- $b = a_V \cos\phi + a_H \sin\phi$

What is UPB(Unconventional Photon Blockade)?

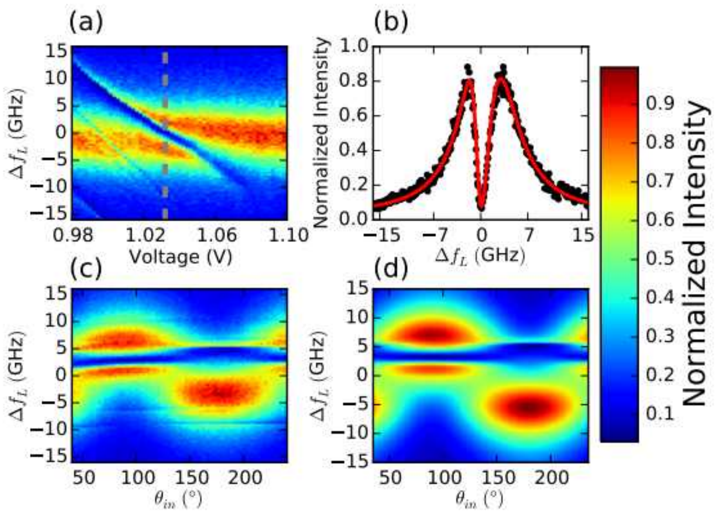


- Introduced by Liew and Savona in 2010 with arbitrarily weak nonlinearities
- Destrcutive interference between two excitation pathways to N=2 photon state
- Alternative explanation: squeezed state

How to identify UPB?

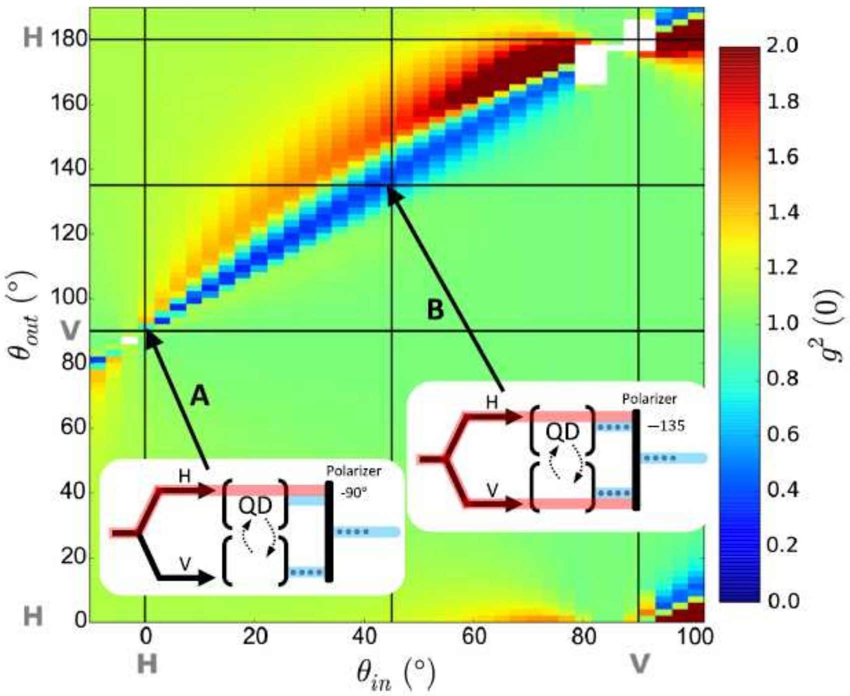
- $g^{(2)}(0) = \begin{cases} 0, \; n = 0,1 \\ 1 - \frac{1}{n}, \; otherwise \end{cases}$ for number states $|n\rangle$
- Observing extremely low $g^{(2)}(0)$ indicates suppressed $|2\rangle$ state and more photon number states

Measuring coefficients



- Δf_L: input laser frequency
- (a)&(b) alter QD frequency via Voltage on it and obtain coupling g = 14±0.4 ns^{-1}, total dephasing rate γ = 0.7 ns^{-1}
- (c)&(d) rotate input polarization and obtain cavity polarization splitting Δf_{cav} = 10±0.1 GHz, QD fine structure splitting Δf_{QD} = 2.4±0.1 GHz and its result shows excellent agreement with calculated transmission (d)

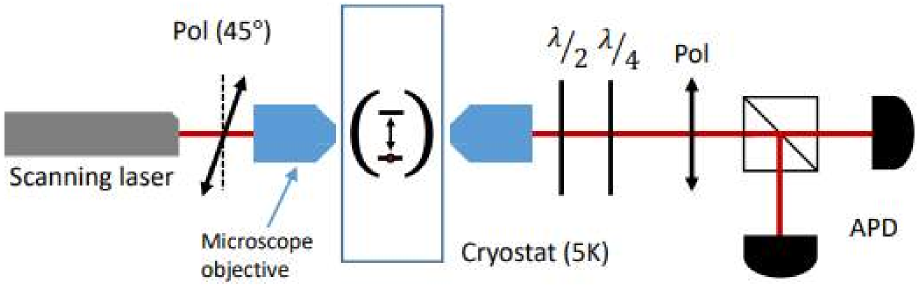
Simulation



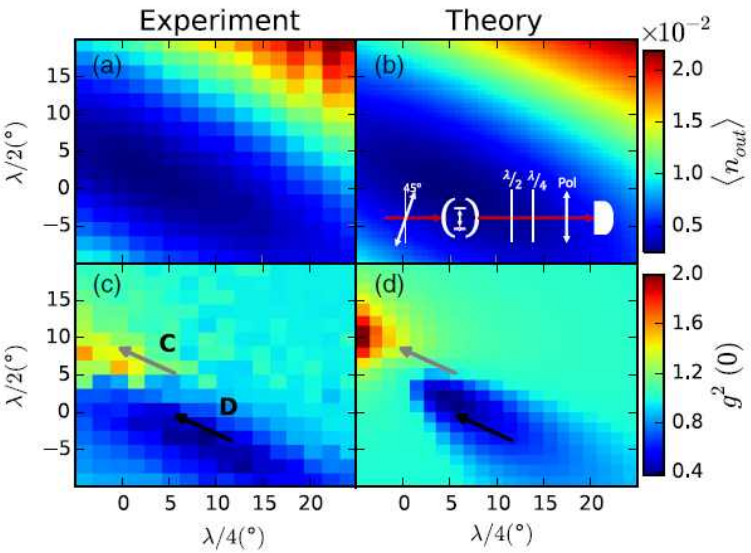
- θ_{out} and θ_{in} are angles of linear input and linear output polarization angle
- κ = 60 ns^{-1}, g = 14 ns^{-1}, γ = 0.5 ns^{-1}, $\langle n_{in} \rangle$ = 0.01
- Look up in region B closely in the next step

Experimental Setup

- Fix polarization angle at input 45° and output 135°
- Put zeroth order wave plate behind output polarizer
- Rotate angle of two waveplates and analyze transmission

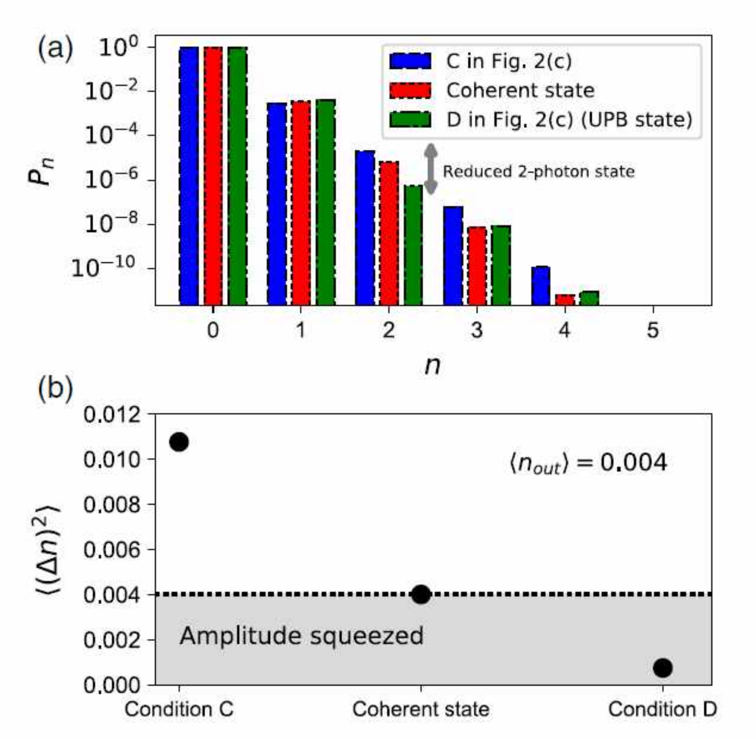


Result



- κ = 60 ns^{-1}, g = 14 ns^{-1}, γ = 0.7 ns^{-1}, $\langle n_{in} \rangle$ = 0.06, Δf_{cav} = 10 GHz for simulation
- $g^{(2)}(0)$ = 0.37±0.04 at minimum, considering detector response function, it drops to $g^{(2)}(0) \approx 0.005$

Alternative Explanation: Gaussian Squeezed State



- Due to the weak nonlinearity, a squeezed state is created
- Even a little bit of squeezing can reduce(or amplify) two photon state probability
- $|\langle 2|D(\alpha)S(\xi)|0\rangle|^2 \approx (\bar{\alpha}^2 - r)^2/2$ for $\alpha = \bar{\alpha}e^{i\vartheta}$, $\xi = re^{i\theta}$
- Condition C => Phase squeezed & Condition D => Amplitude squeezed

Q&A

- How did they revise the value of $g^{(2)}(0)$?
  They considered a factor called 'Detector Response Function'. It emerges because even the photon with the definite energy draws spectrum due to various reasons like Compton scattering. The Detector Response Function is various from detectors to detectors.

- The subject has deep connection with H.J. Carmichael's study. Did the writers noticed his study on antibunching?
  It seems that the writers did not noticed Carmichael's work. His paper was not cited in this paper.

- What is the reason for the polarization splitting?
  There could be many reasons for instance geometry of the cavity. Just like in our setup which has a mirror carved off into L shape so that H and V mode has different mode frequency.

- What kind of cavity did the writers use? How did they place quantum dot inside the cavity?
  InAs/GaAs quantum dot was embedded in a p-i-n junction, separated by a 27nm thick tunnel barrier from the electron reservoir. It was embedded in the micropillar cavity with maximum Purcell factor 11.2