Scattering of a single photon by a single atom
An experiment

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Outline

Exponentially rising single photons

Time inversion

Experiment

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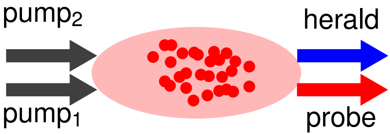
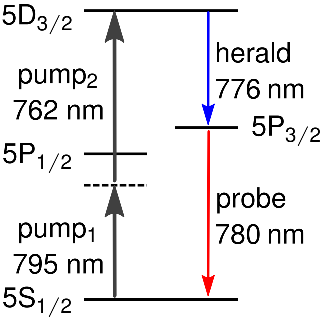
We generate correlated photon pairs using Four-Wave Mixing in cold ^{87}Rb atoms





T. Chanelière, et al., Phys. Rev. Lett. **96**, 093604 (2006)

B. Srivathsan, et al., Phys. Rev. Lett. **111**, 123602 (2013)

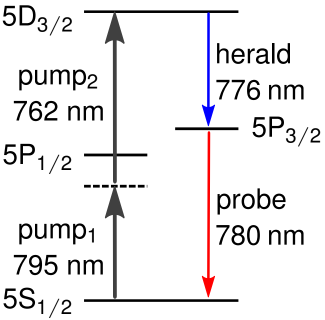
G. K. Gulati, et al., Phys. Rev. A **90**, 033819 (2014)

We generate correlated photon pairs using Four-Wave Mixing in cold ^{87}Rb atoms

heralded single photons
$g^{(2)} \approx 0$

frequency resonant with D2 line
$\lambda_p = 780\ nm$

compatible coherence time
$\tau_p \approx \frac{\tau_0}{2}$



T. Chanelière, et al., Phys. Rev. Lett. **96**, 093604 (2006)

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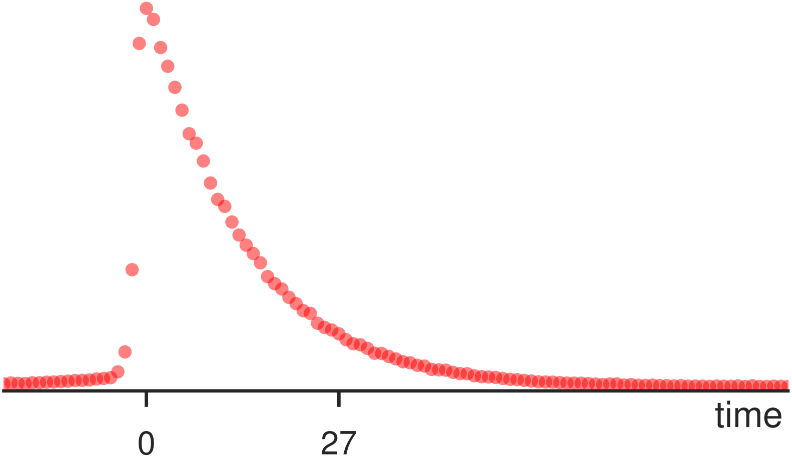
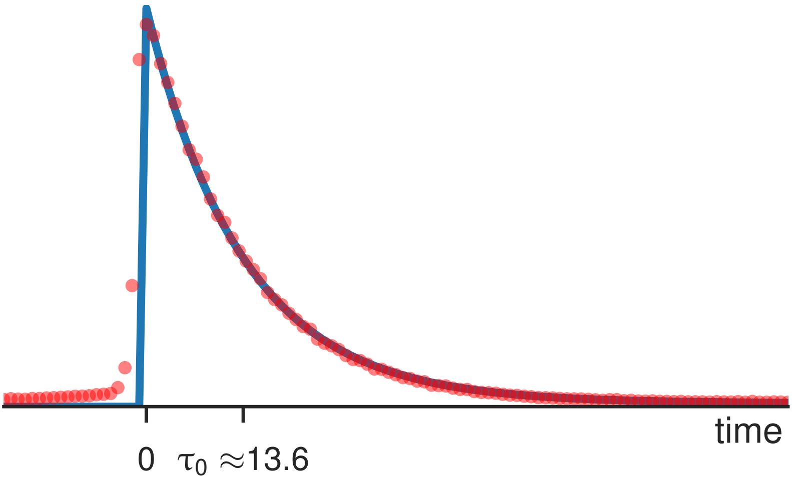
The source generates probe photons with an exponentially decaying temporal shape



The bi-photon state is nicely approximated by

$$\psi(t_s, t_i) = A \exp\left(-\frac{t_i - t_s}{2\tau}\right)\Theta(t_i - t_s)$$



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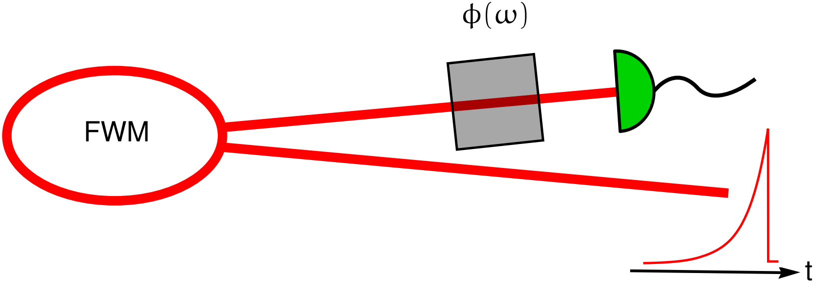
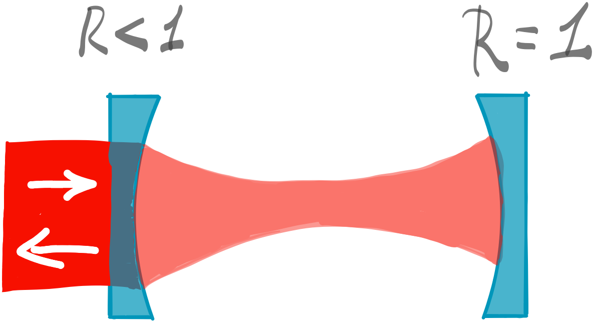
Temporal correlation of the biphoton and heralding allow to change the shape of the probe photon



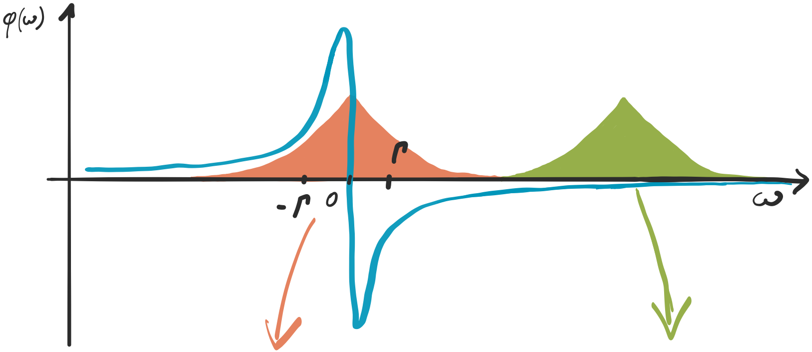
Description of the phase operation



$$C(\delta') = \frac{\sqrt{R_1} - \sqrt{R_2}\, e^{i\,\delta'/\Delta\nu_f}}{1 - \sqrt{R_1\,R_2}\, e^{i\,\delta'/\Delta\nu_f}},$$

We apply the phase operation to the bi-photon

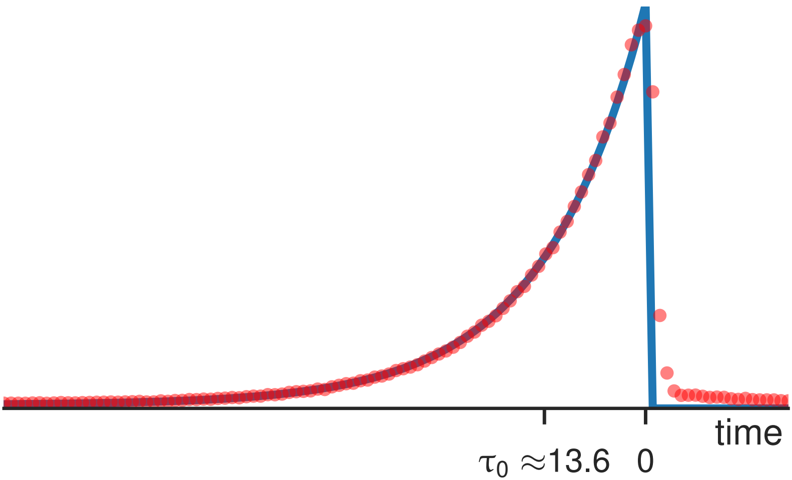
$$\tilde{\psi}(t_s, t_i) = \mathcal{F}_s^{-1}\left[C(\omega_s - \omega_s^0 - \delta)\cdot \mathcal{F}_s\left[\psi(t_s, t_i)\right]\right]$$



$$\tilde{\psi}(t_s, t_i) = A\, e^{(t_i - t_s)/2\tau}\,\Theta(-t_i + t_s)$$

$$\tilde{\psi}(t_s, t_i) = \psi(t_s, t_i)$$

We exploit the temporal correlation of the biphoton to obtain exponentially rising temporal shape



B. Srivathsan, et al., Phys. Rev. Lett. **113**, 163601 (2014)

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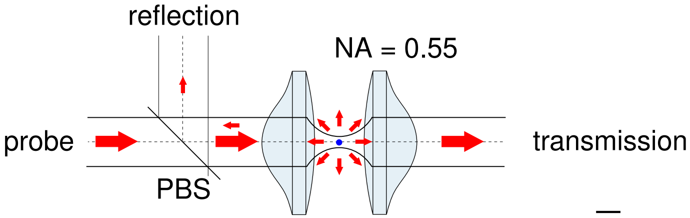
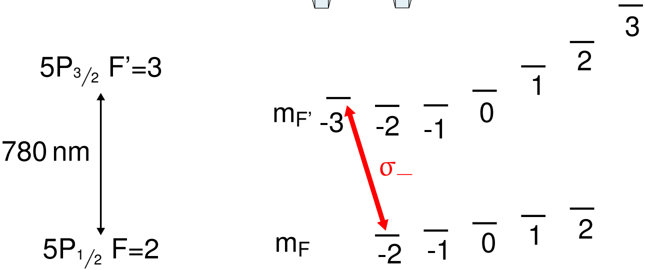
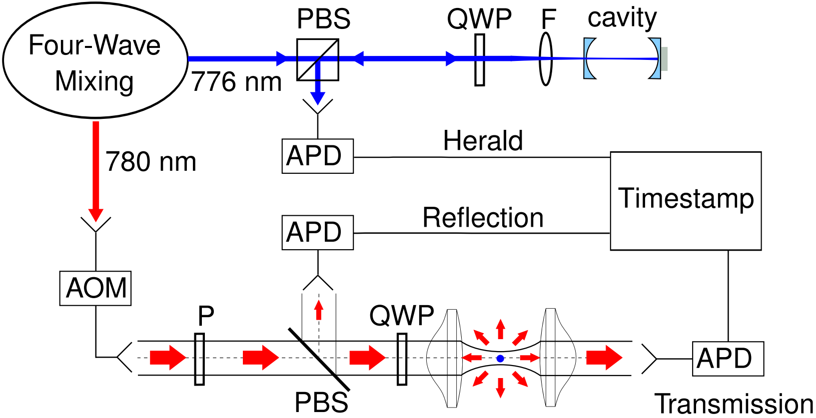
We have a single atom trapped at the focus of a far off-resonant beam



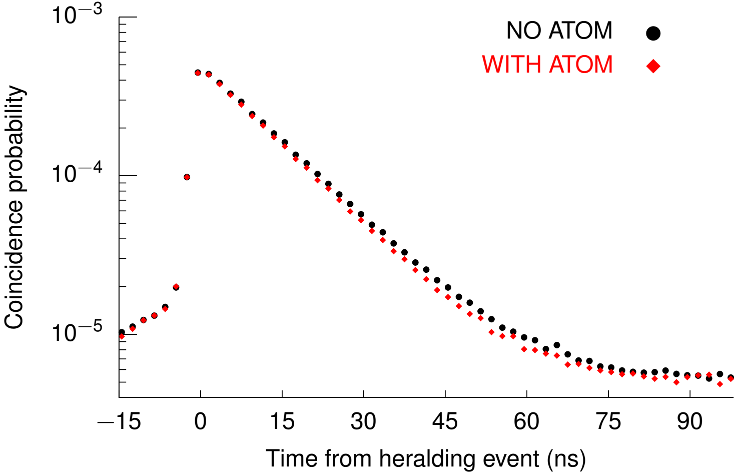


M. K. Tey, et al., Nature Physics **4**, 924 (2008)

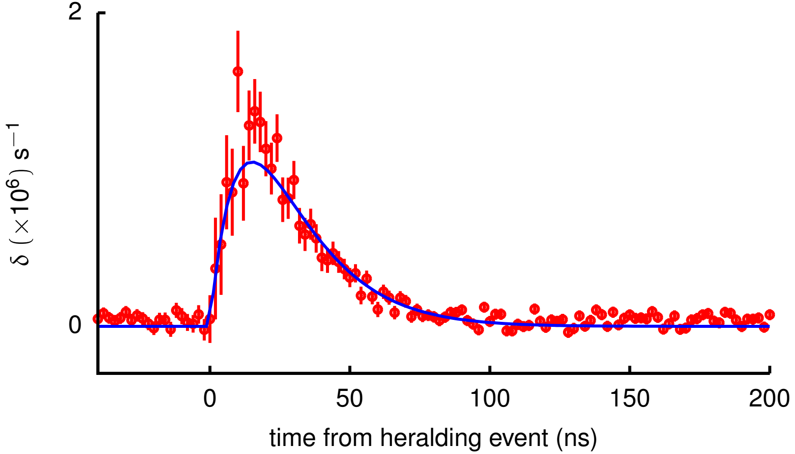
Experimental setup



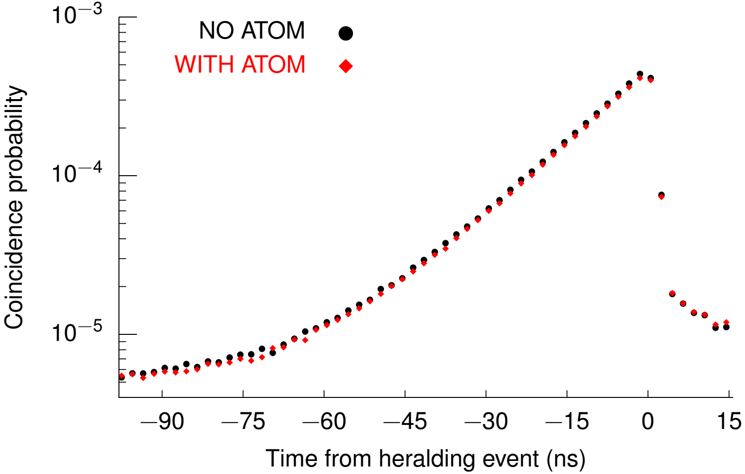
Time resolved transmission of “decaying” photons



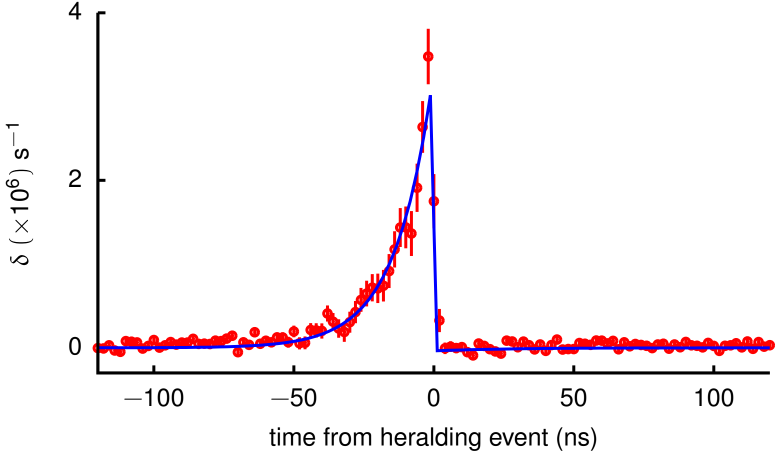
Time resolved extinction of “decaying” photons



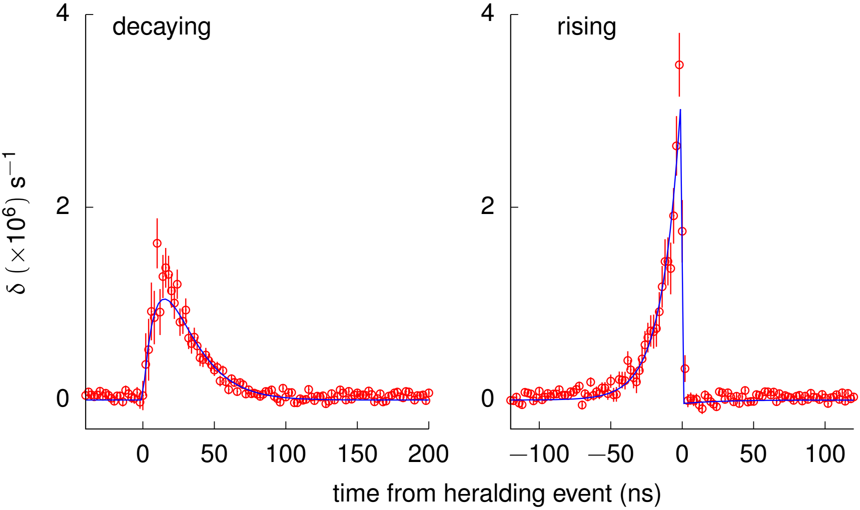
Time resolved transmission of “rising” photons



Time resolved extinction of “rising” photons

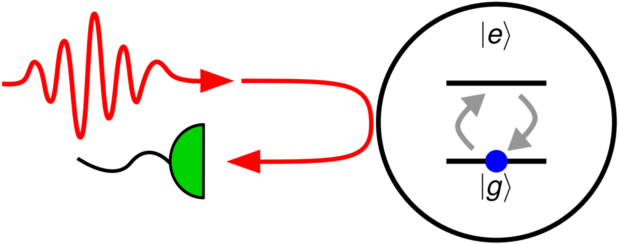


Different shapes lead to different absorption dynamics



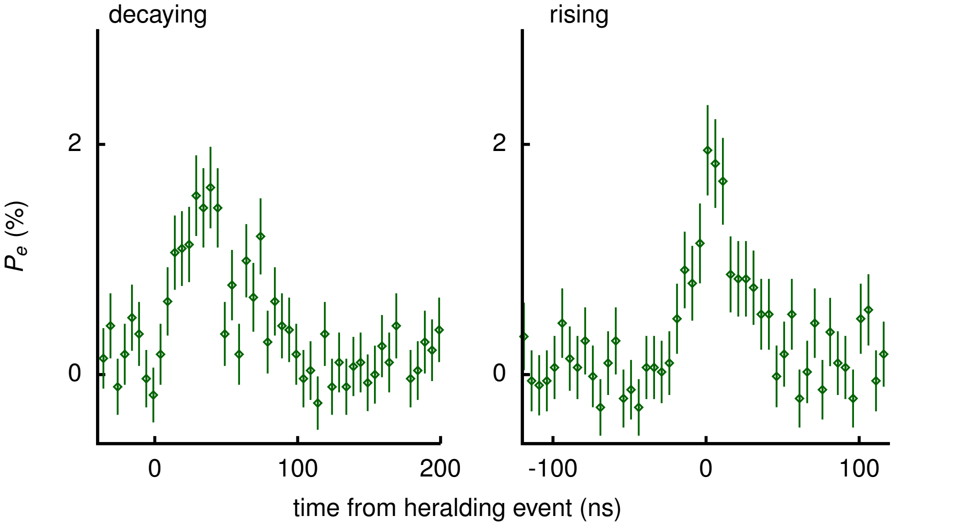
Let's look at the excitation probability:
Scattered light

$$P_e(t) = \frac{\tau_0}{\eta_b} R_b(t)$$



direct
bad signal to noise ratio
depends on calibration of η

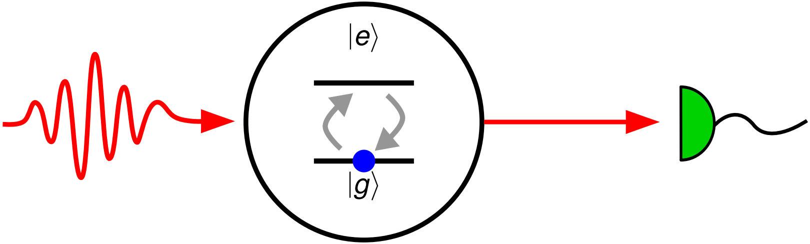
Atomic excitation probability from the time-resolved reflection



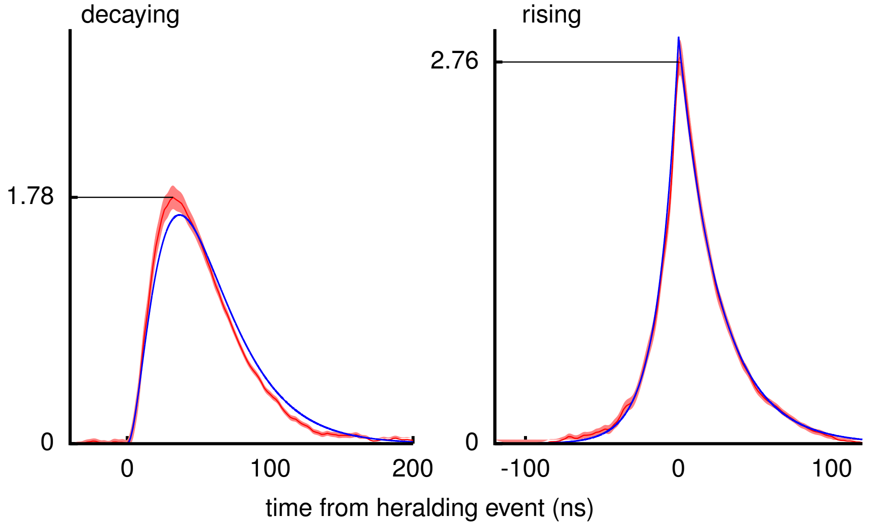
Let's look at the excitation probability:

Extinction

$$\frac{\partial}{\partial t}P_e(t) = \delta(t) - (1-\Lambda)\Gamma_0 P_e(t)$$



Atomic excitation probability from the time-resolved absorption



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