# Two-photon processes in faint biphoton field

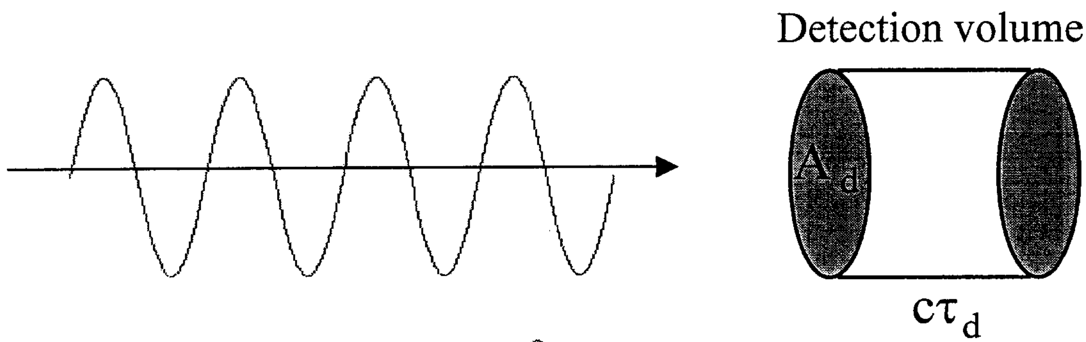
Dmitry Strekalov, Matt Stowe, Deborah Jackson and Jonathan P. Dowling

Quantum Internet Testbed
Jet Propulsion Laboratory

# Outline

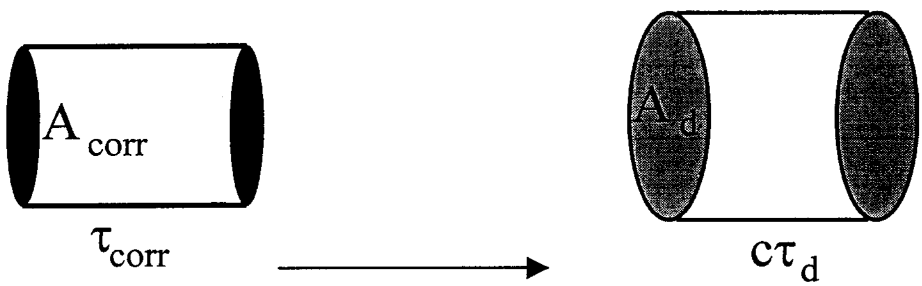
- Motivation: to explore the new aspects of biphoton optics; moving towards practical applications.
- Biphoton field vs. coherent field
- Interactions with an optical nonlinearity
- Interactions with other physical systems
- Conclusions and perspectives

## 1. Two-photon processes in a weak coherent field




$$P^{(2)}_{coh} \approx \frac{<n>^2}{2!}\frac{V_d}{V_{coh}} \propto V_d\, I^2 t$$

## 2. Two-photon processes in a weak biphoton field




If $V_{corr}$ is smaller than $V_d$, $P^{(2)}_{bph} \approx \frac{<n>^1}{1!}\frac{V_d}{V_{coh}} \propto V_d\, I t$

$$\frac{P^{(2)}_{bph}}{P^{(2)}_{coh}} \approx \frac{1}{<n>}$$

*[D.N. Klyshko, Sov. Phys. JETP **56**, 753 (1982)]*

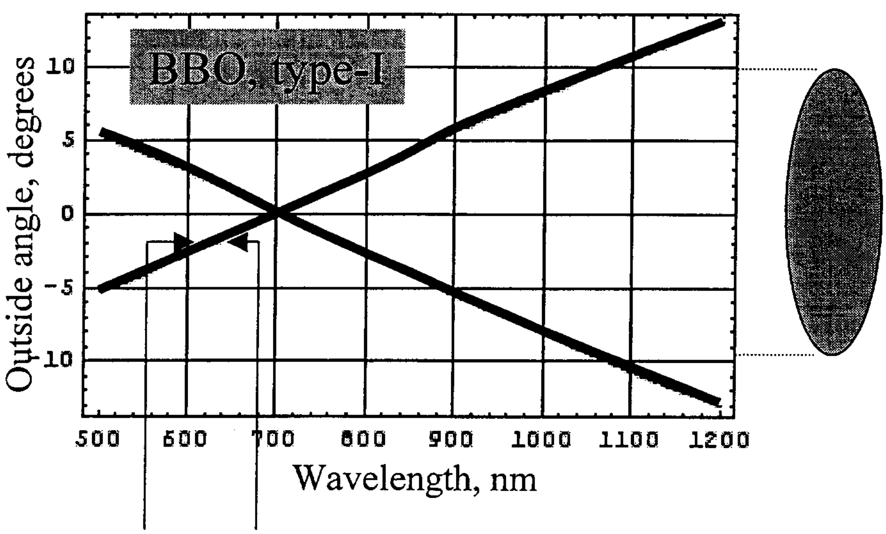
## How large is the biphoton enhancement factor?

$$\frac{1}{<n>} = \frac{S_0}{S} \quad \text{where the brightness is } S \equiv \frac{I}{\Delta\omega\Delta\Omega}$$

and $$S_0 \equiv \frac{\hbar c}{\lambda^3} \approx 10^{-11} \frac{J}{cm^2}$$ For the central wavelength value of 700 nm

Estimating brightness of SPDC light: Power 50 nW

Pump diameter 200 microns



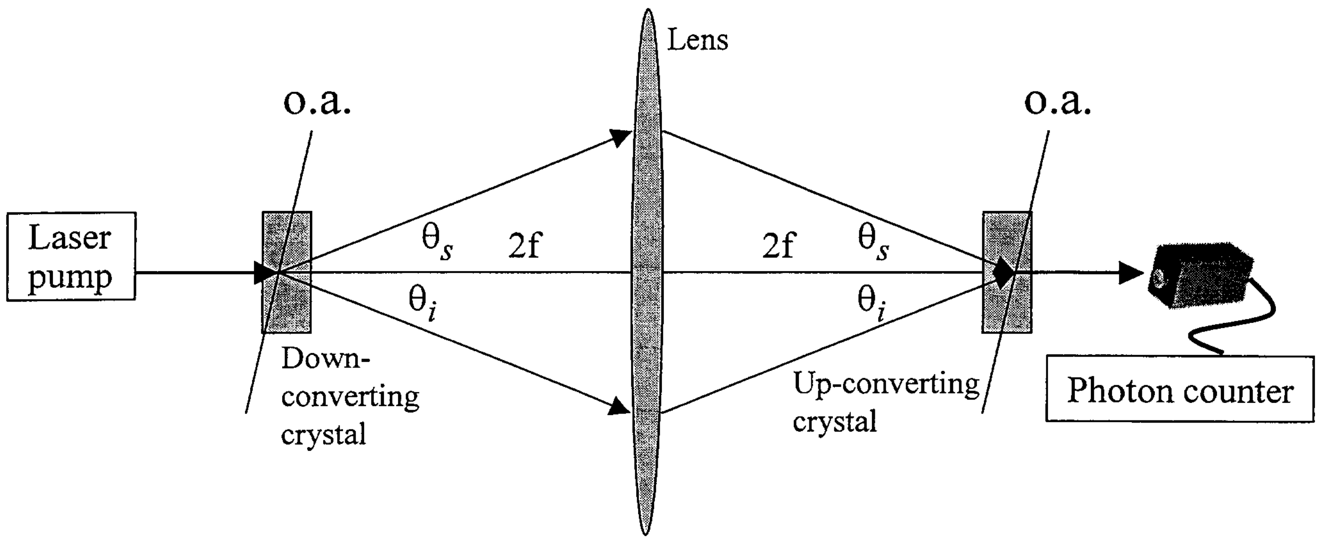

$\Delta\Omega \approx 0.2\ sr$

$\Delta\omega \approx 10^{13}\ s^{-1}$

Combining numbers we get $S \approx 10^{-16} \frac{J}{cm^2}$ and

$$\frac{1}{<n>} \approx 10^5$$

# Second Harmonic generation

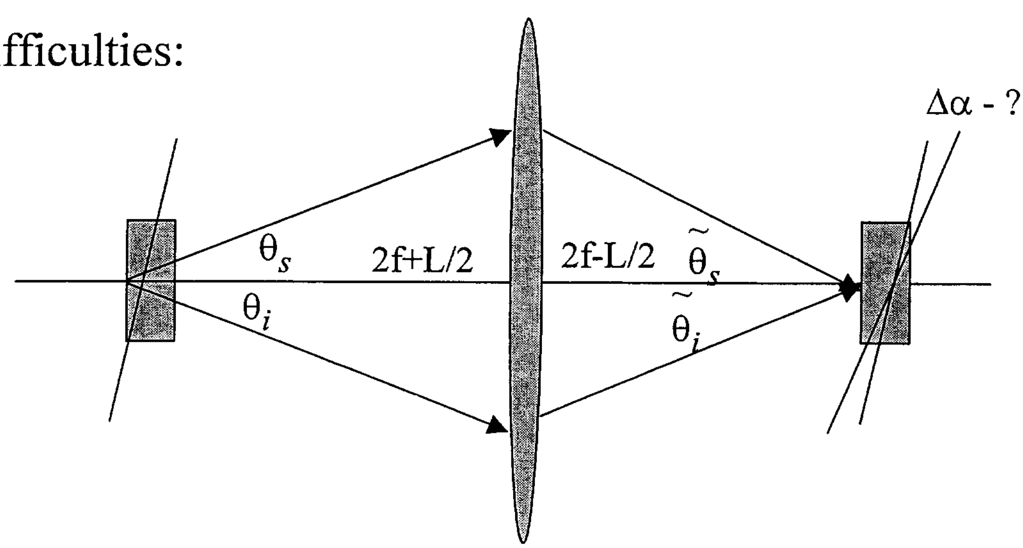



For coherent CW pump: 1W pump → $10^{-5}$ W of SH

50 nW pump → $2.5*10^{-20}$ W or about 0.3 photons/s of SH

With the biphoton enhancement factor $10^5$ and assuming quantum efficiency 1% we can expect a 300 counts/s signal.

Difficulties:

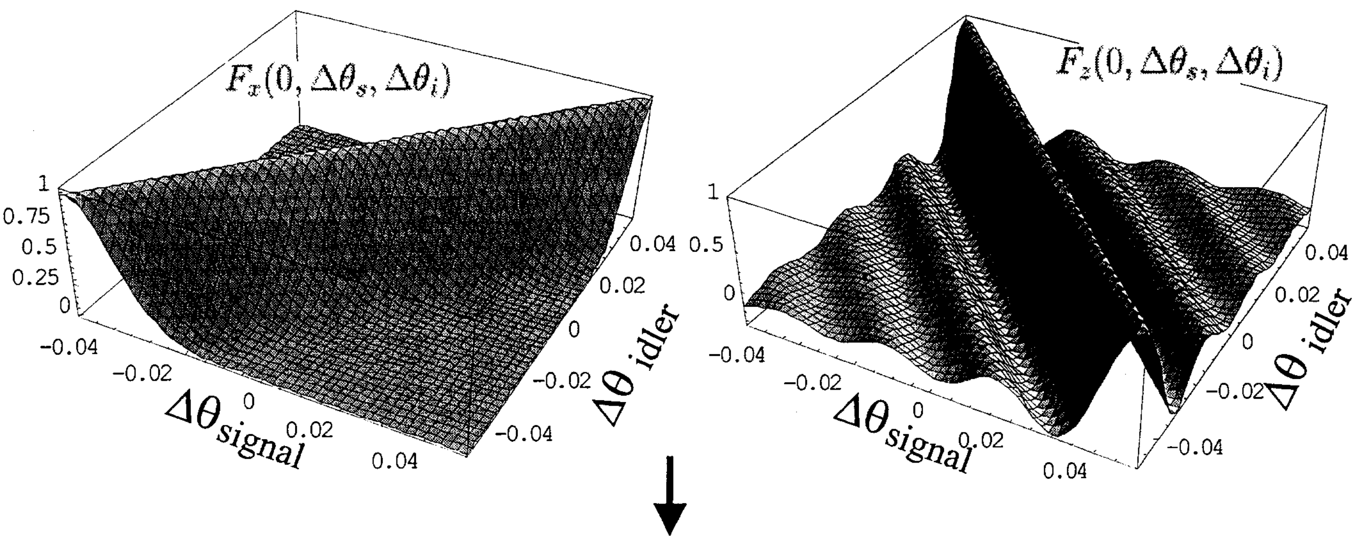


# Transverse correlation of a biphoton

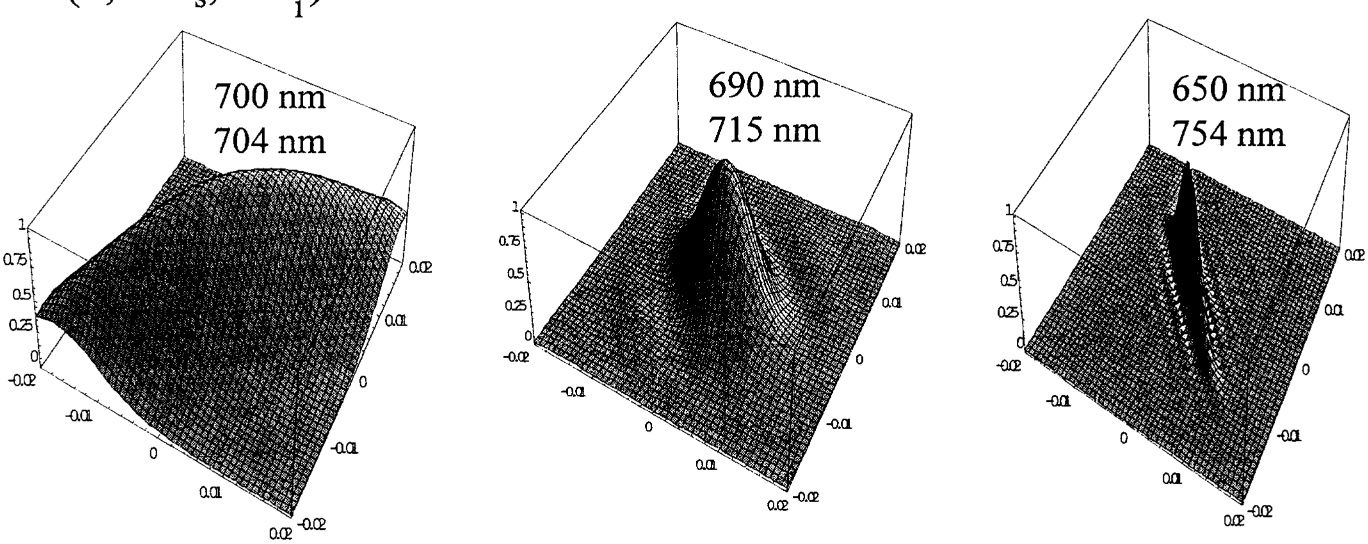
*[M.H. Rubin, Phys. Rev. A.* ***54****, 5349 (1996)]*
*[A.V. Burlakov et. al, Phys. Rev. A.* ***56****, 3214 (1997)]*

$$|\Psi\rangle = \int F(\vec{k}_s, \vec{k}_i)|1\rangle_{\vec{k}_s}|1\rangle_{\vec{k}_i}\, d\vec{k}_s d\vec{k}_i$$

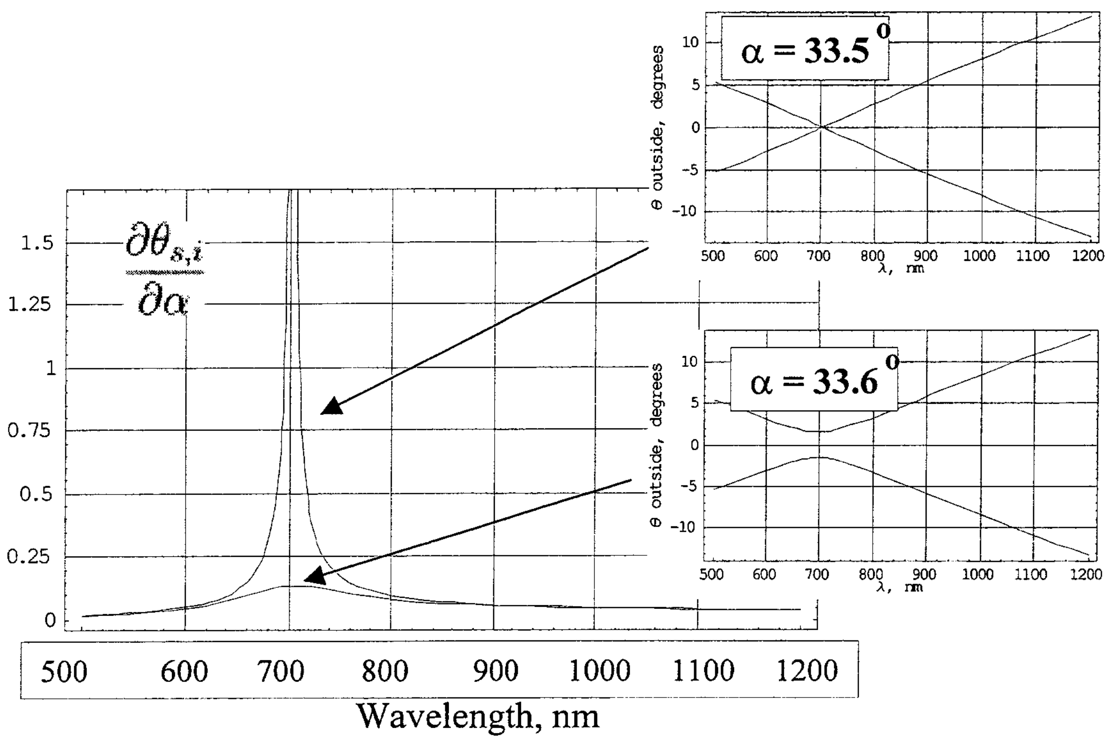
$$F(\vec{k}_s, \vec{k}_i) = F_x(\Delta\omega, \Delta\theta_s, \Delta\theta_i) F_z(\Delta\omega, \Delta\theta_s, \Delta\theta_i)$$



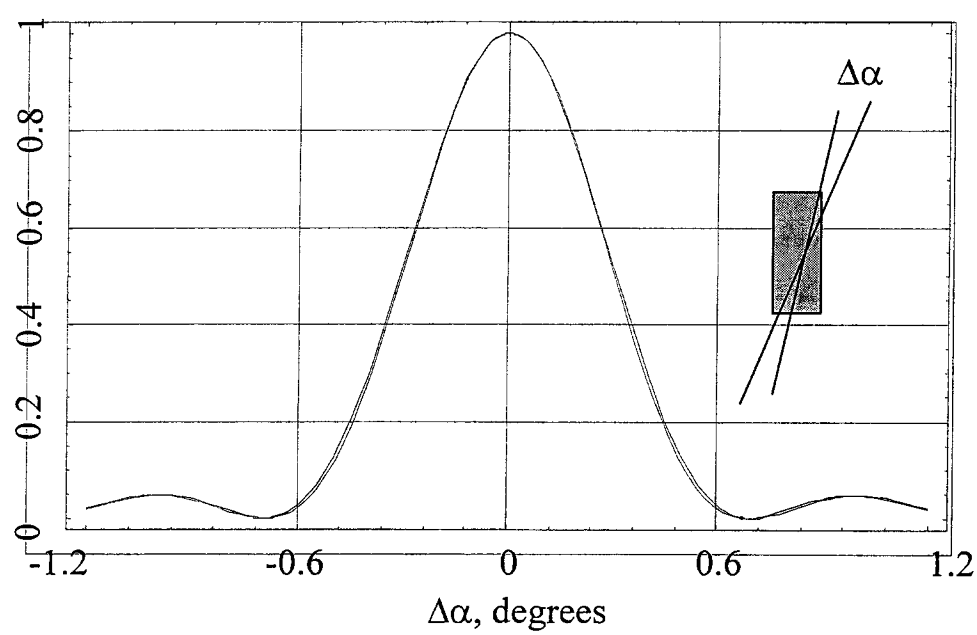

F(0, Δθ s, Δθ i):



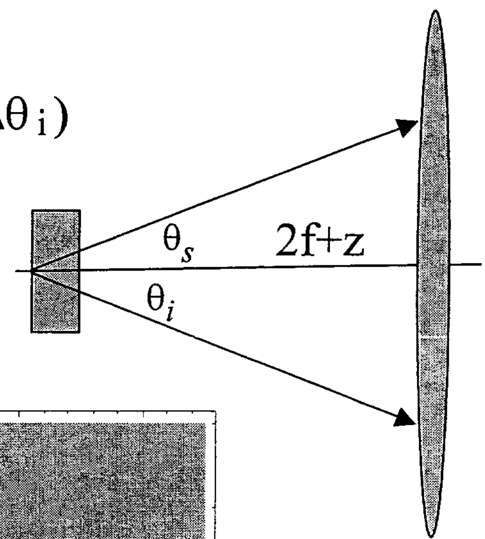
Substituting $\Delta\theta_{s,i} = \frac{\partial\theta_{s,i}}{\partial\alpha}\Delta\alpha$ into $F(0, \Delta\theta_s, \Delta\theta_i)$

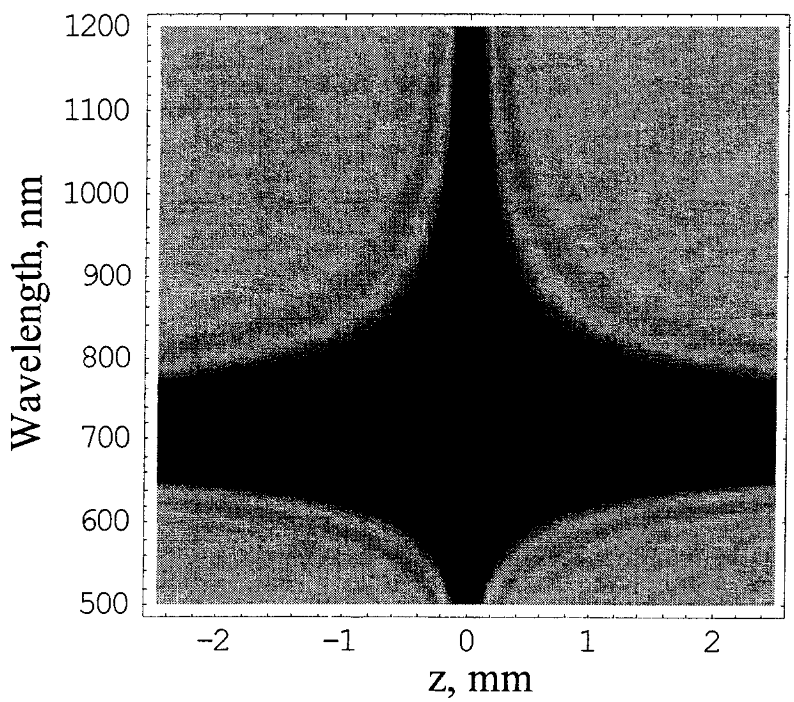



we get the overlap between the correlation and detection volumes as a function of alignment error:



Substituting $\Delta\theta_{s,i}(z)$ into $F(\mathbf{0}, \Delta\theta_s, \Delta\theta_i)$ we get the overlap between the correlation and detection volumes as a function of the offset z:




and for the entire 5 mm - long crystal: