Quantum engineering dealing with photon losses: experimental approach

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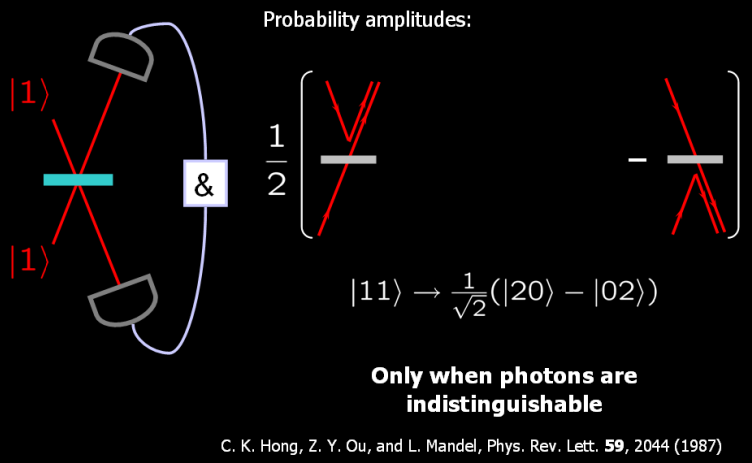
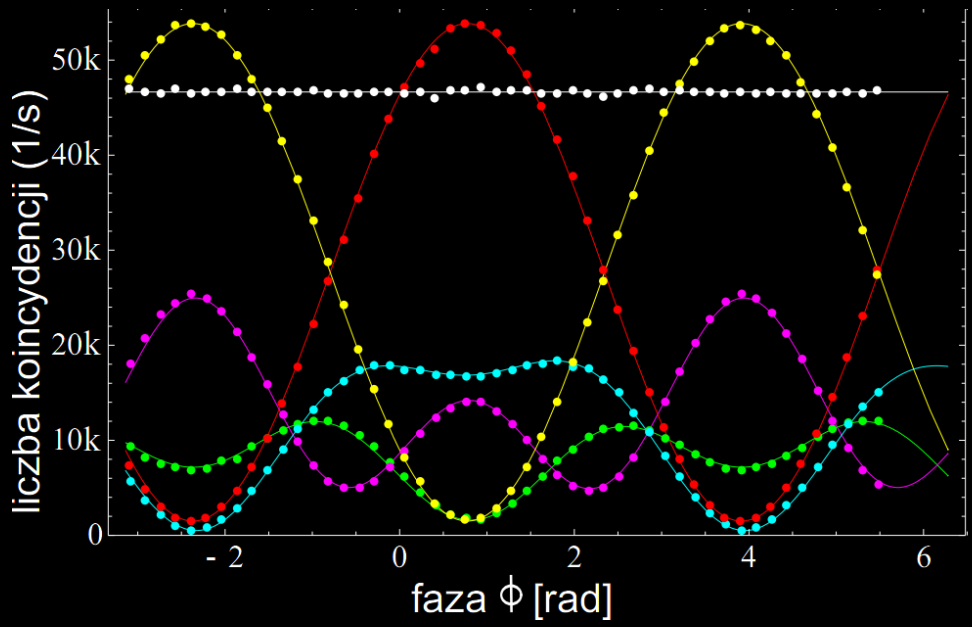
Outline

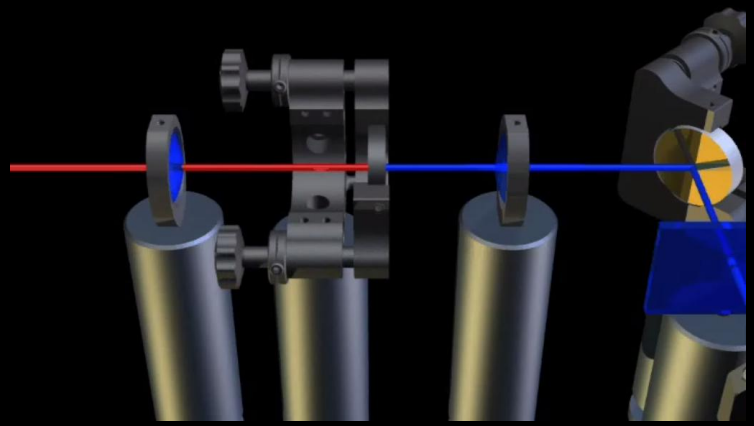
Two-photon interference



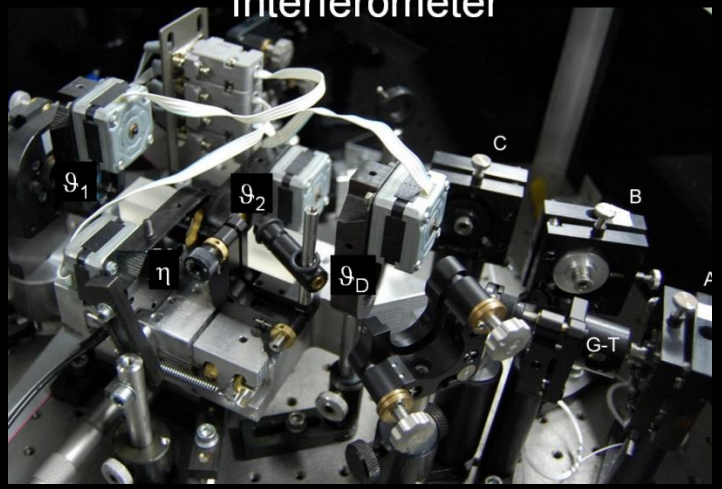
Only when photons are indistinguishable

C. K. Hong, Z. Y. Ou, and L. Mandel, Phys. Rev. Lett. **59**, 2044 (1987)

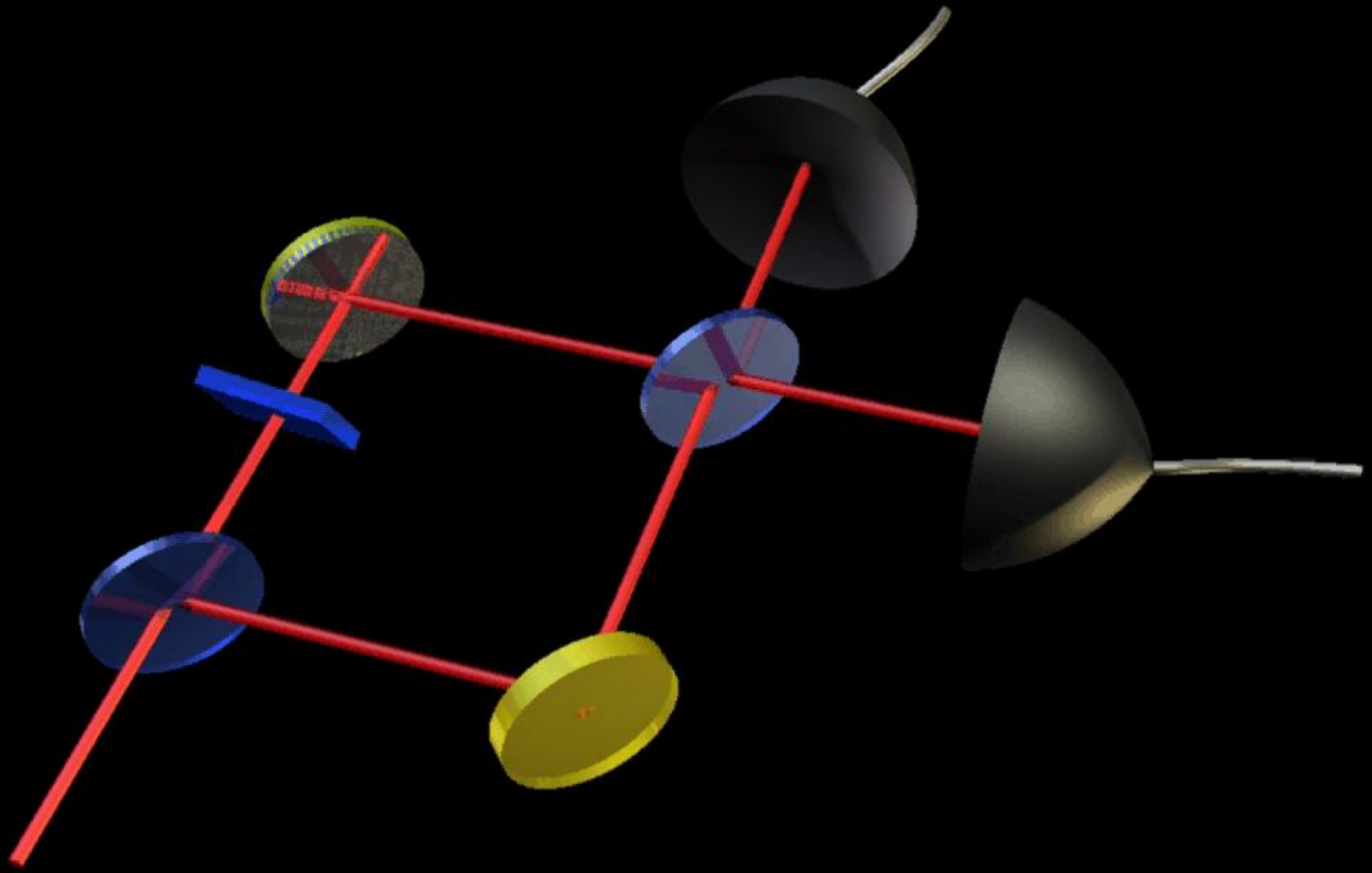




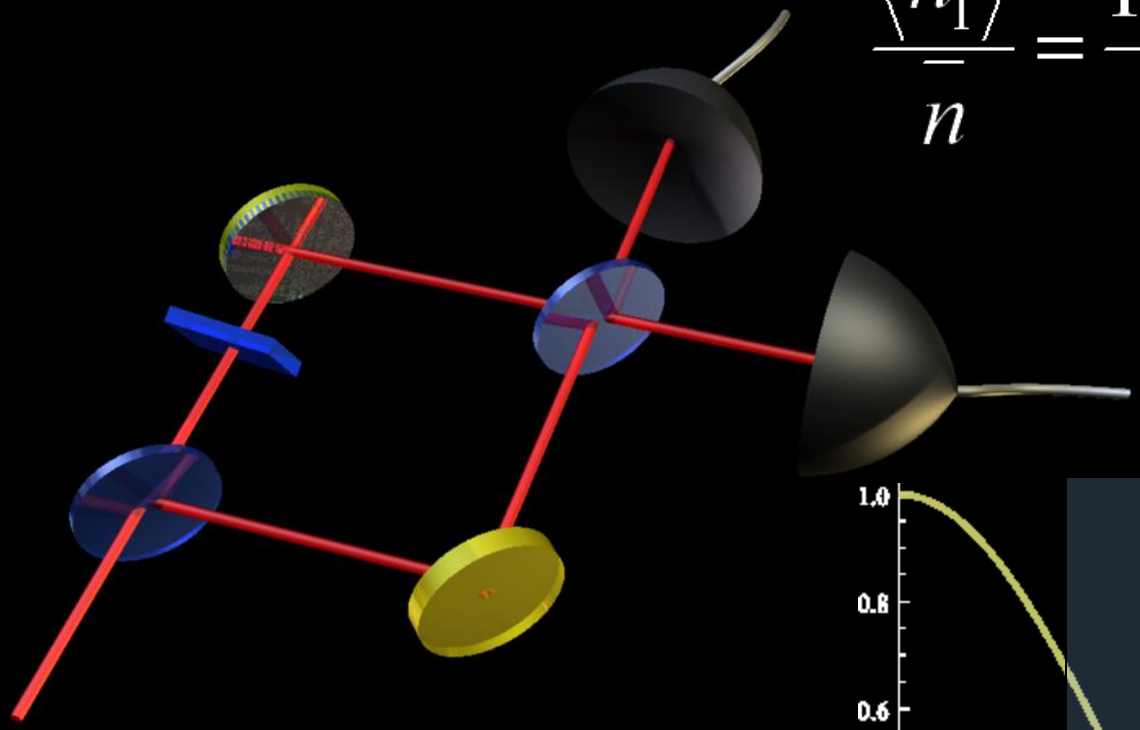
Interferometer



Mach-Zehnder interferometer



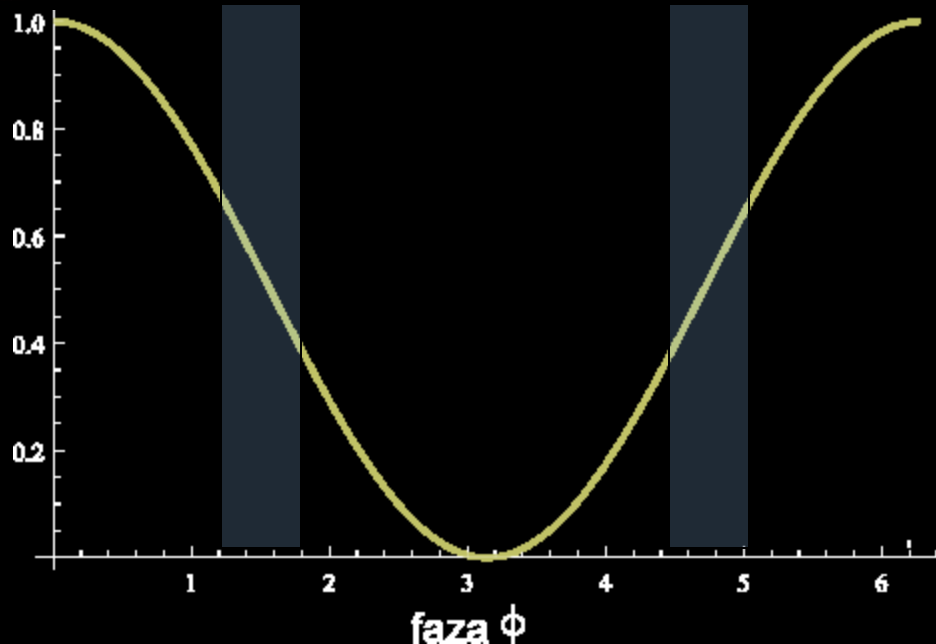
Mach-Zehnder interferometer



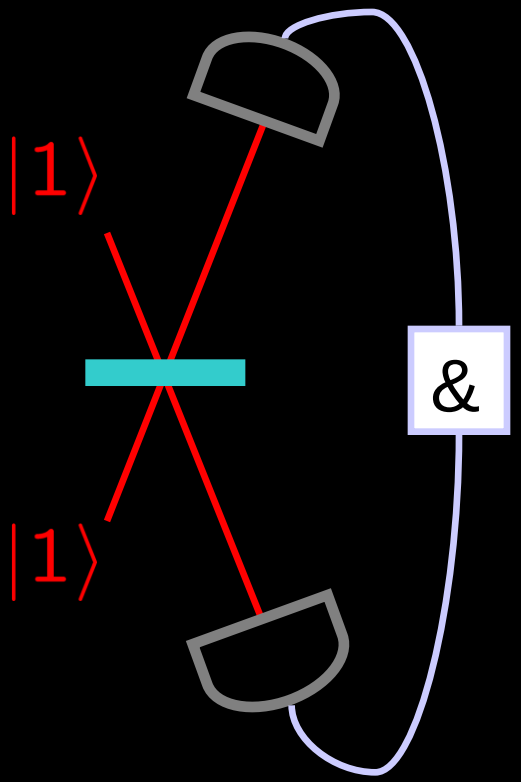
$$\frac{\langle n_1 \rangle}{n} = \frac{1+\cos\varphi}{2}$$

$$\frac{\langle n_2 \rangle}{n} = \frac{1-\cos\varphi}{2}$$

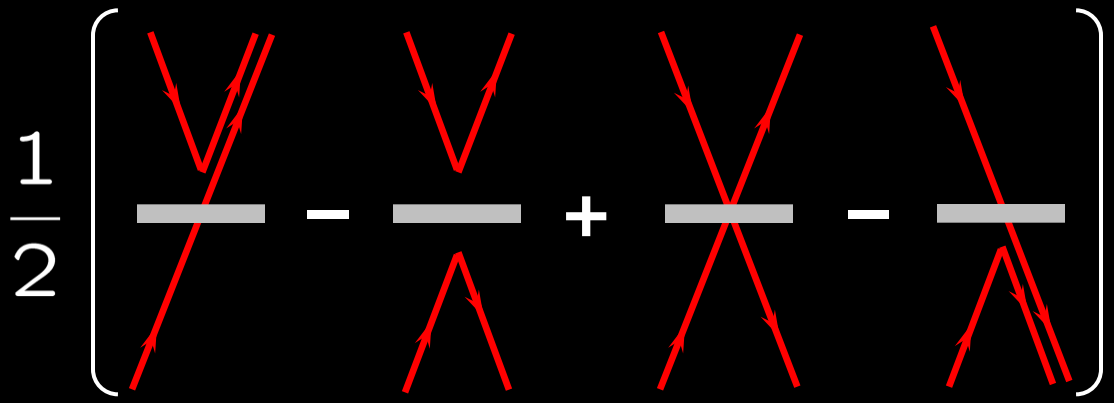
$$\langle n_- \rangle = \langle n_1 \rangle - \langle n_2 \rangle \propto \cos\varphi$$



Two-photon interference



Probability amplitudes:

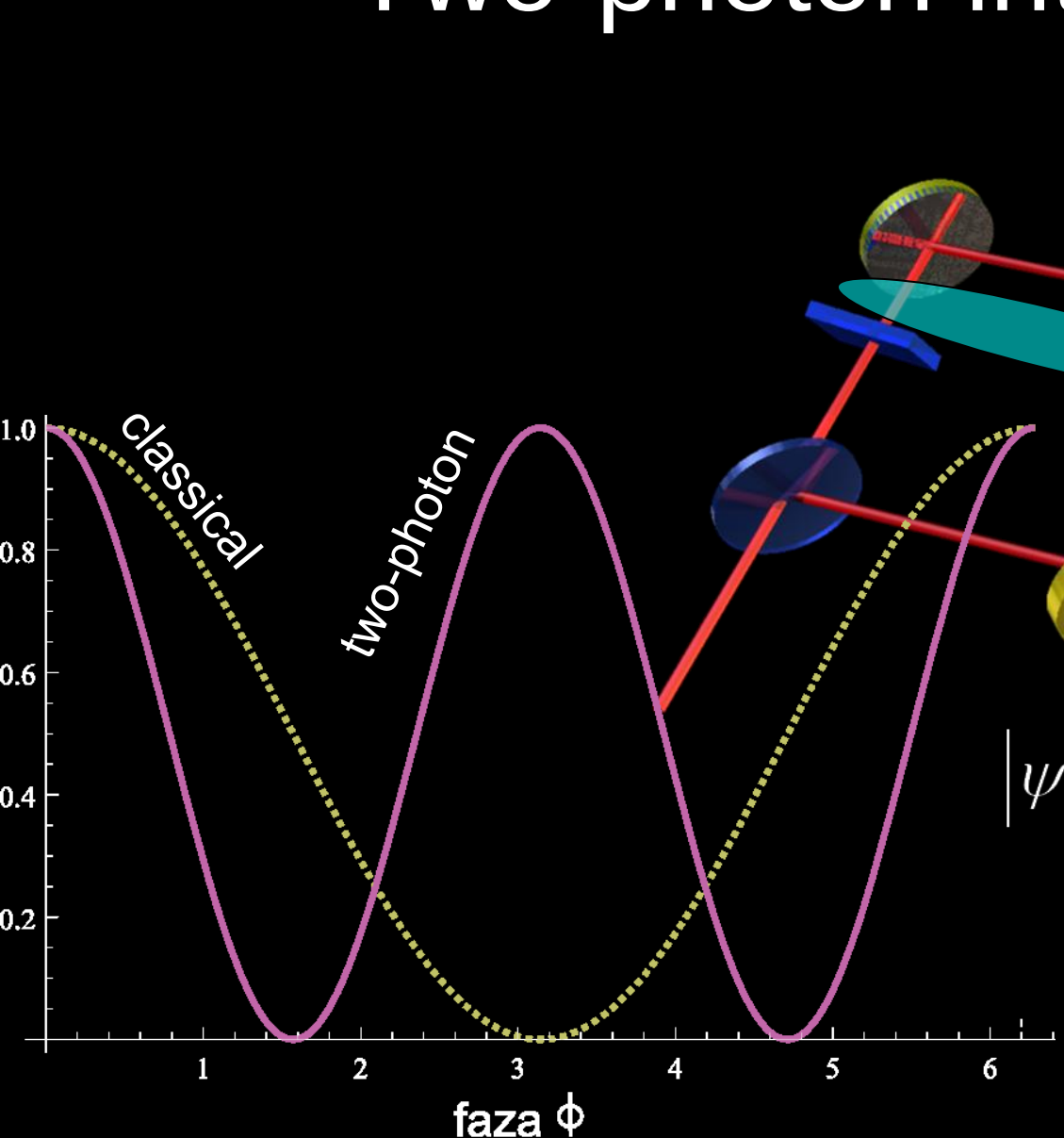


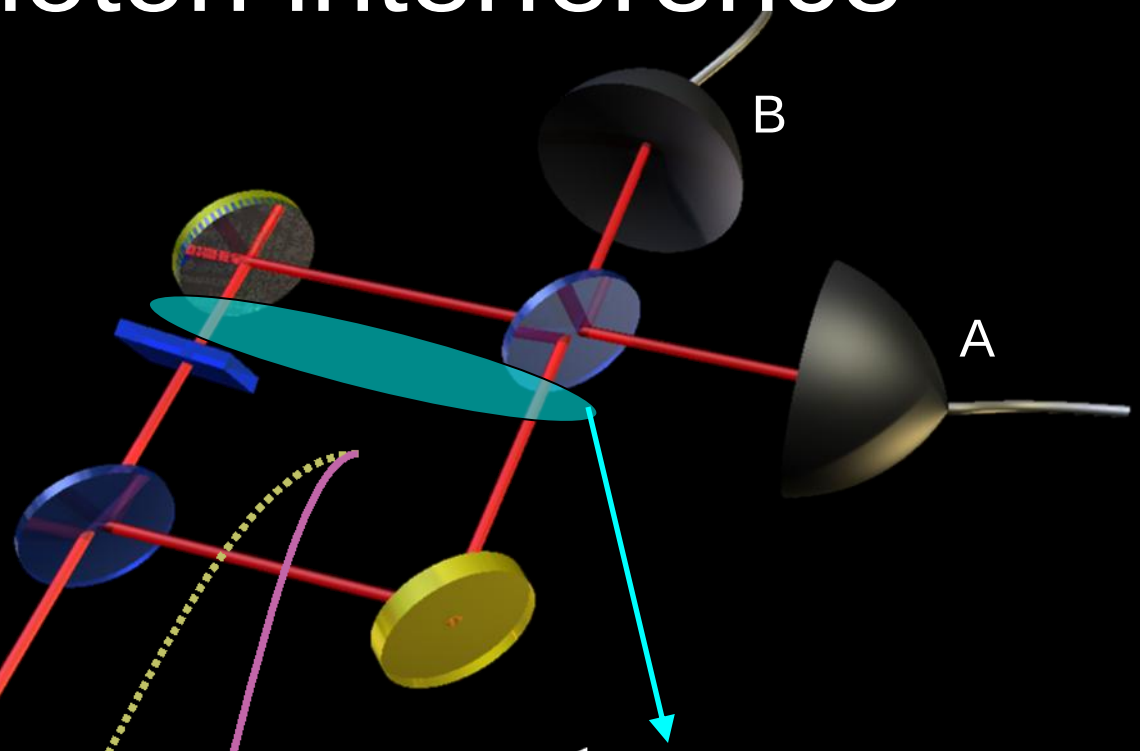
$$|11\rangle \rightarrow \frac{1}{\sqrt{2}}(|20\rangle - |02\rangle)$$

Only when photons are indistinguishable

C. K. Hong, Z. Y. Ou, and L. Mandel, Phys. Rev. Lett. **59**, 2044 (1987)

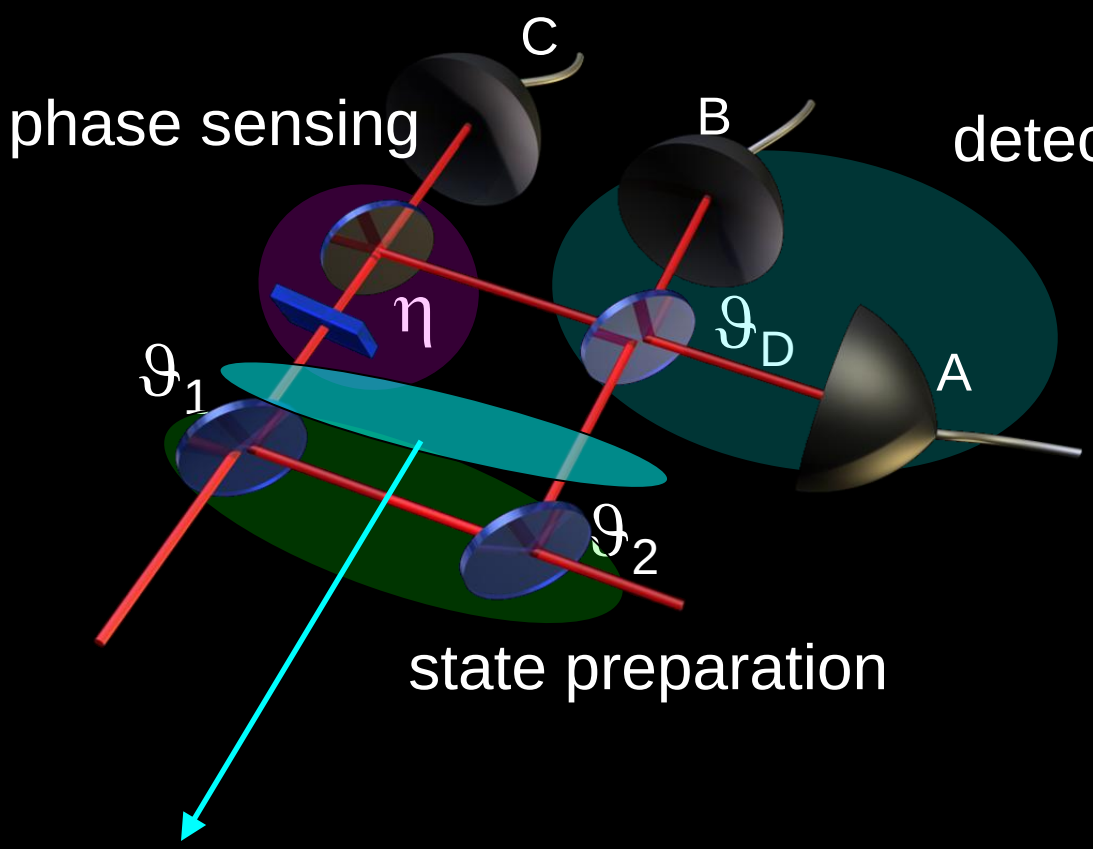
Two-photon interference





$$\left|\psi_{\varphi}\right\rangle = \frac{1}{\sqrt{2}}\left(\left|20\right\rangle e^{2i\varphi} + \left|02\right\rangle\right)$$

Lossy interferometer

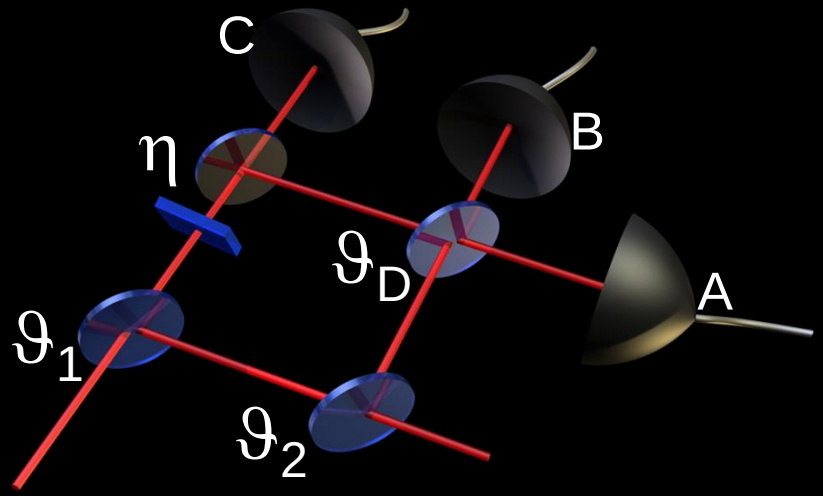


loosing one of the photons of the superposition
|20>+|02>
we loose all the information about the phase

$$|\psi\rangle = \sqrt{x_0}|0,2\rangle + \sqrt{x_1}|1,1\rangle + \sqrt{x_2}|2,0\rangle$$

Phys. Rev. Lett. 102, 040403 (2009)

Quantum interference with losses

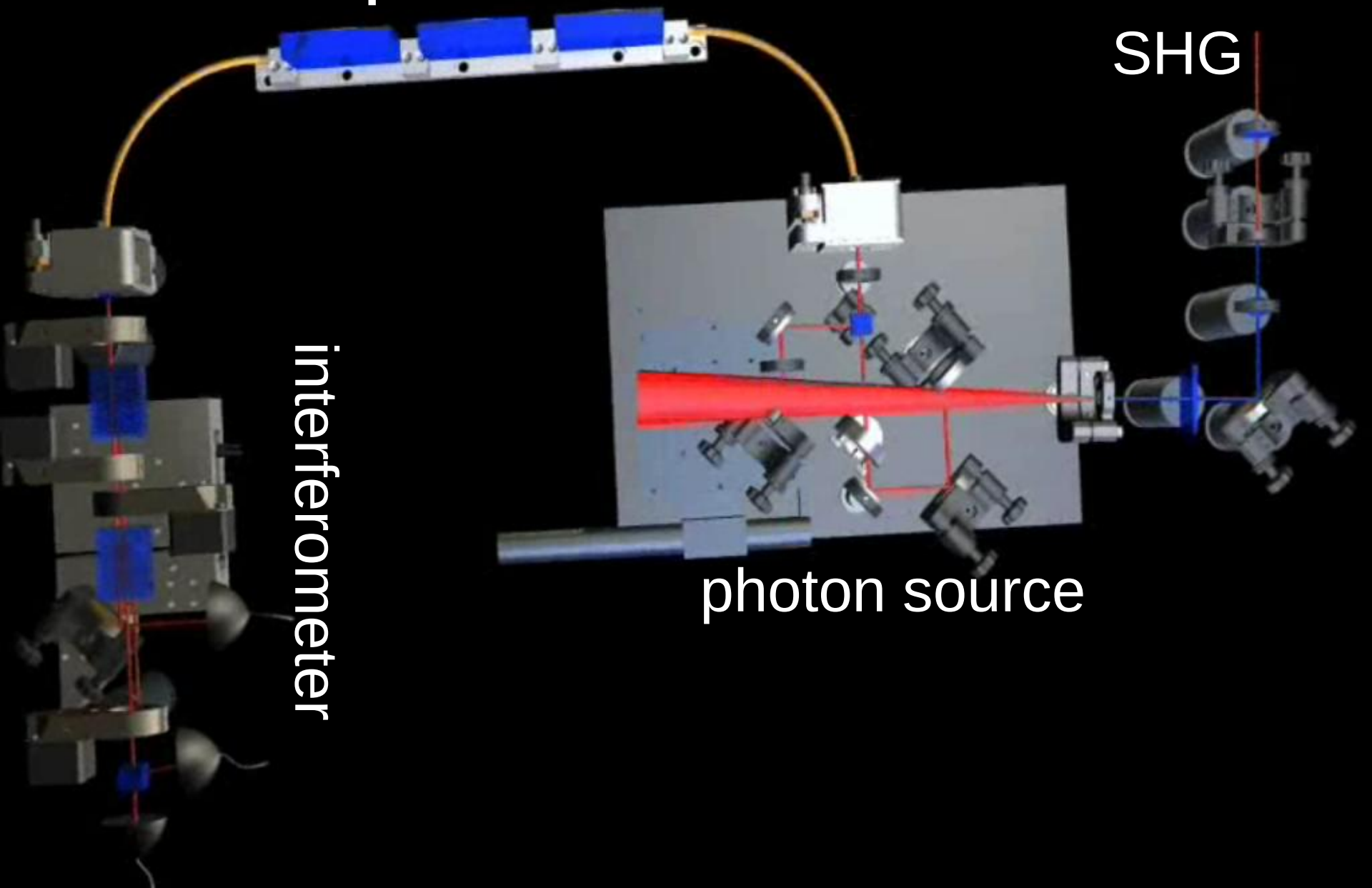


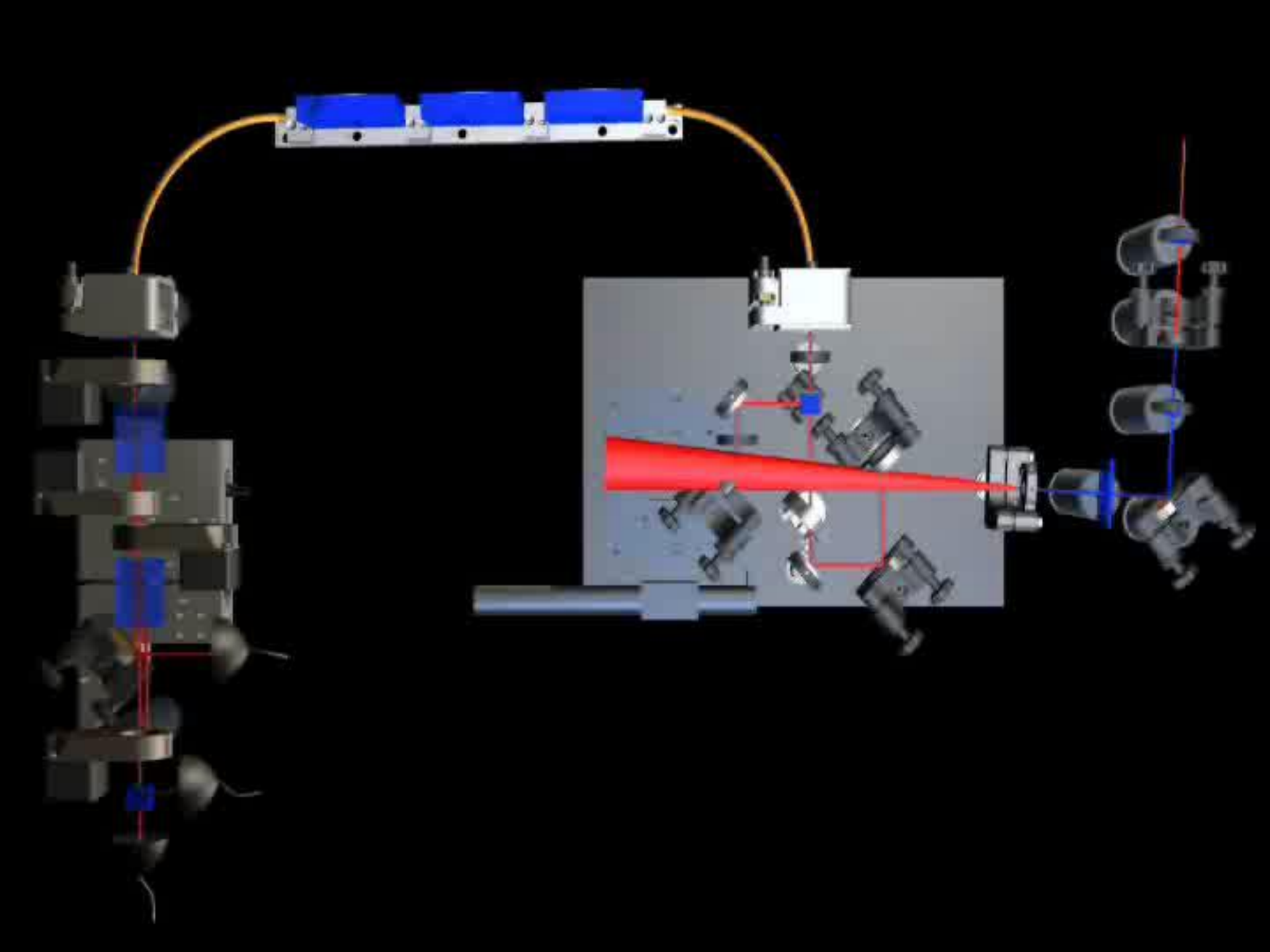
$$|\psi_\varphi^{(0)}\rangle \propto \sqrt{x_0}|0,2\rangle + \sqrt{x_1}\sqrt{\eta}e^{-i\varphi}|1,1\rangle + \sqrt{x_2}\eta e^{-2i\varphi}|2,0\rangle$$

$$|\psi_\varphi^{(1)}\rangle \propto \sqrt{x_1}\sqrt{1-\eta}|0,1\rangle + \sqrt{x_2}\sqrt{2\eta(1-\eta)}e^{-i\varphi}|1,0\rangle$$

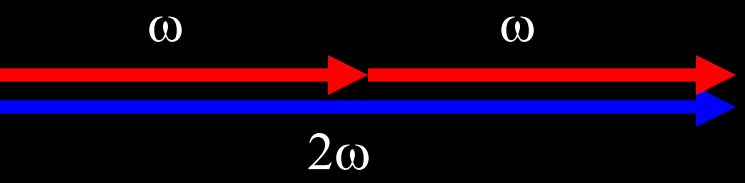
$$|\psi_\varphi^{(2)}\rangle \propto \sqrt{x_2}(1-\eta)|0,0\rangle \longleftarrow$$ no information about phase

The setup



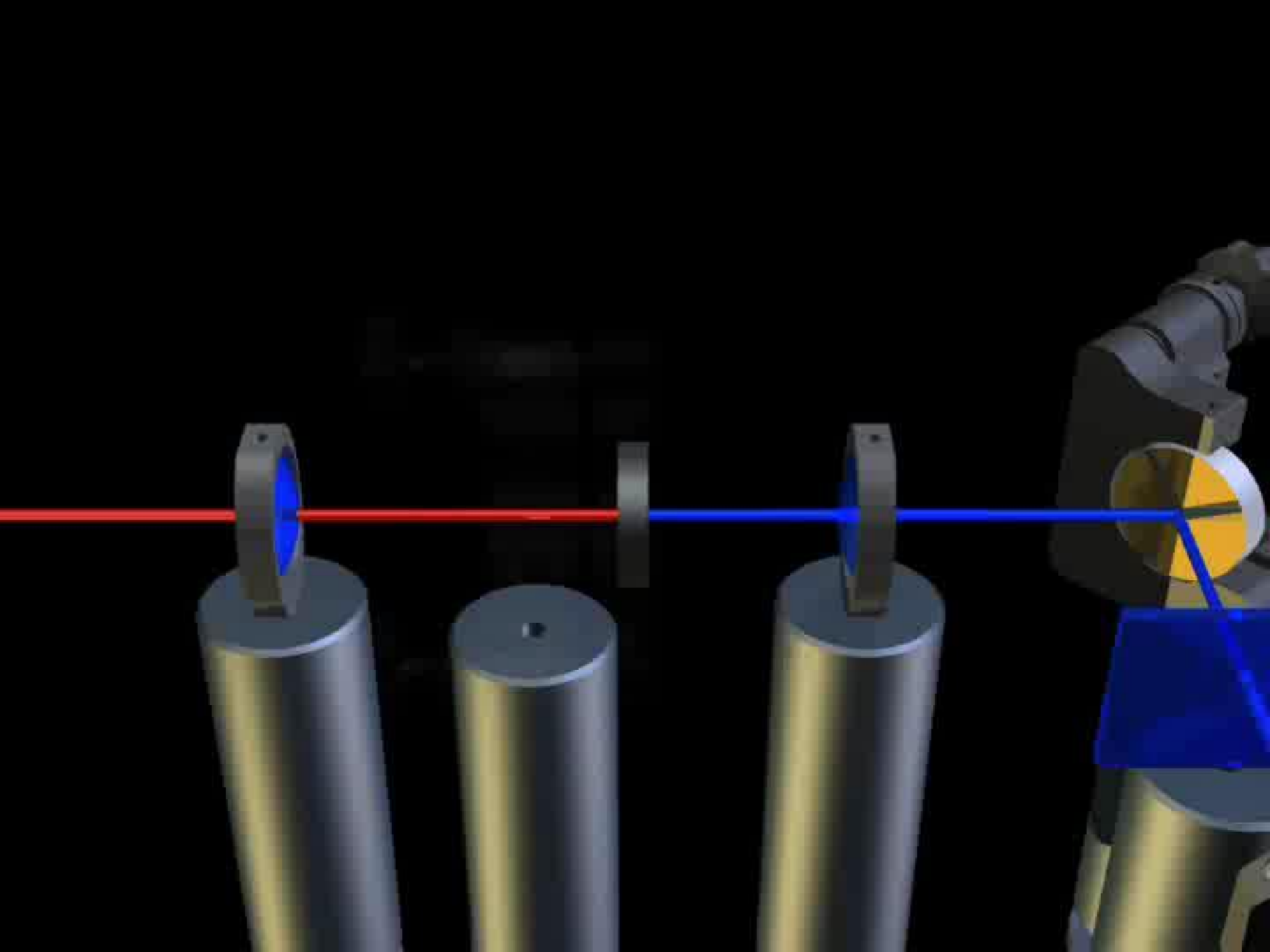


Second harmonic generation

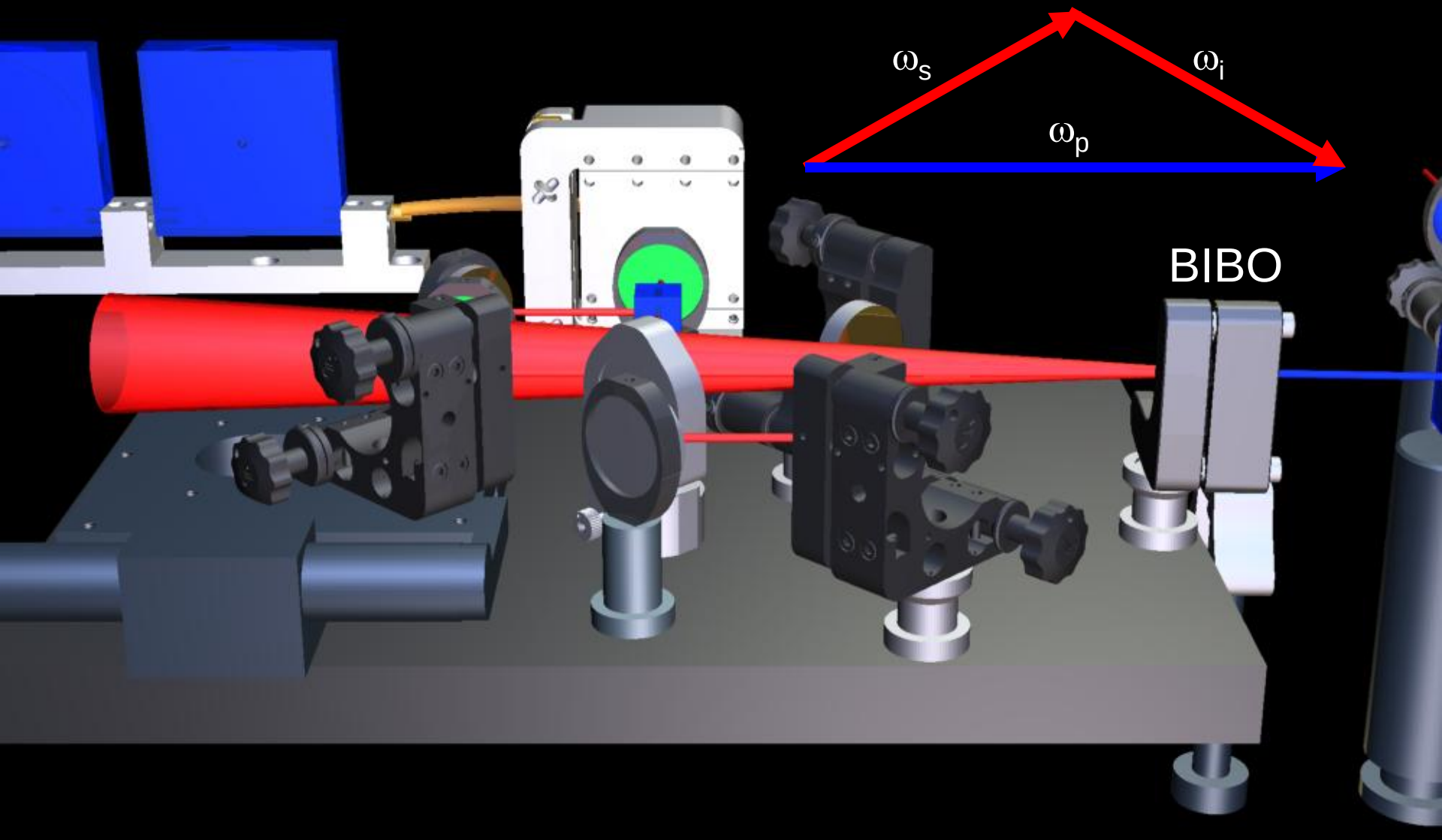


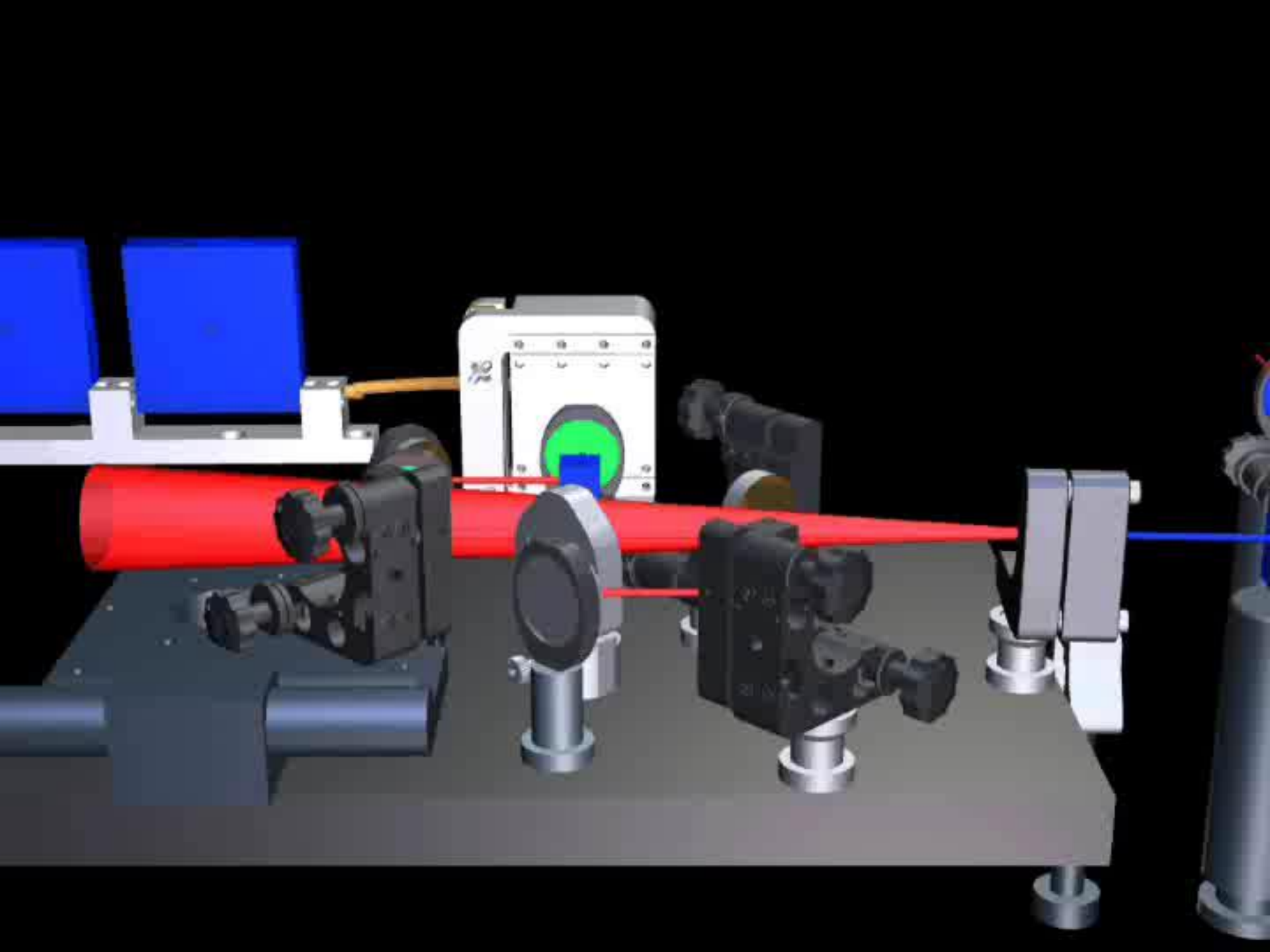
780nm → 390nm

BBO



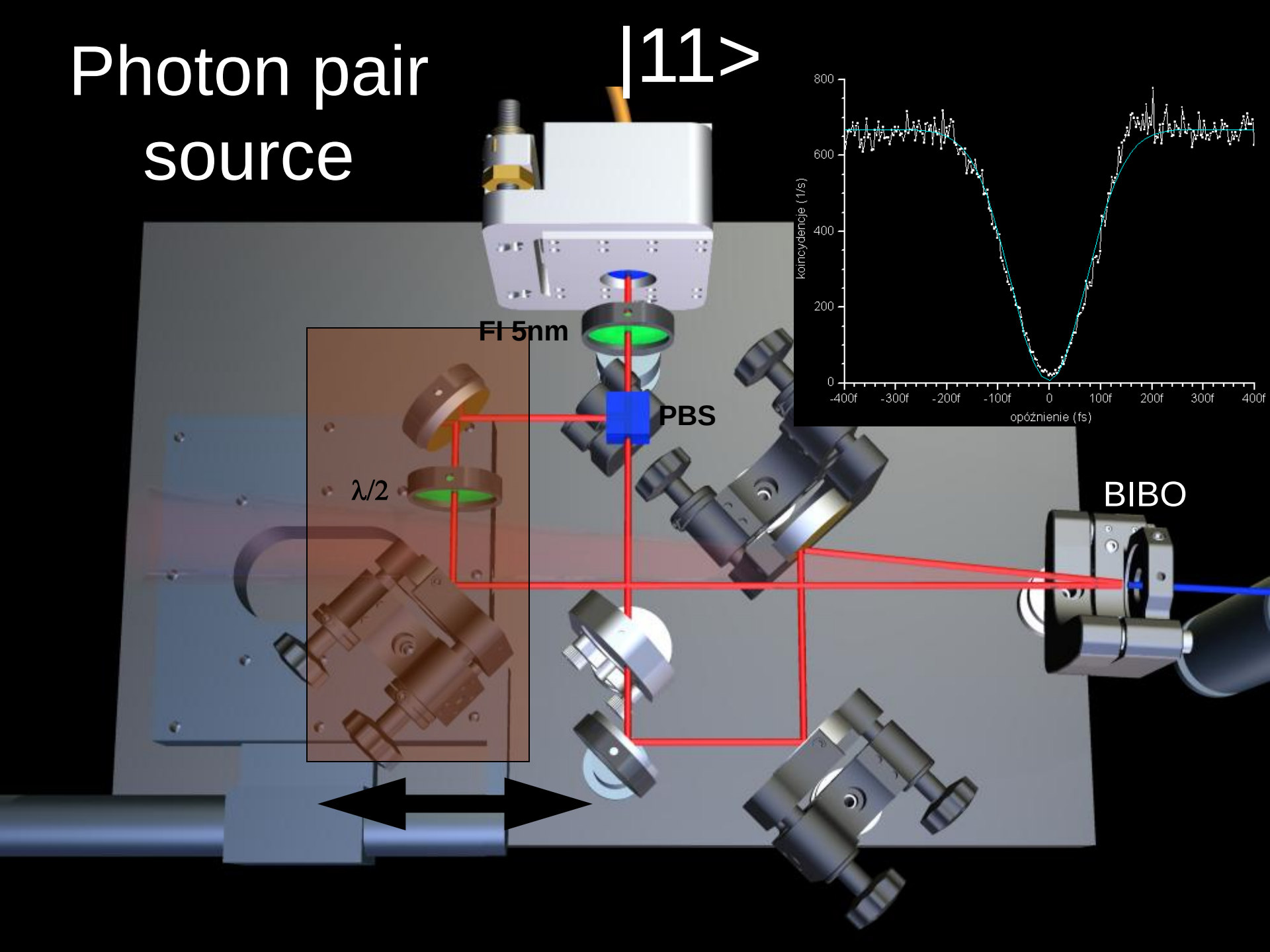
Parametric down-conversion

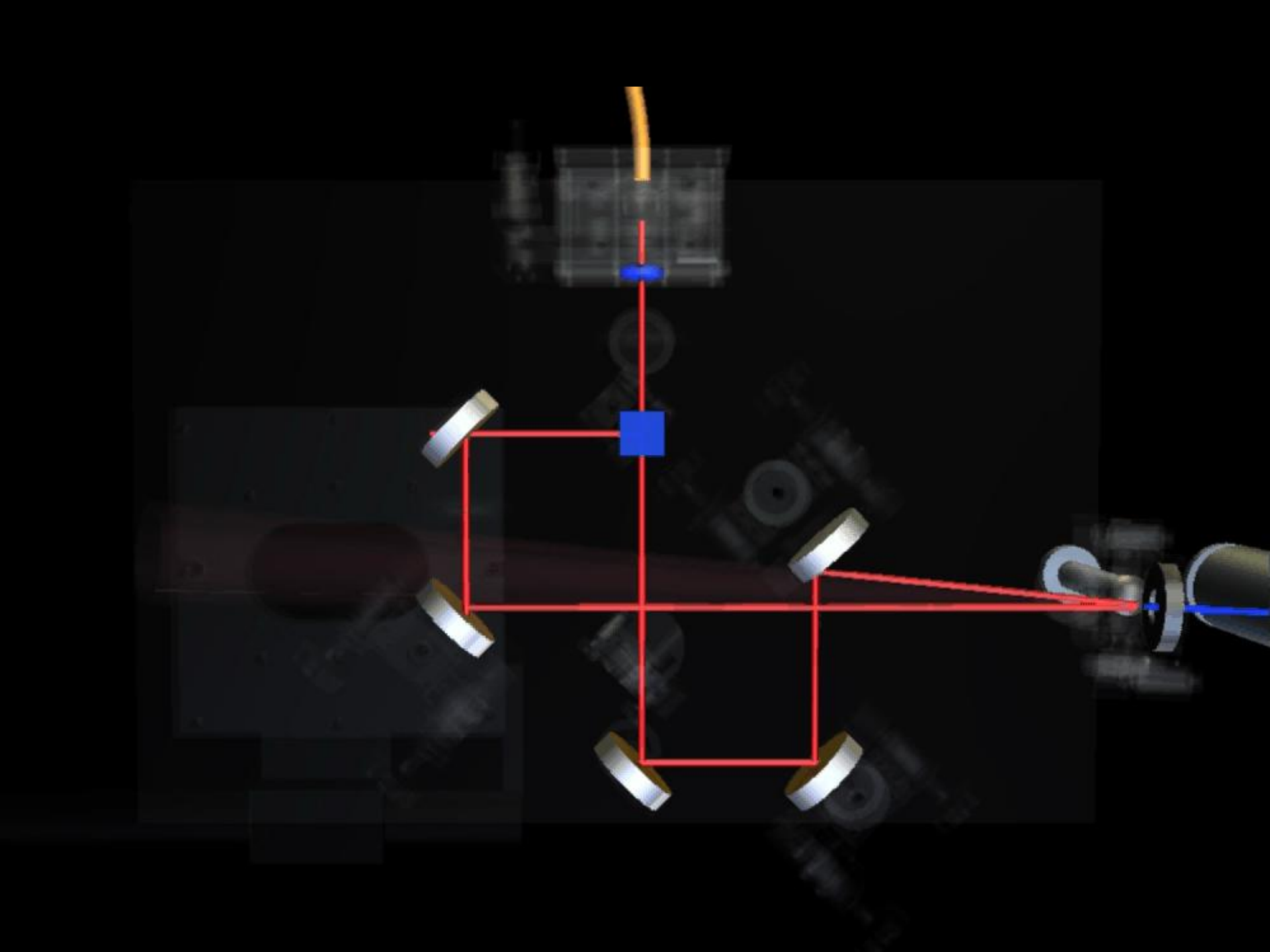




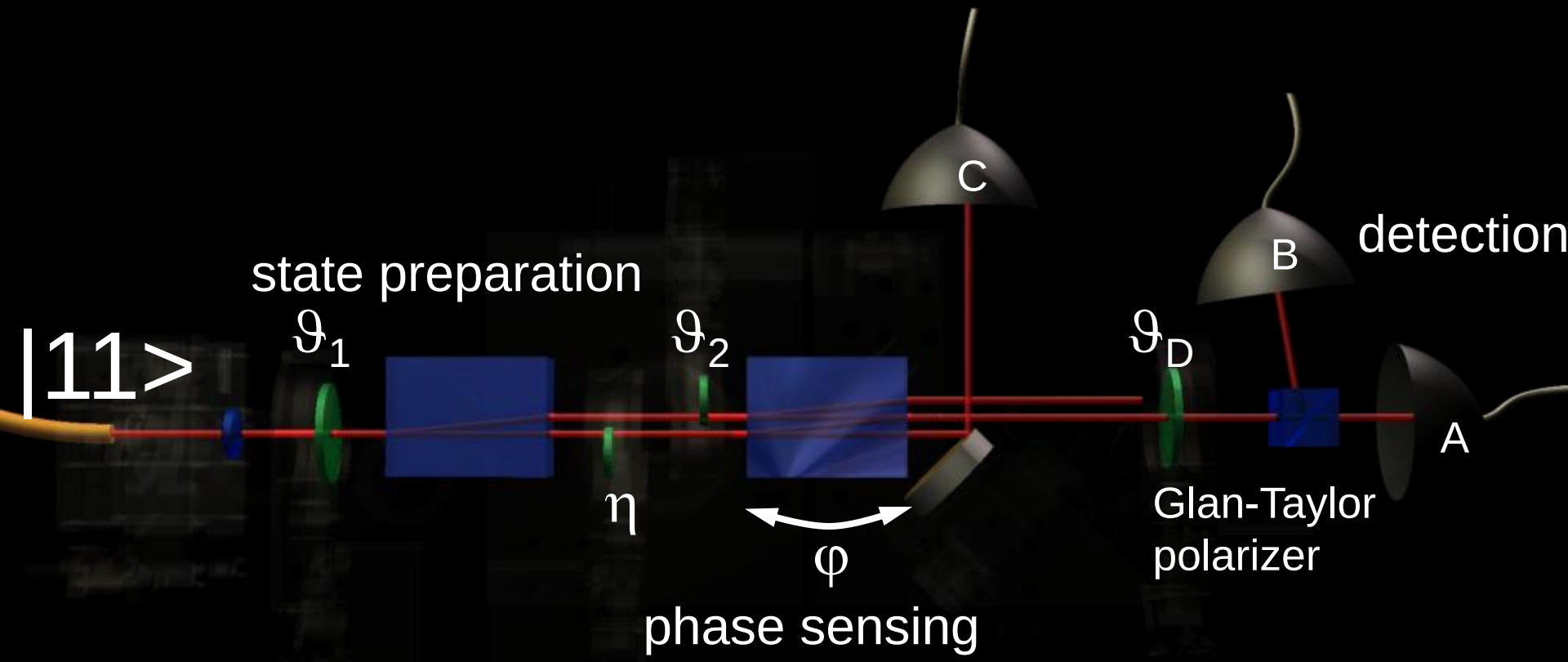
Photon pair source

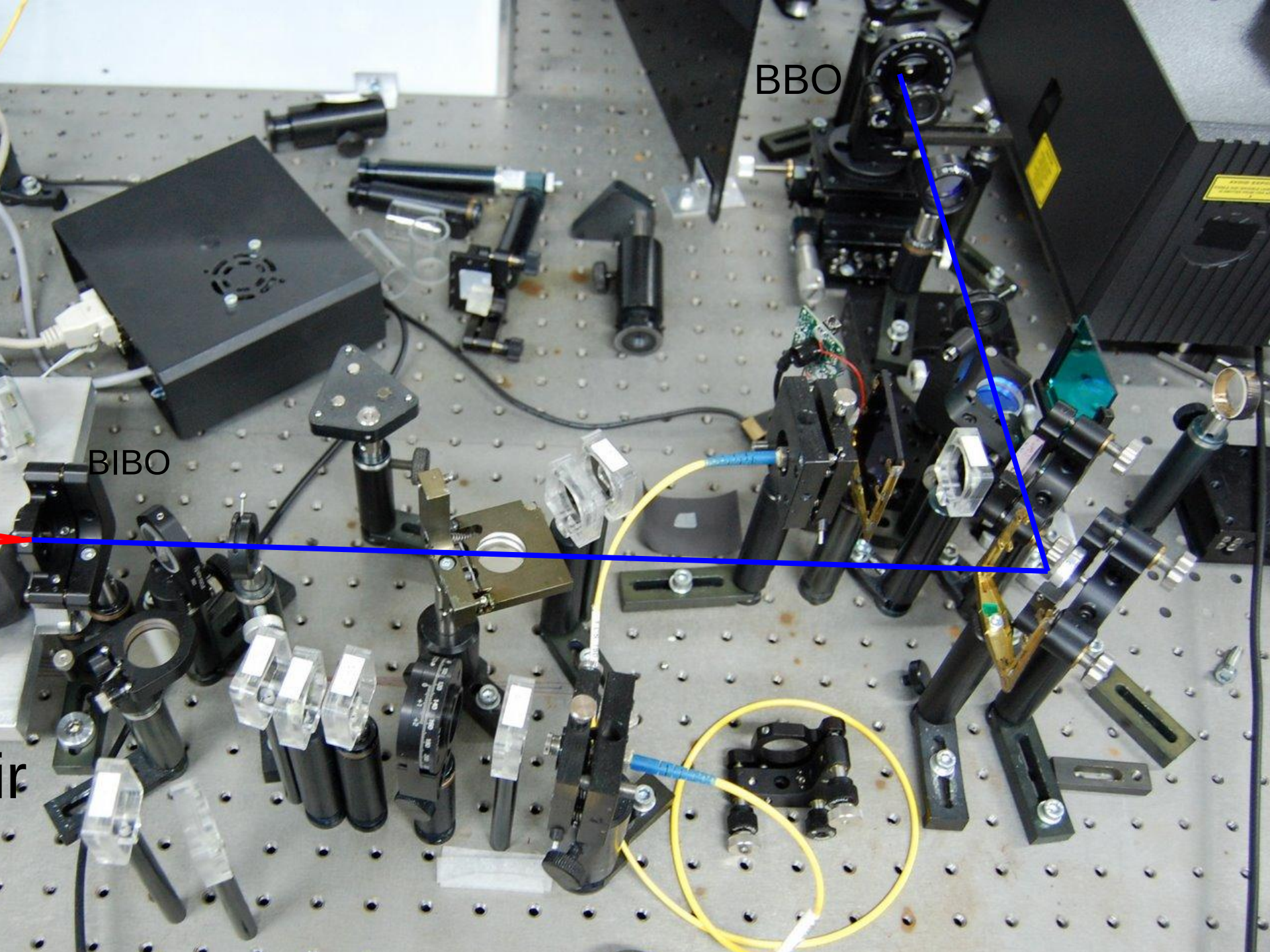
|11>

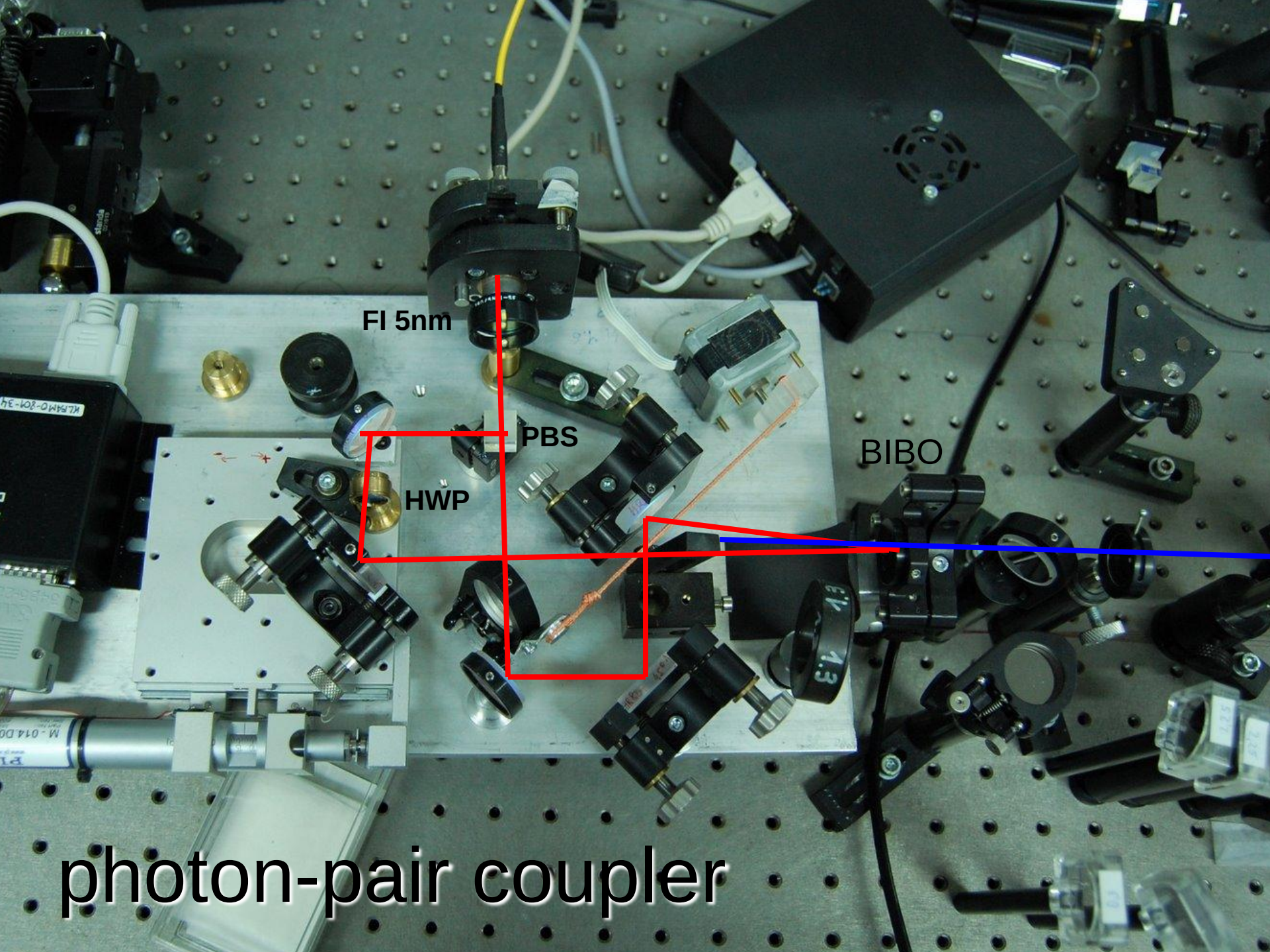




Interferometer

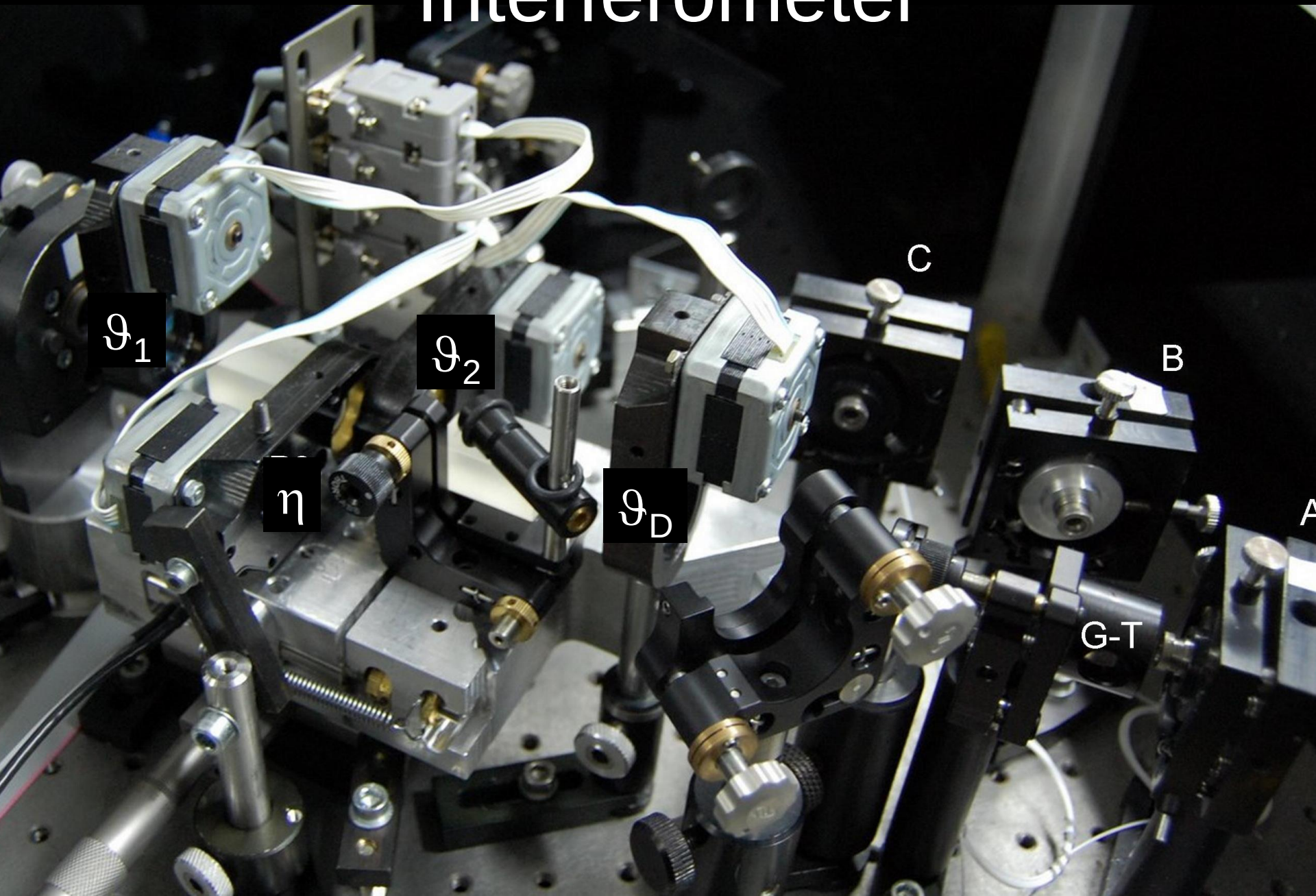



BBO
BIBO

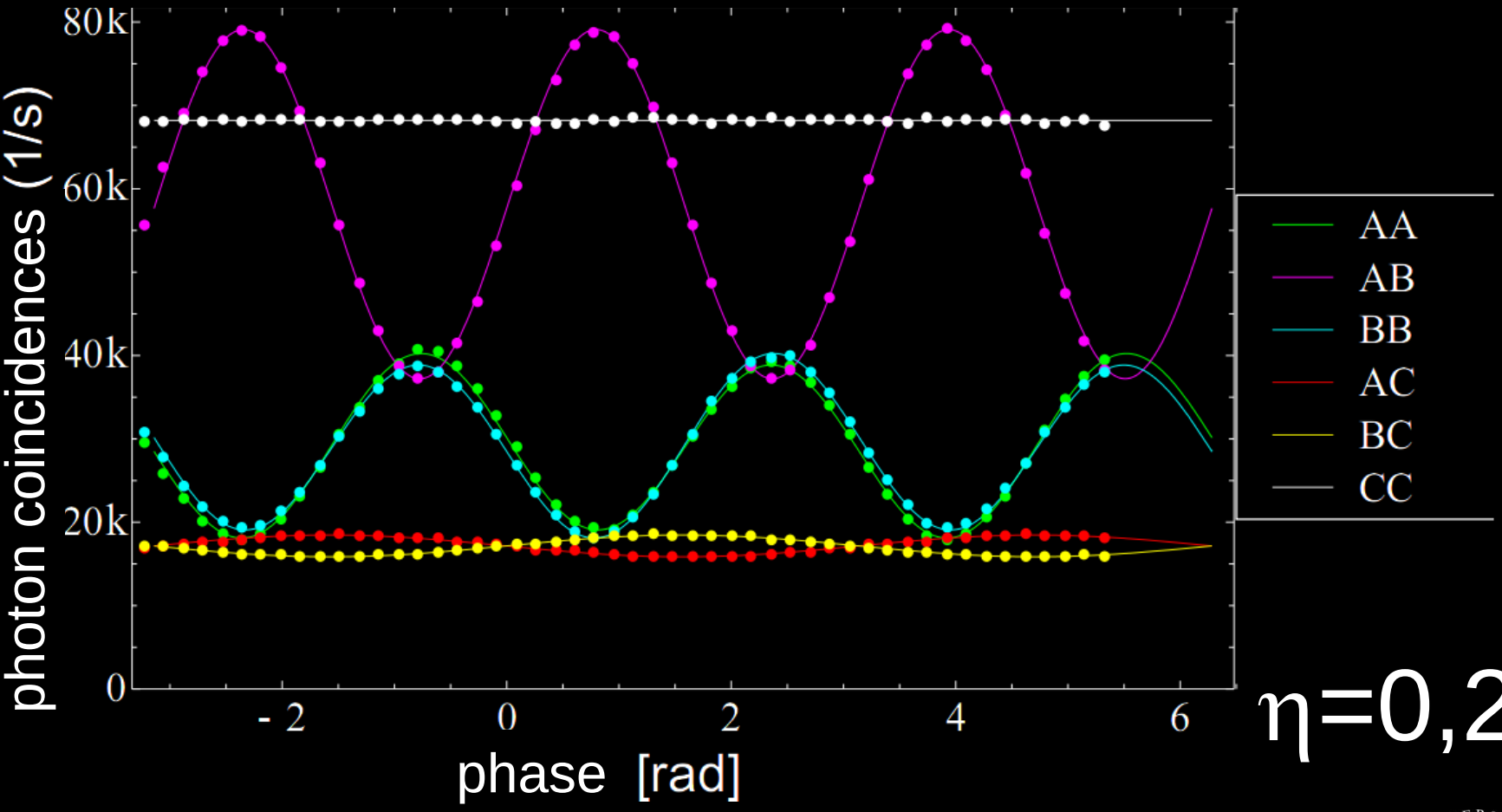


photon-pair coupler

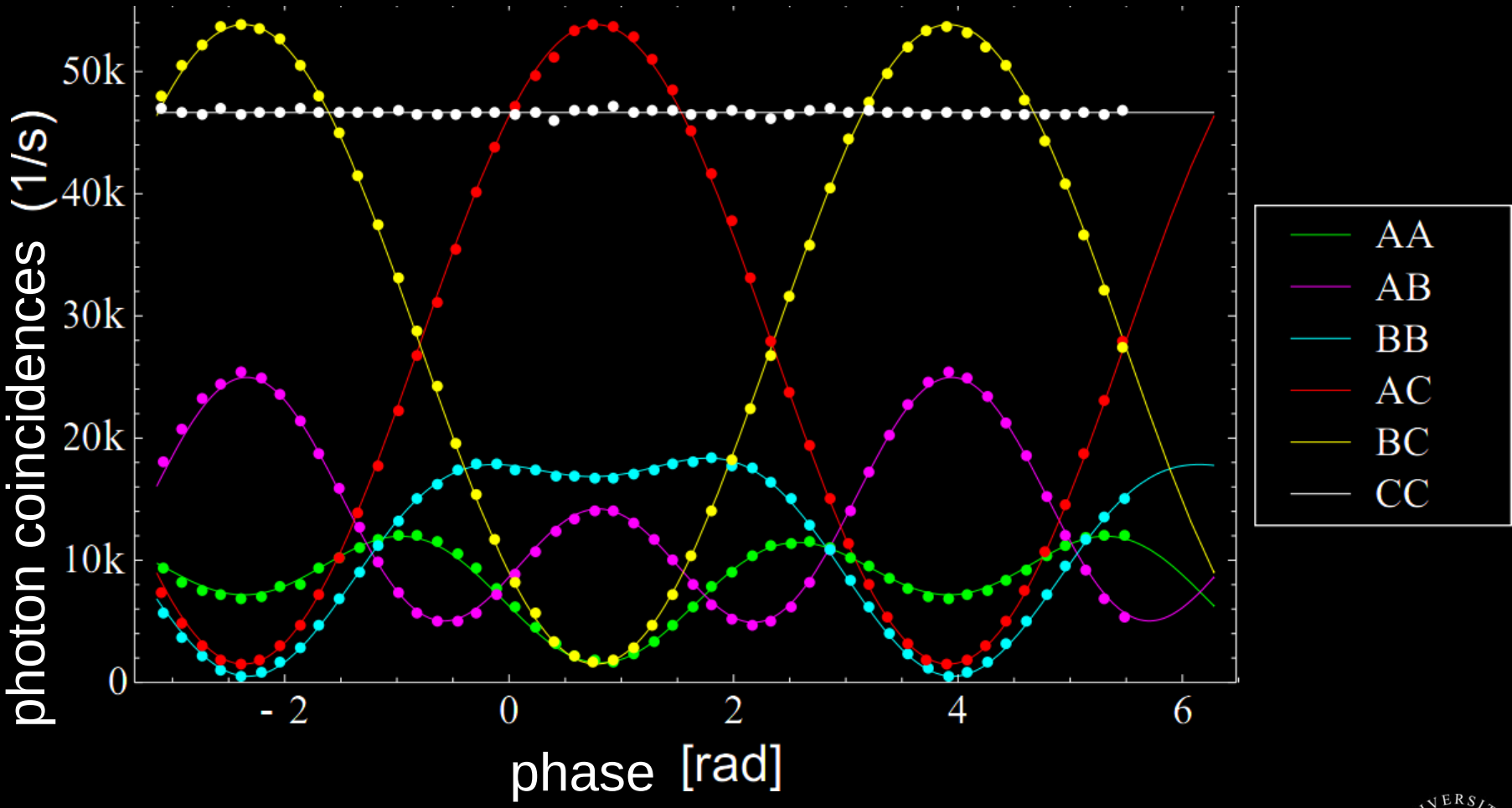
Interferometer



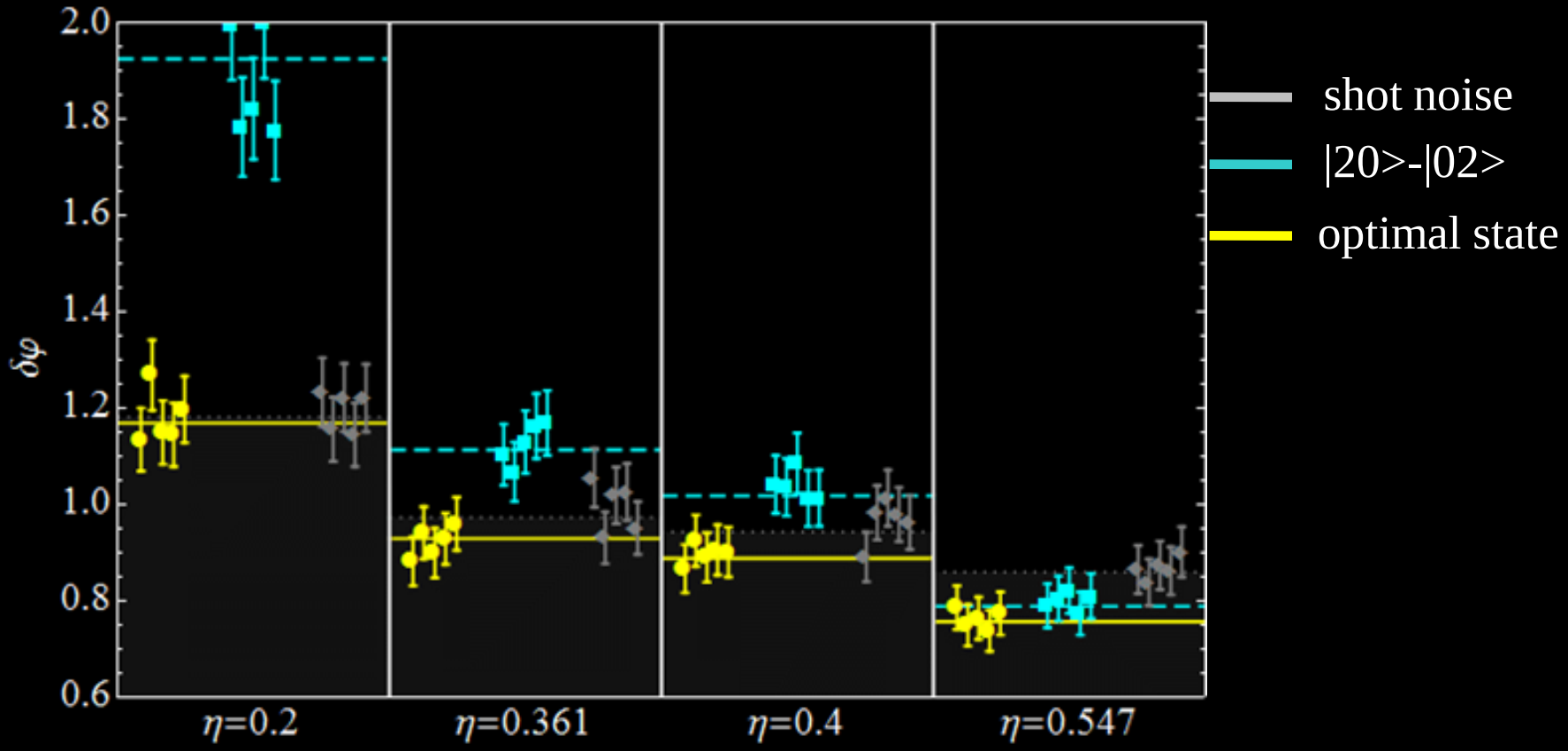
Rough fringes – N00N state



Optimal state η=0,2



How much can we get?



M. Kacprowicz et al., nphoton.2010.39

Summary

- we built the very stable interferometer of high one- and two-photon interference visibility (>98%)
- we can prepare any superposition of two photons
- The conclusionoptimal states → superior estimation accuracy